INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600
CONSONANT GEMINATES:
TOWARDS A THEORY OF INTEGRITY AND INALTERABILITY

by

Chang-Kook Suh

Copyright © Chang-Kook Suh 1997

A Dissertation Submitted to the Faculty of the
DEPARTMENT OF LINGUISTICS
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA

1997
THE UNIVERSITY OF ARIZONA ®
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Chang-Kook Suh entitled Consonant Geminates: Towards a Theory of Integrity and Inalterability and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Diana Archangeli
Michael Hammond
D. Terence Langendoen

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Dissertation Director

Diana Archangeli
STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the copyright holder.

SIGNED: [Signature]
ACKNOWLEDGEMENTS

In the writing of this dissertation, many people helped me in many ways.

First and foremost, I would like to express my sincere gratitude to Diana Archangeli, my dissertation advisor, great teacher, and never-ending source of inspiration and ideas. She has influenced my work at every point. I had long discussion with Diana Archangeli about every part of my dissertation, and the bits and pieces suggested by her slowly formed the core of my dissertation. Without her patience, continuous encouragement, and insightful guidance, I could never have written this dissertation. Special thanks go to the other members of my committee, Mike Hammond and Terry Langendoen, who patiently read the drafts of the dissertation and helped me with insightful suggestions and criticism. Mike Hammond meticulously examined the whole dissertation and helped greatly improve this dissertation both in quality and in style. From Terry Langendoen, I learned precious lesson of translating thinking into logical and lucid argumentation. I consider myself fortunate and privileged to have worked on my dissertation with these three great teachers.

Several people also helped move towards the development of this dissertation: John McCarthy, Donca Steriade, Douglass Pulleyblank, Stuart Davis, Moira Yip, and Paul Smolensky. An initial impetus came through a series of conversation with the above-mentioned people and they gave me the help and reassurance I badly needed.

I am further indebted to other teachers who taught me and contributed to my being a linguist today: Andy Barss, Dick Demers, Dick Oehrle, Susan Steele, Adrienne Lehrer, Janet Nicol, Molly Diesing, Kerry Green, Eloise Jelinek, Kook Chung, Soon-Ham Park, and In-Seok Yang. Special thanks go to Professor Kook Chung, my former academic advisor, for his continued support and encouragement.

I wish to extend my thanks to the fellow graduate students for many helpful discussions on linguistics: Younghyung Cho, Colleen Fitzgerald, Chip Gerfen, Andrea Heiber, Diane Meador, Young-Gie Min, James Myers, Shaun O’Conner, Diane Ohala, Pat Perez, Yongtae Shin, Sung-Hoon Hong, Keiichiro Suzuki. Jane Tsay, Dirk Elzinga, Amy Fountain, Jan Mohammad, Shensheng Zhu, Pilar Pinar, and Tania Zamuner. I owe special thanks to my friend Sung-Hoon Hong for his never-ending mental support. Also, I will never forget the kindness, love and help of Rosemary Emery.

I am specially indebted to my church members here and in Korea, and to the Reverends Jin-Myung Park, Seong-Shik Jo, and Luke K. Pak for their love and prayers for me and my family. Special thanks to Sharon’s family, who graciously let my family stay with them for a couple of months.

Finally, I dedicate this dissertation to my parents, brothers and sister, father-in-law and mother-in-law, my wife Chi-Won, and my daughters Yi-Rey and Da-Hye, and my son Peter, who have endured all the difficult moments during my stay in the U.S.A.
TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................... 12

CHAPTER 1. INTRODUCTION ........................................................................................................... 14

1.1 Scope and Issues: Geminate Integrity and Inalterability ......................................................... 14

1.2 Geminate Facts and Previous Approaches ........................................................................... 15

1.2.1 Geminate Facts .................................................................................................................... 15

1.2.1.1 Integrity .......................................................................................................................... 18

1.2.1.2 Inalterability .................................................................................................................. 21

1.2.2 Previous Approaches to Geminates .................................................................................. 24

1.3 Optimality Theory .................................................................................................................... 27

1.3.1 The Character of the Optimality Theory ......................................................................... 28

1.3.2 An Illustration ..................................................................................................................... 30

1.3.3 Correspondence Theory ..................................................................................................... 34

1.3.4 Factorial Typology ............................................................................................................. 35

1.4 Layout ....................................................................................................................................... 36

1.4.1 Gaps in the Predicted Types of Geminates...................................................................... 45

1.5 The Structure of the Dissertation .......................................................................................... 49

CHAPTER 2. THE NATURE OF CONSONANT GEMINATES ................................................. 51

2.1 Introduction ............................................................................................................................... 51
3.2.5 Palestinian Arabic:
PLONS is subordinate and /...C_1C_1C_2.../ \rightarrow [...C_1C_1C_2...]

3.2.5.1 The Predictions

3.2.5.2 Word-final [-CC#]

3.2.5.3 A Return to Geminates

3.2.5.4 An Added Wrinkle: Fake Geminates

3.2.5.5 Summary and Conclusion

3.2.6 Summary of Medial Geminates

3.3 Final Geminates

3.3.1 Introduction

3.3.2 Ponapean: [-C_1C_1]

3.3.3 Summary of Final Geminates

3.4 Initial Geminates

3.4.1 Introduction

3.4.2 Woleaian: [C_1C_1V-]

3.4.3 Ponapean and Fijian: [CV-]

3.4.3.1 Ponapean

3.4.3.2 Fijian

3.4.4 Marshallese: [CV_C_1C_1V] and [C_1VC_1V]
4.6.3 Summary of the Constraints in Tiberian Hebrew .............................................. 266
4.6.4 The Proof ............................................................................................................. 267
4.6.5 Fake Geminates ................................................................................................. 271
   4.6.5.1 OCP and NOFUSION ................................................................................... 272
4.6.6 Summary ............................................................................................................. 280
4.7 Anti-inalterability Effect I: /C\textsubscript{1}C\textsubscript{2}/ \rightarrow [C\textsubscript{1}C\textsubscript{2}] ................................................................. 281
   4.7.1 Introduction ....................................................................................................... 281
   4.7.2 Velar Palatalization in Luganda ....................................................................... 282
    4.7.3 Summary ......................................................................................................... 291
4.8 Anti-inalterability Effect II: /C\textsubscript{1}C\textsubscript{2}/ \rightarrow [C\textsubscript{1}C\textsubscript{2}] and /C\textsubscript{1}C\textsubscript{2}/ \rightarrow [C\textsubscript{2}C\textsubscript{3}] ................................. 292
   4.8.1 Introduction ....................................................................................................... 292
   4.8.2 Korean Post-Obstruent Tensification: A Case of /C\textsubscript{1}C\textsubscript{2}/ \rightarrow [C\textsubscript{1}C\textsubscript{2}] .................................................................... 292
      4.8.2.1 Constraints and their Interactions in Korean Post-Obstruent Tensification ............................................................................................................ 294
      4.8.2.2 Summary of the Constraints ...................................................................... 303
      4.8.2.3 The Proof ................................................................................................... 305
      4.8.2.4 Summary ................................................................................................... 310
4.8.3 Icelandic Preaspiration:
   A Potential Counterexample to Inalterability (/C\textsubscript{1}C\textsubscript{2}/ \rightarrow [C\textsubscript{1}C\textsubscript{2}]) ................................................................................. 312
   4.8.3.1 Phonetic Aspects of Preaspiration ................................................................. 313
   4.8.3.2 Phonological Aspects of Preaspiration ......................................................... 314
ABSTRACT

This dissertation investigates the geminate consonant phenomena known as *integrity* and *inalterability* with an eye toward providing a general characterization of geminate behavior as well as a deeper understanding of geminates in a principled and systematic way under the Optimality Theoretic framework. The fundamental proposal made in this dissertation is to have the range of surface geminate patterns follow from varying the ranking of key constraints. Depending on the ranking of the key constraints, languages select different output forms from the same input form. Thus, the key constraints not only conspire to produce anti-integrity/anti-inalterability effects, but they also determine what a language does "do" with its input geminates (i.e. integrity/inalterability), giving rise to different resolutions to the geminate puzzle.

A chapter is devoted to an in-depth discussion of integrity effects in geminates. For this purpose, seven key constraints are proposed: MAX-IO, DEP-IO, ONS, PROSHIER, ALIGN(WD-R, M-R), PLONS, NOBREAKING. By varying the key constraints, we can make several predictions about the possible geminate patterns according to the positions in which they occur. Several patterns are exemplified in this dissertation. We have also provided a discussion of the gaps between what is predicted to exist and what cases are attested.

Another chapter is devoted to a more detailed analysis of inalterability effects in geminates. In particular, it is claimed that geminate inalterability matters only when we
deal with weakening processes (e.g. spirantization, sonorantization, etc.). It is also proposed that the constraints IDENT-IO(μSF) and NOBREAKING play a pivotal role in explaining typological differences between weakening and assimilation, and other types of inalterability/anti-inalterability concerning geminates.

The most interesting part of this dissertation is that we can explain both integrity/inalterability and anti-integrity/anti-inalterability cases uniformly depending on the ranking of the key constraints, without assuming any ad hoc conditions or procedures. Thus, those anti-integrity and anti-inalterability effects are produced as a natural consequence of the interaction of the constraints, just as in the cases of integrity and inalterability.

Finally, unlike previous rule-based approaches, our theory allows for a unified account of integrity and inalterability through the interaction of a set of key constraints, making predictions available about both phenomena.
1.1 Scope and Issues: Geminate Integrity and Inalterability


(1) Two Special Behaviors of Geminates (Hayes 1986)

a. Integrity: In so far as they constitute two segments, long segments cannot be split by rules of epenthesis.

b. Inalterability: Long segments often resist the application of rules that a priori would be expected to apply to them.

To account for these special behaviors of geminates, attention has focused on representational properties that distinguish geminates from singletons. These special behaviors have been proposed to result from the unique branching geometry of geminates. This suggests that proper phonological representation of geminates plays an extremely
important role in capturing these phenomena. This seems to be true even in Optimality Theory (OT), but interaction of the constraints more crucially plays an important role in OT. This interaction produces an optimal candidate by means of violable universal constraints and their interactions, i.e. ranking of the constraints in a particular language.

1.2 Geminate Facts and Previous Approaches

My goal in this section is to provide a general description of geminate behavior known as integrity (section 1.2.1.1) and inalterability (section 1.2.1.2) which has been widely discussed in the traditional rule-based approaches (Hayes 1986, Schein and Steriade 1986, etc.). It may prove helpful to see the nature of integrity and inalterability in general, and how these phenomena are accounted for under rule-based approaches. Then, I will identify some major problems found in the previous rule-based approaches with regard to integrity and inalterability.

1.2.1 Geminate Facts

Geminate constitute a representational dilemma for the linear model. Cases exist where some rules are simplified if geminates are represented as sequences, while
other rules are simplified if geminates are represented by a feature such as [+long]. However, a geminate cannot have both of these inconsistent representations in the linear model.¹

For example, Sampson (1973) argues that in Biblical Hebrew geminate consonants demand the feature notation (i.e. [+long]), in describing spirantization (e.g. /yi-kto/ → [yixtov], /gibbor/ → [gibbor], *[givbor]). If the geminate in /gibbor/ is represented as [+long], then the spirantization rule can be defined on postvocalic [-long] stops. If the geminates are represented as a sequence, then spirantization becomes much more complex to state. On the other hand, Barkai (1974) argues that geminate consonants parallel consonant clusters for many other rules of Biblical Hebrew phonology. For example, if geminates are represented as sequences of consonants, then the parallel behavior of /galgul-im/ ‘wheels’ and /sappir-im/ ‘sapphires’ in restricting vowel reduction is explained effectively. The first segments of [lg] and [pp] clusters close the preceding syllable, and thus prohibit vowel reduction, which occurs in the context _CVCV in plural nouns (e.g. malak-im/ → [mɔlaxim] ‘kings’).

On the other hand, in nonlinear phonology, geminates can be represented as a single set of feature specifications associated to two adjacent prosodic positions (2a).²

¹ See Leben (1980) and Kenstowicz (1994a) for further discussion of this issue.
² We are not denying node structure or syllabic/moraic structure; we are just ignoring it for convenience.
The double association makes it possible to capture both segment-like (referring to features) and sequence-like (referring to prosody) behavior of geminates.

Hayes (1986: 327) notes the contrast between two types of geminates which are referred to as *fake* and *true* geminates.

Fake geminates come from morpheme concatenation, indicated by the "+" in (3a). These geminates are accidental. On the other hand, true geminates arise through two different sources: underlying and derived. Underlying true geminates are found within morphemes without undergoing any processes, while derived true geminates result from a total assimilation across morphemes.

This contrast makes a difference in how apparent geminate consonants respond to integrity and inalterability and other phonological phenomena. These differences will be explored in the following chapters.
1.2.1.1 Integrity

In this section, I show how the integrity effect is derived from geminates in connection with vowel epenthesis. Further, it will be shown that fake and true geminates are different with respect to integrity phenomenon.

Kenstowicz and Pyle (1973) first observed that epenthetic segments typically cannot be inserted between the halves of long segments. However, fake geminates differ from true geminates in that they are freely splittable by epenthesis as shown in Palestinian Arabic (Hayes 1986: 327).

(4) a. /CVCC/ → CVCCVCC ‘I enter’

```
  | | | |
+---+---+---+---+
   f u t - t   f u t i t
```

enter-1sg

b. /CVCC CVCC/ → CVCCVCCVCCVCCVCCVCCVCC ‘big fish’

```
  | | | | | | | | | |
+---+---+---+---+
   s a m a k k b i r   s a m a k i k b i r
```

Epenthesis is, however, unable to split underlying true geminates in Palestinian Arabic (Guerssel 1977).

(5) sadd (*sadid) thri
sitt (*sitit) tixy
hubb (*hubib) txe
Considering the fact that triconsonantal clusters and word-final biconsonantal clusters are not allowed in Palestinian Arabic, epenthesis would apply to the forms in (5). However, epenthesis does not occur in this case (e.g. *sadid, *sitit, *hubib). Compare these examples with the form CVC_{i}jC_{j} where epenthesis does occur (e.g. /?ibn/ → [?ibin] 'son'). This seems to show that true geminates are subject to integrity.

A heteromorphemic geminate which is derived from total assimilation also resists epenthesis.³ Pero, a West Chadic Language of Nigeria, shows this sort of examples (Frajzyngier 1980).

(6) yekl-tu [yig^ilu] 'mix-Imp. Vent.'
cugd-na [cugêñna] 'comb-Perf. Vent.'
(Data from Frajzyngier 1980)

In Pero, CCC clusters are not allowed on the surface. Sequences of three consonants will be broken up by an epenthesized vowel. If such clusters contain underlying or derived geminates, then the geminates will show up on the surface without being split by an epenthetic vowel, showing the integrity effect of the geminates (6) (cf. Goldsmith 1990).

Now, let us look at another example from Berber showing that integrity holds with derived geminates.

³ In rule-based approaches, since total assimilation is regarded as the autosegmental spreading of features, it creates true geminates at the output.
In Berber (Guerssel 1978), clusters of the form CCC as in (7) are broken by schwa epenthesis.

(7) \(t^+bz\partialy \rightarrow t\dot{b}z\partialy\)  \hspace{1cm} \('she is wet'\)
\(t^+f\partialr \rightarrow t\partialf\partialr\)  \hspace{1cm} \('she hid'\)

In addition, as shown in (8) and (9), the first of two consecutive coronal segments agrees in voicing with the second

(8) \(t^+dlu \rightarrow ddlu\)  \hspace{1cm} \('she covered'\)
\(ad^+t^+ru \rightarrow attru\)  \hspace{1cm} \('she will cry'\)

Figure (9) displays the integrity effect of the geminate derived by assimilation.

(9) \(/C - C C V/\)

\begin{verbatim}
| | | |
| t d l u |
\end{verbatim}

: Voicing Assimilation

\begin{verbatim}
| / | | |
| d l u |
\end{verbatim}

 BLOCKED : Schwa Epenthesis

\begin{verbatim}
[C C C V]
| / | | |
| d l u |
\end{verbatim}
The examples in (8) all have a three consonant cluster. Thus, we might expect Schwa Epenthesis to apply to the forms in (8). However, such an operation would result in incorrect output forms as shown in (10).

(10) *dɔdlu
    *aŋtru

Here, the /dd/ and /tt/ that result from voicing assimilation create true geminates, which blocks Schwa Epenthesis.

In summary, monomorphemic underlying geminates and heteromorphemic geminates derived by assimilation are subject to integrity, as illustrated in (5), (6), (8) and (9).

1.2.1.2 Inalterability

In this section, I present some typical cases of inalterability that might be useful to show the special behavior of geminates with respect to several phonological processes. As in the integrity case, it will be also shown that fake and true geminates are different regarding inalterability.

Geminates often escape rules when an application would modify one half of the geminate while leaving the other unchanged. For example, according to Hayes (1986), in
Modern Persian [v] is realized as [w] when it follows a short vowel and is not syllable-initial (cf. Cowan and Yarmohammadi 1978, Suh 1995a).

(11) a. σ σ σ
    /||  ||  ||
    miː:-raev-aem
    Pres.-go-ing

b. σ σ
    /||  ||
    bo-row (<bo-raev/)
    Imp.-go

The root [raev] 'to go' is realized as such in [miː-raev-aem] 'I am going', but is realized as [row] in the imperative [bo-row] 'go'. Now we can consider how this /v/-weakening rule might be expected to affect a true geminate /vw/. Since /v/ is linked to a coda position following a short vowel, we might conclude that it would undergo this rule. However, the /v/-weakening rule does not apply to any part of a geminate even though the first half occupies the coda position of a syllable (e.g. ærvæl 'first', morovväet 'generosity', qolovv 'exaggeration'; *[owvæl], *[morovväet], *[qolowv]; *[owvæl], *[morovwäet], *[qoloww]). As we can see in the case of /v/-weakening in Modern Persian, monomorphemic underlying true geminates are subject to inalterability.

---

* A subsequent rule changes [æ] to [o] before [w].
Derived true geminates from total assimilation are also subject to inalterability. Tigrinya spirantization obligatorily turns a postvocalic velar or uvular stop into a spirant (Hayes 1986, Schein and Steriade 1986). However, a true geminate /kk/ derived from assimilation shows no spirantization.

Thus far, we have looked at true geminate structures. Now let us consider fake geminate structures. Fake geminates show a different behavior with respect to inalterability as in integrity cases. Each half of a fake geminate behaves like a normal single consonant. This can be tested in Tigrinya. As can be seen below, we can create a fake geminate /kk/ by attaching a /k/-initial suffix to a /k/-final stem. Such a /kk/ does not respect inalterability.

\[
\begin{align*}
(12) \quad /y\ddot{d}-t-k\ddot{k}\ddot{f}\ddot{a}t/ & \rightarrow y\ddot{d}kk\ddot{f}\ddot{a}t \\
& \quad (*y\ddot{d}xx\ddot{k}\ddot{f}\ddot{a}t/ \ast y\ddot{d}xk\ddot{f}\ddot{a}t) \\
& \quad \text{‘open-Passive-Jussive’}
\end{align*}
\]

\[
\begin{array}{ccc}
V & C & + & C \\
| & | & | & |
\end{array} \quad \rightarrow \quad \begin{array}{ccc}
V & C & C \\
| & | & |
\end{array}
\]

\[
\begin{array}{cc}
t & k & k & (\text{Kenstowicz 1982: 118})
\end{array}
\]

\[
\begin{align*}
(13) \quad /m\ddot{d}rak-ka/ & \rightarrow m\ddot{d}raxka \quad \text{‘calf-2sg. Masc.’}
\end{align*}
\]

\[
\begin{array}{cc}
V & C & + & C \\
| & | & | & |
\end{array} \quad \rightarrow \quad \begin{array}{c}
V & C & C \\
| & | & |
\end{array} \\
\begin{array}{ccc}
k & k & x & k
\end{array}
\]
Accordingly, the first /k/ of the clusters can spirantize as shown in figure (13).

In summary, we have observed that true geminates (monomorphemic underlying, and heteromorphemic derived by total assimilation) are subject to integrity and inalterability, but fake geminates are not.

1.2.2 Previous Approaches to Geminates

This section addresses some problems which are found in the traditional rule-based approaches to geminate behavior. Previous approaches which have been proposed to explain the behavior of geminates can be collectively termed the Linked Gemination Approach (cf. Sherer 1994). Linked gemination takes the doubly-linked structure itself to be relevant to the representation of geminates with respect to phonological phenomena. The underlying representation of a geminate, then, is a consonant linked to two timing slots, such as C or X. This approach includes McCarthy (1979, 1986), Clements and Keyser (1983), Levin (1985), Hayes (1986), Schein and Steriade (1986), Ito (1989), and also Selkirk’s (1990) Two Root Theory. In Selkirk’s Two Root Theory, feature geometry is introduced into this matter employing root nodes (not CV or X) as the timing units. That is, it essentially employs feature geometry to represent linked consonant sequences and geminates. In any case, the double linking is primary not derived. This makes fine contrast with the moraic theory of geminates which includes primarily a mora with a simple consonant without the double linking at underlying representation. Here.
the double linking results on the surface through independent and different motivations from Linked Gemination Approach. Thus, it can be said that while the Linked Gemination Approach represents geminate consonants using length, moraic theory represents geminate consonants using inherent weight (i.e. mora).

Linked Gemination claims that the structural description of a rule should be satisfied by the input and, in turn, the input should be satisfied by the structural description of the rule (Hayes 1986, Schein and Steriade 1986). Satisfaction is determined by matching associations in the structural description and the input.5

There are two major problems with the Linked Gemination model. First, in that model, rules are designed to match against input. That is, the rules are designed to affect only non-geminates, so they cannot affect geminates in every way. However, a prediction about phonological behavior of geminates could be made by some other method. As Scobbie (1992) points out, inalterability cases are often "weakening" examples (cf. Churma 1988). According to the Linked Gemination Approach, the fact that geminates are immune to such rules is not explained by the theory of weakening, but rather is explained by the doubly-linked representations. In other words, it does not account for the fundamental reason why geminates behave differently from singletons in a specific way. Appealing simply to the structural representation does not explain the correlation with "weakening".

5 In this sense, Scobbie (1992) terms the analyses of Hayes (1986), and Schein and Steriade (1986) as the "Strong Satisfaction" approach. For the details, see Scobbie (1992).
Second, according to the linked structure of geminates, geminates are represented as single segments linked to two skeleton units. This structure contrasts with sequences of two identical short segments created by morpheme concatenation, and is assumed to show phonologically different behavior. That is, by the very nature of doubly-linked structure of geminates, geminates are unsplittable by epenthesis, and are subject to the inalterability phenomenon. However, the Linked Gemination Approach is too strong as has been criticized by many researchers (Goldsmith 1990, Selkirk 1990, Scobbie 1992, Cho and Inkelas 1993, among others). Geminates are not always inalterable just because of the linked structure itself. Geminates can be alterable (e.g. palatalization in Hausa and Luganda, Korean Post-Obstruent Tensification, Icelandic Preaspiration, etc.). Geminates can also be seen as being splittable by epenthesis (e.g. Marshallese). For these reasons, I find the Linked Gemination Approach unacceptable. As an alternative, in this thesis, I propose that inalterability and integrity are typical effects due to the interaction of output constraints and not the way in which a rule’s structural description matches against input. By changing our focus from the input to the output, the Optimality Theory approach becomes conceptually quite appealing. In this regard, I turn to an overview of Optimality Theory now.
1.3 Optimality Theory

Optimality Theory (OT) is a system of constraint interactions in phonology (McCarthy and Prince 1993a, 1995, Prince and Smolensky 1993, etc.). OT pursues the best satisfaction of universal constraints, which are ranked into language-specific dominance hierarchies by individual grammars. Thus, it can be said that a language-particular grammar is a means that language uses to resolve the conflicts among universal constraints. One thing to note is that a constraint is not a phonotactic truth at some level of description, but is recognized as a legitimate constraint usable as a general principle of grammar.

OT relies on universal, soft (i.e., violable) constraints that are prioritized on a language-specific basis. With respect to the universality of constraints in OT, McCarthy and Prince (1993a: 34) emphasize that “languages differ only (or principally) in constraint ranking, not in the formulation of constraints.” This says that the set of constraints in OT is universal, and so is their formulation. Thus, only constraint ranking is language-specific in OT.

*LaCharité and Paradis (1993) provide a retrospective on the emergence of constraints, comparing three current constraint-based approaches: Declarative Phonology (DP), Optimality Theory (OT), and the Theory of Constraints and Repair Strategies (TCRS). For more detailed discussion of the framework of DP and TCRS, see Scobbie (1991), and Paradis (1988a,b) and Paradis and Prunet (1988), respectively, among others.*
1.3.1 The Character of the Optimality Theory

The basic assumption of OT is that universal grammar consists of a set of constraints on representational well-formedness. These constraints are so conflicting that some constraints will be violated in any given language.

In Optimality Theory, there is no step by step derivation. Instead, it focuses on the constraints that underlie phonological changes. The course of an OT "derivation" can be characterized as follows. An input form is a morpheme or morpheme concatenation as can be seen in any other theory of phonology. Then the input form is fed into a function called Gen which produces the set of candidates that will undergo evaluation.

There are four basic tenets of OT, as conceived by Prince and Smolensky (1993) and McCarthy and Prince (1993a):

(14) Principles of OT

a. Violability
   Constraints are violable: but violation is minimal.

b. Ranking
   Constraints are ranked on a language-particular basis: the notion of minimal violation is defined in terms of this ranking.

c. Inclusiveness
   The constraint hierarchy evaluates a set of candidate analyses that are admitted by very general considerations of structural well-formedness.
d. Parallelism

Best-satisfaction of the constraint hierarchy is computed over the whole hierarchy and the whole candidate set. There is no serial derivation.

In traditional generative theory, a series of rules would apply to derive attested surface forms. In OT, however, surface forms are freely generated in the grammar by Gen. However, Gen's production of a candidate set is governed by the following three principles which are shown in (15).

(15) Gen (Prince and Smolensky 1993, McCarthy and Prince 1993a)

a. Freedom of Analysis: Any amount of structure may be posited.

b. Containment: No element may be literally removed from the input form. The input is thus contained in every candidate form.

c. Consistency of Exponence: No changes in the exponence of a phonologically-specified morpheme are permitted.

Gen is the function that provides the candidate analyses. Freedom of analysis says that Gen is without language-particular constraints. Containment restricts Gen: every input form is represented or contained in the output. Containment no longer holds in this dissertation, however, since we adopt Correspondence Theory proposed by McCarthy and Prince (1995) (see section 1.3.3 Correspondence Theory). Consistency of exponence
says that whatever phonological material is found in an output candidate, the phonological material representing a particular morpheme is the material found in the input representation (Pulleyblank 1993). Put differently, the purely phonological changes have no morphological effect. This means that epenthetic material has no morphological affiliation, and failure to parse phonological material does not change the make-up of morpheme (cf. Heiberg 1993).

When the constraints have eliminated all but a single candidate, that candidate is considered as the actual output form to which the input form is mapped. This form is called most harmonic or optimal. This optimal form does not satisfy every constraint. It may violate some constraints. However, we call this form optimal since its violation against the set of constraints is minimal when compared with all other competing candidates. In other words, its satisfaction of the constraints are maximal, or most harmonic, thus optimal.

1.3.2 An Illustration

As an illustration, let us take an example from Yawelmani (Archangeli 1997). For a given input form /logw-hin/, Gen, the generator, can create a candidate set of potential output forms: [log.hin], [lo.g/w.hin], [log.whin], [logw.hin], etc. Now, from this potential candidate set, Eval, the evaluator, will select the best (i.e. optimal) output form for that input form. This procedure is given in the following diagram.
In the above example, /logw-hin/ 'pulverized' is given as the input form in Yawelmani.

From this, Gen produces possible output forms. Now, a set of universal constraints. Con, evaluates the candidate set. Here, in Yawelmani, let us suppose that Con contains the following constraints:

(17) Con

a. **FILL:** Do not add anything
b. PARSE: Do not delete anything
c. *COMPLEX: Syllable edges are restricted to one consonant only
d. ONS: Syllables must have onsets

Since constraints can conflict each other, some constraints can be violated. Also, the constraints are ranked. Violation of a lower ranked constraint is tolerated to satisfy a
higher ranked constraint. Ties of a higher ranked constraint are resolved by a lower ranked constraint. A chart, called "tableau", will be used to prove which candidate is the most harmonic, or optimal. FILL is subordinate to PARSE and *COMPLEX in Yawelmani. Thus, the ranking will be like (18).

(18) Ranking of the Constraints in Yawelmani

PARSE, *COMPLEX >> FILL

The constraint ONS is undominated in Yawelmani. That is, in Yawelmani all syllables have onsets. Thus, this constraint (and candidates which violate ONS) will be omitted from our discussion.

(19) Example: Yawelmani

<table>
<thead>
<tr>
<th>/logw-hin/</th>
<th>PARSE</th>
<th>*COMPLEX</th>
<th>FILL</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. [log.hin]</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. [log.whin]</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>c. [logw.hin]</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>d. [log w.hin]</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

The tableau is intended to aid in understanding how constraints interact. A tableau contains a representation of some of the candidates created by Gen for an input
form and some of the constraints evaluating them. In the tableau, constraints are ranked left to right in descending rank. If constraints are not ranked with respect to each other, a dotted or dashed line separates them. The lefthand column shows a partial candidate set of outputs created by Gen. From an infinite number of candidates, only the most likely candidates are given for consideration. A violation of a constraint is marked with an asterisk (*) in the appropriate cell. An exclamation point (!) indicates a fatal violation which removes a candidate from the running. Multiple *s in a cell indicate multiple violations which shows that these are gradient constraints. Optimal candidate selected by Eval is indicated by "o" in the lefthand column. Finally, shaded cells show irrelevant constraints. Since the optimal form is already decided, we do not need to see any more constraints below the shaded point. In addition to these standard notations, I use a dot (.) to indicate syllable boundary.

Now, going back to the tableau (19), we can easily see that candidate (d) is selected as the optimal output form, since the other candidates (a), (b) and (c) crucially violate the higher ranked constraints PARSE and *COMPLEX, respectively. Although candidate (d) violates FILL, this violation is less severe than the violations in (a), (b) and (c), due to the constraint ranking. In this way, [lo.giw.hin] which has an epenthetic vowel on the surface is correctly selected as the actual output form in Yawelmani.
1.3.3 Correspondence Theory

In this dissertation, the analysis of geminate behavior is cast in the framework of Optimality Theory, as developed by Prince and Smolensky (1993), McCarthy and Prince (1993a, b and c, 1995). In particular, aspects of Correspondence Theory expounded by McCarthy and Prince (1995) play a central role in our analysis of integrity and inalterability effects of geminates. According to McCarthy and Prince (1995), Correspondence Theory is set within Optimality Theory, and the argument of which essentially calls on three fundamental ideas of Optimality Theory: parallelism of constraint satisfaction, ranking of constraints, and faithfulness between derivationally-related representations. Correspondence Theory is an extension of the reduplicative copying relation of McCarthy and Prince (1993a) to the domain of input-output faithfulness, and further to any domain where identity relations are established. In place of PARSE/FILL type of system presented in McCarthy and Prince (1993a) and Prince and Smolensky (1993), in which the input is maintained as a literal substructure of the output, a notion of correspondence relation between representations plays a key role. MAX-IO and DEP-IO are defined as follows:

(20) a. MAX-IO: Every segment of the input has a correspondent in the output (No phonological deletion.) (McCarthy and Prince 1995, Prince and Smolensky 1993)

b. DEP-IO: Every segment of the output has a correspondent in the input (Prohibits phonological epenthesis.) (McCarthy and Prince 1993a, Prince and Smolensky 1993)
1.3.4 Factorial Typology

Optimality Theory can offer us a systematic theory which describes possible grammars of the languages through the combination of the set of constraints. Since different languages employ different rankings of the same set of constraints, each hypothesized set of constraints predicts a typology of possible languages. In principle, the number of possible rankings is the factorial of the number of constraints under consideration. If we consider all possible rankings, then we yield what Prince and Smolensky (1993) call a factorial typology.

Suppose a language employs three constraints, A, B, C. Let us assume the following ranking is required for this language: A \(>>\) B \(>>\) C ("\(>>\)" indicates a ranking relationship, with A above B, and again B above C). In addition to this, we can expect 5 more languages with the rankings as shown in (21).

(21) Language 1: \(A >> B >> C\)
Language 2: \(A >> C >> B\)
Language 3: \(B >> A >> C\)
Language 4: \(B >> C >> A\)
Language 5: \(C >> A >> B\)
Language 6: \(C >> B >> A\)
In actuality, however, all these possible combinations are not realized in the grammars of the languages. The reason is that some rankings cannot be distinct from each other, and some constraints can be undominated. Furthermore, some constraints may not interact with each other, and so forth.⁷

1.4 Layout

The major concern of this thesis is how to characterize the special behavior of geminates, known as integrity and inalterability under Optimality Theory. The central argument to be made in this thesis is that the proposed key constraints and their interaction can explain every type of integrity and inalterability as well as anti-integrity and anti-inalterability in a predicted and systematic way. In the following, I lay out the main results of the thesis.

For the analysis of geminate integrity effect, a set of key constraints are proposed according to the positions in which geminates occur. Depending on the ranking of the key constraints, languages select different output forms from the same input form. In other words, the key constraints not only conspire to prefer an anti-integrity effect (i.e. "what not to do"), they also determine what a language does "do" with its input geminates, giving rise to different resolutions to the geminate puzzle.

⁷ For detailed discussion of this issue, see chapters 3 and 6 of Prince and Smolensky (1993). Especially, the reader is referred to chapters 1.3.3 and 2 of Sherer (1994). For a simple yet instructive illustration of the factorial typology using Yawelmani, Spanish and English, see Archangeli (1997).
In the analysis of medial geminates, the three constraints play pivotal roles: MAX-IO, DEP-IO and PLONS. Of the three constraints, the two constraints MAX-IO and DEP-IO are already defined above in (20a and b), so all we need to add here is PLONS.

(22) PLONS: If there are Place features, then they must be in onsets (cf. Steriade 1994)

In medial geminates, four types of geminate behaviors are predicted with the three key constraints as shown in the following chart (23).
(23) The Predicted Typology of Medial Geminates

<table>
<thead>
<tr>
<th>Pattern</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>PLONS</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. [VC_1C_1C_2V]</td>
<td>*</td>
<td></td>
<td></td>
<td>Pero (cf. Ponapean)</td>
</tr>
<tr>
<td>b. [VC_1C_1C_2V]</td>
<td></td>
<td>*</td>
<td></td>
<td>Palestinian Arabic</td>
</tr>
<tr>
<td>c. [VC_1(2)C_1(2)V]</td>
<td>*(seg)</td>
<td></td>
<td></td>
<td>not attested</td>
</tr>
<tr>
<td>d. [VC_1C_2V]</td>
<td>*(μ)</td>
<td>*</td>
<td></td>
<td>unlikely</td>
</tr>
</tbody>
</table>

From the 4 types of patterns, however, only two types are attested: (i) DEP-IO is lowest ranked (a) (i.e. MAX-IO, PLONS >> DEP-IO). (ii) PLONS is ranked below the other two constraints (b) (i.e. MAX-IO, DEP-IO >> PLONS). For the first case, I exemplify Pero, in which an epenthetic vowel is inserted after the geminate breaking up the word-medial
cluster. Here, DEP-IO violation is incurred. Ponapean will be also discussed in this context. For the second case, I exemplify Palestinian Arabic. The other two predicted types are not attested yet. However, I will not be surprised if there exist languages showing the third pattern, in which MAX-IO(seg) is lowest ranked (c). In this sense, I regard this gap as accidental, not systematic. The fourth pattern (d) is not likely to exist since (b) is better under normal circumstances.

Vowel insertion after a word-final geminate causes a discrepancy between word-final and morpheme-final elements. Not surprisingly, ALIGN(WD-R, M-R) plays a pivotal role in the analysis of integrity effects in word-final geminates in addition to the 3 key constraints presented above. ALIGN(WD-R, M-R) is defined as follows:

\[(24)\] ALIGN(WD-R, M-R) The right edge of every word coincides with morpheme final elements (McCarthy and Prince 1993a, b, c, 1994)

The aspects of word-final geminates are shown in the following schematized tableau (25).
(25) The Predicted Typology of Final Geminates

<table>
<thead>
<tr>
<th>/VC₁C₂/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ALIGN (WD-R, M-R)</th>
<th>PLONS</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. [VC₁C₂]</td>
<td></td>
<td></td>
<td>*(μ)</td>
<td>*</td>
<td>Palestinian Arabic, Ponapean</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← If PLONS is lowest ranked (see 23b)</td>
</tr>
<tr>
<td>b. [VC₁]</td>
<td>*(μ)</td>
<td></td>
<td></td>
<td>*</td>
<td>unlikely</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← (a) is better</td>
</tr>
<tr>
<td>c. [VC₁C₂V]</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td>unattested</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← If DEP-IO and ALIGN(WD-R, M-R) are lower ranked than PLONS</td>
</tr>
</tbody>
</table>

In final geminate case, however, only one type is attested (a), out of 3 predicted types of geminate patterns. Palestinian Arabic and Ponapean will be examined for the case where PLONS is low-ranked in final geminates. The other two predicted types are not attested yet. However, I will not be surprised if there exist languages showing the third pattern (c), in which DEP-IO and ALIGN(WD-R, M-R) is lowest ranked (c). In this sense, this pattern remains unexplained as accidental gap. The second pattern (b) is not likely to exist since (a) is better under normal circumstances.
In initial geminates, ONS and PROSHIER are added to the three key constraints. Additionally, NO BREAKING plays a key role in explaining anti-integrity effect shown in Ratak dialect of Marshallese. These constraints are defined as follows:

(26) a. ONS  
Syllables begin with a consonant (Prince and Smolensky 1993)

b. PROSHIER  
All instances of a prosodic category must be dominated by an immediately higher prosodic category, if there is any (cf. Selkirk 1984)

c. NOBREAKING  
No element of the input has multiple correspondents in the output (McCarthy and Prince 1995)

As a result, the predicted typology in initial geminates increases as shown in (27).
(27) The Predicted Typology of Initial Geminates

<table>
<thead>
<tr>
<th>/C&lt;sub&gt;1&lt;/sub&gt;C&lt;sub&gt;1&lt;/sub&gt;V/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>PROS HIER</th>
<th>NO BREAKING</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ/μ</td>
<td>*(μ)</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/C&lt;sub&gt;1&lt;/sub&gt;V/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. [C<sub>1</sub>C<sub>1</sub>V]

Σ

| / | / σ |
| / | /

μ/μ

| / | / |

C<sub>1</sub>V

Woleaian

← If PROSHIER is lowest ranked

b. [C<sub>1</sub>V]

σ

| / | / μ |
| / | /

C<sub>1</sub>V

Ponapean, Fijian

← If MAX-IO(μ) is lowest ranked

c. [VC<sub>1</sub>C<sub>1</sub>V]

σ σ

| \ / |

μ μ/μ

| / | / |

VC<sub>1</sub>V

Berber

← See footnote (8)

d. [VCVC<sub>1</sub>C<sub>1</sub>V]

σ σ

| / / |

μ μ/μ

| / | / |

VC<sub>1</sub>V

Ralik

← If DEP-IO is lowest ranked

e. [CVC<sub>1</sub>C<sub>1</sub>V]

σ σ

| / / |

μ μ/μ

| / | / |

CVC<sub>1</sub>V

Ratak

← If NOBREAKING is lowest ranked
Out of five possible predicted types of initial geminate patterns, four types are attested: (a), (b), (d) and (e).^8

In summary, geminate integrity effect is explained in a systematic and predicted way using the key constraints and their interactions. In this regard, the OT account is favored over the standard “No Crossing” account, which addresses only what languages do not do, but which does not address what they do.

For the inalterability/anti-inalterability effects, the constraint IDENT-IO(μSF) is proposed as defined in (28).

(28) IDENT-IO(μSF): The output correspondent of an input moraic strong feature F is F (McCarthy and Prince 1995)

In the analysis of the inalterability/anti-inalterability effects of geminates, the constraint IDENT-IO(μSF) is very active.

^8 With respect to (c) where DEP-IO and ONS are low ranked, Berber (Saib 1977) seems to fit into this type. However, one thing interesting about Berber is that non-geminate clusters as well as geminate clusters behave in the same way without distinction regarding vowel epenthesis. Thus, Berber is not adequate for the discussion of geminate integrity effects in initial position (That is, non-geminate clusters also show integrity effects in Berber).
First, I argue that *inalterability* effects are the result of the universally top-ranked IDENT-IO(μSF) (where SF is [-sonorant], [-continuant], [-voiced], [+spread glottis]). Thus, only weakening processes show geminate inalterability effects due to the top-ranked IDENT-IO(μSF). As evidence for the weakening cases, I present Klingenheben's Law in Hausa and Tiberian Hebrew Spirantization. On the other hand, *anti-inalterability* effects result from an irrelevant nature of the universally high ranked constraint IDENT-IO(μSF) and low-ranked NOBREAKING. For the cases of anti-inalterability, we give such examples as Hausa Coronal Palatalization, LuGanda Velar Palatalization, Korean Post-Obstruent Tensification and Icelandic Preaspiration.9

In summary, it is argued here that geminate inalterability/anti-inalterability can be more effectively accounted for in a restricted way when it is analyzed in connection with the theory of weakening (see section 2.6.2 Geminate Inalterability under Moraic Theory). According to our assumption, only singletons can undergo weakening. Geminates can only be weakened by degemination. If the features of geminates are affected by some processes, then we can predict that those processes are not weakening, but assimilation or others. These are formally expressed by the ranking of the key constraint, IDENT-IO(μSF).

---

9 I would say, however, that Icelandic Preaspiration is a case of a potential anti-inalterability, since anti-inalterability effect is realized in the phonetic component, not in the phonological component (see section 4.8.3 Icelandic Preaspiration: A Potential Counterexample to Inalterability (/C.C/ → [C.C])).
1.4.1 Gaps in the Predicted Types of Geminates

With respect to the geminate integrity effect, I layed out the types of languages that my model predicts exist (figures (23),(25),(27)). However, we observed that all the predicted types of languages are not attested. We now are in a position to discuss the gaps between what is predicted to exist and what cases are attested. In this section, I provide a discussion of the cases my model predicts exist but for which I found no examples.

First, in medial geminates, we predicted a pattern in which MAX-IO is low ranked, resulting in deletion of the segment in order to satisfy such high ranked constraints as DEP-IO and PLONS (23c). As we can see throughout the analysis of the geminate integrity effects in each position, however, the only case where MAX-IO is low ranked is found in initial geminates (27b). Thus, (23c) is a case of accidental gap. On the other hand, vowel epenthesis is frequently found cross-linguistically.

I attribute this accidental gap to the recoverability of the lexical information. From the perceptual point of view, epenthesis preserves the input information, satisfying conflicting constraints (*COMPLEX, PLONS, etc.) by resolving articulatory problems. On the other hand, deletion can cause the loss of the input information. As a result, in the worst case deletion might bring about some communication problems.

Itô (1986) discusses this issue in view of the interaction between epenthesis and erasure. According to her, stray erasure is universal, while epenthesis is language-
specific. From this assumption, we can infer that epenthesis must always precede erasure in its application, otherwise language-specific epenthesis would not found. It further implies that stray erasure occurs only if there is no language-specific epenthesis. Her argument, then, suggests that languages tend to preserve input information, and deletion may occur when it does not cause any problem in retrieving the input information. For that reason, we can find some cases in which deletion does occur in non-geminate consonant clusters (e.g. Korean, Attic Greek, etc. (Steriade 1982, Itô 1986). That might explain why we find epenthesis more often than deletion cross-linguistically.

As discussed above, epenthesis and deletion are both possible surface patterns, thus, they should be predicted by way of constraint rankings in OT. However, frequency effect is not encoded in the ranking, thus, the surface realization of the predicted patterns (between epenthesis and deletion) will be totally subject to empirical verification.

In summary, with respect to the gap shown in (23c), my prediction is that it is an accidental gap, thus it awaits empirical evidence. However, for the reasons discussed above in relation to epenthesis, deletion will be rather rare compared with epenthesis.

The gap shown in (23d) seems to be different from (23c) in its nature. This time, the gap appears to be systematic, not accidental. The pattern in (23d) is unlikely to occur because (23b) is better. Thus, under my hypothesis, (23b) will appear on the surface instead of (23d).
Now, let us look at the gaps found in final geminates. In final geminates, only one type is attested out of three predicted types of languages. The pattern in (25c) is predicted when \textsc{dep}-\textsc{io} and \textsc{align}(\text{wd-r}, \text{m-r}) are lower ranked than \textsc{plons}. However, this type of languages is not found. In final geminate case, if we put an epenthetic vowel word-finally to satisfy \textsc{plons}, then we also have an \textsc{align}(\text{wd-r}, \text{m-r}) violation, and \textsc{align}(\text{wd-r}, \text{m-r}) violation seems to be critical in some languages. For example, in Ponapean, epenthesis occurs to satisfy \textsc{plons} word-medially. However, epenthesis does not occur word-finally. As a result, \textsc{plons} violation is tolerated to satisfy \textsc{align}(\text{wd-r}, \text{m-r}), word-finally. Word-medial epenthesis can cause the violation of \textsc{align} which requires coincidence between stems and syllables. On the other hand, \textsc{align}(\text{wd-r}, \text{m-r}) violation is incurred word-finally. This seems to suggest that word-final word-morpheme alignment is more important than word-medial stem-syllable alignment. Since \textsc{align}(\text{wd-r}, \text{m-r}) comes into play in word-final position as an additional factor, it is not surprising that we do not always find the same pattern as in medial epenthesis.

Non-geminate consonant clusters behave differently from geminate ones word-finally. Some word-final deletion cases are reported in non-geminate consonant clusters (e.g. Korean, Attic Greek, Lardil (Hale 1973, Wilkinson 1988), etc.). On the other hand.
word-final epenthesis is very rare.\footnote{One exceptional case is found in Harari, a Semitic language of Ethiopia (Itc 1986, Halle and Vergnaud 1987). In Harari, an epenthetic vowel [i] is inserted after the final consonant in a word-final cluster (e.g. 'y-
sābr' \rightarrow [yisābr] '3 masc imperfect-break').} The asymmetry between epenthesis and deletion in word-final position can be partly attributed to the fact that existing final consonants are favored over epenthetic vowels in that position. That is, consonants are better than epenthetic vowels in word-final position if codas are allowed at all (cf. WEAKEDGE (Spaelti 1994). Then, we have to ask why we have deletion word-finally where epenthesis is not allowed. I assume deletion occurs word-finally because of the compulsion of \*COMPLEX in non-geminate clusters. If \*COMPLEX is dominant in a language, MAX-IO will be violated to satisfy \*COMPLEX, in spite of ALIGN(WD-R, M-R) violation. However, deletion is not necessary in word-final geminate clusters, since \*COMPLEX is irrelevant in geminate clusters under my hypothesis.

The pattern in (25b) is predicted, but is not attested. This type of language is not likely to exist since (25a) is better under those constraints and their interaction. Thus, I consider (25b) as a systematic gap.
Finally, let us consider initial geminates. Basically, all types of the languages are attested in initial geminates. The pattern in (27c) is problematic, however, in the sense that both geminate clusters and non-geminate clusters show integrity effects without discrimination as shown in Berber (Saib 1977) which is provided for an evidence for this pattern. Thus, we need languages which show a real case for the geminate integrity effect predicted in (27c).

1.5 The Structure of the Dissertation

This dissertation is laid out as follows. Chapter 2 provides other general assumptions than the basic theoretical tenets of OT, which will be called upon frequently in the course of the analysis of geminate behaviors. This chapter will be mainly the nature of geminates regarding integrity and inalterability, involving proper phonological representation of geminates and discussion of weakening and assimilation with respect to geminate inalterability.

Chapters 3 and 4 turn to the detailed focus on two special behaviors of geminates within the Optimality Theory framework: integrity and inalterability.

Chapter 3 is an analysis of the integrity/anti-integrity effects of geminates in different positions of a language: medial, final and initial. I provide a full Optimality Theoretic analysis of the language data, including the relevant constraints, rankings, and full tableaux for relevant input forms.
Chapter 4 examines two predicted types of the geminate behaviors which are characterized as inalterability and anti-inalterability effects. First, Hausa Palatalization and Klingenehebn's Law data are analyzed to motivate the need of recognizing the distinction between "weakening" and "assimilation" in the analysis of inalterability effect of the geminate. Klingenehebn's Law in Hausa represents the type of weakening known as coda sonorantization, and palatalization represents the type of assimilation. Next, Tiberian Hebrew Spirantization data are presented to show how geminate inalterability is explained in the case of spirantization, known as another type of weakening. For the types of anti-inalterability effects, LuGanda Velar Palatalization, Korean Post-Obstruent Tensification, and Icelandic Preaspiration data are analyzed.

Chapter 5 summarizes this dissertation and provides theoretical and empirical implications of my approach to the behavior of geminates. Some remaining issues will be also discussed.
CHAPTER 2
THE NATURE OF CONSONANT GEMINATES

2.1 Introduction

Geminates have long been observed to exhibit special behavior such as integrity and inalterability including a resistance to rules which affect singletons or sequences of nongeminate consonants. In standard generative phonological approaches, where rules are designed to match against input, the rules are proposed based on non-geminate data, and by doing so, they account for geminate inalterability, indirectly. That is, geminates represented doubly-linked underlyingly do not satisfy the structural description of the rule application, and thus they do not undergo the phonological rule. In this way, inalterability effects are derived.

In this chapter, I will investigate the structural representation of consonant geminates in connection with Moraic Theory. I will also discuss different proposals on the representation of geminates (Selkirk 1990). I will defend standard moraic theory proposed by McCarthy and Prince (1986) and Hayes (1989). The result of this exploration will shed light on some central questions regarding the issues of geminate integrity and inalterability.
2.2 Background: The OCP


(1) Obligatory Contour Principle (OCP)
At the melodic level, adjacent identical elements are prohibited.

For example, in the domain of tone, the OCP rules out representations like (2):

(2) \[ \begin{array}{c}
*H \\
| \\
\sigma
\end{array} \begin{array}{c}
H \\
| \\
\sigma
\end{array} \]

McCarthy (1986) claims that the Obligatory Contour Principle (OCP) is a principle of universal grammar. Among the claims made in McCarthy (1986), I restrict myself to the following claim which is directly related with geminates:

(3) Lexical representations must obey the OCP.¹

¹ Furthermore, McCarthy (1986) argues that the so-called Antigemination restriction on Syncope is the result of the OCP. However, Odden (1988) argues that McCarthy's claims on Antigemination based on the OCP cannot be maintained due to the many counter-examples found cross-linguistically. We will not address this issue here, but those problems raised by Odden (1988) could be resolved under the current approach.
Following the above idea (3), underlying geminates have been represented as having a single segment associated with two skeletal slots (Hayes 1986, Schein and Steriade 1986). Hayes (1986) in particular argues that geminate integrity and inalterability are properly explained if we assume that geminates are single segments associated to two skeletal positions. Given such a doubly-linked representation for geminates, a rule of epenthesis will not be able to insert a vowel between the halves of a single root geminate, since doing so would violate the principle that association lines may not cross (cf. Goldsmith 1976) as shown in (4).

(4) *C V C
   \ \ / \
   \ /\ 
   t i

However, one of the main claims of OT is that there are no constraints on input representations (Prince and Smolensky 1993, and McCarthy and Prince 1993a). This further suggests that it is not necessary that any constraints hold of underlying representations. This, however, raises an interesting question in the case of geminates. If we consider that input constraints are not required, and that the imposition of the OCP is strictly restricted to outputs, then a variety of input types can be postulated. Whatever input is postulated, the ranking of the constraints will correctly produce the optimal
output for the postulated input. This sharply contrasts to the standard derivational theory in which an output is derived by the step-by-step application of rules to some particular input forms, and not others (cf. Pulleyblank 1994). In this dissertation, however, we just follow the central claims of the Optimality Theory about the imposition of the constraints on the output. Thus, the OCP is not imposed as a condition on lexical representations. Then, we have ambiguous representations of the geminate. To clarify this ambiguity of the geminate representations, I employ the Geminate Minimization Principle (Mester 1986), which enforces us to represent the geminate as having a single root node irrespective of the OCP. Note also that Pulleyblank (1994) argues, on the basis of the analysis of harmony system, cases which are thought to require OCP-related constraints on input forms can be derivable strictly from output constraints consideration.2

According to Steriade (1982), Archangeli (1985), Clements (1985), Mester (1986), Sagey (1986), McCarthy (1988), and Selkirk (1990), feature structures are viewed as a hierarchical organization which is a representation of the domination and sisterhood relations between the features (see also Hong 1994). Mester (1986), for example, proposes a theory of the dependent-head relation.

2 For further discussion, see Pulleyblank (1994, section 4. Underlying Representations).
(5) The Dependent-Head Relation (Mester 1986)

\[ \alpha \begin{array}{c} H \\ \mid \\ \beta F \end{array} \] Dependent

(where H dominates F)

When a feature H immediately dominates a feature F as in (5), H and F are said to be in a dependency relation, and H is called the head and F the dependent. Mester (1986) assumes that each of the feature tiers is individually subject to the OCP. However, manner features which correspond to his core composed of [cons], [son] and [cont] in Mester (1986), are not subject to the OCP.³

Following the main idea of Mester (1986), the root, a structural tier like the skeleton, is immune to the OCP. The reason is that if the root were subject to the OCP, a cluster like pt could not exist. They share the same manner features but different place features. The following representation in (6) will clarify the points.

³ Selkirk (1990) also assumes that a sequence of identical specifications for [cont] or for the major class features [cons] and [son] is not subject to the OCP.
We have seen that the OCP cannot enforce a strictly monomelodic representation for the geminates for the reasons given above. Aside from the OCP, however, geminates still can have two possible representations, namely (7a) and (7b).

In (7a), a single root node can be doubly-linked to two different positions in prosodic (syllable/mora) structure. In (7b), however, two root nodes can be separately linked to two different positions in syllable/mora structure.
Mester (1986) proposes the Geminate Minimization Principle to restrict the representational ambiguity of geminates. This principle says that identical root units cannot share all melodic features; in such cases, root nodes will be merged into one, resulting in a single root node for geminates.

Since Hayes (1986) and Schein and Steriade (1986), there has been a lot of discussion on the proper representation of geminates to account for their special behavior. With the continued development of the notion of prosodic theories and feature geometry, representations of geminates have been elaborated with new eyes. Regardless of the differences in details, however, the approaches can be classified into two groups, segmental theories of length and standard moraic theory of length. The segmental theories of length can be collectively called linked gemination approach since the linking itself is central to the representation of geminates (Hayes 1986, Schein and Steriade 1986, McCarthy 1979, Clements and Keyser 1983, Levin 1985, Selkirk 1990, Itô 1989). In the following discussion, I consider two versions of the representation of geminates: (i) standard moraic theory of length, and (ii) segmental theories of length (a.k.a. linked gemination approach). First, we look at standard moraic theory of length (Hyman 1985, McCarthy and Prince 1986, Hayes 1989, Itô 1989, among others).
2.3 Standard Moraic Theory of Length

In this dissertation, the representation of geminates in the lexicon follows that of McCarthy and Prince (1986) and Hayes (1989) in having a geminate be represented in the lexicon as a *simple consonant with a mora*.

Thus, according to standard moraic theory of length, geminates versus singletons are represented as underlying moraic versus nonmoraic, respectively, as shown in (8):

(8) Underlying Representation of Standard Moraic Theory of Length

<table>
<thead>
<tr>
<th>a. Geminate Consonant</th>
<th>b. Single Consonant</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu )</td>
<td>( \mu )</td>
</tr>
<tr>
<td>( \rightarrow )</td>
<td>( \rightarrow )</td>
</tr>
<tr>
<td>( \text{Rc} )</td>
<td>( \text{Rc} )</td>
</tr>
<tr>
<td>( \rightarrow )</td>
<td>( \rightarrow )</td>
</tr>
<tr>
<td>( [F] )</td>
<td>( [F] )</td>
</tr>
</tbody>
</table>

According to (8), there is only one root node preassociated to a mora. On the surface, however, underlying moraic C gets additional prosodic structure (i.e. double-linking) through syllabification.
Let us call this one-root moraic representation of geminate as Standard Moraic Theory of Length.

2.3.1 Motivations for Moraic Structure

In a moraic theory, the prosodic tier which consists of morae replaces the skeletal tier (CV or X tier). In this framework, there is no need for defining a heavy syllable in languages that have a quantity-sensitive stress system since it automatically encodes the weight unit mora in the syllable structure: a syllable is universally considered heavy if it has two morae. In addition to that, the moraic theory has been proven to be quite effective in explaining compensatory lengthening (Hayes 1989) and reduplication phenomena (McCarthy and Prince 1986).
In moraic theory, the mora has a double role. First, it represents weight, the well-known contrast between light and heavy syllables: a light syllable has one mora, a heavy syllable has two. Second, it represents a phonological position: just as in earlier theories, a long segment is represented as being doubly-linked. Thus, weight and phonological timing slots are represented by the same unit, mora (Hyman 1985, McCarthy and Prince 1986, Hayes 1989). It can be seen, however, that moraic theory views the lexical representation of geminate consonants as encoding inherent weight rather than length. Thus, in moraic theory, contrastive mora count, not length per se, is represented underlyingly. In languages with contrastive length, the long vowels and/or consonants are underlyingly associated with morae, to indicate their distinctive status. On the other hand, doubly-linked structure of geminates will be produced by the process of syllabification on the surface. Such a representation has very different implications from a segmental representation where the difference is only on the level of prosodic timing units and not the weight (Lahiri and Koreman 1988).

2.3.2 Weight and Length in Moraic Theory

In standard moraic theory, however, it has not been clearly presented how weight and length work together and why both of the notions are necessary in the description of geminates. As a result, it gives the impression that they overlap and one of them is
redundant somehow. In the following section, I will clarify the function of weight and length perceived in moraic theory.

2.3.2.1 Weight

As we have seen earlier, geminates versus singletons are represented as underlingly moraic versus nonmoraic, respectively. According to the version of moraic theory proposed in Hayes (1989), the cross-linguistic weight variation of coda consonants is achieved by Weight by Position given in (10).

(10) Weight by Position (Hayes 1989: 258)

\[
\begin{array}{c}
\sigma \\
| \\
\mu \\
\rightarrow \\
\mathcal{V} \mathcal{C}
\end{array}
\quad \rightarrow 
\begin{array}{c}
\sigma \\
| \\
\mu \mu \\
| \\
\mathcal{V} \mathcal{C}
\end{array}
\]

Unless consonants are neither a geminate nor syllabic, they are not underlingly moraic. but by WBP coda consonants get a mora in languages where CVC syllables count as heavy. Such syllables then will be called heavy having two moras like CVV syllables. The functional equivalence of CVV and CVC syllables, as opposed to CV syllables holds true for numerous languages over several phonological phenomena, including stress
assignment (e.g. Latin (Hayes 1981, Halle and Vergnaud 1987, Steriade 1988), Lake Miwok (Kiparsky 1973, Hayes 1981, Halle and Vergnaud 1987)). Here, a mora (weight unit) functions to explain the fundamental equivalence of CVV and CVC syllables (including geminates). By contrast, skeletal models explain this fact by means of the CV or X tier. Especially, the skeletal models represent geminate consonants using length (with double linking) not weight, at all stages.

\[(11)\]  
\[\begin{array}{l}
a. \ C \ C \\
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ /\ \\
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ t
b. \ X \ X \\
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ /\ \\
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ t\end{array}\]

2.3.2.2 Length

While weight is represented with an underlying mora, length is realized by association to two prosodic/skeletal positions. A geminate gets additional prosodic structure (i.e. double linking) through syllabification. In standard moraic theory, discussion has been mainly focused on intervocalic geminate consonants, and thus descriptions on peripheral geminates and nonintervocalic ones remained unexplained.

Let us first look at intervocalic geminate cases. Intervocalically, geminates end up in their syllable structures like (12), under the moraic analysis.
This structure results from (i) onsets must be provided if possible (thus ensuring double linking of association lines in geminates) (ii) onsets cannot be moraic (thus ensuring the moraic consonant is also in the coda). However, it is argued here that there is another important point which is not addressed in previous moraic theory. As pointed out in Tranel (1991), some difficulties are caused by moraic theory's notation for geminate consonants when they occur in final position in languages with WBP. On the surface, we cannot distinguish a final geminate from a singleton final coda consonant: both are moraic and singly linked. Thus, to make this point clear, I propose that geminates must be represented with doubly linked consistently through syllabification process. Unlike previous moraic theory, a geminate gets double linking from different motivations according to the positions in which a geminate occurs. The following is the possible types of representations of geminates.
(13) a. [tta]  

\[
\begin{array}{ccc}
\Sigma & \sigma & \sigma \\
/ & / & / \\
\sigma & \sigma & \sigma \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
a & t & a \\
\end{array}
\]

(with WBP)

d. [at]  

e. [aktta]  

\[
\begin{array}{ccc}
\sigma & \sigma & \sigma \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
a & t & a \\
\end{array}
\]

(without WBP)  

(with WBP)

f. [akkta]  

g. [akta]  

\[
\begin{array}{ccc}
\sigma & \sigma & \sigma \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
a & t & a \\
\end{array}
\]

(with WBP)  

(without WBP)

h. [akta]  

\[
\begin{array}{ccc}
\sigma & \sigma & \sigma \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
\mu & \mu & \mu \\
a & t & a \\
\end{array}
\]

(with WBP)  

(without WBP)
Thus, in this thesis, in addition to figure (12), figures (13a), (13b) and (13e & f) are used for the representations of the initial, final, and medial geminates, respectively.

Another problem about moraic theory is identified by Tranel (1991). In such languages as Selkup (Halle and Clements 1983), Malayalam (Mohanan 1986), and Tibbatulabal (Swadesh and Voegelin 1939, McCawley 1969), CVC syllables behave as light, even in geminates. Under standard moraic theory, however, this is problematic since those languages do not have WBP, but the underlying mora assumed to be carried by geminates predicts the wrong results. Moraic theory is too strong in the sense that it predicts that a CVC syllable should always count as heavy if the coda consonant is part of a geminate, even in languages where CVC syllables otherwise count as light as illustrated in (14).

(14)  a. heavy [CVC,CjV]  b. light [CVC,CjV]

\[
\begin{array}{cc}
\sigma & \sigma \\
/\mu & /u \\
/\mu & /\mu \\
/\mu & /\mu \\
CVC,CjV & CVC,CjV \\
\end{array}
\]

On the basis of the assumption that no languages show weight contrast like (14) above, Tranel (1991) proposes the Principle of Equal Weight for Codas: \textit{Coda portions of \ldots}
geminate consonants behave in the same way as other coda consonants with respect to syllable weight.\(^4\)

Moraic theory couched within Optimality Theory, however, would no longer be a problem, since unlike rule-based approaches, Optimality Theory approach can produce nonmoraic geminate consonants on the surface through constraint interactions. We can produce the following three possible output forms from an underlying geminate.

\[(15) \text{ Input: } \mu \]
\[
\begin{array}{l}
\text{ | } \\
\text{/ata/}
\end{array}
\]

\[
\begin{array}{cccc}
\text{Output: a. [atta]} & \text{b. [atta]} & \text{c. [ata]} \\
\sigma & \sigma & \sigma & \sigma \\
\| & \| & \| & \| \\
\mu & \mu & \mu & \mu \\
\| & \| & \| & \| \\
a & t & a & a & t & a
\end{array}
\]

\(^4\) Icelandic might be a counterexample to the Principle of Equal Weight for Codas. Icelandic Preaspiration shows that geminates are moraic, but singleton codas are not moraic. Thus, singleton codas are lengthened (i.e. geminated) to satisfy bimoraic requirement of the stressed syllable (for detailed discussion, see section 4.8.3 Icelandic Preaspiration: A Potential Counterexample to Inalterability (/C,C/ \rightarrow [C,C\_])). If this is a true output fact, then, it means that we have the following patterns: (i) geminates are moraic and singleton codas are not moraic (e.g. Icelandic), (ii) both geminates and singleton codas are not moraic (Selkup, etc.). These output facts will not be a problem to the Moraic Theory within OT, since those patterns can be produced on the surface without any difficulty. However, the Standard Moraic Theory still holds the problem in dealing with the pattern (ii).
In (a) underlying geminate is realized intact on the output form. The forms in (b) and (c) are produced if MAX-IO(μ) is violated.\(^5\)

Given this, the above-mentioned problem is resolved. If we assume MAX-IO(μ) is lower ranked and thus is violated in those languages, then geminate and nongeminate codas will behave equally satisfying the Principle of Equal Weight for Codas. The following table summarizes the predictions made by moraic theory and moraic theory within Optimality Theory with respect to surface geminate facts. Here, [CVC\(_G\)] indicates that the syllable is closed by the first half of a geminate consonant and [CVC] by a simple consonant.

(16) Moraic Theory vs. Moraic Theory within OT

<table>
<thead>
<tr>
<th>[CVC(_G)] - [CVC]</th>
<th>Output Facts</th>
<th>Moraic Theory within OT</th>
<th>Moraic Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy ((\mu\mu)) - Heavy ((\mu\mu))</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heavy ((\mu\mu)) - Light ((\mu))</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Light ((\mu)) - Light ((\mu))</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Light ((\mu)) - Heavy ((\mu\mu))</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

As we can see in (16), Moraic Theory incorrectly predicts that geminates are always moraic (thus, heavy) when non-geminate coda consonants are not moraic (shaded cells in

---

\(^5\) The exact output forms between (b) and (c) will be determined according to the phenomena in question. For example, if we deal with degemination (e.g. \(tt' \rightarrow [t]\)), then the form in (c) will be realized. However, we do not enter into the detailed discussion of this issue here, since it is beyond our scope.
the table shows this aspect). On the other hand, Moraic Theory within OT correctly produces output forms on the assumption that MAX-IO(µ) is lowest ranked and is thus violated in some languages.

Thus far, I have discussed the nature of geminate consonants and their representational characteristics concerning weight and length of moraic theory. Furthermore, I have elaborated some unclear and problematic parts of moraic theory with the perspective of Optimality Theory. I now turn to the discussion of segmental theories of length as comparison with moraic theory of length.

2.4 Segmental Theories of Length

As established in the preceding section, in moraic theory the prosodic tier is represented with a mora instead of the notion of segment, while both CV and X theory can be characterized as segmental views of the prosodic tier. Thus, in CV and X theory, the number of prosodic elements corresponds to the number of segments it contains. Selkirk's (1990) Two-Root Theory of Length is also segmental since two root nodes are introduced as the timing units: geminates are linked to the two timing units. Since I have briefly talked about the assumptions and implications of CV and X theory when I present moraic theory, I will not address the matter here. Instead, I will discuss the two root theory of geminates proposed by Selkirk (1990).
2.4.1 Two-Root Theory of Length

Unlike the moraic theory of geminates, the segmental approach to the representation of geminates directly takes the linking structure itself as relevant. This approach includes McCarthy (1979), Clements and Keyser (1983), Levin (1985) and Selkirk (1990). Specifically, the so-called Two-Root Theory of Length (Selkirk 1990) is discussed for our purposes.

According to this theory, there are two root nodes which are not preassociated to a mora.

(17) Two-Root Theory of Length

\begin{align*}
\text{a. Geminate Consonant} & \quad \text{b. Single Consonant} \\
\bullet \quad \bullet : \quad \text{Root nodes} & \quad \bullet : \quad \text{Root node} \\
\setminus / & \quad / \quad [F] \quad [F]
\end{align*}

According to Selkirk (1990), the Two-Root Theory of Length assumes two root nodes for the geminate structure. In an attempt to explain geminate inalterability and the recalcitrant cases like Icelandic Preaspiration, Selkirk (1990) proposes a two-root representation for the geminates which employs feature geometry in the representation of linked geminates. Thus, the above representation in (17) will be realized as in figure (18).
(18) Two-Root Theory of Length (Selkirk 1990)

a. • Root nodes  b. • Root nodes
    \[\alpha\ cons\] \[\alpha\ cons\] \[\alpha\ cons\] \\
    \[\beta\ son\] \[\beta\ son\] \[\beta\ son\] \\
    \[\chi\ cont\] \[\chi\ cont\] \[\delta\ Place\] \\
    \[\delta\ Place\] \\

According to this representation, Root nodes are made of specifications for the features consonantal and sonorant (cf. McCarthy 1988). In vowel case, geminates have identical root nodes (18b). In consonant case, additionally geminates have the same specification for continuant (18a). The two structures of geminates are doubly linked for Place.

Selkirk (1990) proposes that phonological rules can alter geminates only when the output would be well-formed and in that way is similar to an OT approach. The two relevant well-formedness constraints are the Place-Stricture Dependency Principle (PSDP) and the Multiple Linking Constraint (MLC) (Selkirk 1990).

(19) Place-Stricture Dependency Principle (PSDP)
The major place features (Labial, Coronal, Dorsal) are dependent on the feature Continuant. In the absence of Continuant, they are dependent on the root node.

(20) The Multiple Linking Constraint (MLC)
A multiply linked dependent feature must have identical heads.
The PSDP holds that the place node is a dependent of [cont], or in the absence of that feature, of the Root node complex which is composed of the features [son] and [cons]. The MLC constrains the association between higher and lower structure. Thus, the MLC would predict the blockage of any rules changing such feature values as [cons], [son], and [cont] in just one half of a geminate. Accordingly, rules like spirantization, sonorantization, and vocalization would not occur if such rules would destroy the identity between the heads of the dependent Place features of geminates. That is, it would allow major place assimilation between stops or between fricatives, but not between stops and fricatives, as shown in (21).

(21) • • • • • • : Root nodes  

| | | | | |  

a. [+cont] [+cont]  

\ \ \  

[PI]  

b. [-cont][-cont]  

\ \ \  

[PI]  

c. *[-cont][+cont]  

\ \ \  

[PI]  

These two principles work together with Selkirk's two-root node assumption of geminates, predicting geminate inalterability whenever a phonological rule would change the content of only one Root node of a geminate.

Hayes (1990) and Selkirk (1990) take Icelandic Preaspiration as the case against the one root structure of geminates. The formal expression of preaspiration of Icelandic
does not seem to be straightforward under the one-root structure of geminates. In
Icelandic, the geminate voiceless aspirated stops /pʰpʰ, tʰtʰ, kʰkʰ/ are realized on the
surface as [hp, ht, hk] (Thráinsson 1978, Hayes 1990). As Hayes (1990: 5) presents,
deletion of the supralaryngeal tier produces an incorrect form *[ahha] not [ahpa] as
shown in (22). (22a) shows the input and (22b) shows the surface form.

(22) a. /pʰpʰ/

\[\begin{array}{c}
C C \\
\backslash \\
/ \\
ROOT \\
/ \ \\
LARYNGEAL SUPRALARYNGEAL \\
TIER TIER \\
/ \ \\
[+spread][-\text{voice}] [-\text{nas}] \text{PLACE/MANNER} \\
TIER \\
/ \ \\
\text{MANNER TIER PLACE TIER} \\
/ \ \\
[-\text{son}] [-\text{cont}] \text{LABIAL}
\end{array}\]
b. *[hh]

```
* C C
\ /
ROOT
|  /
LARYNGEAL
TIER
|
[+spread][-voice]
```

Again, the representation provides no way of delinking the supralaryngeal specification of the /pʰpʰ/ from the first half of the geminate, since the two prosodic positions are linked to one Root node. That is, if we remove its first link, we get the incorrect form having an empty C followed by a single [pʰ], not the correct form [hp]:
Examples such as Icelandic Preaspiration seem to pose a serious problem for the standard moraic theory of length due to the one-root gemination structure. It appears that Icelandic Preaspiration cannot be formally expressed, if both supralaryngeal and laryngeal features are doubly-linked to the skeleton through a single Root node.

On the other hand, Selkirk (1990) analyzes Icelandic Preaspiration as a simple delinking process. This is possible since in her representation there are two root nodes. Thus, the laryngeal features can be separated into two separate laryngeal specifications on the two halves of the geminate without violating the MLC. Icelandic Preaspiration under Selkirk’s (1990) analysis is illustrated in (24).
(24) a. /\p^p\p/  

C   C
|   |   Root nodes
  •   •:

[+cons] [+cons]
[-son] [-son]
/ \ / 
L SL   L SL
/ \ / 
[-SG] [-nas] [-SG] [-nas]
[-voice] [-voice] [-voice]
[-cont]   [-cont]   [-cont]
\ / \ 
\ / \ 
\ / \ 
Lab

b. [hp]  

C   C
|   |   Root nodes
  •   •:

[+cons] [+cons]
[-son] [-son]
| / |
L   L SL
/ \ / 
[-SG][-voice] [-voice] [-nas]
\ / 
[voice] [-voice]
\ / 
[voice] [-voice]
\ / 
Lab
Standard moraic theory seems to face difficulties in dealing with Icelandic Preaspiration, but as we will see in detail in chapter 4, those problems can be easily coped with under our OT approach.

Selkirk (1990) also analyzes geminate inalterability based on the above mentioned feature dependency together with the two-root structure of the geminate.\(^6\)

However, some crucial problems with Selkirk's (1990) approach are identified by Inkelas and Cho (1993: 539). First, violations of the MLC occur and are later repaired as in Finnish Gradation. This means that the MLC is not an exact predictor of geminate inalterability. Second, homorganic nasal-obstruent clusters raise objection to this approach. In that structure, nonidentical root nodes share place features. Thus, violation of the MLC occurs in that structure.\(^7\) Third, Selkirk's (1990) theory is limited to inalterability phenomena only. In actuality, other theories also have the same limitation in them. They do not provide a comprehensive analytic method to the issues of integrity as well as inalterability of geminates cross-linguistically. In this sense, the present approach is more comprehensive and has more predictive and explanatory power.

---

\(^6\) See also Archangeli and Pulleyblank (1987), Cho (1989), Hayes (1990), Scobie (1992), Inkelas and Cho (1993), and McDonough (1995) for different approaches to inalterability and discussion of the two-root representation of the geminate. However, none of these approaches say anything about the integrity phenomena.

\(^7\) Inkelas and Cho (1993) also argues that Selkirk's (1990) MLC is problematic by giving evidence from the cases of nasal-fricative assimilation. The MLC would predict that nasals never assimilate in place to fricatives, since in that case [-cont] and [-cont] segments linked to the same place node would violate the MLC. Inkelas and Cho (1993) report nasal-fricative assimilation is found in Spanish (Harris 1969: 8-9, Hooper 1976: 181) and Hausa (Abraham 1959: 154, 158, 160), Kpelle (Welmers 1973: 67). According to Padgett (1992), however, cases of this sort are very rare for the same reason that nasalized fricatives are rare. Furthermore, he suggests that the nasals assimilated to the following fricatives are in fact [-cont], not [-cont]. Considering these controversies, we will not include nasal-fricative assimilation case as the evidence against the MLC.
compared with previous approaches, explaining both integrity and inalterability in a
unified way based on the same theoretical background.

It seems desirable, however, that Selkirk (1990) tries to explain geminate
inalterability from the perspective of output constraints. However, in her approach the
output constraints such as the MLC are hard ones which cannot be violated at all.
Moreover, the MLC is not well defined. For example, the following cases violate the
MLC and cannot be explained in her model. First, /v/ → [w] weakening in Modern
Persian displays the geminate inalterability effect, but it does not violate the MLC.
Second, Place features other than stricture features (cons, son, cont) can cause geminate
inalterability (e.g. Latin) against her prediction. With respect to the first case, the MLC is
contradictory. It is assumed that homorganic nasal-obstruent clusters satisfy the MLC as
shown in (25).

(25) NC Clusters

<table>
<thead>
<tr>
<th>Root nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>[+cons]</td>
</tr>
<tr>
<td>*[+son]</td>
</tr>
<tr>
<td>/</td>
</tr>
<tr>
<td>nasal [-cont]</td>
</tr>
<tr>
<td>\</td>
</tr>
<tr>
<td>Lab</td>
</tr>
</tbody>
</table>
In (25), Lab constitutes a multiply linked structure and has identical heads (i.e. [-cont] and [-cont]). Thus, the NC structure satisfies the MLC. However, this argument cannot be true in the case of /v/ → [w] weakening in Modern Persian.

(26) /vv/ → *[wv] (Persian Weakening)

\[
\begin{array}{c|c}
\text{Root nodes} & \\
\hline
[+cons] & [+cons] \\
[-son] & [-son] \\
\mid & \mid \\
[+cont] & [+cont] \\
\hline
\text{Lab} & \text{Lab} \\
\end{array}
\]

In this case, the MLC would predict that the change of the geminate /vv/ to [wv] is no problem since a multiply linked dependent feature Lab has identical heads (i.e. [+cont] and [+cont]). In Persian, however, the representation in (26) is not well-formed, displaying the geminate inalterability effect against the prediction of the MLC.

Let us consider another example from Klinghenheben’s Law in Hausa. Selkirk demonstrates that the MLC blocks Klinghenheben’s Law in Hausa from affecting geminate obstruents. Inserting [+son] on the first of two root nodes with shared dependents would introduce an asymmetry between the two heads of the geminate, violating the MLC. Thus, the rule is blocked from applying (Selkirk 1990 via Inkelas and Cho 1993: 539).
In actuality, however, according to Selkirk's (1990) MLC, Hausa sonorantization case should not be ruled out by the asymmetry between the two root nodes. In consonant case, [cont] is specified, so the root node cannot play a role as the head of the linked structure. Instead, it will be ruled out due to the asymmetry between the two [cont] heads as shown in (28).

This implies that only [cont] identity is responsible for weakening, contrary to our expectation that both [son] and [cont] are responsible for that in Hausa case. Thus, the MLC is not well-defined and insufficient to explain the linked structure of the geminate with respect to weakening.
With respect to the second case, geminate /ll/ resists l-Velarization in Latin. Thus, geminate /ll/ does not become [ll] on the surface, showing again the geminate inalterability effect. However, in Selkirk's (1990) model, there is no way to rule out this case since Place features cannot constitute the multiple linking structures.

Thus far, we have considered Selkirk's (1990) Two-Root Theory of Length. Although Selkirk's (1990) model tries to capture the geminate inalterability effect using the two surface well-formedness constraints (the PSDP and the MLC), it seems to be inadequate for the theory of the geminate inalterability due to the several problems identified above discussion.

From above discussion, we can capture the following points. First, weakening has two possibilities. In Persian /v/ → [w] case, only root nodes matter since the two linked elements are both [+cont]. In Hausa weakening, known as Klingenberg's Law, however, both root nodes and [cont] do matter. [-cont] elements become [+cont] and [+son]. Second, spirantization cares for only [cont]. That is, root nodes are inert with respect to spirantization. On the basis of the observations made here, I will propose a constraint IDENT-IO(μSF) which will play a central role in the exposition of the geminate inalterability effects in weakening cases (see Chapter 4).
2.5 Current Assumptions: Summary

In this thesis, I assume one root moraic theory of length for the phonological representation of geminates, following McCarthy and Prince (1986) and Hayes (1989). In order to explain geminate behavior effectively, it will be necessary to assume that geminates have a representation with one root node with a mora. In addition to this, I assume the following points regarding the proper representation of the geminates.

(29) Summary of the Representation of Geminates

a. Geminates are doubly-linked in any position.

b. Weight and phonological timing units are represented by the same unit, mora.

c. Mora directly represents weight.

d. Length is represented with double linking of association lines through syllabification process.

2.6 The Nature of Geminate Integrity and Inalterability

In this section, I briefly characterize the overall nature of geminate integrity and inalterability under the Moraic Theory couched within OT, which I will take up in depth in chapter 3 and chapter 4.
2.6.1 Geminate Integrity under Moraic Theory

Integrity does matter when we view geminates that are underlyingly represented as doubly-linked to two timing slots (X-tier, CV-tier, and two root nodes for the geminate). Because geminates are linked to two prosodic tiers in Segmental Theories of Length (a.k.a. Linked Gemination Approach), it is possible in theory to allow the insertion of an epenthetic vowel inside the geminate consonants. Under this view, integrity effects are achieved by the universal No-Crossing Convention (cf. Goldsmith 1976).

(30)

\[
\begin{array}{c}
\text{* C V C} \\
\text{\textbackslash \textbackslash /} \\
\text{\textbackslash /} \\
\text{Rc Rv} \\
\text{[F]}
\end{array}
\quad \text{or} \quad
\begin{array}{c}
\text{* C V C} \\
\text{\textbackslash /} \\
\text{\textbackslash /} \\
\text{\textbackslash /} \\
\text{Rv Rc} \\
\text{[F]}
\end{array}
\]

Under current assumption, however, integrity effects are naturally derived from the one root moraic representation of geminates. Since the geminate is represented as having a single consonant with a mora, there is no reason to split the geminate by inserting an epenthetic vowel between the geminate consonants, under normal circumstances.
Thus, under moraic representation of geminates, integrity effects of geminates are not a difficult issue to deal with and appear to require no further mentioning.

However, OT allows underlying /C_C_V/ to be paired with the output form [C_VC_V] depending on constraints and their ranking as shown in Ratak dialect of Marshallese. So, integrity is an issue under OT, which will be discussed in detail in chapter 3.

In this Optimality Theoretic approach to geminate integrity, I will also provide the model which describes the general patterns of geminates with respect to consonant cluster problem and vowel epenthesis. It will be shown that depending on the ranking of the key constraints, languages select different output forms from the same input form, giving rise to different resolutions to the geminate integrity puzzle.

2.6.2 Geminate Inalterability under Moraic Theory

Schein and Steriade (1986), and Hayes (1986) understand geminate blockage or inalterability to be the result of an input constraint on the application of rules. The proposal I defend here is that geminate inalterability is a consequence of constraint interaction. However, in order to obtain this goal, it is necessary to examine the fundamental nature of geminate inalterability, first.

According to Churma (1988), most cases of inalterability are "weakening" examples (cf. Selkirk 1990, and Scobbie 1992). Thus, recognizing a distinction between
“weakening” and “assimilation” can allow for a theory which has significantly greater predictive power than those of Hayes (1986) and Schein and Steriade (1986). The following discussion is based on the ideas of Churma (1988) and Selkirk (1990).

Geminate inalterability can be partly explained by examining the intrinsic feature content of the rules that are blocked. That is, the inherent “strength” of geminate consonants seems to resist any weakening process other than degemination (cf. Churma 1988). Since the majority cases of the rules that are blocked from applying to geminates in the phonological literature are weakening cases, the fact that geminates are immune to such rules has to be explained in connection with the theory of Weakening (or Lenition) covering both geminates and singletons. Weakening is defined as given in (31).

(31) Weakening:

A weakening process has as output a segment that is higher than the input on the sonority hierarchy.

(Churma 1988)

On the other hand, assimilation is defined as follows.

(32) Assimilation:

An assimilation process has no sonority difference between the input and output, involving autosegmental spreading.

(cf. Churma 1988, Hayes 1986)
Our discussion of geminate inalterability starts from the observation that
geminates behave differently with respect to weakening and assimilation. I assume
weakening occurs according to the following system known as a “strength hierarchy”.

(33) Strength Hierarchy

geminates > voiceless noncontinuants > voiced noncontinuants > voiceless
fricatives > voiced fricatives > approximants > zero

(cf. Lass 1984, Churma 1988)

As we can see in (33), geminates are ranked atop in the strength hierarchy. Because of
this inherent strength of geminates as a unit, geminates resist any weakening process other
than degemination.

In order to make this point clear, I propose the following revised “strength
hierarchy” in (34).

(34) Strength Hierarchy (revised version)

a. geminates > singletons
b. singletons: voiceless noncontinuants > voiced noncontinuants > voiceless
fricatives > voiced fricatives > approximants > zero

According to the revised version of the strength hierarchy (34), we can predict 2
possibilities. The first prediction is about the geminates (cf. 34a), and the second
prediction is about the singletons (cf. 34b). First, concerning the prediction about the
geminates, if a phonological process has the effect of weakening, then a geminate must be
degeminated. That is, degemination does not cause featural change at all as (34a) predicts.
In OT terms, degemination will be possible by the violation of MAX-IO(µ), keeping all
the phonological features of the segments. Second, if a phonological process weakens a
singleton consonant, then weakening occurs according to the strength hierarchy given in
(34b).

The strength hierarchy given in (34a) captures the general observation that
geminates are not weakened cross-linguistically except for degemination. This fact will be
expressed in chapter 4 with a constraint which is essential in barring the weakening of
underlying geminates. From the revised version of the strength hierarchy (34), we can
draw the conclusion that "weakening" affects both geminates and singletons in a different
manner. By weakening, geminates are degeminated keeping all the features (34a). By
contrast, weakening of singletons is possible by changing phonological features as
suggested in Strength Hierarchy (34b). On the other hand, since "assimilation" has
nothing to do with weakening by definition, it can freely affect both simplex and geminate
consonants indiscriminately. That is, in most of the cases, since assimilation does not
result in weakening, geminates cannot be restricted from being affected by assimilation
characterized by autosegmental spreading of the features. Thus, assimilation is the matter
of spreading of the features, not the matter of weakening of the inherent "strength" of a segment (Churma 1988, Schein & Steriade 1986).

Another observation regarding geminates is that one half of the geminates can also be altered in such non-weakening cases as Korean Post-Obstruent Tensification. To capture this point, NOBREAKING will be used to interact with other constraints.

2.7 Summary of Chapter 2

In order to derive the desired result for geminate integrity and inalterability, I assume that geminates have a representation with a single consonant preassociated to a mora. Specifically, in this thesis the inalterability effect is accounted for in connection with the theory of weakening. Based on the observation of the data, I hypothesize that the weakening process cannot affect geminates except for degemination. Thus, if geminates are affected by any process, then we can predict that it is not a weakening process, but an assimilation process, which affects both simplex and geminate consonants indiscriminately.

Under this theoretical background, integrity and inalterability will be discussed, crucially assuming that those phenomena are a consequence of interactions of the universal constraints which are violable in nature. In order to obtain integrity and inalterability effect, I propose that IDENT-IO(\(\mu\)SF) and NOBREAKING are high ranked. In
chapter 3 and chapter 4, we look at specific cases of the geminate, characterizing in detail the integrity and inalterability effects, respectively. Let us begin that effort now.
CHAPTER 3
INTEGRITY EFFECTS IN GEMINATES

3.1 Introduction

Under the segmental approach to geminates, Kenstowicz and Pyle (1973) first observed that epenthetic segments typically cannot be inserted between the halves of long segments (i.e. geminates), a phenomenon known as "geminate integrity". Geminate integrity has been explained by a universal constraint against crossing association lines (Goldsmith 1976, Sagey 1988, Hammond 1988, Hayes 1986, Schein and Steriade 1986). Under this approach, however, there is no way to explain anti-integrity cases (e.g. Marshallese (Abo et al. 1976, Goldsmith 1990)) which seem to have the effect of allowing an epenthetic vowel within a geminate. Thus such cases have to be treated as mere exceptions (cf. Odden 1988, Goldsmith 1990).

Under the Optimality Theory framework, however, the universal constraint against crossing association lines cannot be responsible for the integrity effects of geminates, since GEN can create potential outputs which do not violate a universal No Crossing Constraint as shown in (1) (correspondences are indicated by subscripts).
One constraint ranking might select (b) while other rankings might select more faithful outputs, i.e. ones containing the geminate. Under OT, then, geminate integrity might be viewed as a general tendency, not an inviolable absolute principle.

This line of reasoning has quite far-reaching effects regarding geminate integrity, beyond those usually assumed. The moraic theory couched within OT not only can explain the geminate integrity phenomenon itself but also can explain the other options concerning consonant cluster problems, resulting in various types of integrity effects of geminates (e.g. 

(Here, italicized letters indicate epenthetic segments, and underlined sequences (CC) indicate geminates). In this regard, the OT account contrasts with the standard "No Crossing" story, which addresses only what languages don't do, but which does not address what they do.
3.1.1 Major Key Constraints

In this section, I present seven key constraints for the analysis of the geminate integrity effects (recall that they were already introduced in Chapter 1). Most of these constraints are found in McCarthy and Prince (1993a, 1995), and Prince and Smolensky (1993); they are listed in (2).

(2) a. MAX-IO: Every segment of the input has a correspondent in the output (No phonological deletion.) (McCarthy and Prince 1995, Prince and Smolensky 1993)

b. DEP-IO: Every segment of the output has a correspondent in the input (Prohibits phonological epenthesis.) (McCarthy and Prince 1995, Prince and Smolensky 1993)

c. NOBREAKING: No element of the input has multiple correspondents in the output (a.k.a. "INTEGRITY") (McCarthy and Prince 1995)

d. PLONS: If there are Place features, then they must be in onsets (cf. Steriade 1994)

e. ONS: Syllables begin with a consonant (Prince and Smolensky 1993)

f. ALIGN(WD-R, M-R): The right edge of every word coincides with morpheme final elements (McCarthy and Prince 1993a, b and c)

g. PROSHIER: All instances of a prosodic category must be dominated by an immediately higher prosodic category, if there is any (cf. Selkirk 1984)

These constraints are not new at all. MAX-IO, DEP-IO, and NO BREAKING (2a-c) are faithfulness constraints (Prince and Smolensky 1993, McCarthy and Prince 1995).
According to Correspondence Theory (McCarthy and Prince 1995), which relates two structures, such as base and reduplicant or input and output, constraints on faithfulness of the output to the input (cf. Prince and Smolensky 1993) and constraints on identity between the base and the reduplicant (cf. McCarthy and Prince 1993a) are united formally as correspondence relations.

On the other hand, PLONS and ONS (2d-e) are the wellformedness constraints on syllabification. They limit syllable typology of the languages of the world.

ALIGN(WD-R, M-R) (2f) is a kind of distributional constraint (Pulleyblank 1997; see McCarthy and Prince 1993c on Generalized Alignment), and PROSHIER (2g) might belong to one of the prosodic constraints.

We turn now to discuss each constraint in more detail.

3.1.1.1 Faithfulness: MAX, DEP, and NOBREAKING (2a-c)

First, MAX-IO and DEP-IO are core faithfulness constraints and so they are crucial to the whole OT model. MAX-IO is traced back to the prosodic licensing and stray erasure effects of Itô (1986). According to McCarthy and Prince (1995), the constraint MAX-IO reformulates PARSE in Prince and Smolensky (1993) and other OT work. The MAX family is broader than PARSE in that the former can be applied to the various phonological constituents. Depending on the correspondence relation, the MAX...
constraints will prohibit phonological deletion in syllabification, or will demand completeness of reduplicative copying in reduplication process. Here, MAX-IO prohibits the deletion of segments at the surface.

The DEP-IO constraint is similar to the function of FILL in Prince and Smolensky (1993) and other OT work, which militates against any empty mora or empty segment. Inserting an epenthetic vowel or consonant (empty or not) incurs a violation of DEP-IO. This also extends to reduplication and other correspondence relations.

NOBREAKING is a special type of faithfulness. NOBREAKING is proposed here to capture discrepancies in their segmental elements between the input and output structures. According to the Correspondence Theory of McCarthy and Prince (1995), NOBREAKING is another name for "INTEGRITY". In this thesis, to avoid confusion with the term geminate *integrity*, I will use NOBREAKING for the constraint "INTEGRITY" of McCarthy and Prince (1995). This constraint basically rules out the type of multiple correspondence, phonological copying, where one element of the input is split or cloned in the output, illustrated in (1). This constraint will play a crucial role in the analysis of anti-integrity and anti-inalterability cases.

3.1.1.2 Syllabification: PLONS and ONS (2d-e)

among others. PLONS plays a role in restricting the type of consonants that occupy the coda position. With regard to the constraint PLONS, the main idea of Steriade’s (1994) proposal is that consonantal point of articulation features are directly licensed in the onset, indirectly so in the coda: “[cF], where F is a consonantal point of articulation feature, must be licensed, in at least one associated segment, by membership in the onset.” (Steriade 1994: 43).

In this dissertation, however, I assume a strong version of PLONS, in which only the geminate and a sequence of homorganic nasal+stop satisfy PLONS.¹ Thus, such sequences as [lt], [rt], [dt], etc. are not considered to satisfy PLONS as we can see later in the discussion of Pero. In Pero, for example, /pen-tu/ ‘know and come’ becomes [pindu] instead of [pinnu] on the surface.² In the form [pindu], CODASON and PLONS are satisfied without being a geminate in homorganic NC structures. Thus, we do not need to make a sequence of homorganic nasal+stop a geminate to satisfy PLONS. On the other hand, such clusters as /lt/, /rt/ and /dt/ do not satisfy PLONS, thus they must be either geminated (e.g. [ll] and [rr]) or separated by an epenthetic vowel (e.g. [dvt]). As shown in the following diagrams, I suppose that PLONS is satisfied only if there is no conflicting feature specifications in place-linked structures.

¹ For different interpretation of the nature of codas, see Keating (1988) as she puts it, “coarticulation occurs in part because segments may lack inherent specification for particular articulations,” if a coda lacks a place specification, it is coarticulated with the following onset. See also Heiberg (in prep.) for the detailed discussion of the nature of coda consonants in general and its phonetic and phonological properties.

² Obstruents are voiced in homorganic NC clusters in Pero.
In (3), only (a) does not have a conflicting feature specification by underspecifying the nasal for voicing. In (b) and (c), conflicting feature specifications exist ([+cont] vs. [-cont] and [+voiced] vs. [-voiced]), respectively. Thus, among (a), (b) and (c), only homorganic NC structure (a) satisfies PLONS under our hypothesis. In most languages, a sequence of nasal+stop is found (together with the geminate) even when the languages do not allow coda consonants. This fact seems to support our hypothesis regarding PLONS even more, reflecting the fact that the place feature specification of the nasals is predictable from the following stop (cf. Kenstowicz 1994a: 525). As a result, only geminates and homorganic NC clusters are assumed to satisfy PLONS.

Another syllabic well-formedness constraint is ONS (Prince and Smolensky 1993). ONS requires that all syllables have onsets (i.e., vowel-initial syllables are prohibited). ONS plays an active role in the discussion of initial geminates.

### 3.1.1.3 Distribution and Prosody: ALIGN(WD-R, M-R) and PROSHIER (2f & g)

Following the proposals for alignment by McCarthy and Prince (1993a, b and c), I postulate ALIGN(WD-R, M-R) to capture the morpheme-final requirement on the surface
at the right edge of a word. As can be expected, ALIGN(WD-R, M-R) plays a key role in the analysis of final geminates. Such distributional constraints as ALIGN family of constraints will also play an important role in the cases of *harmony* or *assimilation* requiring that the domain of a feature extend to the edge of a constituent, for example, the edge of the root or the word. (see Pulleyblank 1997 for more discussion on this issue.)

Finally, prosody refers to the organization of sounds into larger phonological units (Hammond 1997). These include the mora (μ), the syllable (σ), the metrical foot (Σ), and the Prosodic Word (ω). The Prosodic Hierarchy in (4) is evolved from that of Selkirk (1980a and b, 1984):

(4) Prosodic Hierarchy

\[
\begin{array}{c}
\omega \\
| \Sigma \\
| \sigma \\
| \mu \\
\end{array}
\]
From the Prosodic Hierarchy in (4), the constraint PROSHIER is proposed, which requests that all instances of a prosodic category must be dominated by an immediately higher prosodic category.\textsuperscript{3}

This constraint is critical in the analysis of initial geminates. For the representation of initial geminates, I assume the following structure:

\begin{equation}
(C_1 V)
\end{equation}

In the above structure, PROSHIER violation is incurred because initial mora is not dominated by the immediately higher prosodic unit, the syllable (\sigma).

\textsuperscript{3} For the study of Prosody and Optimality Theory, see especially McCarthy and Prince (1993a) and Hammond (1997).
3.1.2 Summary

To summarize, we have laid out the key constraints which will be called upon in an analysis of geminate integrity effects. These constraints are independently motivated to explain a broad range of phonological phenomena cross-linguistically. The predictions in the following sections regarding word-medial, word-final and word-initial geminate consonants will be achieved by partially permuting the ranking of the key constraints, exactly as expected under OT.

From the exercise that will follow, we will be able to see that depending on the ranking of the key constraints, languages select different output forms from the same input form, giving rise to different resolutions to the geminate puzzle. In other words, the constraints not only conspire to explain geminate integrity effect itself, but also they determine what a language does with its input geminates. By doing so, we can account for both integrity effect and distributional properties of geminate consonants.

As we will see, geminates behave differently according to the positions in which they occur, word-initially, word-medially, or word-finally. In the following sections, we will address geminate integrity effects in great detail according to the positions, beginning with word-medial geminates.
3.2 Medial Geminates

3.2.1 Introduction

In figure (2), I have presented 7 major key constraints for the analysis of geminate integrity effects. In the analysis of medial geminates, however, only 3 key constraints are necessary out of the 7 constraints in (2).

In my view, there is no issue of an impermissible number of consonants in geminate clusters in a syllable margin since geminates are counted as one segment contrary to the nonmoraic approach to geminates in which geminate consonants are counted as having two segments. As a natural consequence of that reasoning, *COMPLEX is not relevant in the discussion of geminate clusters. (Note, however, that *COMPLEX plays a key role when we deal with word-initial homorganic nasal-obstruent clusters and non-geminate consonant clusters).

(6) *COMPLEX: Syllable edges are restricted to one consonant only (Prince and Smolensky 1993)

*COMPLEX limits syllable typology and is crucial for languages which do not allow C_{1}C_{2} syllable margins. *COMPLEX is motivated to express the prohibition of unacceptable consonant sequences at syllable edges. According to this constraint, tautosyllabic consonant sequences such as C_{1}C_{2} are prohibited. In connection with geminates, this
constraint is not violated in the structure of $VC_1C_1C_2V$ as long as the geminate consonants are syllabified solely as a coda on the surface.

(7) Syllabification of $[VC_1C_1C_2V]$: No *COMPLEX violation

\[
\begin{array}{c c}
\sigma & \sigma \\
\mid & \mid \\
\mu & \mu \\
\mid & \mid \\
VC_1C_2V
\end{array}
\]

This is possible since we assume geminates are single consonants with a mora in their underlying representation.

For that reason, I suggest that PLONS plays a key role in the explanation of the integrity effect in medial geminates.

For an illustration of this issue, let us consider Palestinian Arabic examples. There are two possibilities in explaining the surface pattern of $[VC_1C_1C_2V]$. The first possibility is my view, in which PLONS is low ranked and the geminate consonants are syllabified solely as a coda on the surface as shown in (7) above.
(8) Syllabification of \([VC_1C_1C_2V]\): *COMPLEX (O.K.), PLONS (*)

\[
\begin{array}{c}
\sigma & \sigma \\
\mu & \mu \\
\text{VC}_1\text{C}_2\text{V}
\end{array}
\]

The second possibility is to assume that *COMPLEX is low ranked and the geminate consonants are syllabified both in the coda and in the onset as shown in (9). In this structure, *COMPLEX is violated satisfying PLONS.

(9) Syllabification of \([VC_1C_1C_2V]\): PLONS (O.K.), *COMPLEX (*)

\[
\begin{array}{c}
\sigma & \sigma \\
\mu & \mu \\
\text{VC}_1\text{C}_2\text{V}
\end{array}
\]

Looking at medial geminates only, we cannot decide which view is right and effective in accounting for the geminate integrity effect in general. However, given the fact that *COMPLEX must be high ranked in Palestinian Arabic considering non-geminate consonant cluster data, the view that PLONS is low ranked seems to be more convincing than the view that *COMPLEX is low ranked. Since multiple segments are broken up by
an epenthetic vowel in Palestinian Arabic (e.g. /?ibn-ha/ → [?ibinha], *[/?ibnha] ‘her son’),
the view that *COMPLEX is low ranked cannot be maintained any more.

Thus, from now on I will assume that \([VC_1C_1C_2V]\) is realized on the surface because of the low ranked PLONS, not because of the low ranked *COMPLEX. For that reason, *COMPLEX is not included in the key constraints in explaining geminate consonant cluster issue. However, I do not argue that PLONS replaces *COMPLEX, and *COMPLEX is not necessary at all. On the contrary, *COMPLEX plays a pivotal role in word-initial homorganic NC clusters and critically in non-geminate consonant clusters. Thus, in a language where both geminate and non-geminate clusters are found we need *COMPLEX as well as PLONS in order to account for the overall pattern of the data, since either PLONS or *COMPLEX alone is not sufficient for the explanation of the behavior of those patterns.

Since the predictions are made solely based on the geminate data, I use PLONS instead of *COMPLEX. This movement from *COMPLEX to PLONS is owing to the moraic representation of the geminate in which geminate consonants are counted as single segment associated to a mora. Their functions seem to overlap somehow, but in reality their functions are quite different in many ways. Generally speaking, *COMPLEX actively deals with quantity problem (i.e. the number of the impermissible consonant sequences), while PLONS is essentially concerned with quality problem (i.e. restricting permissible featural quality of the coda-onset sequence).
By my consideration, ONS, NOBREAKING, ALIGN(WD-R, M-R) and PROSHIER are demonstrably irrelevant in the analysis of medial geminates. I do not include ONS since its violation necessarily induces DEP-IO violation, as well. NOBREAKING is not included because its violation also incurs DEP-IO and PLONS. ALIGN(WD-R, M-R) is not included merely because medial is not word-edge. PROSHIER is not included, either, because in [VC1C1C2V] form, moraic geminates are properly dominated by the syllable node.4

In summary, we have shown that 4 constraints out of the 7 proposed key constraints in (2) are not relevant in the discussion of medial geminates. In the following section, predictions will be made regarding the geminate integrity effect in medial position on the basis of the three key constraints, MAX-IO, DEP-IO and PLONS.

3.2.2 The Predicted Typology

This section lays out the predictions about geminate consonants in medial clusters that follow from permuting the three key constraints. In particular, we will try to show that different surface patterns result due to the lowest ranked constraint.

---

4 The two forms /...VC1C1C2V.../ and /...VC1C2C2V.../ can be syllabified differently on the surface and can have different effects with regard to the constraints. The first form is realized on the surface if PLONS is low ranked. On the other hand, the second form can be realized on the surface only when both PROSHIER and PLONS are low ranked, since I am assuming that *COMPLEX is not relevant in medial geminates. Under this view, then, the first pattern is predicted to occur more frequently than the second pattern since the former violates constraints less than the latter. For example, Palestinian Arabic displays the first pattern, not the second pattern. However, in order to claim that the first pattern is prevailing across the languages, we will have to examine the data more extensively. In spite of this asymmetry between the two forms, in this dissertation, I address the /...VC1C1C2V.../ pattern as representative of medial geminate clusters.
Optimality Theory is characterized by a system of ranked constraints. By varying the ranking of the given set of constraints, we predict different grammars, with different surface effects. This process of varying the ranking, called “factorial typology”, is discussed in Prince and Smolensky (1993). (See also Sherer 1994: chapter 2).

According to a factorial typology, 6 (3!=3x2x1) different rankings are possible out of the 3 key constraints given for medial geminates. However, the 6 possible cases are not realized in the case of medial geminates. When the constraints are considered in the context of word-medial geminates, only 4 effects are possible, and 2 empirical effects are attested: [VC₁C₂V] and [VC₁C₁V₁C₂V]. As is illustrated by (10), these output forms are produced if one of the key constraints is lowest ranked. That is, if DEP-IO is lowest ranked, then we will have [VC₁C₁V₁C₂V] on the surface. If PLONS is lowest ranked, we will have [VC₁C₁C₂V] output form. Here, two patterns are attested out of four: such languages as Pero, Palestinian Arabic, and Ponapean show these patterns.

To begin, consider the following chart showing input word-medial geminates in /VC₁C₁C₂V/ clusters and the constraint violations incurred by various output candidates.⁵

In medial geminates, four types of geminate behaviors are predicted with three key constraints as shown in the following chart (10).

⁵ Unsyllabified elements are omitted in the tableau.
The Predicted Typology of Medial Geminates (cf. figure (23) in Chapter 1)

<table>
<thead>
<tr>
<th>/VC_1C_1C_2V/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>PLONS</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/VC_1C_2V/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. [VC_1C_1VC_2V]  | *      |        | Pero  | (cf. Ponapean) |
| σ σ σ            |        |        | Unless DEP-IO is lowest ranked |
| \ | / | \ | / | \ | / | VC_1VC_2V |

b. [VC_1C_1.C_2V]  | *      |        | Palestinian Arabic |
| σ σ               |        |        | Unless PLONS is lowest ranked |
| \ | / | \ | / | \ | / | VC_1C_2V |

c. [VC_1(2)C_1(2)VC_2V] | *(seg) |        | Not attested |
| σ σ               |        |        | Unless MAX-IO(seg) is lowest ranked |
| \ | / | \ | / | \ | / | VC_1(2)VC_2V |

d. [VC_1.C_2V]      | *(μ)   | *      | Unlikely |
| σ σ               |        |        | Unless (b) is better |
| \ | / | \ | / | \ | / | VC_1C_2V |

The leftmost column in (10) shows how word-medial geminates might be realized on the surface through the interaction of the key constraints. In (10a), an epenthetic vowel is inserted after the geminate, violating DEP-IO alone, satisfying PLONS.
In (10b), input and output forms are identical, and this causes PLONS violation.

In (10c), there is deletion of the non-geminate/geminate consonant segment, thereby incurring a violation of MAX-IO(seg).

In (10d) both MAX-IO(µ) and PLONS are violated if half of the geminate is lost, which is worse than (10b).

From the 4 types of patterns, however, only two types are attested: (i) (10a): DEP-IO is lowest ranked (i.e. MAX-IO, PLONS >> DEP-IO) (ii) (10b): PLONS is ranked below the other two constraints (i.e. MAX-IO, DEP-IO >> PLONS). For the first case, I exemplify Pero (section 3.2.3), in which an epenthetic vowel is inserted after the geminate resolving the PLONS problem in a word-medial cluster⁶. Ponapean will be also discussed in this context (section 3.2.5). For the second case, I exemplify Palestinian Arabic (section 3.2.2). The other two types are not attested yet. However, since (10d) violates both MAX-IO(µ) and PLONS, it will not be selected in normal cases, regardless of the relative ranking of MAX-IO and PLONS. Instead, (10b) will be selected. According to our prediction, (10c) is a possible output pattern, which is subject to the empirical evidence.⁷

In the following, we examine case studies illustrating the two types of geminate integrity effects.

⁶ According to Kenstowicz (1994b), in many languages including English, Arabic and Yawelmani, the epenthetic vowel can freely enter inside a morpheme. On the other hand, Chukchee and Sierra Miwok (Sloan 1991) restrict the epenthetic vowel to morpheme gaps. In Axininca Campa, V+V hiatus is resolved by epenthesis of [t] in morpheme boundary. By contrast, within a morpheme VV sequences are permitted (cf. Payne 1981, Spring 1990, McCarthy and Prince 1993a, Kenstowicz 1994b).

⁷ For the detailed discussion of this gap, see section 1.4.1 Gaps in the Predicted Types of Geminates.
3.2.3 Pero: DEP-IO is subordinate and /C₁C₂/ → [C₁C₂V₂]

In this section, we look at a case which has been viewed as involving vowel epenthesis in order to break up impermissible consonant sequences. However, this epenthesis is not able to apply if it would separate the halves of a geminate. This characteristic seems to reflect the integrity effects of geminate consonants, and shows that geminates do not act like normal sequences of consonants.

In Pero, a West Chadic Language of Nigeria, sequences of three consonants are not allowed at the surface, and thus they are broken up by an epenthesized high vowel. However, the position of the epenthetic vowel depends on the position of a geminate, if any, in the three consonants. Thus, we cannot decide whether the vowel will be inserted in the position C_ CC or the position CC_ C until we know the phonological relationships among the three consonants (cf. Goldsmith 1990). The following data are from Frajzyngier (1980) and Goldsmith (1990).

(11) a. add -tu [adduru] ‘eat many and come’
    add -ji [addjii] ‘always eat many’
    dill -t- [dilluro] ‘fetch water-pl-IMPERATIVE’
    cadd -t- [cadduro] ‘carry-pl-IMPERATIVE’

As we can see in the above data, the epenthesis sites vary. For example, /add-tu/ 'eat many and come' (11a) has an epenthetic vowel after the surface geminate which is also an underlying geminate, becoming [adduru]. However, /yekl-tu/ 'mix-Imp. Vent.' (11b) has the epenthetic vowel before the surface geminate (due to the assimilation of -lt-to -ll- on the surface). Generally, whether the vowel is inserted in the position C₁-C₂-C₃ or the position C₁C₂-C₃ depends on the phonological relationships among the three consonants. In any way, it will always be the case that one of the pairs C₁-C₂ or C₂-C₃ forms either a geminate cluster or a sequence of homorganic nasal+stop (Goldsmith 1990: 78). Take /yekl-tu/ 'mix-Imp. Vent.', for an instance. First, since the two stem-final consonants are not a geminate, the epenthetic vowel is inserted between them (/yekl-tu/ → [yigu-tu]). Second, /lt/ sequence becomes geminate [ll] owing to the assimilation ([yigu-tu] → [yigu-lu]). Thus, underlying /yekl-tu/ becomes [yigu-lulu] on the surface.

By contrast, in the current analysis, however, vowel epenthesis is viewed as being motivated to satisfy high ranked PLONS.

3.2.3.1 Epenthesis in C₁C₁C₂

Traditionally, it has been assumed that in Pero CCC clusters are not allowed on the surface. Thus, sequences of three consonants will be broken up by an epenthized vowel. If such clusters contain underlying or derived geminates, however, then the geminates will show up on the surface without being split by an epenthetic vowel.
showing the integrity effect of the geminates (11a, b). This implies that geminate consonants are counted as two segments and the site of epentheses is dependent upon the nature of feature specification of the consonants. In summary, according to the previous rule-based approaches, vowel epentheses occur to break up impermissible CCC clusters. That is, to satisfy *COMPLEX (Goldsmith 1990).

By contrast, under the current moraic approach to geminates, geminate consonants are represented with one consonant preassociated to the mora. Thus, in CCC clusters containing a geminate, *COMPLEX cannot force vowel epentheses since the CCC clusters are not three segments but two segments. That is, in the present analysis, there is no *COMPLEX violation, but there is vowel epentheses to satisfy top-ranked PLONS. As we can see later, the overall patterns of the Pero data support for the present analysis. Pero generally allows only geminate consonant cluster and homorganic NC clusters on the surface manifesting PLONS effect.

To understand the first pattern presented in (11) above, we need to consider the examples based on our discussion of (10) above. According to the predicted pattern (10), we expect a low-ranked DEP-IO in Pero. That is, the actual output forms in (11) \((C_1VC_2C_2 \text{ or } C_1C_1VC_2)\) suggest that DEP-IO is ranked below the other two key constraints (i.e. MAX-IO, PLONS >> DEP-IO). In fact, this accounts perfectly for the epentheses site in forms with geminates, as illustrated by (12).
The forms which crucially violate one of the two highest ranked constraints are eliminated and the form (a) [addwu] which violates DEP-IO survives for the optimal output form.\(^3\)

The two forms (c) and (d) require further mentioning. In chapter 2, I have hypothesized that geminates are doubly-linked on the surface to be distinctive from

\(^3\) The exact phonetic form is not given here. Detailed discussion will follow in the course of this section.
singleton moraic consonants by Weight by Position. In the above tableau, the two forms are not distinctive at all with the existing constraints. To account for the different surface realization of the two forms, I suggest a constraint on moraic consonant: "C-COND.

(13) "C-COND: Input moraic consonants are doubly-linked on the surface, and vice versa

When this constraint interacts with other ones, the two forms will be different on the surface.

(14) /add-tu/ 'eat many and come'

<table>
<thead>
<tr>
<th></th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>DEP-IO</th>
<th>&quot;C-COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/ad-tu/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>σ</td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\ /</td>
<td>/ \</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μμ</td>
<td>/μ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\ /</td>
<td>/ \</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ad tu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>σ</td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\ /</td>
<td>/ \</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μμ</td>
<td>/μ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\ /</td>
<td>/ \</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ad tu</td>
<td></td>
<td></td>
<td></td>
<td>!</td>
</tr>
</tbody>
</table>
As tableau (14) shows, given the choice, underlying geminates favor the form with double-linking (14a) over the form with single-linking (14b) on the surface, which is captured by the constraint "C-COND.

Furthermore, "C-COND is very useful in explaining the Weight by Position (Hayes 1989) effect in moraic coda languages. Consider the following tableaux.

(15) a. /ν"C/ → [ν"C]

<table>
<thead>
<tr>
<th>μ</th>
<th>/νC/</th>
<th>&quot;C-COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. σ</td>
<td>μ μ</td>
<td>\</td>
</tr>
<tr>
<td>b. σ</td>
<td>μ μ</td>
<td>\</td>
</tr>
</tbody>
</table>

*!
b. /VC/ → [V^C] (by Weight by Position)

<table>
<thead>
<tr>
<th>/VC/</th>
<th>&quot;C-COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
</tr>
<tr>
<td>σ</td>
<td></td>
</tr>
<tr>
<td>\</td>
<td></td>
</tr>
<tr>
<td>μ μ</td>
<td></td>
</tr>
<tr>
<td>V C</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*!</td>
</tr>
<tr>
<td>σ</td>
<td></td>
</tr>
<tr>
<td>\</td>
<td></td>
</tr>
<tr>
<td>μ μ</td>
<td></td>
</tr>
<tr>
<td>V C</td>
<td></td>
</tr>
</tbody>
</table>

Tableau (15a) shows that input moraic consonants are doubly-linked on the surface due to the constraint "C-COND. By contrast, tableau (15b) shows that the moraic coda consonant by Weight by Position must be singly-linked on the surface. By doing so, we can distinguish the difference between the moraic coda from underlying geminates and surface singleton moraic codas by Weight by Position: /V^pC/ → [V^pC] vs. /VC/ → [V^pC].

In summary, due to the constraint "C-COND, we can make the prediction that only underlying geminates can be doubly-linked on the surface, and singleton moraic consonants by Weight by Position cannot be doubly-linked.

Now, we go back to the discussion of Pero. To complete our analysis of Pero, further facts must be addressed. The following tableau makes the need explicit. In tableau
(16), candidates (a) and (b-e) are eliminated by violating high ranked MAX-IO and PLONS, respectively, but the remaining 5 candidates all tie.

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. yektu</td>
<td>*!</td>
<td>(*)</td>
<td></td>
</tr>
<tr>
<td>b. yekltu</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. yelltu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>d. yikltu</td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>e. yikltu</td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>f. yillru</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>g. yikkiru</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>h. yikallu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>i. yigattu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>j. yiggallu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

In order to correctly produce the optimal output (j), constraints are needed to force [g], not [k] (h), and to force [ll] not [tt] (i). Also, we need a constraint to rule out the candidates (f & g). Each of these constraints has to do with general properties, which Pero shares with other languages.⁹

In the following sections, I explore these aspects in connection with geminate integrity effects in Pero.

⁹ Note here that [i], not [e] is the actual output phonetic form corresponding to the input /e/, but I ignore this problem.
3.2.3.2 PLONS and Assimilation in CC

First, we need to take care of the forms (b-e). Owing to the various kinds of assimilation, it will always be the case that the general pattern of Pero allows only a geminate cluster or a sequence of homorganic nasal+stop (cf. Goldsmith 1990).

\[(17)\] a. add-tu \quad [adduru] \quad 'eat many and come'
b. tekk-l-tu \quad [tekkillu] \quad 'rub and come'
c. tekk-l-na \quad [tekkilla] \quad 'he rubbed and came'
d. cugd-na \quad [cuginna] \quad 'comb-Perf. Vent.'

(cf. pen-tu [pindu] 'know and come')

In short, codas are allowed only if they are part of geminates and homorganic NC clusters.

To capture this general pattern of Pero consonant sequence structure, we use the constraint PLONS the definition of which is already given above. For convenience, I repeat it in (18):

\[(18)\] PLONS: If there are Place features, then they must be in onsets (cf. Steriade 1994)

PLONS plays a central role in restricting the type of consonants that occupy the coda position. Thus, in Pero, if the coda consonants are not acceptable and thus violate
PLONS, vowel insertion is employed to remedy that problem caused by unacceptable consonant sequences.

Now, going back to the discussion of [yigillu], the following tableau will display how PLONS functions to get rid of the forms (b-e).

(19)

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. yekltu</td>
<td>*!1(l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. yelltu</td>
<td>*!1(l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. yikelu</td>
<td>*!1(l)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>e. yiklu</td>
<td>*!1(k)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>j. yigillu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Because of PLONS, the four forms (b-e) are eliminated except for (j). However, not only [yi.gillu] (j) but also [yilliru] (f) and [yikkiru] (g) satisfy PLONS, since geminates satisfy PLONS. The following section addresses that issue in some detail.

3.2.3.3 No Loss of Place: Choosing between [yigillu], [yilliru] and [yikkiru]

In Pero, consonant assimilation occurs between two homorganic consonants across a morpheme boundary; if the input consonants are not homorganic, no assimilation occurs (cf. (20) vs. (21)).

(20) a. tekk-l-tu  [tekkillu]  'rub and come'
b. tekk-l-na  [tekkilla]  'he rubbed and come'
c. yekl-tu  [yigillu]  'mix-imp. Vent.'
d. cugd-na  [cuginna]  'comb-perf. Vent.'
(21)  
   a. kap-ji \quad [kav\textsuperscript{ji}] \quad 'always talk'
   b. cug-ji \quad [cug\textsuperscript{ji}] \quad 'always fall down'
   c. kaj-ko \quad [ka\textsuperscript{jo}yo] \quad 'tharf'
   d. maj-ko \quad [ma\textsuperscript{jo}yo] \quad 'tharf'
   e. pej-tu \quad [pi\textsuperscript{j}uru] \quad 'thatch and come'

The examples in (21) even more support for our assumption that Pero disfavors coda consonants except geminates and homorganic nasal+stop sequences.\textsuperscript{10} Here, consonant assimilation does not occur between the two consonants which have different place features. Instead, vowel epenthesis occurs here even when there is no problem of impermissible number of consonant sequences (i.e. CCC). Based on this general pattern of Pero, we introduce IDENT-IO(Pl).

(22) IDENT-IO(Pl): Output correspondents of an input segment have identical values for the feature Place

IDENT-IO (Pl) requires that correspondent segments be featurally identical to one another, with regard to place features.\textsuperscript{11} In general, phonological alternations are explained

\textsuperscript{10} These data also show the effect of *V[-vd]V (26) (cf. section 3.2.3.4).

\textsuperscript{11} IDENT is proposed to replace the PARSE-feature and FILL-feature-node apparatus of Containment type of OT (McCarthy and Prince 1995). IDENT presupposes that only segments stand in correspondence, so featural identity comes through correspondent segments. However, this concept has problems in dealing with “floating” feature analyses like those seen in Archangeli and Pulleyblank (1994) and Akinlabi (1994). In this sense, MAX-IO(F) and DEF-IO(F) will be a better idea to represent the featural disparity between the input and output forms. In this thesis, however, since there are no cases of floating features, we will use the term IDENT instead of MAX(F) or DEF(F) for convenience.
by the crucial domination of one or more IDENT constraints, which leads to featural disparity.

Now we will see how IDENT-IO(Pl) deals with the following three forms by giving a tableau.

(23)

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>IDENT-IO(Pl)</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>f. yill'ru</td>
<td>*(k)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>g. yikk'ru</td>
<td>*(l)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>j. yi.g'llu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Among the three candidates, the two forms [yill'ru] (f) and [yikk'ru] (g) are eliminated by the violation of IDENT-IO(Pl). This shows that consonant assimilation is preferred between the consonants having the same point of articulation.

The data in (21) also show that vowel epenthesis is required to remedy illicit coda consonants containing place features. That is, these data strongly enforce us to introduce PLONS which requires vowel insertion. This means that to permit vowel insertion PLONS must dominate DEP-IO as IDENT-IO(Pl) does dominate DEP-IO. The following tableau illustrates this point again supporting our prediction given in (10a).
3.2.3.4 Intervocalic Voicing

In Pero, intervocalic single consonants are always voiced (Frajzyngier, 1980).

(25) a. app-c-ani [appijaani] ‘they open-StaL’
    b. yekl-tu [yigfllu] ‘mix-Vot.’
    c. pinn-ko [pinnigo] ‘they washed’

To explain intervocalic voicing in Pero and in other languages, we introduce the constraint

*V[-vd]V.\(^{12}\)

\(^{12}\) Lass (1984:181) states that intervocalic position (i.e. V_V) is a primarily preferred weakening environment. Thus, all things being equal, we can expect lenition here. This suggests that V_V should be more effective as a voicing trigger than V or V since two vowels are more vocalic than one, and hence double the voicing process. Conversely, we can say that two consonants (i.e. geminates) are more consonantal (and thus, stronger) than one, and hence double the resistance to the weakening processes. See chapter 4 on this issue. See also Foley (1977) for more discussion on positional strength hierarchies.
(26) \( *V[-vd]V \): Voiceless single consonants are prohibited in intervocalic position

The constraint \( *V[-vd]V \) captures the language universal tendency that intervocalic single consonants are realized as voiced (e.g. Korean (Kim-Renaud 1974), Tohoku Japanese (Ohno, to appear), etc.). The following tableau shows how \( *V[-vd]V \) rules out the form [yikillu] (h).

(27)

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>( *V[-vd]V )</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>h. yikillé</td>
<td>( \star )</td>
<td>( \star )</td>
<td>( \star )</td>
</tr>
<tr>
<td>e j. yigillé</td>
<td>( \star )</td>
<td>( \star )</td>
<td>( \star )</td>
</tr>
</tbody>
</table>

In the above tableau, \( *V[-vd]V \) correctly rules out the form (h) which contains voiceless single consonants intervocalically.

3.2.3.5 Sonorant Codas

Finally, we need to explain why we have to choose [yigillé] (j) over [yigittu] (i).

This should also explain why sonorants prevail over obstruents in the coda position as illustrated in the following examples.\(^{13}\)

---

\(^{13}\) I have not found Stop-Liquid examples in sources on Pero. The analysis given here predicts that any underlying homorganic Stop-Liquid sequences are realized as Liquid geminates on the surface.
(28) (i) Liquid-Stop

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. yekj-tu</td>
<td>[yigilu]</td>
<td>'mix-imp. Vent.'</td>
</tr>
<tr>
<td>b. bel-tu</td>
<td>[billu]</td>
<td>'break and come'</td>
</tr>
<tr>
<td>c. bebul-tu</td>
<td>[bibullu]</td>
<td>'break many and come'</td>
</tr>
<tr>
<td>d. per-tu</td>
<td>[pirru]</td>
<td>'announce and come'</td>
</tr>
</tbody>
</table>

(ii) Nasal-Stop

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. pen-tu</td>
<td>[pindu]</td>
<td>'know and come'</td>
</tr>
<tr>
<td>b. tond-ji</td>
<td>[tundiji]</td>
<td>'always sew'</td>
</tr>
<tr>
<td>c. foje-n daba</td>
<td>[fojan daba]</td>
<td>'Daba's chicken'</td>
</tr>
<tr>
<td>d. pen-jujo</td>
<td>[penjujo]</td>
<td>'see many'</td>
</tr>
</tbody>
</table>

(iii) Stop-Nasal

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. cugd-na</td>
<td>[cuginna]</td>
<td>'comb-perf. Vent.'</td>
</tr>
<tr>
<td>b. piit-na</td>
<td>[piinna]</td>
<td>'made fire and came'</td>
</tr>
</tbody>
</table>

In Pero, -It-, -dn-, -rt-, -nt-, are realized on the surface as -11-, -nn-, -rr-, and -nd-. respectively. This strongly suggests that obstruents assimilate to sonorants resulting in sonorant geminates to satisfy both CODASON and PLONS. To capture this point, we propose the following coda related constraint, CODASON.

(29) CODASON: Codas are sonorants

Iverson and Salmons (1992). According to Ito and Mester (1994), Goldsmith (1990), Scobbie (1992), and Prince and Smolensky (1993), the coda is a degenerate (i.e. weak or secondary) licenser, a sort of inherently weak position which in the unmarked case licenses only the most sonorous features. On the other hand, the onset is a strong position in which any type of segment is possible, in general. This constraint reflects the onset/coda licensing asymmetry which says that cross-linguistically the inventory of possible codas is a subset of the inventory of possible onsets, but not vice versa (Prince and Smolensky 1993: 130). Furthermore, CODASON and PLONS are independently needed to explain such phonological phenomena as coda sonorantization (e.g. Persian, Hausa), place assimilation and neutralization processes which are frequently found in many languages.

Because of CODASON, sonorants will always win when there is assimilation between sonorants and obstruents of the same place of articulation. Figure (30) gives a tableau showing that CODASON rules out the form [yigittu] in favor of [yigillu].

(30)

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>CODASON</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. yi.gittu</td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>s. j. yi.gillu</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

3.2.3.6 The Final Touch

Finally, to complete our analysis of Pero data, we need to address IDENT-IO(F) which concerns the phonological change between the input and output forms.

(31) IDENT-IO(F): Output correspondents of an input segment have identical values for the phonological features (McCarthy and Prince 1995)

This constraint is similar to IDENT-IO(PI), but I assume IDENT-IO(F) is about the correspondence between the input and output forms regarding manner, sonorant, or voicing features, whereas IDENT-IO(PI) is about the correspondence regarding place features. Thus, any featural changes other than place features will violate IDENT-IO(F). In Pero, consonant assimilation occurs frequently violating this constraint, to satisfy other higher ranked constraints discussed so far. From this, we assume that IDENT-IO(F) is lowest ranked.

3.2.3.7 Summary of the Constraints in Pero

The following diagram summarizes overall hierarchy of the constraints in Pero discussed so far. The three key constraints regarding geminate integrity effects are bolded.
As we have seen above, these constraints are needed to account for the overall phonological patterns in Pero. However, it should be noted that the key constraints and their ranking explain the integrity effect of geminates itself as well as the distribution of geminates regardless of the added constraints. That is, the added constraints can dominate the key constraints or can be dominated by the key constraints, but their ranking does not affect the predicted effect on geminates concerning the ranking of the key constraints.

3.2.3.8 The Proof

In order to conclude our discussion of Pero, we provide the full tableaux containing all the relevant constraints motivated above. The following tableaux will clearly illustrate those points made above. First, we give the case of underlying geminates followed by a single consonant.
In order to ensure that place features are in an onset, we can think of the insertion of an epenthetic vowel inside the consonant clusters. Now, let us examine what will happen if we put an epenthetic vowel in the position CC _ C to break up the unacceptable consonant clusters as in (a) (/add-tu/ → [adduru]). In this case, DEP-IO, CODASON and IDENT-IO(F) are violated to satisfy the more highly ranked PLONS and *V[-vd]V. Thus, in tableau (33), candidate (a) [adduru] is selected as the optimal output form among the candidates, manifesting the integrity effect of geminates. Candidate (b) is eliminated by crucially violating one of the key constraints PLONS.
We can think of other possibilities of ensuring that place features are in an onset other than insertion of an epenthetic vowel inside the consonant clusters. That is, we can delete one of the segments as shown in (c). However, this crucially violates MAX-IO which is top ranked in the constraint hierarchy (/add-tu/ → *[addu]). Finally, candidate (d) is also eliminated by the crucial violation of *[V[-vd]V]. The violation of *[V[-vd]V is incurred because [t] is seen in the intervocalic position.

Now, let us consider the derived geminate case.
In order to concentrate on the main issue of geminate integrity phenomena, we will disregard the discussion of phonetic changes from t → r, and e → i, here. See Frązyngier (1980) for detailed discussion of these issues.

<table>
<thead>
<tr>
<th>/yekl-tu/</th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>IDENT-IO(PI)</th>
<th>V-V[1-vo]V</th>
<th>DEP-IO</th>
<th>CODA-SON</th>
<th>IDENT-IO(F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. yek.tu</td>
<td>*!</td>
<td>*(k)</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. yekl.tu</td>
<td>*!(k,l)</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. μ</td>
<td></td>
<td>*(l)</td>
<td>*(k)</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yeltu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. yi.kl.tu</td>
<td>*!(l)</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. yik.k.tu</td>
<td>*!(k)</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. μ</td>
<td></td>
<td>*(k)</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yilrru</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. μ</td>
<td></td>
<td>*(l)</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yikr.ru</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yi.k+l.u</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yi.g+tu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j. μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yi.g+lu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In tableau (34), candidate (a) is eliminated by the crucial violations of MAX-IO and PLONS. Candidates (b-e) are all eliminated since they crucially violate PLONS. Under our hypothesis, since they are neither geminates nor homorganic NC clusters, these four forms do not satisfy PLONS. Candidates (f-g) are also eliminated because they crucially violate IDENT-IO(Pi). Candidate (h) is ruled out because it crucially violates *V[-vd]V due to the voiceless consonant [k] between vowels. Between candidates (i) and (j), (j) is selected as the optimal output since (i) has additional CODASON violation.

3.2.3.9 Summary and Conclusion

In summary, as seen in the analysis of Pero data, vowel epenthesis occurs between geminates and singleton consonants. Contrary to the previous rule-based approaches, it is argued here that vowel epenthesis is needed to fix unacceptable place features not in an onset, instead of impermissible number of consonants (i.e. CCC). Consequently, not *COMPLEX but PLONS plays an active role in the exposition of vowel epenthesis with regard to geminate consonant clusters. That is, in Pero an epenthetic vowel is inserted to satisfy top-ranked PLONS.

Turning to the facts of the integrity effect of geminates and their distribution, then, geminates, whether underlying or derived by assimilation, display the geminate integrity effect in Pero. In our analysis, there is no sense that geminate consonants resist the insertion of a vowel that would break up its halves, since geminates are represented
as one segment with mora underlyingly and NOBREAKING does not take any effect on medial geminate clusters. Thus, the integrity effect of geminates is easily obtained and the distributional patterns of the geminates are effectively captured by the constraint interaction model of OT.

From the above discussion of the Pero data, we have found that DEP-IO is lower ranked than MAX-IO and PLONS. Specifically, we have observed that the 3 key constraints of the different rankings are responsible for the integrity effect of geminates itself as well as different distributional pattern of geminate consonants as has been predicted by our system (here in Pero, MAX-IO, PLONS » DEP-IO). Furthermore, it has also been shown that the added constraints do not detract from the key constraint set, since regardless of the added constraints, the essential patterns of the rankings of the key constraints are maintained.

We now turn to an instance where DEP-IO is low ranked, but PLONS is high ranked, again resulting in the geminate integrity effect: Ponapean (Suh 1996b). *COMPLEX is irrelevant here. The Ponapean data are interesting since they do not have a C1C1C2 sequence word-medially, and yet they show the same kind of geminate integrity effect as seen in the above Pero case.
3.2.4 Ponapean: \(...\text{C}_1\text{C}_2...\) \rightarrow \[...\text{C}_1\text{V}\text{C}_2...\]

Ponapean data also support the above line of analysis. In Ponapean, vowel epenthesis occurs to satisfy PLONS in \(\text{C}_1\text{C}_2\) clusters word-medially, despite the fact that there is no medial CCC sequence in the input.

It has been thought that languages differ according to the closed/no closed syllable parameter (Kaye 1990): some languages do not allow codas (e.g. Hawaiian, Desano, Fijian), while other languages allow codas, resulting in word-medial consonant clusters and one or more than one consonants at the end of a word (e.g. Yawelmani, English, Arabic). In some languages, which allow codas, only a restricted set of consonants make licit codas (e.g. Axininca Campa, Diola Fogny, Italian, Japanese, Lardil, Ponapean, Selayarese, etc.).

Specifically, in Ponapean, coda consonants are prohibited except for geminates and place-linked NC clusters. Vowel epenthesis remedies unacceptable coda consonants word-medially. On the other hand, word-final syllables can have single coda consonants, or two, if they are geminates or homorganic NC clusters (Itō 1989: 226). Geminate sonorants and NC clusters can occur initially in the morpheme. However, geminates are degeminated in word-initial position at the surface (Rehg 1986, Levin 1989: 39).

According to Rehg (1981), and Rehg and Sohl (1979), word-medial biconsonantal clusters are split by the insertion of a vowel. But, geminates and place-linked NC clusters resist the vowel insertion between them. Furthermore, morpheme-initial and word-final geminates and place-linked NC clusters behave differently from each other. At
issue is the integrity effect of the geminates with respect to vowel epenthesis in this language as well as characterizing the distribution of consonant clusters according to the positions, word-medially, word-finally and word-initially.

On the basis of the data analysis of Ponapean, I will make the following two points: (i) vowel epenthesis is motivated to satisfy PLONS as in the case of Pero. (ii) The geminate integrity effect is again the result of a specific ranking of the 3 key constraints. Specifically, PLONS is higher ranked than DEP-IO, thus allowing a vowel insertion to resolve unacceptable coda problem by changing the problematic coda consonant into an onset.

3.2.4.1 Word-medial CC

Ponapean does not allow medial CC sequences unless they share the same place of articulation. That is, geminate clusters and place-linked NC clusters are possible word-medially in Ponapean. The Ponapean data cited here are collected from Rehg and Sohl (1981), McCarthy and Prince (1986), Levin (1989), and Itō (1989).

(35) a. arewalla ‘to return to the wild’
    kemmad ‘to change into dry clothing’
    uremma ‘lobster’
    nap pa ‘Chinese cabbage’ (loanword)
Otherwise, in Ponapean, biconsonantal clusters resulting from morpheme concatenation are broken up by an epenthetic vowel. Thus, an epenthetic vowel breaks up the C1C2 sequence (C1C2 → C1VC2) as shown in (36).16

(36) /ak-dei/ [akedei] ‘a throwing contest’
    /ak-p’unu/ [akup’unu] ‘petty’
    /ak-tanatu/ [akatanatu] ‘to abhor’
    /kitik-men/ [kitikimen] ‘rat, indef’
    /p’iik-men/ [piikimen] ‘pig, indef’

The surface syllables seen in (35) and (36) suggest the importance of PLONS, which dictates that Place features be in the onset, prohibiting independent Place features in the coda position. Forms with a vowel added (36) satisfy PLONS in medial C1C2 cases since the inserted vowel makes all internal consonants onsets.17

In geminate clusters and place-linked NC clusters (35), insertion of a vowel between the clusters does not occur, since they satisfy PLONS without inserting a vowel

---

16 The examples given in (36) are all k-final morphemes. However, this should not be considered as significant. In Ponapean, biconsonantal clusters resulting from morpheme concatenation are broken up by an epenthetic vowel (e.g. /lus-san/ → [lusisan] ‘jump from’, /daur-di/ → [dauridi] ‘climb downwards’, etc.) (Ito 1986). The nature of the epenthetic vowel is not discussed here. For detailed discussion about the nature of epenthetic vowels in Ponapean, see Rehg and Sohl (1981), McCarthy and Prince (1986), Levin (1989), and Ito (1989). Following Rehg and Sohl (1979), [t] indicates retroflex affricates and [d] represents voiceless dental stops (cf. Ito 1986).

17 Word-final consonant cluster cases are dealt with in section 3.3.2.
inside the clusters. Due to the linked nature of their representation, place features are correctly in onsets in those cases.

The following tableau exemplifies this aspect. Here, the ranking PLONS >> DEP-IO is crucial.

(37) /ak-dei/ 'a throwing contest'

<table>
<thead>
<tr>
<th>/ak-dei/</th>
<th>PLONS</th>
<th>DEP-IO</th>
</tr>
</thead>
</table>
| a. ak.dei | *! | | *
| b. a.ke.dei | | |

In (37), [ak.dei] (a) crucially violates PLONS, and thus it is ruled out. The form in (b) [a.ke.dei] has a vowel insertion between [kd] cluster. This incurs DEP-IO violation, but satisfies the higher ranked constraint PLONS. Thus, candidate (b) [a.ke.dei] is chosen as the optimal output form.

Thus far, we have looked at the aspects of epenthetic vowels in word-medial consonant clusters. Specifically, I have argued that PLONS is pivotal in the exposition of a vowel insertion between the C_1C_2 clusters, in which there is no problem of impermissible CCC clusters. The analysis so far, then, predicts no word-final consonants, but there exist such cases: e.g. [kemmad], [akatantat], [kitikimen], etc..

In Ponapean, we cannot put a vowel in word-final position to satisfy PLONS. Thus, in word-final position, PLONS violation is tolerated. This suggests that we need a
constraint which can explain the tolerance of PLONS in word-final position, essentially
ALIGN(WD-R, M-R) (2f). I will return to this point later when I discuss word-final
geminates (section 3.3.2).

3.2.4.2 Summary of the Constraints

According to (10a), the predicted pattern of the key constraints for Ponapean
would be like this:18

(38) MAX-IO, PLONS >> DEP-IO

Considering the general pattern of Ponapean data, we suggest the following
ranking for Ponapean word-medial clusters.19

(39) Ranking of the Constraints in Ponapean I (to be revised)

\[
\begin{align*}
\text{MAX-IO} \\
\text{PLONS} \\
\text{DEP-IO}
\end{align*}
\]

18 In the analysis of Ponapean initial geminate data, we need to differentiate between MAX-IO(seg) and
MAX-IO(μ) because they essentially function in a significantly different way (see section 3.4.3.1 for details).
However, I will use MAX-IO covering both MAX-IO(seg) and MAX-IO(μ) in the analysis of medial and
final cases since using it does not make any difference in those positions. Besides, *COMPLEX is not
relevant in the discussion of medial geminates, since there is no case of CCC consonant clusters medially.
However, it is necessary when we analyze initial and final geminates because of NC clusters. Regardless of
*COMPLEX, the predicted pattern of the key constraints would hold.

19 Such constraints as MAX-BR, IDENT-BR(PI), DEP-BR, and IDENT-BR(son) will be addressed later in the
discussion of reduplication data (e.g. 'par' $\rightarrow$ [parapar] 'to cut', etc.).
3.2.4.3 The Proof

Now let us see how this ranking works for the analysis of the integrity effect in medial C₁C₁ cases (i.e. geminates) in Ponapean.

(40) /urenna/'lobster'

<table>
<thead>
<tr>
<th></th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>σ σ σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/urenna/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>σ σ σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/urenna/</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Word-internal sonorant geminate cases like /urenna/ satisfy PLONS. Thus, candidate (a) which is faithful to the input form will be considered as the optimal output form. Candidate (b) shows that deletion of word-internal element causes more severe violation when it is one half of the geminate.

Now, let us examine word-internal obstruent geminate case.
In the case of /napa/ which contains obstruent geminate in the middle of the word, the optimal output form will be the same with the input form. Candidate (a) violates no constraints. On the other hand, candidate (b) has the fatal violation of MAX-IO by underparsing of the mora. Thus, (a) is selected as the optimal one.

Next, we will consider word-internal homorganic NC cluster data.
In NC clusters like /nampar/, just as in the case of true geminates, the completely faithful candidate (a) is optimal. Especially, insertion of an epenthetic vowel between the NC cluster causes the violation of DEP-IO as well as PLONS as shown in (b). Because of that, this is eliminated. In (c), because of the deletion of word-internal segment, we have also crucial MAX-IO violation. As we can see in (d), changes in word-final position do not help either. That is, deletion of word-final consonant causes fatal MAX-IO violation. Thus, they are all eliminated.

Thus far we have seen the cases in which medial CC clusters are either geminates or place-linked NC sequences. In those cases, there is no epenthesis, since they do not have complex consonant clusters in their syllable margins and they essentially satisfy the key constraint, PLONS. In this way, the geminate integrity effect is explained.

---

20 In order to focus on word-internal behavior of consonant clusters, I omit the forms like [nampara] which essentially requires of the constraint ALIGN(Wb-R, M-R). This issue will be addressed in detail in section 3.3 Final Geminates.
Now, we turn to the case where the CC sequence does not constitute a wellformed coda-onset sequence. The following case exemplifies epenthesis: the CC sequence /k-d/ is not a wellformed coda-onset sequence. Thus, to remedy this problem, epenthesis occurs in the middle of the /k-d/ sequence. For that reason, we have a vowel insertion in this sequence, although we do not have complex consonant clusters in the syllable margins.

As an illustration, let us look at the following tableau.

(43) /ak-dei/ 'a throwing contest'

<table>
<thead>
<tr>
<th>/ak-dei/</th>
<th>MAX-IO</th>
<th>PLONS</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ak.dei</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b. a.ke.dei</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c. dei</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

The word /ak-dei/ 'a throwing contest' is composed of prefix ak- 'to demonstrate or demonstrating' and stem dei 'far, far along'. The completely faithful candidate (a) crucially violates PLONS, because coda consonant [k] has its own place feature in that position. Rather, the optimal candidate has an epenthetic vowel within the cluster to resolve the illicit coda consonant (b). In (b), PLONS is satisfied at the cost of violating the lowest-ranked constraint, DEP-IO. Case (c) satisfies PLONS, but it crucially violates MAX-IO. Thus, it is eliminated from the competition. Among the candidates, (b) is
selected as the optimal output form. This convincingly tells us that DEP-IO can be easily violated to satisfy more highly ranked constraint like PLONS.

3.2.4.4 Summary

To summarize, we have seen that medial non-homorganic CC sequences in Ponapean are split by an epenthetic vowel, which resolves an illicit coda problem by changing the illicit coda consonant into the onset consonant. In the analysis of the Ponapean data, we have also found that the predicted pattern of the key constraints is basically responsible for the integrity effects of geminates and homorganic NC clusters, as in the cases of CCC sequences.

In the following section, we will consider some cases of reduplication in Ponapean which support the integrity effect of geminates (and NC clusters) and the current assumption that PLONS is responsible for the vowel insertion in Ponapean.

3.2.4.5 Reduplication

The goal of Correspondence Theory proposed by McCarthy and Prince (1995) is to explain the relation between two structures, such as base-reduplicant, or input-output, etc. Correspondence was first introduced into OT as a base-reduplicant relation (McCarthy and Prince 1993). Later, it was extended to the input-output domain.
(McCarthy and Prince 1995). Thus, it will be worthy of examining the reduplication data in the same language to accomplish the goal of Correspondence Theory.

The reduplication data presented below are not complete, but our goal here is to show that integrity effect of geminate (and NC cluster) and coda-related constraints can be effective even in the domain of reduplication, and ultimately in any domain of the phonology where the relevant forms appear. Moreover, reduplication data support our analysis made for the word-internal CC clusters.

The reduplication examples given here are one of the eleven common patterns of reduplication process found in Ponapean (cf. Rehg and Sohl 1979).

(44) Reduplication

a. \( C_1=C_2=\)Sonorant (Same Place)

\[
\begin{array}{lll}
\text{lal} & \text{lal-lal} & \text{\`make a sound}\n\\
\text{rer} & \text{rer-rer} & \text{\`terrible}\n\\
\text{mem} & \text{mem-mem} & \text{\`sweet}\n\end{array}
\]

b. \( C_1=C_2=\)Obstruent (Same Place)

\[
\begin{array}{lll}
\text{pap} & \text{pam-pap} & \text{\`swirl}\n\\
\text{dod} & \text{don-dod} & \text{\`frequent}\n\\
\text{kik} & \text{ki\text{\-}n-kik} & \text{\`kick}\n\end{array}
\]

c. \( C_1=\)Obstruent, \( C_2=\)Sonorant (Same Place)

\[
\begin{array}{lll}
\text{dil} & \text{din-dil} & \text{\`penetrate}\n\\
\text{ka\text{\-}n} & \text{ka\text{\-}n-ka\text{\-}n} & \text{\`at}\n\end{array}
\]
d. \(C_1=\text{Obstruent}, C_2=\text{Sonorant/Obstruent (Different Place)}\)

\[
\begin{array}{ccc}
p^\text{wil} & p^\text{wil-i-p^wil} & \text{\#w} \\
\text{par} & \text{par-a-par} & \text{\#ca'p} \\
\text{tep} & \text{tep-e-tep} & \text{\#ik'} \\
\end{array}
\]

The data in (44) display that there is no vowel insertion if \(C_1\) and \(C_2\) are the same sonorant (44a). If \(C_1\) and \(C_2\) have the same place features, and \(C_1\) is not a nasal consonant, then \(C_3\) becomes nasal consonants to form an NC cluster (44b and c). Finally, if \(C_1\) and \(C_3\) have different place features, then a vowel is inserted (44d).

With this general observation, let us closely examine the reduplication data. For the reduplication analysis, i.e., base-reduplicant faithfulness relations, we use \text{MAX-BR}, \text{DEP-BR}, and \text{IDENT-BR(son)} as we use \text{MAX-IO}, \text{DEP-IO}, and \text{IDENT-IO(son)}, respectively, for the input-output faithfulness relations.

\begin{itemize}
\item[(45)] \text{MAX-BR:} \quad \text{Every segment of the base has a correspondent in the reduplicant (McCarthy and Prince 1995)}
\item[(46)] \text{DEP-BR:} \quad \text{Every segment of the reduplicant has a correspondent in the base (McCarthy and Prince 1995)}
\item[(47)] \text{IDENT-BR(son):} \quad \text{Reduplicant correspondents of a base segment have identical value of sonorancy (McCarthy and Prince 1995)}
\end{itemize}
Correspondence relationship holds between base and reduplicant, as does between input and output structures. Thus, the ranking relations of the matching constraints between the input-output and base-reduplicant domains overlap in many cases (e.g. MAX-IO = MAX-BR, DEP-IO = DEP-BR, etc.). However, ranking differences between the two domains (i.e. input-output and base-reduplicant) are also found in some cases (e.g. IDENT-IO(son) >> IDENT-BR(son)). Besides, since there is no difference between IDENT-IO(son) and IDENT-IO(PI), we can use only one constraint (here, IDENT-IO(son) is used) for the input-output relation, but we need both IDENT-BR(son) and IDENT-BR(PI) for the base-reduplicant relation (here, IDENT-BR(PI) dominates IDENT-BR(son)). As we can see later, IDENT-IO(son) dominates CODASON (cf. figure (52)). In addition to this, I assume NOFUSION is lowest ranked.\textsuperscript{21} Thus, the ranking of the constraints in Ponapean will be like (48), when the reduplication data are included. The ranking argument of these constraints, however, will be made in the course of relevant data analysis.

\textsuperscript{21} NOFUSION is defined as follows: \textit{No element of the output has multiple correspondents in the input} (McCarthy and Prince 1995) (cf. figures (73) and (74)). For more details, see section 3.2.5.4.
(48) Ranking of the Constraints in Ponapean II (to be revised)

**MAX-IO (MAX-BR)**

| IDENT-IO(son)
| PLONS : CODASON
| IDENT-BR(pl) \[22\]
| DEP-IO (DEP-BR)
| IDENT-BR(son) : NOFUSION

With this ranking hierarchy, let us first look at sonorant-sonorant sequences.

\[22\] This constraint will be addressed later in the discussion of 'par' → [parapar] 'to cut'.
All candidates violate PLONS once, due to the word-final [l]. Ignoring this violation, the first candidate (a) still violates PLONS since the two laterals /ll/ come together side by side without forming a true geminate. Candidate (b) violates DEP-BR because there is a vowel insertion in the reduplicant form. The CV reduplicant [la] in candidate (c) crucially violates MAX-BR. Finally, candidate (d) violates the lowest-ranked DEP-IO(\(\mu\)). The two /ll/ are merged to form a geminate causing a DEP-IO(\(\mu\)) violation, but this linked structure satisfies PLONS in medial position. (Recall that a PLONS violation is incurred by the word-final /l/). Thus, candidate (d) is selected as the optimal output since its constraint violation is minimal among the candidates.

A parenthesized (*) in PLONS will be lost if candidates violate ALIGN(\(WD-R, M-R\)). However, it will be no use since ALIGN(\(WD-R, M-R\)) is top-ranked in Ponapean (cf. figure (85)). Thus, the forms violating ALIGN(\(WD-R, M-R\)) will be omitted in the tableaux of reduplication.
Now consider the form /pap/ "swim" in which onset and coda have the same obstruents. In the analysis of this type of the form, the following constraints play an additional role.

(50) CODASON: Codas are sonorants
(repeated from (29))

(51) IDENT-IO(son): Output correspondents of an input segment have identical values for the phonological feature sonorant (McCarthy and Prince 1995) (see also (31) on IDENT-IO(F))

IDENT-IO(son) requires that segments in input-output correspondence show exactly the same value of sonorancy (McCarthy and Prince 1995).

As we can see in (52), it is necessary that IDENT-IO(son) must dominate CODASON, since CODASON is violated not to violate IDENT-IO(son). For example, in /RED-pap/ "swim", input base form /pap/ is also [pap] on the surface. It does not become [pam] to satisfy CODASON because that causes more severe IDENT-IO(son) violation. Thus, we have the following ranking for Ponapean: IDENT-IO(son) >> CODASON.

Tableau (52) illustrates how the base form /pap/ is reduplicated through the interaction of the constraints considered thus far.
(52) /RED-pap/ ‘swim’

<table>
<thead>
<tr>
<th>/RED-pap/</th>
<th>MAX -BR</th>
<th>IDENT -IO(son)</th>
<th>PLONS</th>
<th>CODASON</th>
<th>DEP -BR</th>
<th>IDENT -BR(son)</th>
<th>NO FUSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. pap.pap</td>
<td></td>
<td>(*)</td>
<td></td>
<td>!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. pa.pa. pap</td>
<td></td>
<td>(*)</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. pam. pam</td>
<td></td>
<td>*!</td>
<td></td>
<td>(*)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. pa.pap</td>
<td>(*)</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. µ</td>
<td>(*)</td>
<td></td>
<td></td>
<td>!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. ra- pam.pap</td>
<td>(*)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All candidates violate PLONS once, due to the word-final [p]. Ignoring this violation, the first candidate (a) is eliminated by violating PLONS once and CODASON twice. In candidate (b), CODASON and DEP-BR are violated because of the word-final [p] and epenthetic vowel [a], respectively. Candidate (c) crucially violates IDENT-IO(son). In this form, IDENT-IO(son) violation results since input /pap/ is realized as [pam] on the output form. Here, reduplicant has also [pam] from the input base form /pap/, which is expressed by IDENT-BR(son). Candidate (d) is also ruled out since it crucially violates MAX-BR. The violation of MAX-BR is incurred in candidate (d) because the base form [pap] is realized as [pa] in the reduplicant. Candidate (e) is ruled out because it crucially
violates CODASON (twice). CODASON is violated because of the obstruent [p] in the coda position. DEP-IO(μ) violation is also incurred because the two [p]s form a true geminate on the surface. Finally, candidate (f) violates CODASON and IDENT-BR(son). CODASON violation is incurred by the word-final [p]. This form also violates IDENT-BR(son) because the base form /pap/ becomes [pam] in the reduplicant. Between (b) and (f), however, candidate (f) is chosen as the optimal output since it violates IDENT-BR(son) which is lower ranked than DEP-BR in the ranking hierarchy. From this we know that IDENT-IO(son) must dominate IDENT-BR(son). For that reason, homorganic NC cluster is produced in the medial position in Ponapean reduplication process from the base form /pap/.

The cases in which C₁ is obstruent and C₂ is sonorant having the same place features are analyzed in the same manner as shown just above. Thus, [kaŋ-kaŋ] is realized on the surface from input /kaŋ/ 'eat'.

Now, let us look at /tep/ 'kick' in which onset and coda obstruents have different place of articulation. Again violations due to word-final codas are parenthesized, and ignored in the subsequent discussion.
Candidate (a) violates DEP-BR due to the epenthetic vowel [e] in the reduplicant.

Candidate (b) crucially violates CODASON and PLONS due to the first coda [p].

Candidate (c) also crucially violates PLONS because the place feature (cf. [m]) is in the coda. Finally, candidate (d) is also eliminated since it crucially violates MAX-BR due to a CV reduplicant. Thus, candidate (a) is selected as the optimal output form because its constraint violation is minimal. For that reason, in /RED-tep/ type of reduplication, vowel insertion is favored over other options to resolve non-geminate obstruent clusters.

Finally, let us consider the cases where C₁ and C₂ are obstruents and sonorants, respectively, and having different place of articulation. For example, the reduplicated form of /par/ ‘to cut’ is [parapar]. This suggests that vowel insertion is preferred to making homorganic NC clusters to satisfy PLONS. Without IDENT-BR(pl), however, we would wrongly predict that [pampar] is the optimal output, instead of [parapar] as shown in (54).
(54) /RED-par/ ‘to cut’

<table>
<thead>
<tr>
<th>/RED-par/</th>
<th>PLONS</th>
<th>DEP-BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. pa.ra.par</td>
<td>(*)</td>
<td>!</td>
</tr>
<tr>
<td>b. par.par</td>
<td>!(* )</td>
<td></td>
</tr>
<tr>
<td>c. pam.par</td>
<td>(*)</td>
<td></td>
</tr>
</tbody>
</table>

To fix this problem, we need to have IDENT-BR(PI).

(55) IDENT-BR(PI): Reduplicant correspondents of a base segment have identical values for the feature Place (cf. McCarthy and Prince 1995)

If we assume this constraint is ranked above DEP-BR, we can correctly select the optimal output as shown below.

(56) /RED-par/ ‘to cut’

<table>
<thead>
<tr>
<th>/RED-par/</th>
<th>PLONS</th>
<th>IDENT-BR(PI)</th>
<th>DEP-BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. pa.ra.par</td>
<td>(*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. par.par</td>
<td>!(* )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. pam.par</td>
<td>(*)</td>
<td>!</td>
<td></td>
</tr>
</tbody>
</table>
All candidates violate PLONS due to the word-final coda [r]. Ignoring this violation, candidate (a) violates DEP-BR which is the lowest ranked among the three constraints. Candidate (b) is eliminated by the crucial violation of PLONS due to the coda [r] in the reduplicant. Between candidates (a) and (c), (a) is correctly selected as the optimal output aided by IDENT-BR(PI). That is, candidate (c) is eliminated by the crucial violation of IDENT-BR(PI). In candidate (c), reduplicant and base segments do not have the same place feature (i.e. [m] vs. [r]). This suggests that we cannot form homorganic NC clusters if the two consonants do not have the same place features. That is, if the two consonants do not have the same place features, vowel insertion is needed to satisfy PLONS.

3.2.4.6 Summary and Conclusion

Ponapean allows only geminates and homorganic NC clusters word-medially. To explain this fact, we crucially depended on the key constraint PLONS. By doing so, we could effectively characterize the close relation between vowel epenthesis and coda-related phenomena in Ponapean.

In order to remedy unacceptable coda consonants in medial position, vowel insertion is needed to break up the C1C2 sequence. However, in geminates and homorganic NC clusters, vowel insertion does not occur since these two sequences satisfy PLONS through their linking structures.
Here, the geminate integrity effect is again explained through the predicted pattern of the proposed key constraints and their ranking. We have also provided the reduplication data to support our analysis made for the word-internal CC clusters. We have shown that integrity effect of geminates (and NC clusters) and such coda-related constraints as PLONS and CODASON are effective even in the domain of reduplication.

Now let us consider another type of the language containing medial geminates which shows different predicted pattern by our system, Palestinian Arabic.

3.2.5 Palestinian Arabic: PLONS is subordinate and /...C₁C₂.../ → [...C₁C₁C₂...]

As we have shown above, if PLONS is lowest ranked, then the consonant sequences containing geminates will surface intact (cf. 10b). In this section, we exemplify this pattern of constraint ranking through the discussion of Palestinian Arabic data. The Palestinian Arabic data are from Abu-Salim (1980), Guerssel (1977) and Hayes (1986). Underlying geminates surface intact as seen in (57), both word-finally (a) and word-medially (b).

(57) a. ?imm [?imm] ‘mother’
sadd [sadd] ‘thir’
sitt [sitt] ‘ły’
hubb [hubb] ‘teś’

b. ?imm-na [?immna] ‘our mother’
sitt-na [sittna] ‘our grandmother’
kimm-na [kimmna] ‘our sleeve’
3.2.5.1 The Predictions

Specifically, Palestinian Arabic data are examined with special emphasis on geminate integrity. The first prediction can be made from the data given in (57b). The word-medial /...C_1C_1C_2.../ case which contains geminate consonants is produced by placing PLONS at bottom.

(58) /?imm-na/ 'our mother'

<table>
<thead>
<tr>
<th></th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b</td>
<td></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>c</td>
<td></td>
<td></td>
<td>*!</td>
</tr>
</tbody>
</table>

But this ranking makes the WRONG prediction for non-geminate clusters, predicting that the clusters surface intact as shown in (59).
(59) /?ibn-ha/ ‘her son’

<table>
<thead>
<tr>
<th>/?ibn-ha/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ?ibn</td>
<td>✔</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>b. ?ib.n/i</td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>c. ?ibn</td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>d. ?in</td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
</tbody>
</table>

The form (c) is the actual output form, however, the ranking from (58) selects the wrong output form (a). In Palestinian Arabic, nongeminate triconsonantal (CCC) and word-final biconsonantal (-CC#) sequences are not allowed. These impermissible sequences are resolved by inserting an epenthetic vowel as seen in (60a, b).

(60) a. ?ibn [?ibin] әәә
b. ?ibn-ha [?ibinha] ‘her son’

Figure (58) suggests that the ranking be MAX-IO >> DEP-IO >> PLONS. With these constraints and their ranking, however, we cannot correctly produce optimal output form as given in figure (59). To unravel this problem, we need to introduce a third constraint, C. The following tableau illustrates this aspect.
In (61), the violation of the constraint C is fatal and this violation wipes out the effect of the lower ranked constraints. (61a) is ruled out by the violation of C, which suggests the constraint *COMPLEX. (61b) is also ruled out by the violation of the constraint C, which suggests this time another constraint ALIGN. From above, I suggest that *COMPLEX and ALIGN must dominate both DEP-IO and PLONS. Thus, we have the following ranking:

*COMPLEX, ALIGN >> DEP-IO >> PLONS.

If *COMPLEX and ALIGN are ranked over PLONS and DEP-IO, we can correctly produce the optimal output forms in Palestinian Arabic. As those two constraints imply, epenthesis should not occur between two morphemes (61b). Vowel insertion is possible as long as stem-final consonants are also syllable final (61c). If we insert a vowel at the morpheme boundary to satisfy *COMPLEX, then it causes a crucial violation of ALIGN (61b). On the other hand, if we have multiple segments in syllable edges, then we fatally violate *COMPLEX (61a). The definition of ALIGN is given in (62) below.

(62) ALIGN: Align (Stem-R, σ-R) (i.e. ]Stem = ]σ) (McCarthy and Prince 1993a,b,c)
ALIGN states that the right edge of every stem must coincide with the right edge of some syllable; this particular version of ALIGN was proposed first in McCarthy and Prince (1993a).

Given the actual ranking *COMPLEX, ALIGN >> DEP-IO >> PLONS, we now can correctly select the optimal output form between [?ibn/ha] and [?ibn/ha]. Since ALIGN bars epenthesis at the morpheme boundary, we predict epenthesis will occur within a morpheme [?ibn/ha] (63c), instead of between the morphemes [?ibn/ha] (63b), which is exactly the case of Palestinian Arabic.

(63) /?ibn-ha/ 'her son'

<table>
<thead>
<tr>
<th>/?ibn-ha/</th>
<th>*COMPLEX</th>
<th>ALIGN</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ?ibn</td>
<td>ha</td>
<td>*!</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>b. ?ib.ni.</td>
<td>ha</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>c. ?ib.|ni.</td>
<td>ha</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Candidates (a) and (b) are ruled out by the violations of higher ranked constraints *COMPLEX and ALIGN, respectively, and we correctly produce the optimal output form [?ibn/ha] (c).

The above constraint ranking can also correctly select the optimal output form between [?immna] and [?imm/na].
Between (a) and (b), (b) is eliminated by the crucial violation of higher ranked constraint ALIGN. ALIGN is violated due to the epenthetic vowel [i]. Because of [i], stem-final does not coincide with syllable-final, thus ALIGN violation. Thus, (a) [?immna] is selected as the optimal output form.

3.2.5.2 Word-final [...CC#]

Word-final (...CC#) case is also explained in a similar fashion given above. In general, we cannot put a vowel in word-final position to satisfy some constraints (here, PLONS) in Palestinian Arabic. Thus, in word-final position, PLONS violation is tolerated.
This suggests that we need a constraint which can explain the tolerance of PLONS in word-final position. To capture this point, we use the constraint ALIGN here.²⁴

As a natural consequence of the ranking, vowel epenthesis occurs inside the consonant cluster. (Recall the ranking above: *COMPLEX, ALIGN >> DEP-IO >> PLONS).²⁵

(65) /?ibn/ 'son'

<table>
<thead>
<tr>
<th>/?ibn/</th>
<th>*COMPLEX</th>
<th>ALIGN</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ?ibn</td>
<td>*!</td>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>b. ?ibni</td>
<td>!</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c. *i</td>
<td>!</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>?ibn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First, (a) is eliminated by the crucial violation of *COMPLEX due to the multiple segments in the syllable edge. Both (b) and (c) violate DEP-IO and PLONS. DEP-IO is violated because of the epenthetic vowel [i]. PLONS is violated because of the coda consonant [b] and [n], respectively. Between (b) and (c), however, (c) is chosen as the optimal one. In (b), there is a crucial ALIGN violation because stem-final is not syllable-final due to the epenthetic vowel [i], and thus it is eliminated.

²⁴ In monomorphemic words, ALIGN(STEM-R, σ-R) can replace the job of ALIGN(WD-R, M-R), however, the need of ALIGN(WD-R, M-R) as well as ALIGN(STEM-R, σ-R) is essential in the cases of polymorphemic words, and their interaction will be addressed in the discussion of fake geminate case (e.g. /fut-ʊ → [fút] 'I entered'). ALIGN(WD-R, M-R) will be used when we analyze polymorphemic words.

²⁵ As we can see later, ALIGN(WD-R, M-R) is not dominated by any other constraints: while, ALIGN is violated, and thus dominated by some other constraints such as ALIGN(WD-R, M-R) and MAX-IO.
Above example suggests that DEP-IO can be violated to satisfy higher ranked constraints, especially *COMPLEX, here. From this example, we see that vowel epenthesis occurs between the two non-identical consonants in word-final position. Vowel insertion after the consonant clusters in word-final position is strongly prohibited by the higher-ranked constraint ALIGN which bars vowel or consonant epenthesis at stem-final (here, word-final) position. Word-final geminate case is discussed in detail in section 3.3 Final Geminates.

3.2.5.3 A Return to Geminates

As already seen, in geminate C_1C_1-C_2 clusters, epenthesis never occurs; all consonants surface, despite the violation of PLONS. We observed that ALIGN ranks above DEP-IO which in turn dominates PLONS. The following tableau shows again how ALIGN functions to decide the optimal output form in C_1C_1-C_2.
Candidate (a) violates PLONS because place feature is specified in the coda (i.e. [m]). In order to avoid PLONS violation in word-medial C₁C₁-C₂ clusters, we can put a vowel between the geminates and singleton consonants as in (b). However, that causes fatal ALIGN and DEP-IO violations due to the epenthetic vowel [i]. If we underparse the mora, then we crucially violate MAX-IO(μ) which is one of the top-ranked constraints in the ranking hierarchy (c). Thus, candidate (a) which only violates PLONS is selected as the optimal output. As we can see in this analysis of consonant clusters containing geminates, if we put a vowel after the geminates to satisfy PLONS, then we commit a more severe violation, ALIGN. Thus, it is better not to operate any changes on medial C₁C₁-C₂ clusters, resulting in [ʔimmna].

Now, let us turn to the word-final geminate case.
In (a), PLONS is violated due to the word-final segment [m]. We can think of many ways of resolving this problem. The first possibility is to insert a vowel after the geminate cluster (b). However, this causes crucial ALIGN violation, and thus it is eliminated. Another possibility is to underparse the mora (c). However, this causes crucial violation of MAX-IO(μ). Considering all these, (a) is ultimately selected as the optimal output, since the violation of PLONS is minimal among the competing candidates. This results in the geminate integrity effect in word-final position in Palestinian Arabic.

### 3.2.5.4 An Added Wrinkle: Fake Geminates

As Hayes (1986) observes, fake geminates differ from true geminates in that they are freely splittable by epenthesis as shown in (68).
As shown above, epenthesis is unable to split underlying true geminates in Palestinian Arabic. On the other hand, other clusters in Palestinian Arabic are broken up by an epenthetic vowel including fake geminates (cf. Guerssel 1977).

Let us examine a fake geminate case.

(69) /fut-t/ 'I entered'

<table>
<thead>
<tr>
<th></th>
<th>*COMPLEX</th>
<th>ALIGN</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>!</td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>fut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*!</td>
<td>!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>fut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>!</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>fut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this tableau, with those constraints and their ranking given above we cannot choose the correct output form. We wrongly predict that (c) is the optimal output. However, the actual output form is [fut/t] (b). Thus, we need a constraint to produce correctly the optimal output form (b), ruling out the other forms including (a) and (c).
Here, \texttt{ALIGN(WD-R, M-R)} plays a pivotal role in the cases of polymorphemic
words like fake geminates.\textsuperscript{26}

\textbf{(70) ALIGN(WD-R, M-R): } The right edge of every word coincides with morpheme
final elements (\texttt{[WD = ]M}) (cf. McCarthy and Prince
1993a,b,c, 1994, Itô and Mester 1994) (cf. figure (24) in
Chapter 1)

This constraint requires that the right edge of each word corresponds to the right
edge of some morpheme.

Since fake geminates are composed of two segments and are not in sequence in the
input because they are not in one morpheme, the representation of them will be as shown
in (71).

\textbf{(71) Underlying Representation of Fake Geminates}

\begin{center}
\begin{tabular}{cc}
•_i & •_j \\
| & | \\
F & F
\end{tabular}
\end{center}

\footnotesize
\textsuperscript{26} Probably, the OCP will also be useful in explaining this point (Myers 1993). The forms which are not
linked to form true geminates on the surface will violate the OCP. However, we use \texttt{ALIGN(WD-R, M-R)}
since this constraint is actively playing the role in word-final position across the languages, and is needed
for cases where the 2 consonants are not identical.
In figure (71), the two identical segments are represented independently since they are in separate morphemes in the input. With this background, let us now look at how ALIGN(WD-R, M-R) works to resolve the problem raised in (69) above.

(72)

<table>
<thead>
<tr>
<th>/fut-t/</th>
<th>ALIGN (WD-R, M-R)</th>
<th>*COMPLEX</th>
<th>ALIGN</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. fut</td>
<td></td>
<td>*!</td>
<td>*</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>b. fi</td>
<td>fu.t/t</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>c. fi</td>
<td>fut.t/i</td>
<td>*!</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Here, if we do not put an epenthetic vowel between them, i.e., when the two identical segments are specified separately on the surface, a *COMPLEX violation is incurred (a). By contrast, if we put an epenthetic vowel between them, *COMPLEX will be satisfied. Instead, it will cause ALIGN and DEP-IO violations due to the epenthetic vowel [i] (b). As (c) shows, insertion of an epenthetic vowel at word-final position crucially causes a top-ranked ALIGN(WD-R, M-R) violation. Thus, it is eliminated.

In the discussion of fake geminates, we need to have one more constraint: NOFUSION. I define the constraint as follows:

(73) NOFUSION: No element of the output has multiple correspondents in the input (McCarthy and Prince 1995)
NOFUSION rules out a type of multiple correspondence—coalescence, where two elements of the input are fused in the output (cf. Itô 1986). According to McCarthy and Prince (1995), NOFUSION is a specific instantiation of UNIFORMITY constraint family. This constraint can be used to describe the behavior of geminates. That is, if underlying /C-C/ becomes ["C] by fusion, then it incurs NOFUSION violation. If underlying /C-C/ remains [CC] without fusion, then it will incur *COMPLEX or the OCP violations (cf. section 4.6.5.1 OCP and NOFUSION). According to this, the following will be construed as violating NOFUSION.

(74) a. Input

k₁ - k₂  Fusion

|    | → |

Dor  Dor

b. Output

μ

/|

k₁₂

| |

Dor

In order to ensure vowel insertion between fake geminates, we have to assume that NOFUSION must outrank ALIGN (and DEP-IO). The following tableau shows how this constraint works to select the optimal output form.

---

27 NOBREAKING rules out another type of multiple correspondence-phonological copying, where one element of the input is split or cloned in the output. We have seen that this constraint is very important in accounting for the anti-integrity effect in Ratak dialect of Marshallese.
Candidate (a) is ruled out since it crucially violates NOFUSION. Here, NOFUSION is violated because two segments in the input become one segment with mora in the output. Thus, candidate (b) which has vowel insertion between the fake geminates is selected as the optimal output form.

The following full tableau summarizes our discussion of fake geminates shown in Palestinian Arabic.
(76) /fut-t/ ‘I entered’

<table>
<thead>
<tr>
<th>fut-t</th>
<th>ALIGN (WD-R, M-R)</th>
<th>NO FUSION</th>
<th>MAX-IO</th>
<th>*COMPLEX</th>
<th>ALIGN</th>
<th>DEP-IO</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>d.</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>e.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>f.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

In this tableau, candidate (a) is first eliminated by the crucial violation of ALIGN(WD-R, M-R). Candidate (b) is also ruled out since it violates NOFUSION which bars coalescence, where two segments of the input are fused in the output. Candidate (c) is also ruled out due to the crucial violation of MAX-IO. Candidate (d) fatally violates ALIGN(WD-R, M-R) as well as NOFUSION, and thus it is eliminated from the running. Finally, between (e) and (f), (f) is chosen as the optimal output since (e) crucially violates *COMPLEX which is higher ranked than DEP-IO and PLONS.

As we can see in the above discussion with respect to the fake geminate case, we can freely insert a vowel to fix an unacceptable consonant cluster. This is possible due to
the fact that fake geminates are represented as two separate segments underlyingly. For this reason, fake geminates behave differently from true geminates regarding integrity effect. As a result, the integrity effect of geminates is accounted for without recourse to involving the universal constraint against crossing association lines. Also, we can explain the difference between true and fake geminates through the interaction of the constraints with distinct underlying representation between them.

3.2.5.5 Summary and Conclusion

The following diagram expresses overall Palestinian Arabic constraint hierarchy discussed so far.

(77) \(\text{MAX-IO : ALIGN(Wd-R, M-R) : NOFUSION} \)

\[ \text{*COMPLEX : ALIGN} \]

\[ \text{DEP-IO} \]

\[ \text{PLONs} \]

The crucial point to note about the constraint ranking is that the central properties of geminate integrity systems can be derived from the interaction of these universal
phonological constraints, every one of which is independently motivated to explain unrelated phenomena. Specifically, in our system the predicted pattern of the proposed key constraints correctly produces the geminate integrity effect and the distributional properties of geminates in Palestinian Arabic.

Under the current approach, geminate integrity does not require any special explanation. Geminate integrity results since geminates are represented with a single consonant having a mora and MAX-IO(μ) is highly ranked. Besides, as we have suggested, the integrity effect results since NOBREAKING is high-ranked. This contrasts with the traditional rule-based approaches, since integrity effects are systematically predicted and derived as the by-product of competing universal constraints rather than characterizing every case according to the languages without any explanation or prediction.

We have explored 2 cases with low ranked DEP-IO and PLONS. The geminate integrity effect and its distributional patterns are achieved through the interaction of the constraints. Specifically, the key constraints effectively predict different patterns of the geminate integrity effect.
3.2.6 Summary of Medial Geminates

The analyses I have presented here show that the facts of geminate integrity and epenthesis come down very much on the side of OT. This property is fundamental to OT, since it follows from the essential notions of the proposed key constraint ranking and violation under domination (Prince and Smolensky 1993). Though our primary focus has been the geminate integrity effect itself situated in moraic theory under OT, the relations between epenthesis and distributional patterns of the geminates have been broadly discussed as well.

It is now appropriate to summarize the results of medial geminates and their distributional patterns considered thus far. According to the previous rule-based approaches, in Pero, vowel epenthesis occurs to break up impermissible CCC clusters, that is, to satisfy *COMPLEX (Goldsmith 1990). In the present analysis, however, vowel epenthesis occurs to satisfy top-ranked PLONS, instead of *COMPLEX: /C₁C₁C₂ʃ/ → [C₁C₁V₃C₂]. I showed that the overall patterns of the Pero data support the present analysis. Pero generally allows only geminate consonant clusters and homorganic NC clusters on the surface manifesting a dominant PLONS effect.

Ponapean data also support the present line of analysis. In Ponapean, vowel epenthesis occurs to satisfy PLONS in C₁C₂ clusters word-medially, despite the fact that there is no medial CCC sequence.
Previous rule-based approaches to Palestinian Arabic only stipulate that vowel epenthesis occurs between the first two consonants to resolve impermissible consonant sequence problem (Abu-Salim 1980, Guerssel 1977, Hayes 1986). On the other hand, the present analysis explains that (i) a vowel epenthesis is not required in the $C_1C_1C_2$ sequence since $\text{PLONS}$ is lowest ranked and there is no $\ast\text{COMPLEX}$ violation (ii) vowel epenthesis occurs between the first 2 consonants in the $\text{CC-C}$ sequence to satisfy the higher ranked $\text{ALIGN}$. Vowel epenthesis between the last 2 consonants in the $\text{CC-C}$ sequence will crucially violate $\text{ALIGN}$ since most of the cases this position coincides with the morpheme boundary in Palestinian Arabic.

Thus far, we have shown that integrity effect and the distribution of geminates in medial geminates are captured through the constraint interaction model of OT. In medial geminates, four types of geminate behaviors are predicted. From the four types, two types are exemplified: $\text{PLONS}$ is low-ranked (e.g. Palestinian Arabic), and $\text{DEP-IO}$ is low ranked (e.g. Pero, Ponapean). But, one type is not attested yet: $\text{MAX-IO}$ is low ranked. Thus, this type remains an accidental gap. The other type in which both $\text{MAX-IO}$ and $\text{PLONS}$ are low ranked is not likely to occur—a systematic gap.
3.3 Final Geminates

3.3.1 Introduction

In this section, we consider geminate integrity effects in word-final position. Not surprisingly, ALIGN(WD-R, M-R) plays a pivotal role in the analysis of integrity effects in word-final geminates in addition to the key constraints essentially used in medial geminate cases, because vowel insertion after the word-final geminate causes a discrepancy between word-final and morpheme-final elements. I give the definition of ALIGN(WD-R, M-R) below again for convenience:


This makes a striking contrast with word-initial geminates in which ONS plays a pivotal role in the analysis of integrity and anti-integrity effects in word-initial position. Thus, in addition to the three key constraints discussed in medial geminates, ALIGN(WD-R, M-R) is added in the discussion of final geminates.

Of the rest of the major key constraints, ONS and PROSHIER are irrelevant just because they do not deal with final geminates, and NOBREAKING is excluded because it is too bad by incurring not only NOBREAKING violation but also DEP-IO and PLONS.
violations. As a result, the following four key constraints are used in the discussion of final geminates: MAX-IO, DEP-IO, ALIGN(WD-R, M-R) and PLONS.

Now, let us consider the following schematized tableau.

(79) The Predicted Typology of Final Geminates (cf. figure (25) in Chapter 1)

<table>
<thead>
<tr>
<th>/VC₁Cᵢ/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ALIGN(WD-R, M-R)</th>
<th>PLONS</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. [VC₁Cᵢ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Palestinian Arabic, Ponapean</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← If PLONS is lowest ranked (see 10b)</td>
</tr>
<tr>
<td>b. [VCᵢ]</td>
<td>*(μ)</td>
<td></td>
<td></td>
<td></td>
<td>unlikely</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← (a) is better</td>
</tr>
<tr>
<td>c. [VCᵢCᵢV]</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>unattested</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>← If DEP-IO and ALIGN(WD-R, M-R) are lower ranked than PLONS</td>
</tr>
</tbody>
</table>

The leftmost column in (79) shows how word-final geminates are realized on the surface through the interaction of constraints. In (a), output form is identical with input form, violating PLONS. If PLONS is ranked below the other 3 constraints, then the geminate
surfaces intact in word-final position. Palestinian Arabic and Ponapean (Rehg and Sohl 1979) provide this type of examples in word-final position.

Consider (b) next. MAX-IO and PLONS are violated if half of the geminate is lost: a language which ranks both MAX-IO and PLONS at the bottom may map underlying geminates to surface singleton consonants. In normal cases, however, (b) will not be realized since (a) is better. In (c), an epenthetic vowel is inserted after the geminate satisfying PLONS. This sort of epenthesis, however, violates ALIGN(WD-R, M-R) in addition to DEP-IO.

In final geminate cases, however, only one type is attested (a), out of 3 predicted types of geminate patterns. Palestinian Arabic and Ponapean will be examined for the case where PLONS is low ranked in final geminates. We do not expect (79b) to occur, but (79c) may occur if ALIGN(WD-R, M-R) and DEP-IO are low-ranked, which is subject to empirical evidence. Thus, this type remains unexplained.28

3.3.2 Ponapean: [-C\textsubscript{1}C\textsubscript{1}]

As we have seen in Ponapean analysis earlier, vowel epenthesis is due to illicit coda consonants word-medially. That is, vowel epenthesis is necessary to satisfy PLONS, not to satisfy *COMPLEX. However, the story becomes quite different if we consider final consonant clusters.

---

28 For more details, see section 1.4.1 Gaps in the Predicted Types of Geminates.
In Ponapean, only geminates and place-linked (i.e. homorganic) NC clusters can be placed in word-internal syllables. In other words, coda consonants are prohibited except for the geminates and place-linked NC clusters. On the other hand, word-final syllables can have single coda consonants, geminates or homorganic NC clusters (Itô 1989: 226).

Given the assumption that ALIGN(WD-R, M-R) dominates PLONS, we can explain why we can not insert a vowel word-finally to satisfy PLONS.\textsuperscript{29} The following tableau illustrates this point.

(80)

<table>
<thead>
<tr>
<th>/kitik-men/</th>
<th>ALIGN(WD-R, M-R)</th>
<th>PLONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ki.ti.ki.me.ni</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b. ki.ti.ki.men</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

As we can see in the above tableau, vowel epenthesis in word-final position satisfies PLONS (a), but it causes a more severe ALIGN(WD-R, M-R) violation. According to ALIGN(WD-R, M-R), the rightmost edge of the morpheme must coincide with the rightmost edge of the word. In this sense, (b) satisfies this constraint, despite the PLONS violation. Thus, there is no epenthesis word-finally in Ponapean.

Let us consider the following examples.

\textsuperscript{29} Vowel epenthesis occurs word-internally to satisfy PLONS in Ponapean. This means that ALIGN is lower-ranked than PLONS. In this regard, I ignore ALIGN in the analysis of Ponapean data.
The examples in (81) clearly show that sonorant geminates and homorganic NC clusters can occur in word-final position. This means that *COMPLEX violation is tolerated in word-final position in Ponapean. In this regard, I suggest that both ALIGN(WD-R, M-R) and CONTIGUITY must be higher ranked than *COMPLEX to ensure these forms in word-final position: ALIGN(WD-R, M-R), CONTIGUITY » *COMPLEX.

If we look at just final geminates, PLONS is lowest ranked (cf. (79a)). However, if we consider both medial and final geminates, then it is imperative that we should modify ranking of the constraints. That is, if we consider both (48) and (79a), we get the following ranking: ALIGN(WD-R, M-R), MAX-IO » PLONS » DEP-IO (especially, note the ranking relation between PLONS and DEP-IO). Thus, contrary to the ranking predicted for final geminates in (79a) (i.e. DEP-IO » PLONS), we must assume the reversed ranking (i.e. PLONS » DEP-IO) (cf. figure (48)).

Now, let us look at word-final geminate case first.
Candidate (a) is eliminated by crucially violating MAX-IO and PLONS by deleting the first half of the geminate. In (b), we have a vowel insertion after the geminate. This, however, causes crucial ALIGN(WD-R, M-R) violation as well as DEP-IO. On the other hand, candidate (c) violates PLONS only. Thus, word-final geminate (c) is produced as the optimal output form.

Next, homorganic NC cluster is examined in word-final position. It is a general observation that disrupting the contiguity of morpheme elements is not allowed in Ponapean. For this, we propose CONTIGUITY.

(83) CONTIGUITY: Adjacent elements in the lexical representation of a morpheme should not be separated by an extraneous segment in prosodic structures (Kenstowicz 1994b, McCarthy and Prince 1995)
CONTIGUITY is a special type of faithfulness. The constraint CONTIGUITY says that if two segments /X/ and /Y/ are adjacent each other in the lexical representation of a morpheme, then it is not optimal when /X/ and /Y/ are separated by extraneous segments in prosodic structure. As given in the definition, this constraint is against gaps as well as dummies (cf. "no skipping" provision of Marantz 1982, and McCarthy and Prince 1986). According to Kenstowicz (1994b), the CONTIGUITY constraint has some parsing motivation preferring candidates in which the input is realized as a substring of the output. That is, CONTIGUITY predicts that the epenthetic vowel should appear at the morpheme boundary, as it does in Chukchee (Kenstowicz 1994b). This will also extend to the domain of base-reduplicant identity, and to other relations (cf. McCarthy and Prince 1995). Because of this constraint, Ponapean strongly prohibits insertion of a vowel within a morpheme.

The following tableau shows how NC clusters are possible in word-final position in Ponapean through the interaction of the constraints. Specifically, the ranking \textsc{ALIGN}(WD-R, M-R), \textsc{CONTIGUITY} \gg \textsc{*COMPLEX} correctly selects the NC clusters word-finally.
In the above tableau, the first candidate (a) which violates \text{*COMPLEX} and PLONS is chosen as the optimal output form. If we delete the word-final consonant as in (b), then we can satisfy \text{*COMPLEX}. However, we crucially violate MAX-IO and ALIGN(WD-R, M-R) in exchange for that, and thus it is eliminated. If we put a vowel after the word-final consonant cluster as in (c), then we satisfy PLONS and \text{*COMPLEX}. However, this causes a more severe violation of ALIGN(WD-R, M-R). Thus, candidate (c) is also eliminated. If we put a vowel between the word-final consonant cluster as in (d), then we satisfy \text{*COMPLEX}. However, we have a more severe CONTIGUITY violation. Thus, this candidate is also eliminated. In this way, the word-final homorganic NC cluster is selected.

Now, we are in the position to provide the ranking of the constraints in Ponapean discussed so far, considering final and medial positions including Reduplication data. The complete constraint ranking of Ponapean will be given when we consider initial position.
(85) Ranking of the Constraints in Ponapean III (to be revised)

\[
\begin{align*}
\text{MAX-IO [MAX-BR]} & : \text{CONTIGUITY} : \text{ALIGN(Wd-R, M-R)} \\
& \mid \text{IDENT-IO(son)} \\
& \mid \text{*COMPLEX} \\
& \mid \text{PLONS : CODASON} \\
& \mid [\text{IDENT-BR(PI)}] \\
\text{DEP-IO [DEP-BR]} & \mid [\text{IDENT-BR(son)}] : \text{NOFUSION}
\end{align*}
\]

### 3.3.3 Summary of Final Geminates

To summarize, as we can see in the analyses of word-final examples, geminates and NC clusters appear on the surface, violating \*COMPLEX, PLONS. However, despite these violations they are considered as the optimal output forms since other forms have more severe constraint violations. Thus, geminates and NC clusters are realized on the surface in Ponapean.

Palestinian Arabic can also be analyzed in the same manner as shown in Ponapean final consonant clusters. Previous rule-based approaches to Palestinian Arabic propose that vowel epenthesis occurs between the 2 consonants to resolve impermissible
consonant sequence problem (including geminates). By contrast, the present analysis explains that vowel epenthesis is not required in word-final geminates since PLONS is lowest ranked and there is no \*COMPLEX violation. We have also seen that, since fake geminates have two consonant segments, vowel epenthesis in fake geminates does satisfy \*COMPLEX. We will not repeat Palestinian Arabic analysis here since it has been fully presented in sections 3.2.5.2 and 3.2.5.3.
3.4 Initial Geminates

3.4.1 Introduction

In this section, we consider geminate integrity and anti-integrity effects in word-initial position. According to the moraic theory, underlying initial geminates are so unstable because of their moraicity in that position that they are realized in several different forms on the surface to fix unstable initial moraic status of geminates. Not surprisingly, the constraints ONS and PROSHIER play pivotal roles to account for general behavior of initial geminates and NOBREAKING plays a key role in explaining anti-integrity effect shown in Ratak dialect of Marshallese. PLONS and ALIGN(WD-R, M-R) will not be required in the discussion of initial geminates. Thus, in addition to the two key constraints (MAX-IO and DEP-IO), ONS, PROSHIER and NOBREAKING are added in the discussion of initial geminates. As a result, the predicted typology increases.

Let us consider the following schematized tableau.
## The Predicted Typology of Initial Geminates (cf. figure (27) in Chapter 1)

<table>
<thead>
<tr>
<th>/CiC_iV/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>PROS HIER</th>
<th>NO BREAKING</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/CiV/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. [CiC_iV]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Woleaian</td>
</tr>
<tr>
<td>( \Sigma )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /\sigma )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /\mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /C_1V )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. [CiV]</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>Ponapean. Fijian</td>
</tr>
<tr>
<td>( \sigma )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /\mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /C_1V )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. [V_iC_1\Sigma V]</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>Berber</td>
</tr>
<tr>
<td>( \sigma )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /\mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /V_1C_1V )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. [V_1C_1\Sigma V]</td>
<td></td>
<td></td>
<td>**</td>
<td></td>
<td></td>
<td>Ralik</td>
</tr>
<tr>
<td>( /\mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /V_1C_1V )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. [Ci_1V_iC_1V]</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>Ratak</td>
</tr>
<tr>
<td>( \sigma )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /\mu )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( /C_1V_1C_1V )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**If PROSHIER is lowest ranked**

**If MAX-IO(\( \mu \)) is lowest ranked**

**If DEP-IO is lowest ranked**

**If NOBREAKING is lowest ranked**
The leftmost column in (86) shows how word-initial geminates might be realized on the surface through the interaction of constraints. In (a), input and output forms are identical, which violates PROSHIER. If PROSHIER is ranked below the other 4 constraints, then the geminate surfaces intact. Woleaian (Sohn 1976) provides an example.

Consider (b) next. MAX-IO(\mu) is violated if half of the geminate is lost: a language which ranks MAX-IO(\mu) at the bottom maps underlying geminates to surface singleton consonants, satisfying other constraints, but violating MAX-IO(\mu). This is exemplified in the discussion of Ponapean and Fijian (Dixon 1988).

In (c), an epenthetic vowel is inserted before the geminate to satisfy PROSHIER in word-initial position. Since this is word-initial, not medial or final, simple epenthesis violates ONS, too. This contrasts with non-initial epenthesis, where there is material to the left of the epenthetic vowel to create an onset. However, nothing is available to the left of a word-initial geminate. Both DEP-IO and ONS must be low-ranked, with ONS lower than DEP-IO, for this pattern to arise. Berber (Saib 1977) shows this type of initial geminate clusters.

In (d), a core syllable (i.e. CV) is inserted before the word-initial geminate. DEP-IO must be low-ranked in this type of language. I exemplify languages like this in my discussion of Ralik, a dialect of Marshallese (Abo et al. 1976).

Finally, (e) presents the anti-integrity case. I exemplify this type of languages in my discussion of Ratak, a dialect of Marshallese (Abo et al. 1976).
To summarize, the predictions regarding word-initial geminate consonants are achieved by partially permuting the ranking of the constraints. Depending on the ranking of the constraints, different output forms can result from the same input form, giving rise to different resolutions to the geminate puzzle. This point is a key advantage of the OT approach over previous rule-based approaches.

In the following sections, Woleaian and both Ponapean and Fijian are briefly presented as simple cases of PROSHIER (a) and MAX-IO(μ) (b) violations, respectively. More detailed discussion of the other two types of the geminate behavior follows in sections on Ralik Marshallese (d) and Ratak Marshallese (e). However, the analysis of Berber (c) is not given here since there is no difference between geminates and nongeminate consonant clusters (cf. section 1.4.1 Gaps in the Predicted Types of Geminates). That is, nongeminate consonant clusters as well as geminates show contiguity and initial epenthesis without distinction.

3.4.2 Woleaian: [C₁C₁V-]

In this section, we examine the case in which consonant geminates (i.e. initial C₁C₁V-) are realized on the surface. In order to get this pattern, we have to assume that PROSHIER is ranked at the bottom as predicted in (86a). In this regard, Woleaian (Sohn 1976. 1984) fits into this type.
Woleaian consonants are either singletons or geminates (Sohn 1976, 1984).

Woleaian has geminates, but not consonant sequences, except in very recent loanwords (Sohn 1976, 1984; Sherer 1994). The following are examples in which geminates appear in word-initial position. The following examples come from Sohn (1984: 220).

(87) /ppiye/ [ppiye] 'sand'
/ttiri/ [ttiri] 'des'
/ccaa/ [ccaa] 'blood'
/kkaŋi/ [kkaŋi] 'shop'
/ppese/ [ppese] 'white'
/ffaxe/ [ffaxe] 'cough'
/ssaapu/ [ssaapu] 'fishing kit'
/mmate/ [mmate] 'awake'
/ŋŋawe/ [ŋŋawe] 'hut'
/mmuto/ [mmuto] 'to vomit'

As we can see in the above examples, Woleaian maps underlying geminates to surface as geminate consonants, although this language has basically CV syllable structure. Thus, we have to explain why geminates are allowed, but consonant sequences are not allowed in this language.

According to our prediction given in (86a), PROSHIER is ranked at the bottom.

This suggests the following ranking relations for the 4 key constraints:

(88) MAX-IO, DEP-IO, ONS, >> PROSHIER
The following tableau is a simple illustration of this ranking.

(89)/tiri/ ‘fast’

<table>
<thead>
<tr>
<th></th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>PROSHIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/tiri/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>Σ</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/ σ σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>μ/μ</td>
<td>μ/μ</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>tiri</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>σ σ σ</td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/ /</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>μ/μ/μ</td>
<td>μ/μ</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>tiri</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>σ σ</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/ /</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/μ/μ</td>
<td>/μ</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>tiri</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this tableau, candidate (a) violates PROSHIER, but is preferred in this case because PROSHIER is lowest ranked. On the other hand, the rest of the candidates are ruled out since they violate one or more than one constraints which are ranked higher than PROSHIER. Candidate (b) crucially violates DEP-IO and ONS due to the word-initial
epenthetic vowel [i]. Candidate (c) also crucially violates MAX-IO(μ) due to the underparsing of the input mora.

However, if we consider word-medial cases, the story becomes quite complicated. Let us compare the following tableaux. (The examples are from Sherer 1994: 65).

(90)

<table>
<thead>
<tr>
<th>( \mu )</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>PROSHIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>/bunu/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>( \sigma ) ( \sigma ) ( \sigma ) ( \sigma ) ( \mu )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>( \sigma ) ( \sigma ) ( \mu ) ( \mu )</td>
<td>( \star (\mu) )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this tableau, the medial geminate is correctly selected as optimal as predicted by the given ranking of the constraints. That is, it is better to have a coda consonant in geminate case. However, the following example raises a contradiction.
In Woleaian, nongeminate sequences are not found. Therefore, unlike the geminate case, it is worse to have a coda consonant in nongeminate case. That is, (b) should be the actual output form. However, the above tableau wrongly predicts that (a) is optimal, instead of (b).

In order to resolve this contradiction, we suggest a constraint C-ONS which is in the same family as PLONS.

(92) C-ONS: Consonant features are in onsets

The constraint C-ONS basically says that consonants are not allowed except when part of an onset. While both geminates and homorganic NC clusters satisfy PLONS, only geminates satisfy C-ONS. In a homorganic NC structure, the coda alone has the feature [+nasal], although it shares place feature with the following onset. Thus, the NC structure violates C-ONS. On the other hand, geminates satisfy C-ONS as well as PLONS since all the features are in onsets through the linked nature of geminate structures.

<table>
<thead>
<tr>
<th>/buntu/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>PROSHIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ✓ bun.tu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. ✓ bu.tu</td>
<td>┴</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This constraint motivates the deletion of the non-geminate coda consonants, in which *COMPLEX does not force any deletion since there are no CCC clusters medially. Thus, this can be a specific case of NOCODA of Prince and Smolensky (1993), dealing only with geminate codas.

Since non-geminate coda consonants are deleted and geminates are never degeminated in Woleaian, MAX-IO should be dominated by C-ONS to allow only a segmental deletion of nongeminate sequences. Below is the summary of the ranking of the constraints for Woleaian:

(93) DEP-IO : ONS : IDENT-IO(F) : C-ONS
    |    |    |    MAX-IO
    |    |    | PROSHIER

To see how the interaction of the constraints works to produce the predicted typology, I provide the summary of each relevant cases examined above.

First, as we have seen in (89) above, by ranking PROSHIER at the bottom, we allow initial geminates in Woleaian: e.g. [ttiri] 'fast'.
Second, medial geminate sequences are also realized on the surface, since there is no constraint violation in this form as shown in (90).

Finally, as we can see in the following tableau (94), C-ONS plays a pivotal role to rule out the form containing nongeminate coda (b). Candidates (c) and (d) are also eliminated due to the violations of DEP-IO and IDENT-IO(F), respectively. As a result, candidate (a) which violates MAX-IO is selected as the optimal output form.

To summarize, we have illustrated how geminates are allowed in Woleaian, ruling out nongeminate sequences. Especially, by dint of the added constraint, C-ONS and its interaction with the key constraints, the integrity effects of geminates in Woleaian has been accounted for. By ranking PROSHIER at the bottom and C-ONS on the top, we have correctly eliminated nongeminate clusters, ensuring only geminate clusters. In this way,
we have only gemmates, but no other sequences on the surface as shown in Woleaian word-initial clusters.

3.4.3 Ponapean and Fijian: [CV-]

This section illustrates the second predicted pattern in which $\text{MAX}-\text{IO}$ is low ranked. Fijian and Ponapean are discussed to show that only [CV-] syllable structures are allowed on the surface regardless of the input structures. In Ponapean, however, we will have to rearrange the ranking due to the different patterns in medial, final and initial positions. Despite this complexity in their positions, I deal with Ponapean in this section because this language shows [CV-] pattern in initial position.

3.4.3.1 Ponapean

Let us first look at word-initial consonant cluster examples in Ponapean. The following data are collected from Rehg and Sohl (1979), McCarthy and Prince (1986), Itô (1989), and Levin (1989).

(95) Geminates and Sequences in Ponapean

\begin{align*}
\text{a. } & \text{m} & \text{met} & \text{[met]} & \text{fil} \\
& \text{was} & \text{wwas} & \text{[was]} & \text{‘obnoxious’} \\
& \text{m} & \text{m} & \text{m} & \text{m} & \text{us}^{31} & \text{[m} & \text{us}] & \text{‘omir’} \\
& \text{η} & \text{η} & \text{η} & \text{ar} & \text{[ηar]} & \text{we’} \\
& \text{η} & \text{net} & \text{[net]} & \text{‘par’}
\end{align*}

\text{31} \text{m} & \text{is velarized voiced bilabial nasal, and } \text{p} & \text{is unaspirated velarized voiceless bilabial stop.}
In Ponapean, geminates contrast with non-geminates in morpheme-initial and final positions. Word-initially, underlying geminates are degeminated. Rendered word-internal by morphology, however, underlying geminates are realized without degemination (e.g. /mme/ \(\rightarrow [mme] \) \(\) 'fill' vs. /ka+mme/ \(\rightarrow [kamme] \) 'cause to be full').

According to Rehg and Sohl (1979), one interesting thing about Ponapean is that on the one hand word-initial geminates are degeminated in Ponapean, on the other hand word-initial homorganic NC clusters are preceded by an epenthetic vowel instead of deletion of the segments.\(^{33}\) That is, geminates and homorganic NC clusters behave differently to resolve word-initial consonant cluster problem. To capture this point, we employ MAX family constraints: MAX-IO(seg) and MAX-IO(\(\mu\)).\(^{34}\) As the following

\(\begin{array}{lll}
\text{b. mpe} & [\text{impe}] & \text{'beside it'} \\
\text{mpek} & [\text{impek}] & \text{'search for lice'} \\
\text{m}\text{p}\text{ul} & [\text{um}\text{p}\text{ul}]^{32} & \text{'to flame'} \\
\text{nda} & [\text{inda}] & \text{'ay'} \\
\text{ŋkel} & [\text{ŋkel}] & \text{'of breadfruit or bananas'}
\end{array}\)

\(^{32}\)/\(u\)/ appears with rounded initial consonants or when the vowel of the first syllable is round (Rehg and Sohl 1981).

\(^{33}\)Rehg and Sohl (1979) distinguish between Prothesis of /\(i\)/ and /\(u\)/ in word-initial position and Epentheisis of /\(i\)/ and /\(u\)/ to break up any impermissible cluster. However, their function seems to be the same and choice between /\(i\)/ and /\(u\)/ is phonetically predictable on the same grounds in both the cases (cf. McCarthy and Prince 1986). Thus, we will consider them as a same vowel insertion phenomenon motivated to resolve impermissible consonant clusters.

\(^{34}\)Another possibility is to use ALIGN-L(F) to account for the different behavior between geminates and NC clusters word-initially: ALIGN-L(F): Align features (Stem-L, PrWd-L). According to McCarthy and Prince (1993b), ALIGN-L says that the left edge of any stem must coincide with the left edge of a PrWd. That is to say, the satisfaction of the ALIGN-L demands a faithful parse at the left edge of the stem. Deletion of an element is in the violation of this constraint. An unparsed element comes to de-align the PrWd and the stem, since the unparsed element which belongs to the stem does not occupy any position at all in the PrWd. In sum, for ALIGN-L to be satisfied, the stem-initial element must occupy initial position in a
diagrams show, degemination of geminates violates MAX-IO(μ) and deletion of the nasal consonant in NC clusters violates MAX-IO(seg).

(96) I. Degemination of Geminates: MAX-IO(μ) violation

a. Geminate

b. Degemination

As the above diagram shows, degemination does not cause the misalignment of the PrWd and stem with respect to features at the left edge. In the case of NC clusters, however, deletion of the nasal consonant causes a violation of ALIGN-L(F), since input and output forms have different features at the left edge. That is, deletion of the first Root node in NC cluster will cause featural misalignment.

II. /NC/ → [C]

a. NC

b. C

Thus, both insertion and deletion cause the misalignment of the PrWd and stem. McCarthy and Prince (1993b) give the definition of PrWd with respect to prosodic hierarchy and discuss the issue of the assymetry between ALIGN-L and ALIGN-R in their reference to prosodic categories.
II. /NC/ → [C]: MAX-IO(seg) violation

a. NC

- Root nodes

b. C

- Root node

According to the ranking of the predicted pattern, MAX-IO(\(\mu\)) is lowest ranked. However, to ensure vowel epenthesis before NC clusters barring deletion of the nasal consonant, we have to assume that MAX-IO(seg) and *COMPLEX must be higher ranked than DEP-IO and ONS: MAX-IO(seg), *COMPLEX » DEP-IO, ONS » MAX-IO(\(\mu\)).

Let us first look at the ranking in which MAX-IO(seg) dominates DEP-IO and ONS.

(97) MAX-IO(seg) » DEP-IO, ONS

<table>
<thead>
<tr>
<th>/nda/</th>
<th>MAX-IO(seg)</th>
<th>DEP-IO</th>
<th>ONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\varepsilon)</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>in.da</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. (\varepsilon)!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>da</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With regard to *COMPLEX, it must also outrank both DEP-IO and ONS as shown in (98):
Another constraint is motivated to deal with syllabic consonants. Consonants are usually non-syllabic, but a resonant consonant can be syllabic.\textsuperscript{35} Since the majority of syllabic consonants are either liquids or nasals, I suggest \textsc{peak} to capture that aspect in Ponapean. That is, resonant geminates can be syllabic (e.g. \textipa{/mmet/} $\rightarrow$ \textipa{[M.met]} \textsuperscript{36}).

The definition of \textsc{peak} is given in (99):

(99) \textsc{peak}: Every syllable has a vowel (Archangeli 1997)

With respect to the ranking between \textsc{peak} and \textsc{dep-io} and \textsc{ons}, it is clear that \textsc{peak} should dominate both \textsc{dep-io} and \textsc{ons} as shown in (100).

\textsuperscript{35} Although most syllabic consonants are resonants, even fricatives or stops may also be syllabic in a few languages such as Imdawn Tashlihiyt Berber (Dell and Elmedlaoui (1985), Suh (to appear)).

\textsuperscript{36} Syllabic consonants are capitalized in the examples.
Finally, considering NC clusters of Ponapean, we need to have CONTIGUITY which allows no disrupting contiguity of morpheme elements in Ponapean. This constraint has already been introduced in the analysis of geminates and NC clusters in word-final position in Ponapean (section 3.3.2).

Summarizing thus far, we have the following ranking with regard to word-initial NC structures.

(102) MAX-IO(seg), *COMPLEX, PEAK. CONTIGUITY >> DEP-IO, ONS
Now, I address the ranking argument concerning word-initial geminates in Ponapean. The following tableau suggests that PEAK should dominate MAX-IO(µ).

(103) **PEAK >> MAX-IO(µ)**

<table>
<thead>
<tr>
<th>µ</th>
<th>/met/</th>
<th>PEAK</th>
<th>MAX-IO(µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>met</td>
<td>*(µ)</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>σ σ</td>
<td>*!</td>
<td></td>
</tr>
</tbody>
</table>

PROSHIER should also dominate MAX-IO(µ) as illustrated in (104).

(104) **PROSHIER >> MAX-IO(µ)**

<table>
<thead>
<tr>
<th>µ</th>
<th>/met/</th>
<th>PROSHIER</th>
<th>MAX-IO(µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Σ /</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/σ /</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>µ/µ |</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/\ met</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>met</td>
<td>*(µ)</td>
<td></td>
</tr>
</tbody>
</table>
Finally, DEP-IO and ONS must dominate MAX-IO(µ) to avoid inserting a vowel before the initial geminates.

(105) DEP-IO, ONS >> MAX-IO(µ)

Now, we can establish the following ranking with respect to initial geminates in Ponapean.

(106) PEAK, PROSHIER >> DEP-IO, ONS >> MAX-IO(µ)

Summarizing thus far, we have made the following ranking arguments for the initial behavior of Ponapean consonant clusters.
(107) a. MAX-IO(seg), *COMPLEX, PEAK, CONTIGUITY >> DEP-IO, ONS
    b. PEAK, PROSHIER >> DEP-IO, ONS >> MAX-IO(μ)

From (107), we derive the following ranking.

(108) MAX-IO(seg), PROSHIER, CONTIGUITY, PEAK, *COMPLEX >> DEP-IO, ONS >> MAX-IO(μ)

If we include the constraints and their ranking which are responsible for the behaviors of initial geminates and NC clusters, then it is inevitable to modify the ranking hierarchy established in medial position (48) and final position (85), above. The following is the finally revised ranking hierarchy of Ponapean, considered all three positions, word-medial (and reduplication), word-final and word-initial.
200

(109) Ranking of the Constraints in Ponapean (final version)

\[
\text{MAX-IO(seg)} [\text{MAX-BR}] : \text{CONTIGUITY} : \text{ALIGN(Wd-R, M-R)} : \text{PEAK} : \text{PROSHIER} \\
| \\
| \text{IDENT-IO(son)} \\
| \\
| *\text{COMPLEX} \\
| \\
\text{PLONS} : \text{CODASON} \\
| \\
[\text{IDENT-BR(Pl)}] \\
| \\
\text{DEP-IO} [\text{DEP-BR}] : \text{ONS} \\
| \\
\text{MAX-IO(\mu)} : [\text{IDENT-BR(son)}] : \text{NOFUSION}
\]

With this ranking hierarchy, now let us examine word-initial data.

Word-initial geminate cluster case is first examined. Degemination essentially results from the ranking PEAK, PROSHIER >> DEP-IO, ONS >> MAX-IO(\mu).
(110) /mmeʃ/ ‘full’

<table>
<thead>
<tr>
<th></th>
<th>PEAK</th>
<th>PROSHIER</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>MAX-IO(μ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td>!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/meʃ/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/a\</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>μ /μ/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/met</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td>!</td>
<td>! *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/a\</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>μ μ μ/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/met</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/met</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Candidate (a) is first eliminated, due to the fatal violation of the constraint PROSHIER. Here, PROSHIER violation is incurred because the prosodic category mora (μ) is directly dominated by the prosodic category foot (Σ), not by the syllable node (σ). Candidate (b) is also eliminated by the crucial violation of PEAK. The reason is that the first syllable does not have a vowel. Candidate (c) is also ruled out because the insertion of an
epenthetic vowel before the geminate crucially causes DEP-IO and ONS violations. Note that these constraints are ranked higher than MAX-IO(μ). Finally, candidate (d) is chosen as the optimal output since it violates only lowest ranked MAX-IO(μ). In this way, we have degemination in word-initial position on the surface in Ponapean.

Our next job is to examine word-initial NC cluster data which show a different behavior from geminate clusters. Vowel epentheses before the NC cluster results from the ranking MAX-IO(seg), CONTIGUITY, PEAK >> *COMPLEX >> DEP-IO, ONS.

(111)/nda/ ‘say’

<table>
<thead>
<tr>
<th>/nda/</th>
<th>MAX-IO(seg)</th>
<th>CONTIGUITY</th>
<th>PEAK</th>
<th>*COMPLEX</th>
<th>DEP-IO</th>
<th>ONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>in.da</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>da</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ni.da</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>nda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>na</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td>σ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.da</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Candidate (a) violates DEP-IO and ONS due to the vowel epenthesis word-initially. On the other hand, candidate (b) crucially violates top-ranked MAX-IO(seg). Candidate (c) also crucially violates CONTIGUITY because vowel epenthesis occurs within the morpheme. Candidate (d) is eliminated by the crucial violation of *COMPLEX. Candidate (e) is also ruled out because it crucially violates MAX-IO(seg) and CONTIGUITY. These violations result from the deletion of the morpheme-internal segment [d]. Finally, candidate (f) is eliminated by the crucial violation of the constraint PEAK due to the lack of a vowel in the first syllable. Thus, candidate (a) is correctly selected as the optimal output form among the competing candidates. In this way, in initial position vowel insertion before the NC cluster is preferred to other options.

To summarize, we have considered Ponapean word-initial geminates and NC sequences. Owing to the core interaction of the key constraints, we could make the prediction that geminates behave differently from NC clusters word-initially. Since degemination violates lowest-ranked MAX-IO(µ), we are able to have singletons in initial position. Deletion of the segments in NC clusters, however, causes top-ranked MAX-IO(seg) violation. By contrast, insertion of an epenthetic vowel before the NC cluster causes DEP-IO and ONS violations. As a result, word-initial epenthesis is favored over deletion in NC clusters, since MAX-IO(seg) is higher-ranked than DEP-IO and ONS in Ponapean. In this way, we can explain different behavior of geminates and NC clusters of Ponapean in initial position.
In the following section, another predicted pattern regarding word-initial geminates is examined.

3.4.3.2 Fijian

This section is concerned with another language which illustrates the type of pattern in which MAX-IO is ranked at the bottom. As Ponapean initial geminates show, where MAX-IO is ranked at the bottom, an initial input geminate will surface as a singleton consonant by degemination effect. To take a case, let us consider Fijian (Dixon 1988, Sherer 1994).

Fijian is a case where there are neither geminates nor consonant sequences. The roots of Fijian are all vowel-final and there are no prefixes. Suffixation does not create underlying consonant sequences. Thus, our discussion of geminates and sequences in Fijian is a purely hypothetical one. However, the fact that there are no sequences in Fijian cannot be attributed to the sole property of the underlying representation or input due to the absence of constraints holding solely of the input (under OT). Even if there are no underlying consonant sequences in Fijian, we can still argue that the same result can be attributed to the constraint interaction in Fijian which leads to the barring of consonant sequences on the surface. This line of reasoning is also found in Sherer (1994).

The following examples show that Fijian allows only CV syllable structures on the surface regardless of the input structures. That is, Fijian does not necessarily have
such underlying representations, but the surface constraints are of importance, not the underlying forms in OT.

To explain the codaless nature of Fijian, we need the constraint NOCODA.

*COMPLEX does not play any role in cases where there are no CCC clusters medially.

(112) NOCODA: Coda consonants are not allowed (Prince and Smolensky 1993)

According to Prince and Smolensky (1993), this constraint is a restriction on the occurrence of any consonants in the coda position. This simply says that coda consonants are dispreferred. In order to allow only CV syllable structures on the surface, MAX-IO is assumed to be ranked at the bottom.

Let us first look at the word-initial geminate case.
(113) Word-initial Geminates

<table>
<thead>
<tr>
<th></th>
<th>DEP-IO</th>
<th>ONS</th>
<th>NOCODA</th>
<th>PROSHIER</th>
<th>MAX-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td>!</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the tableau, candidate (a) is first ruled out by the crucial violation of PROSHIER. Candidate (b) is also eliminated since it crucially violates DEP-IO, ONS and NOCODA. Finally, candidate (c) is selected as the optimal output since it has the least violation of MAX-IO. As a result, geminates are degeminated word-initially in Fijian.

Let us consider geminates and non-geminate clusters in word-internal position.
(114) Geminates in Word-medial Position

<table>
<thead>
<tr>
<th>μ</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>NoCODA</th>
<th>PROSHIER</th>
<th>MAX-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>/kanu/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. μ</td>
<td></td>
<td></td>
<td>!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/kanu/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. ka.nu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*(μ)</td>
</tr>
</tbody>
</table>

(115) Nongeminate Sequences in Word-medial Position

<table>
<thead>
<tr>
<th>/kantu/</th>
<th>DEP-IO</th>
<th>ONS</th>
<th>NoCODA</th>
<th>PROSHIER</th>
<th>MAX-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. kan.tu</td>
<td></td>
<td></td>
<td>!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. ka.tu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>c. ka.ni.tu</td>
<td></td>
<td></td>
<td>!</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the above tableaux, underlying medial geminates (114) and medial CC clusters (115) have CV syllable structures on the surface. This is possible since NoCODA and DEP-IO dominate MAX-IO in Fijian.

To summarize, in Fijian, or other CV languages, it is more harmonic to degeminate or delete segments to maintain CV syllable structure on the surface, excluding CCV or CVC. This is achieved by ranking NoCODA on the top and MAX-IO at the bottom.
Consequently, neither geminates nor consonant sequences can exist on the surface regardless of the input forms.\textsuperscript{37}

3.4.4 Marshallese: $[CVC_1C_1V]$ and $[C_1VC_1V]$\textsuperscript{38}

In this section, I offer an analysis of Marshallese, an Austronesian language of the Oceanic branch, as cases of our discussion of geminate integrity and anti-integrity in Optimality Theoretic terms. Marshallese is a good example since this language essentially displays both integrity and anti-integrity effects in the dialects of the same language.

Ralik and Ratak dialects in Marshallese show different behavior with respect to word-initial geminates. Underlying word-initial geminates in Ratak are separated by an epenthetic vowel—an apparent case of anti-integrity (cf. Goldsmith 1990, Abo et al. 1976), while in Ralik, epenthesis precedes the geminate. Apparently, Ralik respects integrity whereas Ratak does not.

In describing the dialectal variation shown in Marshallese, I show that the dialectal difference between Ralik and Ratak of Marshallese can be accounted for with the basic strategy of different ranking of the constraints. That is, the constraint interaction model

\textsuperscript{37} In Fijian, there is no reason to posit geminates and CC clusters underlyingly. As I mentioned at the outset of this section, however, this discussion is purely hypothetical. What is emphasized here is that the surface constraints and their interactions are of importance, not the underlying forms in OT.

\textsuperscript{38} An earlier version of this section was presented at the 12th Eastern States Conference on Linguistics held at Dartmouth College, Hanover, New Hampshire, October 24-25, 1994. I would like to express my gratitude to Deborah Schmidt and Naomi Nagy for helpful comments. This was also published in the Proceedings of the Twelfth Eastern States Conference on Linguistics (1995: 308-317) under the title of “Variation as Optimality in Marshallese Word-initial Geminates”.

of OT incorporates variability directly without ad hoc or multiple procedure of rules and rule ordering (Kenstowicz 1994b, Iverson and Lee 1994, Hong and Suh 1995).

Furthermore, I show in this section that Lexicon Optimization (Prince and Smolensky 1993, Itô, Mester and Padgett (1995) forces us to choose the input form that matches with an output form in the way least offensive to the constraint hierarchy, where multiple inputs result in identical optimal outputs. As a result, in Marshallese, anti-integrity is only apparent, not real, once we adopt the concept of Lexicon Optimization.

3.4.4.1 The Dialect Difference in Marshallese

Now, let us look at the data. I selected examples from the Marshallese-English Dictionary by Abo, Bendor, Capelle, and Debrum (1976).^1

(116) Data (Abo, Bendor, Capelle, and Debrum 1976)

<table>
<thead>
<tr>
<th>Gloss</th>
<th>Ralik</th>
<th>Ratak</th>
<th>UR (Abo et al. 1976)</th>
</tr>
</thead>
<tbody>
<tr>
<td>to inhibit</td>
<td>yebbaar</td>
<td>bebaar</td>
<td>bbaar</td>
</tr>
<tr>
<td>to grow</td>
<td>yeddek</td>
<td>dedek</td>
<td>ddek</td>
</tr>
<tr>
<td>to look up</td>
<td>yejjed</td>
<td>jejed</td>
<td>jed</td>
</tr>
<tr>
<td>to entice</td>
<td>yekkal</td>
<td>kekal</td>
<td>kkal</td>
</tr>
<tr>
<td>sandbank</td>
<td>yeppe</td>
<td>pepe</td>
<td>ppe</td>
</tr>
</tbody>
</table>

^1 Many examples of each pattern are found in their Dictionary, but here only representative cases are given for the analysis.
Abo, Bendor, Capelle, and Debrum (1976) posit the same lexical entries in their dictionary despite the dialectal difference between Ralik and Ratak dialects in Marshallese. There are many words that begin with consonant geminates. Take, *ppe* 'sandbank', for example. In the pronunciation of the Ralik dialect, /ppe/ is realized as [yeppe], with /ppe/ preceded by [ye]. On the other hand, /ppe/ is realized as [pepe] in the pronunciation of the Ratak dialect. For that reason, they list the same dialect-neutral form /ppe/ for the two dialects instead of listing each of these words at two different places in the dictionary (Abo et al., 1976). They further argue that speakers of either dialect can give the word their actual customary pronunciation based on the form listed in the dictionary.

In Marshallese, however, rule-based approaches do not explain why Ralik and Ratak behave differently in resolving unacceptable underlying word-initial geminate consonants, whereas constraint interaction model of OT can provide the answer why they act differently with respect to the same phenomenon by simply reranking the relevant constraints, for example, A » B vs. B » A. In this regard, the OT approach has more explanatory power than a rule-based one.

As shown in the discussion of (86d), the relation between /llu/ and [yullu] in Ralik is characterized by ranking DEP-IO below all other constraints: PROSHIER. ONS. MAX-IO, NO BREAKING » DEP-IO. This is illustrated in (117).
In the above, the four candidates (a, b, c and d) crucially violate PROSHIER, ONS, MAX-IO, and NOBREAKING, respectively. In (a), PROSHIER is violated because initial mora is directly dominated by the prosodic category foot. In (b), ONS violation is incurred due to the epenthetic vowel [i]. In (c), MAX-IO(μ) is violated due to the underparsing of the underlying mora. In (d), both NOBREAKING and DEP-IO are violated as a result of vowel insertion between the geminate consonants. On the other hand, in (e), there is only DEP-
IO violation (twice) by the insertion of both a consonant and a vowel before the geminate. However, candidate (e) is selected as the optimal output, since DEP-IO is ranked lowest.

The existence of the second Marshallese dialect, Ratak, is predicted by the ranking PROSHIER, ONS, MAX-IO, DEP-IO >> NOBREAKING (cf. Figure (86e)). This is illustrated with tableau (118) below.

(118) Ratak: Tableau for /lu/ → [lulu]

<table>
<thead>
<tr>
<th></th>
<th>PROSHIER</th>
<th>ONS</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>NO BREAKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>**!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tableau (118) shows that candidates (a, b and c) are first eliminated by the crucial constraint violations PROSHIER, ONS, and MAX-IO, respectively. Between candidates (d) and (e), (e) should be considered as the optimal output, since NOBREAKING is lowest ranked. Thus, the Ratak dialect has an epenthetic vowel separating the geminates.

To summarize, Marshallese geminate data support the basic assumption of OT that different rankings give different dialects from the same set of constraints. In particular, we have observed that the reranking of NOBREAKING and DEP-IO produces the variations in Marshallese (i.e. Ralik and Ratak). As a result, the geminate integrity effect is seen in Ralik Marshallese, and anti-integrity effect in Ratak Marshallese. In the next section, we will look at the issue of Lexicon Optimization with respect to integrity effects of geminates.

3.4.4.2 Lexicon Optimization: What Does OT Say about the Nature of URs?

The idea of Lexicon Optimization is provided in the following, along the lines of Itô, Mester, and Padgett (1995).

(119) Lexicon Optimization:

Of several potential inputs whose outputs all converge on the same phonetic form, choose as the real input the one whose output is the most harmonic.

(Itô, Mester, and Padgett, 1995)
Itō, Mester, and Padgett's (1995) experiment in Japanese NC shows that the theory of underlying feature minimization is not necessary, on the grounds that the constraint hierarchy itself forces the correct output, regardless of the input specification. On this view, even a redundant feature specification is allowed in the input forms.

According to Itō, Mester, and Padgett (1995), however, this idea is restricted by learnability factors, and the choice of the proper UR is made on the basis of the 'simplest' choice, which is characterized by the constraint hierarchy. That is, the language learner will make use of the idea of Lexicon Optimization to decide the real input.\(^{40}\)

Returning to the discussion of Marshallese, we cannot establish the contrastive relationship between the forms given in (116), above. Because there is no meaning contrast between them, the three forms ppe, yeppe and pepe for example can be individually posited as the input form for the word meaning 'sandbank'. Between the two possible pairs of inputs, ppe–pepe (CCV–CVCV) in Ratak, and ppe–yeppe (CCV–CVCCV) in Ralik, the forms of pepe (CVCV) and yeppe (CVCCV) are chosen as the real inputs, since the input-output match is the most harmonic with respect to the constraint hierarchy.

\(^{40}\)This concept is characterized by the term 'Stampean occultation'. See Prince and Smolensky (1993: Ch. 4.3.1 and Ch. 9) for a detailed discussion of this idea.
In this occasion, the technique of Tableau des Tableaux is extremely useful.\textsuperscript{41}

First, we will consider Ralik case using the technique of Tableau des Tableaux.

Tableau des Tableaux: evaluating outputs of the different inputs

(120) Ralik

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>PROSHIER</th>
<th>ONS</th>
<th>MAX-IO</th>
<th>NOBREAKING</th>
<th>DEP-IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. μ /lv/</td>
<td>(\mu) (/) yilu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>**!</td>
</tr>
<tr>
<td>b. μ /v/ yilu</td>
<td>(\mu) (/) yilu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>c. (\varepsilon) μ /yilu/</td>
<td>(\varepsilon) μ (/) yilu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In tableau (120), the three different input forms produce the same optimal output form [yilu]. The first pair (a) violates DEP-IO twice. The second pair (b) violates DEP-IO once. The third pair (c) does not violate any constraints. Thus, the pair in (c) is the most harmonic with respect to the constraints, since the input-output relation is truly faithful.

If we analyze the same data in Ralik using the idea of Lexicon Optimization, then we will

\textsuperscript{41} The technique of Tableau des Tableaux helps us evaluate outputs of the different inputs. For details, refer to Itô, Mester, and Padgett (1995).
have /yillu/ as the input form of the output [yillu]. That is, the input form will be identical with the output form in the Ralik dialect.

Finally, let us consider the issue of anti-integrity in Ratak. In the following section, I will argue that anti-integrity may not an issue in Ratak under the OT using the concept of Lexicon Optimization.

3.4.4.3 Lexicon Optimization and Anti-integrity in Ratak

This section concentrates on the analysis of Ratak, which poses an interesting question regarding geminate integrity—an apparent case of anti-integrity. The following Tableau des Tableaux (121) clarifies this point.

(121) Ratak

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>PROSHIER</th>
<th>ONS</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>NOBREAKING</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. μ /lu/</td>
<td>[μ]</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>b. [μ] /lulu/</td>
<td>[lulu]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In (121), the input-output pair (a) violates DEP-IO and NOBREAKING. However, the input-output pair (b) does not violate any constraints and truly faithful in their relation. From this, we know that the pair in (b) is the most harmonic. Thus, if we analyze the
same data using the idea of Lexicon Optimization, then we will have the same input form with the actual output form (e.g. /lilu/ → [lilu]) in Ratak, as in Ralik case.

Once we adopt the concept of Lexicon Optimization in the analysis of Marshallese data, then there is no geminate anti-integrity effect in Ratak, since the input form is identical with the output form in Ratak. As a result of that, anti-integrity turns out to be only apparent, not real, in the Ratak dialect.

Because we assume that the optimal input is associated with the most harmonic of the different outputs, the analysis using Lexicon Optimization forces the language learner to choose the input form that matches with an output form in the way least offensive to the constraint hierarchy. This suggests that the principle of Lexicon Optimization be the decisive guideline for the learner to choose the input, even disregarding the requirement of the principle of the underlying information minimization as shown in Japanese NC (Itô, Mester, and Padgett, 1995).

On the basis of Lexicon Optimization and Tableau des Tableaux, OT resolves the problem of anti-integrity that standard theories left dangling. If we assume /yillu/ and /lilu/ as the inputs of Ralik and Ratak, respectively, then we can analyze the above data without involving the anti-integrity effect. Then, Marshallese may not constitute the exceptional case to the integrity effects of geminates.

In sum, I have analyzed Marshallese geminate data under the OT framework. Through the analysis of Marshallese geminate data, I have claimed the following points.
First, Marshallese supports the OT assumption that different rankings give different dialects, Ralik and Ratak. Second, Lexicon Optimization can resolve the problem of anti-integrity in Ratak. Thus, Marshallese data empirically support that anti-integrity is only apparent, not real, once we adopt the concept of Lexicon Optimization.

Although Itō, Mester, and Padgett's (1995) argument on Lexicon Optimization is based on the discussion of the specific facts of Japanese NC, this idea can be supported by Marshallese data.

3.4.4.4 Summary

Marshallese provides us with several points of interest with respect to geminate integrity and anti-integrity. It has been argued that the dialectal differences in Marshallese are the result of having different rankings of the constraints. In particular, the reranking of NOBREAKING and DEP-IO produces the variation in Marshallese.

Also of interest in the Marshallese case is the interaction of DEP-IO with NOBREAKING regarding geminate integrity and anti-integrity. In both Ralik and Ratak dialects, DEP-IO and NOBREAKING are responsible for integrity and anti-integrity of geminates. In Ralik case, integrity effect is achieved by ranking NOBREAKING over DEP-IO (i.e. NOBREAKING >> DEP-IO). Because of this ranking, geminate is not split by an epenthetic vowel. In Ratak case, however, the situation is reversed. Since DEP-IO dominates NOBREAKING (i.e. DEP-IO >> NOBREAKING) in Ratak, it is easier to put an
epenthetic vowel separating the geminates—an apparent case of anti-integrity. Thus, geminate can be split by an epenthetic vowel in Ratak.

Finally, it is suggested that Lexicon Optimization can resolve the issue of anti-integrity in Ratak, since according to Lexicon Optimization we will have the same input form with the actual output form (e.g. /lilu/ → [lilu]), as in Ralik case (e.g. /yillu/ → [yillu]). Then, Marshallese data will empirically support that anti-integrity is only apparent, not real, cross-linguistically, from the viewpoint of typology.

Thus far, we have considered the implications of the key constraints with respect to geminate integrity and anti-integrity. We have also studied in the preceding sections individual languages which essentially share these key constraints. In the course of the presentation of the languages, we have noticed that those proposed key constraints continue to play important roles in the analysis of geminate integrity and anti-integrity in each case. Moreover, we have shown that added constraints in each case do not detract from the roles of the key constraint set regarding integrity and anti-integrity. The point is that although some other constraints are added from the phonological reasons in order to describe overall pattern of a language, the key constraint set will still crucially take effect on the integrity and anti-integrity effect of geminates, regardless of the added constraints and their interaction with other constraints.
3.5 Summary of Chapter 3

This chapter has been an exploration of geminate integrity. In this chapter, I proposed seven key constraints which are responsible for the integrity effects of the geminate: MAX-IO, DEP-IO, ONS, PROSHIER, ALIGN(Wd-R, M-R), PLONS and NOBREAKING. Based on the concept of a factorial typology, I also proposed a typology of languages in connection with those key constraints. By varying the key constraints, we could make several predictions about the pattern of sequences and geminates in the world's languages and could exemplify several patterns that we could find.

First, in medial geminates two types of the languages are attested: Pero, Ponapean and Palestinian Arabic. In Pero, DEP-IO is ranked at the bottom. Thus, an epenthetic vowel is inserted after the geminate to satisfy PLONS in word-medial cluster, violating DEP-IO alone. Ponapean is also discussed in this category, although there is no consonant clusters in medial position. Here, DEP-IO is assumed to be ranked at the bottom to allow vowel insertion to remedy unacceptable coda consonants word-medially. Palestinian Arabic geminates basically show that PLONS is ranked at the bottom. Because of the effects of the constraints ALIGN and *COMPLEX, we are able to explain why epenthesis should occur and also why it must occur between the first 2 segments in CCC clusters.
Second, in final geminates only one type of the languages is attested: Palestinian Arabic and Ponapean. Because of the high-ranked status of $\text{ALIGN(WD-R, M-R)}$, word-final geminate clusters are realized intact on the surface.

Third, in initial geminates five types of the languages are attested: Woleaian, Fijian and Ponapean, Berber, Ralik dialect of Marshallese and Ratak dialect of Marshallese. Specifically, $\text{ONA, PROSHIER}$ and $\text{NOBREAKING}$ effectively account for different patterns of geminate behavior in word-initial position.

The most interesting part of this integrity exercise is that we can explain both integrity and anti-integrity effects uniformly depending on the ranking of the constraints. Thus, in our system, the geminate puzzle is resolved in a predicted way. Moreover, the geminate integrity effect as well as the distributive pattern of the geminates and other consonant clusters are also captured in a predicted way, thus we can grasp the general patterns of consonant clusters (including geminates) with respect to epenthesis and deletion phenomena.

Some predicted patterns are attested, but some are not yet attested. Of those unattested cases, we could make predictions that some of them are not possible on the surface because they are too bad compared with other patterns (i.e. systematic gaps), and some of them are possible on the surface but are subject to empirical verification (i.e. accidental gaps) (see section 1.4.1 Gaps in the Predicted Types of Geminates for the details).
One thing to note here is that NOBREAKING is not relevant in much of the discussion of the geminate integrity effect for reasons of incurring too many violations together with that violation itself in the case of integrity phenomenon. However, NOBREAKING will play an extremely important role in the analysis of the geminate inalterability/anti-inalterability (Chapter 4).
4.1 Introduction

In Chapter 3, we investigated one major class of phenomena involving geminates, integrity effects. We saw that both integrity and anti-integrity effects of geminates are effectively accounted for by the constraint interaction model of OT. Specifically, we observed that the different rankings of the key constraints are responsible for the integrity and anti-integrity effects of geminates, which are systematically predicted and explained by our system.

In this chapter, we will discuss the second big issue involving geminates. Geminates have long been observed to exhibit special behavior resisting the application of rules that otherwise apply to singleton segments. This has been attributed to a general phenomenon known as 'geminate inalterability' (Hayes 1986, Schein and Steriade 1986). As with integrity, inalterability effects will be analyzed in a systematic way predicted by our system mainly composed of the key constraints proposed for the analysis of the geminate integrity effect. Because of the characteristic of the inalterability phenomenon itself, however, IDENT-IO(μSF) (cf. figure (28) in Chapter 1) will be added to the discussion of geminate inalterability. By varying the ranking of the key constraints, we predict different patterns of languages with regard to geminate inalterability.
In standard generative phonological approaches, rules are designed to match against the input. Geminate blockage or inalterability has been understood to be the result of an input constraint on the application of rules. Rules are postulated to account for non-geminate behavior, and by doing so they indirectly account for geminate inalterability. However, those rules cannot affect geminates and thus cannot be verified in any empirical sense, since those rules are designed to affect only non-geminates (Scobbie 1992).

Moreover, all geminate behavior is not predicted this way. There exist cases in which geminates are not immune to phonological processes (cf. Churma 1988). Either all of a geminate or half of a geminate can be affected by phonological processes and phonetic manifestation, which is the case of anti-inalterability. Since inalterability of geminates cannot be systematically accounted for by the way in which the rules match against input, a prediction about phonological behavior of geminates should be made by some other approach. Here, the OT approach to this issue seems to be promising in that OT has no specific rules, but rather employs interaction of universal constraints which are violable in nature.

As we have mentioned in Chapter 2, the current analysis can properly explain different phonological behavior between "weakening" and "assimilation" by employing the strength hierarchy in the theory of weakening. Thus, aside from the Optimality Theoretic elements of this analysis, an interesting point here is that by recognizing a
distinction between "weakening" and "assimilation", we can make the current analysis more predictive and explanatory than the standard generative phonological approaches, such as Hayes (1986), and Schein and Steriade (1986) (cf. Churma (1988)). The following section addresses the issue of "weakening" in connection with the Strength Hierarchy.

4.2 Weakening, Strong Features and Strength Hierarchy

4.2.1 Weakening and Strengthening

The term weakening together with strengthening has been familiar in the discussion of both synchronic and historical phonologies (Foley 1970, 1977, Vennemann 1972, Hooper 1972, 1976, Schane 1973, Hyman 1975, Lass and Anderson (1975), Sommerstein 1977, Lass 1984, etc.). However, its definition has tended to remain intuitive rather than explicit. An explicit definition of weakening has been put forward by Vennemann (see Hyman 1975, 165): ‘A segment X is said to be weaker than a segment Y if Y goes through an X stage on its way to zero ’.1 The above definition necessarily requires the Strength Hierarchy given in (1).

(1) Strength Hierarchy (repeated from (34) in Chapter 2)

a. geminates > singletons
b. singletons: voiceless noncontinuants > voiced noncontinuants > voiceless fricatives > voiced fricatives > approximants > zero

---

1 Strengthening, on the other hand, is mostly weakening in reverse.
The definition given above, however, does not provide what "weakening" is, but just mentions how the Strength Hierarchy is interpreted. That is, it does not characterize the nature of the "weakening" process itself, but it says how weakening proceeds in the Strength Hierarchy. In this regard, to clarify the nature of weakening, I give a definition of weakening in the following:

(2) Weakening (repeated from (31) in Chapter 2)

A weakening process has as output a segment that is higher than the input on the sonority hierarchy.

(Churma 1988)

Now, with this definition of weakening, the relationship between the Strength Hierarchy and weakening becomes clearer and more meaningful. The Strength Hierarchy given in (1) is mostly the inverse of the Sonority Hierarchy with a gap in sonorants. Perhaps the best way to describe weakening is in terms of two factors: openness and sonority (cf. Lass 1984, 177-178).

(3) a. Stop > Fricative > Approximant > Zero
   b. Voiceless > Voiced
In (3a), each step to the right increases the permeability of the vocal tract to airflow. This also increases sonority. In (3b), the change voiceless → voiced seems to increase sonority, but the motivation for openness is not clear. Regarding this matter, Lass (1984, 177) makes a comment that the change voiceless → voiced is a precursor to opening of stricture.

Now, it is clear why nasal consonants are not included in the steps of the weakening process along the Strength Hierarchy. Among sonorants, nasals do not increase the opening of stricture since they are all stops, but approximants do allow the opening of stricture. Thus, only approximants appear in the Strength Hierarchy for the class of sonorants. In this regard, the opening of stricture seems to be directly responsible for the weakening phenomena, which results in a sonority increase.

Klingenheben’s Law in Hausa clearly shows this aspect of weakening. In Hausa, labial and velar stops are weakened to [w] and [r], respectively. In other words, Hausa shows weakening of stops to approximants, not to nasals, resulting in the coda sonorantization effect. When looked at from the viewpoint of weakening, this is a natural movement since the change stops → approximants increases the permeability of the vocal tract to airflow and sonority, which causes weakening phenomenon. (cf. section 4.5.2.1 Klingenheben’s Law).
4.2.2 Strong Features and Strength Hierarchy

The terms strong (features) is based on the notion of Markedness (and Unmarkedness), and is called strong because these features conspire to make the segment stronger (i.e. more consonantlike) in the Strength Hierarchy. The notion of markedness was first developed by the Prague School (Trubetzkoy 1939) and later elaborated and applied in many ways in Generative Phonology (Greenberg 1966, Chomsky and Halle 1968, Ch. 9, Postal 1968, Ch. 8). To generative phonologists, markedness values are considered to be universal and innate. That is, markedness is no longer treated as a property of individual languages, but rather as part of the general phonological theory.

Based on the notion of markedness, if we look at consonants only, [-sonorant] (i.e. obstruents) is more unmarked to the production of consonant sounds. Next, within the class of obstruents, [-continuant] and [-voiced] (i.e. stops and voiceless consonants) are thought to be more unmarked (i.e. more consonantlike). From this, we get strong features [-sonorant], [-continuant] and [-voiced]. However, this is not always as straightforward as it may seem. For example, aspirated stops ([+spread glottis]) are more marked than plain ones, but I assume the [+spread glottis] feature is strong, following Foley (1977) and Hyman (1975). Anyway, in general, we can say that unmarked features are strong in the sense that they characterize stronger consonant segments as illustrated in the Strength Hierarchy (1).
From the above discussion, we can sort out the following strong features:

[-sonorant], [-continuant], [-voiced] and [+spread glottis].

Since according to the Strength Hierarchy (1), geminates can be weakened only by degemination, we cannot change strong features of the underlying geminates. That is, underlying geminates keep strong features intact regardless of the prosodic structure change. However, features that have no strength value in underlying geminates (e.g. [coronal], [anterior], etc.) can be freely changed.

In order to capture this point, I propose IDENT-IO(µSF) which will play an extremely important role in the analysis of inalterability and anti-inalterability.

(4) IDENT-IO(µSF): The output correspondent of an input moraic strong feature F is F (cf. McCarthy and Prince 1995)

(repeated from figure (28) in Chapter 1)

By strong features, I mean the features {-cont, -son, +SG, -vd}. As we have discussed above, these strong features are drawn from the notion of markedness and the Strength Hierarchy (1). The constraint IDENT-IO(µSF) is motivated to explain that the strong features in underlying geminates are not changed (weakened) on the surface.

---

³The Strength Hierarchy given in (1) is concerned with only consonants. Although [-vd] is one of the strong features, the discussion of weakening caused by voice assimilation is omitted in this thesis.
As the Strength Hierarchy (1) shows, weakening occurs in two ways. First, degemination (CC→C) is a kind of weakening, and thus geminates become singletons if MAX-IO(μ) is low-ranked (e.g. Ponapean initial geminates) (1a). Second, only singletons are weakened through featural changes according to the Strength Hierarchy (1b).

In the analysis of the inalterability and anti-inalterability effects of geminates, the constraint IDENT-IO(μSF) is very active. I hypothesize that IDENT-IO(μSF) is top-ranked universally on the basis of the Strength Hierarchy. As a result, underlying geminates which contain strong features will not be changed except degemination. Thus, IDENT-IO(μSF) is essential in barring the change of the strong features of underlying geminates. This also suggests that geminates are freely changeable in non-weakening cases (e.g. assimilation) since no IDENT-IO(μSF) violation is incurred in those cases.

Thus, we can automatically predict inalterability and anti-inalterability effects by ranking IDENT-IO(μSF) on the top of the ranking hierarchy universally. That is, if we deal with weakening (i.e. raising the sonority), then the universally high-ranked IDENT-IO(μSF) will produce the geminate inalterability effect. By contrast, if we deal with the non-weakening phenomena (i.e. not raising the sonority), then we will produce the geminate anti-inalterability effect since IDENT-IO(μSF) is not effective. As a result, we can explain the different behavior of geminates between assimilation and weakening in a predicted way. In this context, the findings of Churma (1988) (see also Selkirk 1990)
seem to be in accord with our observation concerning the different behavior of geminates between weakening and assimilation. The following hypothetical schematic table will help illustrate this aspect.

(5) Weakening and Palatalization

<table>
<thead>
<tr>
<th>( V_ttV )</th>
<th>IDENT-IO (( \mu[-\text{son, -cont}] ))</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. VrrV</td>
<td>*!</td>
<td>No Weakening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \leftarrow ) IDENT-IO(( \mu[-\text{son, -cont}] )) violation is crucial</td>
</tr>
<tr>
<td>b. VccV</td>
<td>( \sqrt{(O.K.)} )</td>
<td>Palatalization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \leftarrow ) IDENT-IO(( \mu[-\text{son, -cont}] )) is not effective</td>
</tr>
</tbody>
</table>

In (5a), \( /tt/ \rightarrow [rr] \) is less strength and thus is a weakening case. The weakening of geminate \( /tt/ \) to \([rr]\) crucially violates IDENT-IO(\( \mu[-\text{son, -cont}] \)) since we assume that IDENT-IO(\( \mu[-\text{son, -cont}] \)) is universally high ranked. On the other hand, in (5b), the palatalization of the geminate \( /tt/ \) to \([cc]\) is not a weakening case since there is no strength change between \( /tt/ \) and \([cc]\). In other words, the output geminate \([cc]\) is faithful to the underlying strength. Thus, IDENT-IO(\( \mu[-\text{son, -cont}] \)) is not violated in palatalization. From this, we can conclude that the violation of the constraint IDENT-IO(\( \mu[-\text{son, -cont}] \)) is especially worse when it deals with the weakening of the geminate consonants. Otherwise, we can predict its violation would not be incurred at all. These facts are formulated as in (6).
(6) IDENT-IO(μSF) is universally *high-ranked*, where SF is either [-sonorant], [-continuant], [+spread glottis] or [-voiced]

In other geminate related cases, it is predicted that IDENT-IO(μSF) is not effective, since the features other than [-sonorant], [-continuant], [+spread glottis] and [-voiced] would not cause any weakening effect.
4.3 Major Key Constraints

In this section, I present several key constraints for the analysis of geminate inalterability effects. Most of these constraints are already introduced except for PAL.¹


b. IDENT-IO(μSF): The output correspondent of an input moraic strong feature F is F (cf. McCarthy and Prince 1995) (repeated from (4) in this chapter)

c. NOBREAKING: No element of the input has multiple correspondents in the output (a.k.a. “INTEGRITY”) (McCarthy and Prince 1995) (repeated from (2c) in Chapter 3)

d. MAX-IO: Every segment of the input has a correspondent in the output (No phonological deletion.) (McCarthy and Prince 1995, Prince and Smolensky 1993) (repeated from (2a) in Chapter 3)

e. CODASON: Codas are sonorants (repeated from (29) in Chapter 3)

f. IDENT-IO(F): Output correspondents of an input segment have identical values for phonological features (McCarthy and Prince 1995) (repeated from (31) in Chapter 3)

Since the constraints (7b-f) were already presented, I will focus on the constraint PAL (7a).

¹ PAL and CODASON are added to the set of major key constraints as representing assimilation and weakening, respectively, solely for expository purposes.
In explaining palatalization itself, I follow Hume's (1992) proposal. In palatalization (in her terms, Coronalization), the target's major articulator changes to [coronal, -anterior]. Palatalization is represented as below (cf. Hume 1992:183).

(8) a. Velar Palatalization: /k/ → [ć]

```
   k       i
CONS     CONS
/     /
place   place
                     \  \  stricture
[dorsal]               \  \  [coronal]  [+high]
                       \  \  [-anterior]
```

b. Coronal Palatalization: /t/ → [ć]

```
   t       i
CONS     CONS
/     /
place   place
\  \  VOC
\  \  \  \  stricture
[coronal]  [coronal]  [+high]
\  \  \  \  [-anterior]
```
Relevant in the above representation for our purposes is that velar or coronal consonants tend to be palatalized before front vocoids (i.e. /i, e, y/). As illustrated in detail in Hume (1992), the articulation of front vowels is produced behind the alveolar ridge, with the constriction extending for a considerable distance along the hard palate. Thus, in articulatory terms, front vowels are \([-\text{anterior}, +\text{distributed}]\). For our analysis, however, we will use only \([\text{coronal}]\) and \([-\text{anterior}]\) for the front vocoids and their interaction with consonants.

PAL is suggested to capture the general tendency that \([+\text{anterior}]\) coronal consonants are palatalized before the front vowels /e, i/ and the glide /y/ (8b). It can also explain velar palatalization (8a). Since front vocoids are specified with \([\text{coronal}]\) and \([-\text{anterior}]\) as shown in (8a) and (8b), preceding \([+\text{anterior}]\) coronals and velars must be \([-\text{anterior}]\) coronals to avoid violating PAL.

Unlike geminate integrity cases, it is difficult to generalize the key constraints due to the nature of the inalterability phenomenon itself. That is, inalterability cases are mainly about featural changes, which suggests that we can have different kinds of constraints depending on the characteristics of the phonological phenomena we are dealing with. In this sense, the major key constraints listed above are typical ones. To be more specific, PAL represents the category of “non-weakening” constraints. In addition to PAL, other non-weakening constraints will be called upon when we analyze such antinalterability cases as Korean Post-Obstruent Tensification and Icelandic Preaspiration.
By contrast, CODASON represents the category of "weakening" constraints. Later, another weakening constraint will be introduced when we inspect Tiberian Hebrew Spirantization.

Those constraints discussed above form the backdrop of our analysis of geminate inalterability. In order to extend the OT model to the systems we consider in this chapter, we need to first make predictions concerning the interaction of the constraints proposed here.
4.4 The Predicted Typology

This section lays out the predictions about geminate consonants regarding inalterability and anti-inalterability that follow from the interaction of the key constraints given in (7).

In weakening, no cases in which IDENT-IO(μSF) is violated have been attested crosslinguistically (e.g. Klinghenheben's Law in Hausa, Tiberian Hebrew Spirantization, Tigrinya Spirantization, Persian /v/ → [w], etc.). Thus, I first assume that IDENT-IO(μSF) is top-ranked universally on the basis of the Strength Hierarchy.5 In laying out the predicted patterns of the geminate, it is essential to assume that IDENT-IO(F) must be ranked lowest to allow for featural disparity between input and output structures. Finally, the group of constraints, either weakening or non-weakening, (e.g. CODASON or PAL) is represented as C to facilitate to make generalization of the predicted patterns of the geminate.

Summarizing above discussion, since IDENT-IO(μSF) is ranked on the top and IDENT-IO(F) is ranked at the bottom, the following prediction can be made with the proposed key constraints in (7).

---

5 Note again that, however, in some assimilation cases, IDENT-IO(μSF) is not effective at all, even though it is top ranked. Hausa Palatalization, Luganda Palatalization, Korean Post-Obstruent Tensification are the examples of this type.
(9) Prediction: Inalterability/Anti-inalterability

<table>
<thead>
<tr>
<th>/NCCV/</th>
<th>IDENT-IO(µSF)</th>
<th>NO BREAKING</th>
<th>MAX-IO</th>
<th>C</th>
<th>IDENT-IO(F)</th>
<th>e.g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. [VtV]</td>
<td>σ σ</td>
<td>* (e.g. CODA-SON)</td>
<td></td>
<td></td>
<td></td>
<td>Inalterability:</td>
</tr>
<tr>
<td></td>
<td>μ /μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Klingeheben's Law in Hausa</td>
</tr>
<tr>
<td></td>
<td>/V t V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(cf. Tiberian Hebrew Spirantization)</td>
</tr>
<tr>
<td>b. [VtV]</td>
<td>σ σ</td>
<td>* (e.g. PAL)</td>
<td></td>
<td></td>
<td></td>
<td>Anti-inalterability I:</td>
</tr>
<tr>
<td></td>
<td>μ /μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/C,C/ → [C,C]</td>
</tr>
<tr>
<td></td>
<td>/V t V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Palatalization in Hausa</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&amp; Luganda</td>
</tr>
<tr>
<td>c. [VtV]</td>
<td>σ σ</td>
<td>* (e.g. CODA-ONS.)</td>
<td></td>
<td></td>
<td></td>
<td>Anti-inalterability II:</td>
</tr>
<tr>
<td></td>
<td>μ /μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/C,C/ → [C,C]</td>
</tr>
<tr>
<td></td>
<td>/V t V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Korean POT</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(cf. Icelandic Preaspiration: /C,C/ → [C,C])</td>
</tr>
<tr>
<td>d. [VtV]</td>
<td>σ σ</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td>Anti-inalterability III:</td>
</tr>
<tr>
<td></td>
<td>μ /μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Finnish Intervocalic Degemination</td>
</tr>
<tr>
<td></td>
<td>/V t V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* [VtFtV] can be a possible output pattern. However, in this tableau, this form cannot be realized due to the violations of DEP-IO and NOBREAKING. Moreover, in other processes, it has more constraint violations. Thus, hereafter, this pattern will be omitted in our discussion of inalterability-anti-inalterability.
The tableau in (9) shows that the form [VrrV] will be ruled out by violating the top-ranked constraint IDENT-IO(\(\mu\)SF). In this tableau, the set of constraints C changes some features of [t] depending on the phonological phenomena at hand (and the set of constraints C is parenthesized in the tableau to indicate this point). Then comes the following: in (9a), C (e.g. CODASON) is violated in order to satisfy the top ranked IDENT-IO(\(\mu\)SF) constraint. This happens if C forces the changing of moraic strong features (e.g. [-son]).

But can C ever be satisfied? Yes, it can be satisfied in two ways: (i) if C is *not* weakening and C >> IDENT-IO(F), and (ii) if C is *weakening* and C >> MAX-IO(\(\mu\)). But there are variations in the case of (i). As shown in (9b), if C is higher ranked than IDENT-IO(F), then that results in a changed geminate (e.g. Hausa Coronal Palatalization, Luganda Velar Palatalization). On the other hand, as shown in (9c), if C is higher ranked than IDENT-IO(F) and NOBREAKING, then it results in a change of half of the geminate (e.g. Korean Post-Obstruent Tensification). In the case of (ii), if C is higher ranked than MAX-IO(\(\mu\)), then degemination will be incurred as shown in (9d) (e.g. Finnish Intervocalic Degemination (Skousen 1972)).

In summary, according to the above prediction, the geminate inalterability effect results when IDENT-IO(\(\mu\)SF) is top-ranked and a constraint C (e.g. CODASON) is ranked below NOBREAKING and MAX-IO (a). On the other hand, three types of anti-inalterability effects result through the interaction of the three key constraints
(NOBREAKING, MAX-IO and C) because the top-ranked IDENT-IO(µSF) is not effective and IDENT-IO(F) is lowest ranked.

In the following, we will exemplify each cases, providing relevant examples to illustrate how the proposed hypothesis works. Degemination cases (9d), however, are not discussed in this chapter, rather the focus here is on the three typical inalterability and anti-inalterability cases shown in (9a-c). Thus, the issue of degemination will be remained for further research.

4.5 Prolegomena to Inalterability and Anti-inalterability: A case of Hausa

4.5.1 Introduction

Before we consider the above hypothesis case by case, we begin our discussion of inalterability and anti-inalterability by investigating Klingenheben's Law and palatalization in Hausa. In Hausa, geminates display different behavior with regard to weakening (e.g. Klingenheben's Law) and assimilation (e.g. palatalization). That is, as we have mentioned in Chapter 2, palatalization can freely affect both simplex and geminate consonants indiscriminately. By contrast, Klingenheben's Law can affect only singletons. Geminates are not affected at all in this case, resulting in the geminate inalterability effect.

In this regard, Hausa provides a good example for the purpose of illustrating different

---

7 An earlier version of this section was presented at the Twelfth Northwest Linguistics Conference held at the University of Washington, Seattle, Washington, on October 23-24, 1995. I would like to express my gratitude to Rachel Walker and Vem Lindblat for helpful comments. An earlier version of this section also appears in Working Papers in Linguistics, vol 14, 203-25. ed. by Hideo Makihara. University of Washington, Seattle, Washington.
geminate behaviors according to the phonological phenomena, which is expressed in terms of constraint interactions.

4.5.2 Klinghenheben's Law and Palatalization in Hausa

In this Optimality Theoretic approach, palatalization (an assimilation case) and Klinghenheben's Law (a weakening case) in Hausa are explained through the interaction of the same set of constraints. Specifically, we will observe that the key constraints and their interaction ensure both inalterability and anti-inalterability effects in the same language.

An interesting point is that featural changes in geminates can be ranked differently according to the nature of the features in question. As we have mentioned before, IDENT-IO(μ[-son, -cont]) has the effect of prohibiting the weakening of the geminates. Thus, it is assumed to be highly ranked, universally. On the other hand, in palatalization case, the output geminates are faithful to the input strength. Thus, IDENT-IO(μ[-son, -cont]) does not prohibit the changing of coronal geminates into palatal ones since this is not a case of weakening according to our definition (cf. figure (31) in Chapter 2) and the Strength Hierarchy. Thus, coronal geminates easily undergo palatalization.
4.5.2.1 Klingengheben’s Law

The data presented below are the case of weakening known as Klingengheben’s Law in Hausa. A historical change known as Klingengheben’s Law in Hausa which sonorized (weakened) coda obstruents (labials and velars → /w/, alveolars → /r/) became the synchronic condition that only sonorants appear in the coda position (Hayes 1986, Cho and Inkelas 1993). However, this rule fails to affect geminates; thus, obstruents can occur in the coda only when they are geminates. The data are from Hayes (1986), and Cho & Inkelas (1993).

(10) Klingengheben’s Law: Weakening

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /sabroo/</td>
<td>/biyad/</td>
<td>[saw.roo] [bi.yar]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘mosquito’ ‘fee’</td>
</tr>
<tr>
<td>b. gulma</td>
<td>abinci</td>
<td>*[a.win.ci]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘mischief-making’ ‘toof’</td>
</tr>
<tr>
<td>c. dabbab</td>
<td>littaafi</td>
<td>salla</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘anna’ ‘tuk’ ‘prayer’ ‘afternoon’</td>
</tr>
</tbody>
</table>

According to Klingengheben’s Law, only sonorants appear in the coda position as shown in (10a) and (10b). However, obstruents appear in the coda so long as they are geminates as shown in the first two examples in (10c). Sonorants do not make any
difference whether they are geminates or not, since in any case sonorants are in the coda positions (e.g. *salla* 'prayer', *yamma* 'afternoon').

The case of the non-geminate coda in (10a) is analyzed with the following tableau (11). As the prediction (9a) shows, CODASON should dominate IDENT-IO(-son) to make singleton obstruents correspond to sonorants in the coda. In order to satisfy CODASON, we cannot delete or insert an element as will be shown in geminate examples later. This confirms that MAX-IO and DEP-IO are higher ranked than CODASON in Hausa, so no segments are added or deleted (11a,b). Thus, the following ranking is suggested: MAX-IO. DEP-IO >> CODASON >> IDENT-IO(-son, -cont).
(11) /sabro:/ → [sawro:] 'mosquito'

<table>
<thead>
<tr>
<th>/sabro:/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>CODASON</th>
<th>IDENT-IO (-son, -cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-son]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. sa. bro:</td>
<td></td>
<td></td>
<td>!</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-son]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. sa. ro:</td>
<td></td>
<td>!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-son]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. sab. ro:</td>
<td></td>
<td></td>
<td></td>
<td>!</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-son]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. saw. ro:</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[+son]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the above tableau, (11a) and (11b) are eliminated by violating DEP-IO and MAX-IO, respectively. Between (11c) and (11d), candidate (11d) wins—even though it violates IDENT-IO(-son, -cont) due to the change of [b] to [w], it satisfies all other higher ranked constraints including CODASON. That is, the violation here is minimal, and thus it is selected as the optimal output. On the other hand, competing candidate (11c) is eliminated by CODASON whose violation is crucial compared with the violation committed in (11d).
Now, we turn to the geminate coda case, which shows inalterability effects. In this geminate data, the constraint IDENT-IO(μ[-cont, -son]) plays a pivotal role in explaining the geminate inalterability effect. Now, let us see what happens if we change the strong features in the geminate to satisfy CODASON. Here, note again that IDENT-IO(μ[-cont, -son]) dominates CODASON. On the basis of the prediction made in (9a), I give the following ranking of the constraints for Hausa: IDENT-IO(μ[-son,-cont]).

NOBREAKING, MAX-IO, DEP-IO >> CODASON >> IDENT-IO(-son, -cont).
In the above tableau, the first candidate (a) crucially violates \( \text{IDENT-IO}(\mu[-\text{son},-\text{cont}]) \), and thus it is ruled out from the running. In this form, geminate [bb] becomes a geminate sonorant [ww] satisfying \( \text{CODASON} \). However, this causes a crucial violation. \( \text{IDENT-} \)
IO(μ[-son, -cont]) which is high ranked, universally. The second candidate (b) has degemination, a kind of weakening, but this is ruled out since it has a crucial MAX-IO(μ) violation. The third candidate (c) is also ruled out because it crucially violates both IDENT-IO(μ[-son, -cont]) and NOBREAKING. Here, the two violations are caused because the underlying ["b] becomes ["wb] on the surface. Finally, the fourth candidate (d) is chosen as the optimal output form, since this form has only a CODASON violation.

From the above, we can conclude that in geminate cases, coda weakening does not occur, resulting in the geminate inalterability effect. Since IDENT-IO(μ[-son, -cont]) is higher ranked than CODASON and IDENT-IO(-son, -cont), the changing of any strong features of the geminate will cause more severe constraint violations.

In summary, as we can see in the analysis of the weakening data in Hausa, simple obstruents become sonorants at the cost of violating IDENT-IO(-son, -cont) to meet the more higher ranked constraint CODASON (cf. (11d)). However, geminates resist weakening of obstruents to sonorants, resulting in the geminate inalterability effect. If geminates are weakened, then this will crucially violate IDENT-IO(μ[-son, -cont]), which is top ranked in the ranking hierarchy. In this way, the effect of geminate inalterability is accounted for in such weakening processes known as Klingenheben's Law in Hausa.
4.5.2.2 Palatalization in Hausa

Now, let us turn to the assimilation case: palatalization in Hausa.

The following palatalization data are from Cho & Inkelas (1993).

(13) a. saːt-a:  ‘steal (-verb)’
    saːʔ-e:  ‘steal (-before pron. obj.)’
    saːʔ-i  ‘steal (-before noun obj.)’

b. fans-a:  ‘redeem’
    fans-ʔ-e:  ‘redeem (-before pronoun obj.)’
    fans-ʔ-i  ‘redeem (-before noun obj.)’

c. gaːd-a:  ‘inherit’
    gaːʔ-e:  ‘inherit (-before pronoun obj.)’
    gaːʔ-i  ‘inherit (-before noun obj.)’

d. Ɂiːz-a:  ‘bite (-verb)’
    Ɂiːʔ-e:  ‘bite (-before pronoun obj.)’
    Ɂiːʔ-i  ‘bite (-before noun obj.)’

In Hausa palatalization, the obstruents /t,s,d,z/ palatalize to [ɐ,ʃ,ʃ,ʃ], respectively before front vowels /i,e/ as shown in (13a,b,c,d).

Interestingly, unlike Klingenheben’s Law, Hausa Palatalization affects geminates as well as simplex coronal obstruents as shown in (14), exhibiting no geminate inalterability effects.
(14) a. fas-a: fas-a§§-e
   'broken one (m.)'

b. zant-uka: zanč-e:
   'conversation-pl'
   'conversation'

c. bat-att-u: bat-čiya:
   'lost one(s)'
   'lost one (f)'

In explaining the palatalization process, I use PAL and IDENT-IO(+ant). The two constraints are essentially based on the discussions of Hume (1992) and McCarthy and Prince (1995). Since PAL is already discussed earlier in this chapter, I only give the definition of IDENT-IO(+ant), here.

(15) IDENT-IO(+ant): Output correspondents of an input [+anterior] segment are also [+anterior] (McCarthy and Prince (1995))

PAL is suggested to capture the general tendency that [+anterior] coronal consonants are palatalized before the front vowels /e,i/ and the glide /y/. On the other hand, IDENT-IO(+ant) requires that corresponding segments be featurally identical to one another, with regard to the [+anterior] feature (cf. McCarthy and Prince 1995). However, phonological alternations result from the crucial domination of these IDENT constraints by other ones.
which leads to featural disparity. Specifically, palatalization occurs if IDENT-IO(+ant) is dominated by PAL.

The following is an illustration of the ranking relationship between them (cf. 9b).

(16) PAL >> IDENT-IO(+ant)

<table>
<thead>
<tr>
<th></th>
<th>PAL</th>
<th>IDENT-IO(+ant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/t - i/</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor</td>
<td>Cor</td>
<td></td>
</tr>
<tr>
<td>[+ant][-ant]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>t i</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor</td>
<td>Cor</td>
<td></td>
</tr>
<tr>
<td>[+ant][-ant]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>ç i</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor</td>
<td>[-ant]</td>
<td></td>
</tr>
</tbody>
</table>

In this tableau, (a) crucially violates PAL, because a palatal does not come before a front vowel [i]. Candidate (b) satisfies PAL, but it violates IDENT-IO(+ant), instead. Since [çi] (b) is the actual output form, PAL must dominate IDENT-IO(+ant), which exactly conforms to the prediction made in (9b).

The Hausa data, however, pose an interesting question about the geminate inalterability issue. Within a language, geminates behave differently according to the nature of the processes. On the basis of the observation, we see the different behavior of
geminates with respect to sonorant codas and palatalization. That is, in Hausa, geminates behave differently with respect to weakening and assimilation. In weakening (Klingenheben’s Law), geminates are not affected at all. On the other hand, assimilation (palatalization) affects both simplex and geminate consonants indiscriminately. Thus, the inalterability issue seems to matter only when we refer to weakening processes. As we have assumed in Chapter 2, assimilation (here, palatalization) is distinguished from weakening in that the former (i.e. assimilation) is defined as involving no sonority difference between the input and the output forms, the effects of which are expressed by the IDENT-IO(|ISF) constraint and its ranking. As a matter of fact, the anti-inalterability effect of the geminates in assimilation cases is achieved by the high ranked IDENT-IO(|ISF). Although IDENT-IO(|ISF) is high ranked, it does not make any effect on geminates in assimilation cases since strong features are not involved in that operation. On the other hand, the latter (i.e. weakening) is defined as raising the sonority of the input segment on the output form, the effects of which are expressed by the high ranked IDENT-IO(|ISF).

Summarizing so far, above all things, PAL, IDENT-IO(|ISF) and IDENT-IO(-ant) are suggested to play pivotal roles in explaining coronal palatalization. Especially, PAL prohibits the occurrence of [+anterior] coronal and [-anterior] coronal sequences in Hausa. Thus, *[ti], for example, will be excluded by violating PAL. Instead, IDENT-IO(-ant), which says that correspondent segments in input and output have identical values for the
feature [+anterior], will be violated in exchange for the satisfaction of the higher ranked PAL. These are the main strategy of the coronal palatalization process. The effect of the constraint interactions is illustrated with the data containing both simplex and geminate consonants in tableaux (17) and (18), respectively. Let us consider the non-geminate coronal case first. In this case, IDENT-IO(+ant) is violated to satisfy higher ranked constraints such as MAX-IO, DEP-IO and PAL.

---

1 This was pointed out to me by John McCarthy (p.c). The same strategy can be used for the analysis of velar palatalization, too. For details, see section 4.7.
(17) /sa:t-i/ $\rightarrow$ [sa:ɔi] 'steal (-before noun obj.)'  

<table>
<thead>
<tr>
<th>/sa:t - i/</th>
<th>MAX-IO</th>
<th>DEP-IO</th>
<th>PAL-IO</th>
<th>CODA-SON</th>
<th>IDENT-IO(+ant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cor Cor [-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| a. | sa: $\check{\epsilon}$i |        |        |          |             |
|    | ∨ Cor [-ant]             |        |        |          |             |
| b. | sa: $\check{t}$i        |        | *!     |          |             |
|    | Cor Cor [-ant]           |        |        |          |             |
| c. | sa: .i                  | *!     |        |          |             |
|    | Cor [-ant]               |        |        |          |             |
| d. | sa: $\check{t}$V .i     |        | *!     |          |             |
|    | Cor Cor [-ant]           |        |        |          |             |

In tableau (17), the first candidate (a) is selected as the optimal output, since it violates only IDENT-IO(+ant). Candidate (b) is eliminated by violating PAL. Finally, candidates (c) and (d) are also eliminated by the violations of MAX-IO and DEP-IO.

*Here and elsewhere, [-anterior] coronals are represented as just Cor without [-anterior] specification, for ease of explanation. This further implies that IDENT-IO(-ant) is ranked at the bottom to allow featural disparity between the input and the output forms. The reason that [-anterior] wins over [-anterior] comes from two sources. First, [-anterior] is chosen since vocoids characterized with both [coronal] and [-anterior] articulations have not been attested (cf. Hume 1992, footnote 33). Second, [-anterior] is chosen by the high ranked PAL. Given this fact, [-anterior] is parsed, instead of [-anterior], resulting in coronal palatalization. This will be addressed in greater detail when we analyze velar palatalization in Luganda (section 4.7).
respectively. Thus, in non-geminate coronal cases, palatalization is required to avoid violating PAL.

Now, let us turn to the geminate case, which shows anti-inalterability effects. The following tableau (18) demonstrates that underlying geminate coronals are also palatalized, against the general hypothesis of geminate inalterability. This kind of anti-inalterability case, which has been recalcitrant to the past accounts of geminate inalterability, can be readily accounted for under the current approach. In this case, CODASON and IDENT-IO(+ant) are violated to satisfy PAL, MAX-IO and DEP-IO.
(18) /bat-att-iya:/ → [batačiyːa:] ‘lost one (f.)’

<table>
<thead>
<tr>
<th></th>
<th>IDENT-IO(μSF)</th>
<th>NO BREAKING</th>
<th>MAX -IO</th>
<th>DEP -IO</th>
<th>PAL</th>
<th>CODA</th>
<th>IDENT -IO(+ant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/bat-att-iya/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>batač i. y a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>batać i. y a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>batać i. y a</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>bata tē i. y a</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In tableau (18), candidate (a) is selected as the optimal output, even though it violates CODASON and IDENT-IO(+ant). That is, to satisfy the higher ranked PAL, IDENT-IO(+ant) is violated by spreading [-anterior] from the high front vowel /i/ to the coronal obstruents. Candidate (b) is first eliminated by the crucial violation of PAL. Candidate (c) is also eliminated by the crucial violation of NOBREAKING because underlying segment /n/ is broken into two segments [ntc] on the surface. Candidates (d) and (e) are also excluded from the optimal output consideration; (d) violates MAX-IO(\mu). and (e) violates NOBREAKING and DEP-IO. In this way, the so-called anti-inalterability effect of geminates is explained in Hausa Palatalization.

4.5.3 Summary

To sum up, in Hausa, geminates behave differently with respect to weakening and assimilation. In such weakening cases as Klingendieben’s Law, geminates are not affected at all, exhibiting geminate inalterability effects. On the other hand, assimilation cases such as palatalization affect both simplex and geminate consonants indiscriminately, showing a case of anti-inalterability.

The conclusion we draw from this discussion is that geminate inalterability matters only when we deal with weakening processes (e.g. spirantization, sonorantization, etc.). Specifically, it has been proposed that the constraints IDENT-IO(\mu SF) and NOBREAKING play a pivotal role in explaining typological differences
between weakening and assimilation concerning geminates. In Hausa, both inalterability and anti-inalterability result due to the high ranked IDENT-IO(μ[-son, -cont]) and NOBREAKING. Inalterability is produced in weakening (i.e. Klinghenheben's Law). Since weakening of the geminate crucially violates high-ranked IDENT-IO(μ[-son, -cont]).

geminates will not be weakened. By contrast, anti-inalterability is produced in palatalization. Since palatalization of the geminate does not incur the high ranked IDENT-IO(μ[-son, -cont]) violation, and IDENT-IO(+ant) is low-ranked, we can easily palatalize the geminate. Here, NOBREAKING must be also high ranked to ensure palatalization of the whole geminate. Furthermore, we observed that geminate palatalization is due to the fact that palatalized geminates are faithful to underlying strength (cf. figure (1b)).

Unlike previous approaches, we can freely operate on the geminate structures and the job of the constraints blocks all but the optimal output under the current analysis. Thus, inalterability (and anti-inalterability) is the result of the interaction of universal constraints (and universal rankings). In this regard, the current analysis has more accurate predictive power regarding geminate behaviors.

In the following sections, we will take up each predicted case one by one (9a-c), and will show that each predicted pattern is attested.¹⁰

¹⁰ Recall, however, that we are not dealing with degemination case (9d) in this thesis.
4.6 Inalterability Effect: Tiberian Hebrew Spirantization (THS)

4.6.1 Introduction

In this section, a classic but very instructive case of geminate inalterability is discussed: Tiberian Hebrew Spirantization (THS). In Tiberian Hebrew, short postvocalic stops are turned into fricatives by spirantization process (Hayes 1986, Cho and Inkelas 1993, Scobbie 1992, Malone 1993). Because of this weakening process (here, spirantization), the fricatives are found in complementary distribution with the stops with which they alternate. That is, stops are found word-initially and after a consonant, and fricatives are found postvocally. However, what is at issue is the geminate cases. Geminates are not affected by spirantization, and show the inalterability effect as has been predicted by our hypothesis (9a). According to the prediction (9a), the following ranking should be responsible for the geminate inalterability effect: IDENT-IO(μSF), NOBREAKING, MAX-IO >> *VOBS[-cont] >> IDENT-IO(cont). The two constraints *VOBS[-cont] and IDENT-IO(cont) are discussed shortly with their definitions.
4.6.2 Constraints and their Interactions in Tiberian Hebrew Spirantization

In Tiberian Hebrew, stops and fricatives are in complementary distribution as summarized in (19):

(19) Distribution of Stops and Fricatives in Tiberian Hebrew

\[ \begin{align*}
\text{p t k b d g} : & \text{initial, post-consonantal, geminate} \\
\text{f \theta x v \delta \gamma} : & \text{post-vocalic nongeminate}
\end{align*} \]

The following data are collected from Malone (1993). In word-initial and post-consonantal positions, we find only [-cont] obstruents as shown in (20a) and (20b), respectively.

(20) a. word-initial

\[ \begin{align*}
\text{pe\thetaah} & \quad \text{\`ye\`}\text{e} \\
\text{taha\θ} & \quad \text{\`instead of} \\
\text{kaa\thetaav} & \quad \text{\`he wrote} \\
\text{bayi\θ} & \quad \text{\`ahouse} \\
\text{dibber} & \quad \text{\`he spoke} \\
\text{ga\thetaal} & \quad \text{\`he became great}
\end{align*} \]

b. post-consonantal

\[ \begin{align*}
\text{ni\thetapast} & \quad \text{\`you (fem.) were taken} \\
\text{haalaxi} & \quad \text{\`you (fem.) walked} \\
\text{malki} & \quad \text{\`my king} \\
\text{yir\b\uu} & \quad \text{\`they may increase} \\
\text{nerd} & \quad \text{\`spikenard} \\
\text{ti\thetagar} & \quad \text{\`you should contend}
\end{align*} \]
In geminate cases, however, spirantization does not occur even though stops come right after the vowel (i.e. in the coda position).

(21) geminate

<table>
<thead>
<tr>
<th>Term</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>sappiirim</td>
<td>'sapphires'</td>
</tr>
<tr>
<td>sattuu</td>
<td>'they set'</td>
</tr>
<tr>
<td>?ahalolekkaa</td>
<td>'I will praise thee'</td>
</tr>
<tr>
<td>sabbo6ii</td>
<td>'I have turned'</td>
</tr>
<tr>
<td>wayqaddes</td>
<td>'and he sanctified'</td>
</tr>
<tr>
<td>nigaayoon</td>
<td>'solemn sound'</td>
</tr>
</tbody>
</table>

As we can see in the following data, spirantization occurs after a vowel, when the consonants do not form a geminate.

(22) post-vocalic

<table>
<thead>
<tr>
<th>Term</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>heenaftaa</td>
<td>'(if) thou lift up'</td>
</tr>
<tr>
<td>ba9</td>
<td>'(the) daughter (of)'</td>
</tr>
<tr>
<td>melex</td>
<td>'the king'</td>
</tr>
<tr>
<td>haayaa</td>
<td>'the'</td>
</tr>
<tr>
<td>sohaif</td>
<td>'reward'</td>
</tr>
<tr>
<td>wayyexel</td>
<td>'and he carried away'</td>
</tr>
</tbody>
</table>

In order to explain the special behavior of geminates (i.e. inalterability effect) and the complementary distribution of stops and fricatives among obstruents, the following three constraints are proposed for Tiberian Hebrew: IDENT-IO(\mu[-cont]). *VOBS[-cont]
and IDENT-IO(cont). The definitions of *VOBS[-cont] and IDENT-IO(cont) are provided below.

(23) a. *VOBS[-cont]: Stop obstruents are prohibited after the vowel (Scobbie 1992)

b. IDENT-IO(cont): Output correspondents of an input segment have identical values for the [cont] feature (cf. McCarthy and Prince 1995)

*VOBS[-cont] states that an obstruent containing [-cont] is prohibited after the vowel. Concerning spirantization, Churma (1988) treats cases of this type as the weakening of segments that are in metrically weak position. However, it is unclear whether spirantization is properly viewed as metrical process or as assimilating [+cont] from the preceding vowel (cf. Kenstowicz 1994a: 35). As for the motivation for the constraint IDENT-IO(cont), it is almost the same as IDENT-IO(son) and IDENT-IO(+ant).

Now, the ranking arguments between the proposed three constraints appear in the following discussion. The following ranking is suggested for the analysis of THS: IDENT-IO(μ[-cont]) >> *VOBS[-cont] >> IDENT-IO(cont). First, I start the ranking argument with the alternation between [t] and [θ] as in the form /bat/ → [baθ] 'the"

---

11 See Selkirk (1984) for discussion of strength in connection with metrical structure within the syllable.
daughter (of). The underlying /t/ is realized as [θ] after the vowel on the output form.

This argument concerns the two constraints, *VOBS[-cont] and IDENT-IO(cont).

(24) *VOBS[-cont] >> IDENT-IO(cont)

<table>
<thead>
<tr>
<th>/bat/</th>
<th>*VOBS[-cont]</th>
<th>IDENT-IO(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. bat</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>[-cont]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. baθ</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>[+cont]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Of the two possible candidates [bat] and [baθ], *VOBS[-cont] is violated by the first candidate [bat] (a). On the other hand, the constraint IDENT-IO(cont) is violated by the second candidate [baθ] (b), in exchange for the satisfaction of *VOBS[-cont]. Since the second candidate [baθ] is the actual output form, *VOBS[-cont] should dominate IDENT-IO(cont).

Another ranking argument is made from the geminate form /sattu/ 'they set'. This ranking argument concerns the relation between IDENT-IO(µ[-cont]) and *VOBS[-cont].
In the above tableau, geminate consonants are not affected by spirantization. This fact confirms that IDENT-IO(µ[-cont]) must be higher ranked than *VOBS[-cont]. That is, in geminate case, *VOBS[-cont] violation is tolerated to avoid violating more highly ranked constraints like IDENT-IO(µ[-cont]).

Because of the highly ranked status of the constraint IDENT-IO(µ[-cont]), geminates are not spirantized (i.e. weakened). As has been shown in the Strength Hierarchy (figure (34) in Chapter 2 and figure (1) in this chapter), geminates are not weakened except for degemination. Even in degemination case, the segment contains
strong features. Only prosodic structures are changed by a MAX-IO(μ) violation. As a consequence, whole elements of the geminate cannot be spirantized.

This time, however, we have to ask why we cannot change only half of the geminate. In geminate case, if we spirantize only the first half of the geminate, then we violate NOBREAKING as well as IDENT-IO(μ[-cont]), as shown below.

(26) a. Input  

\[
\begin{array}{c}
\mu \\
| \\
t \\
[\text{-cont}] \\
\text{Cor}
\end{array}
\]

b. Output  

\[
\begin{array}{c}
\mu \\
| \\
θ \\
| \\
[+\text{cont}][-\text{cont}]: \\
\text{Cor}
\end{array}
\]

In (26), the underlying single segment is broken into two segments (\(\text{\textbar{}} t \rightarrow \text{\textbar{}} θ t\)) which causes NOBREAKING violation. Also, changing [-cont] into [+cont] violates IDENT-IO(μ[-cont]). Since the two highly ranked constraints are violated, we cannot change only half of the geminates.
Either a IDENT-IO(μ[-cont]) violation or a NOBREAKING violation will be ruled out from the optimal output running, since they are both higher ranked than *VOBS[-cont].

We can think of degemination to resolve the problem at issue. However, this does not help resolve it. From this, we infer that MAX-IO(μ) is higher ranked than *VOBS[-cont].
4.6.3 Summary of the Constraints in Tiberian Hebrew

Below is a summary of the rankings discussed so far. If we combine the above discussed rankings considering direct and transitive ranking relations, we get the following ranking. But there is no clear ranking relation between the four constraints IDENT-IO(μ[-cont]), NOBREAKING, MAX-IO and DEP-IO.

(28) Ranking of the Constraints

\[
\text{IDENT-IO(μ[-cont]), NOBREAKING, MAX-IO, DEP-IO} \gg \text{*VOBS[-cont]} \gg \text{IDENT-IO(cont)}
\]

The following diagram will be useful in capturing the overall hierarchy of the constraints in Tiberian Hebrew.

(29) \[
\begin{array}{c}
\text{IDENT-IO(μ[-cont]) : NOBREAKING : MAX-IO : DEP-IO} \\
| \\
| \\
*\text{VOBS[-cont]} \\
| \\
| \\
\text{IDENT-IO(cont)}
\end{array}
\]

As can be easily seen in the above constraint ranking hierarchy in (29), we can capture the following points in Tiberian Hebrew Spirantization: (i) IDENT-IO(cont) can be violated
to satisfy more highly ranked constraint \( \ast \text{V OBS}-[\text{-cont}] \) (e.g. /bat/ \( \rightarrow \) [baθ]). (ii) \( \ast \text{V OBS}-[\text{-cont}] \) is violated to satisfy the higher ranked constraints IDENT-IO(µ[-cont]) and NOBREAKING (e.g. /giddel/ \( \rightarrow \) [giddel]).

4.6.4 The Proof

In order to see how the proposed constraints work together to explain Tiberian Hebrew Spirantization, we will examine all the representative examples including the above predicted cases, providing full tableaux for the relevant forms.

First, the post-consonantal obstruent case is analyzed with tableau (30).

(30) malki 'my king'

<table>
<thead>
<tr>
<th>/malki/</th>
<th>IDENT-IO</th>
<th>NO BREAKING</th>
<th>MAX -IO</th>
<th>DEP -IO</th>
<th>( \ast \text{V OBS}-[\text{-cont}] )</th>
<th>IDENT-IO(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/malki/</td>
<td>µ[-cont]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. <strong>malki</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. <strong>mal.xi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. <strong>ma.li</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. <strong>ma.lV.ksi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the above post-consonantal case, (a) is selected as the optimal output, since there is no constraint violation here. Thus, there is no spirantization after the consonant.

Now, we turn to post-vocalic non-geminate case shown in (31).

(31) /bat/ → [baθ] ‘(the) daughter (of)’

<table>
<thead>
<tr>
<th>/bat/</th>
<th>IDENT-IO (μ[-cont])</th>
<th>NO BREAKING</th>
<th>MAX-IO</th>
<th>DEP-IO [-cont]</th>
<th>*VOBS [-cont]</th>
<th>IDENT-IO(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>a. baθ</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. bat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
</tr>
<tr>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. ba</td>
<td></td>
<td></td>
<td></td>
<td>!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. ba.t'V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>!</td>
</tr>
<tr>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In tableau (31), the first candidate (a) violates IDENT-IO(cont) because input stop /t/ is changed into fricative [θ]. Candidate (b) is eliminated by violating *VOBS[-cont]. According to this constraint, a [+cont] sound should come right after a vowel. Candidates (c) and (d) are also eliminated: (c) violates MAX-IO, and (d) violates DEP-IO and *VOBS[-cont]. Consequently, (a) is chosen as the optimal output despite the violation of IDENT-IO(cont). This confirms that the constraint IDENT-IO(cont) is ranked lower than
the other constraints. In this way, simplex obstruents undergo spirantization in the post-vocalic position.

Finally, let us consider the geminate case.
(32) gidde:l ‘he raised (educated)’

<table>
<thead>
<tr>
<th></th>
<th>IDENT-IO (µ[-cont])</th>
<th>NO BREAKING</th>
<th>MAX -IO</th>
<th>DEP -IO</th>
<th>*VOBS [-cont]</th>
<th>IDENT-IO(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>µ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>gidde:l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>µ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>gidde:l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[+ct][-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>µ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>gidde:l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[+ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
<td></td>
<td></td>
<td>* (µ)!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>gi de:l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>gi de:l</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[+ct] [+ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In tableau (32), candidate (a) is selected as the optimal output regardless of the *VOBS[-cont] violation, since the violation is minimal here. Candidates (b) and (c) are first eliminated by fatally violating IDENT-IO(µ[-cont]). NOBREAKING and IDENT-IO(µ[...-cont])
cont]), respectively. This shows that strong features (here, [-cont]) cannot be changed in the geminate. Candidates (d) and (e) are also excluded from consideration, because they crucially violate MAX-IO(µ), NOBREAKING, and DEP-IO, respectively.

In summary, in Tiberian Hebrew Spirantization, geminates are not affected at all, exhibiting the geminate inalterability effect. If we change only half of the geminate, then we violate IDENT-IO(µ[-cont]) as well as NOBREAKING. If we change both of the elements in the geminate, then we violate IDENT-IO(µ[-cont]). Since IDENT-IO(µ[-cont]) and NOBREAKING are the highest ranked constraints in Tiberian Hebrew, it is better to remain unchanged at the cost of violating *VOBS[-cont]. With the key roles of IDENT-IO(µ[-cont]) and NOBREAKING, the constraint interaction model of OT explains effectively the geminate inalterability effect in Tiberian Hebrew Spirantization.

Next, the behavior of "fake geminates" is considered in connection with the inalterability effect of geminates.

4.6.5 Fake Geminates

A very recalcitrant fact in Tiberian Hebrew Spirantization is that fake geminates (i.e. heteromorphemic geminates) also resist spirantization showing inalterability effect. McCarthy (1981) cites [karatti], from /karat+ti/ 'I cut', where ti is a suffix. In this case, spirantization is blocked from applying to fake geminates, too.
Tigrinya fake geminates, however, form a fine contrast with Tiberian Hebrew fake geminates regarding spirantization. As Tigrinya /mirak-ka/ ‘calf-2sg.Masc.’ shows, the first /k/ of the cluster can spirantize, resulting in [miraxka] on the surface. In Tigrinya, a South Semitic language spoken in Eritrea, the velar stops /k g l$/ become fricatives [% x x$], respectively, when they follow a vowel. However, geminates do not undergo spirantization, showing the geminate inalterability effect (Schein 1981, Kenstowicz 1982, Hayes 1986, Schein and Steriade 1986, McCarthy 1986, Odden 1988). As the facts and arguments are essentially almost the same as in Tiberian Hebrew Spirantization, I will not enter into a specific analysis of Tigrinya here, but instead I will discuss in some detail the different behavior of fake geminates with respect to inalterability effects found in Tiberian Hebrew and Tigrinya.

4.6.5.1 OCP and NOFUSION

In the discussion of fake geminates, we need NOFUSION as well as the OCP, both of which were already introduced and discussed in detail in the previous chapter.

In the analysis of the fake geminates, the constraint NOFUSION closely interacts with the OCP in both languages. Now, let us first consider the Tiberian Hebrew case. In Tiberian Hebrew, OCP(Cor) must dominate NOFUSION as shown below:
In order to derive the desired result of geminate inalterability in fake geminates, we need another type of constraint which restricts place-linked structures: Place Linking Constraint (PLC).

(34) Place Linking Constraint (PLC): Place-linked structures must have the identical feature values for [continuant] (Selkirk 1990)

The PLC is the revised version of the Multiple Linking Constraint (MLC) of Selkirk (1990) which says that multiply-linked dependent features must have identical heads. In our analysis, however, dependency relation of features is not possible, since we do not adopt the feature geometry (cf. Padgett 1995). Regardless of the featural geometry, however, the constraint PLC will be effective, if a structure has the same place features.
The PLC ensures the featural identity between the two [cont] segments in the place-linked structures.\(^\text{12}\)

The following tableau shows that the PLC must dominate *VOBS[-cont] and NOFUSION.

\[(35)\] PLC >> *VOBS[-cont] >> NOFUSION

\[
\begin{array}{|c|c|c|}
\hline
/karat - ti/ & PLC & *VOBS[-cont] & NOFUSION \\
| [-ct] [-ct] & Cor & Cor & \\
| [-ct] & Cor & Cor & \\
\hline
a. kara\(\theta\) ti & *! & & \\
| [+ct][-ct] & \slash / & \slash / & \\
| Cor & Cor & Cor & \\
\hline
b. \(\varepsilon\) & & \(\mu\) & * \\
| \slash / & karati & * & * \\
| [-ct] & Cor & & \\
\hline
\end{array}
\]

Now, a full tableau illustrates the inalterability effect in fake geminates through the constraint interactions in Tiberian Hebrew.

---

\(^{12}\) In true geminate cases, NOBREAKING violations will also incur PLC violations. This means that if NOBREAKING is highly ranked in a language, it will do the job of the PLC. Thus, in that case, we can do without the PLC. In fake geminate cases, however, the PLC is essential to restrict linked structures since NOBREAKING is not applicable to that structure.
(36) Inalterability Effect in Fake Geminates: Tiberian Hebrew

<table>
<thead>
<tr>
<th>/karat-ti/</th>
<th>OCP (COR)</th>
<th>PLC</th>
<th>IDENT-IO(μ[-ct])</th>
<th>*VOBS [-cont]</th>
<th>IDENT-IO(cont)</th>
<th>NoFUSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>karat ti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-ct][-ct] Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>karatθ ti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[+ct][-ct] Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>karatθ ti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[+ct][-ct] Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td></td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cor Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the above tableau (36), candidate (a) is selected as the optimal output despite the violations of NOFUSION and *VOBS[-cont]. These violations are incurred due to the fusion of the two separate segments into one (i.e. /t-t/ → [pt]). Candidates (b) and (c) are eliminated by the crucial violation of OCP(COR). Candidate (d) is also ruled out by violating top-ranked constraint PLC. Candidate (e) crucially violates IDENT-IO(μ[-cont]).

Here, an IDENT-IO(μ[-cont]) violation is incurred since [pθ] is not derived from the direct result of fusion, but rather fusion followed by spirantization (that is, /t-t/ → [pt] → [pθ]). Thus, this form has the violations of NOFUSION (/t-t/ → [pt]) and IDENT-IO(μ[-cont]) ([pt] → [pθ]). Thus, in Tiberian Hebrew, underlying fake geminates formed by morpheme concatenation also resist spirantization as in true geminates. Thus, contrary to our expectation, the inalterability effect results even in fake geminates in Tiberian Hebrew, through the interaction of the constraints.

In Tigrinya, by contrast, NOFUSION dominates the OCP (DOR) to allow spirantization in fake geminates.
(37) NoFusion >> OCP(DOR)

<table>
<thead>
<tr>
<th>/mirak - ka/</th>
<th>NoFusion</th>
<th>OCP(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>![]</td>
</tr>
<tr>
<td>/[-ct] [-ct]</td>
<td>![]</td>
<td></td>
</tr>
<tr>
<td>Dor Dor</td>
<td></td>
<td>![]</td>
</tr>
</tbody>
</table>

In addition to this, it is crucial that the PLC should dominate the OCP(DOR) to determine the correct output. The following tableau shows this point.
As for the ranking relations of the other constraints, there is no difference between Tiberian Hebrew and Tigrinya, so in the analysis of Tigrinya, we will assume the ranking of Tiberian Hebrew as given without further mentioning. Below is the summary of the rankings in Tigrinya:

(39) Ranking of the Constraints in Tigrinya

\[
\text{NOFUSION, PLC, IDENT-IO(μ[-cont]) >> OCP(DOR) >> *VOBS[-cont] >> IDENT-IO(cont)}
\]

The following full tableau summarizes our discussion of fake geminate in Tigrinya.

As the tableau (40) shows, the first /k/ of the fake geminate (/k-k/) formed by concatenating /k/-final and /k/-initial morphemes undergoes spirantization.
(40) Spirantization in Fake Geminates: Tigrinya

<table>
<thead>
<tr>
<th>/mirak-ka/</th>
<th>NO FUSION</th>
<th>PLC</th>
<th>IDENT-IO (μ[-cont])</th>
<th>OCP(DOR)</th>
<th>*VOBS [-cont]</th>
<th>IDENT-IO(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[-ct][-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor Dor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. μ</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>/ miraka</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-ct]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| b. mirax ka | | *! | | | | *
| [-ct][-ct] | | | | | | |
| / Dor | | | | | | |
| c. μ | *! | | * | | | |
| / miraxa | | | | | | |
| [+ct] | | | | | | |
| Dor | | | | | | |
| d. mirak ka | | | * | *! | | |
| [-ct][-ct] | | | | | | |
| Dor Dor | | | | | | |
| e. ε | | | | | | |
In the above tableau, candidates (a), (b) and (c) are all eliminated because of their crucial violations of NOFUSION, the PLC, NOFUSION and IDENT-IO(μ[-cont]), respectively. In (b), the place-linked structure avoids violating the OCP, but the PLC violation is caused instead, because [+cont] and [-cont] are linked together with the same place feature. In (c), NOFUSION and IDENT-IO(μ[-cont]) are violated due to the fusion and weakening (/t-t/ → ["t] → ["θ]). Finally, between the two candidates (d) and (e), (e) is correctly selected as the optimal one. They both violate OCP(DOR), but (d) has worse a violation of *VOBS[-cont] than (e) which has the lowest ranked IDENT-IO(cont) violation. In this way, we can explain the spirantization of fake geminates in Tigrinya.

4.6.6 Summary

In summary, we have shown another type of geminate inalterability based on Tiberian Hebrew Spirantization. In the case of Tiberian Hebrew Spirantization, the inalterability effect is achieved because IDENT-IO(μ[-cont]) and NOBREAKING are ranked on the top of the ranking hierarchy. Also, the different behavior of fake geminates in Tiberian Hebrew and Tigrinya has been examined within the OT framework. It has been shown that different rankings of NOFUSION and the OCP produce inalterability and anti-inalterability effects in two different languages: OCP(COR) >> NOFUSION (Tiberian Hebrew) vs. NOFUSION >> OCP(DOR) (Tigrinya). That is, Tiberian Hebrew shows the inalterability effect in fake geminates by ranking OCP(COR) over NOFUSION. On the
other hand, Tigrinya shows the anti-inalterability effect by having a reversed ranking (i.e., NOFUSION >> OCP(DOR)). In this way, a messy corner of the rule based approach regarding the inalterability and anti-inalterability of fake geminates is effectively accounted for under the OT approach by appealing to NOFUSION, dealing with a type of multiple correspondence relations, and its interaction with other independently motivated constraints.

In the following sections, we investigate cases of anti-inalterability which are due to different rankings of the key constraints.

4.7 Anti-inalterability Effect I: /CjCj/ \[CjCj]\n
4.7.1 Introduction

In the preceding section, we have considered a case of the geminate inalterability effect: Tiberian Hebrew Spirantization. We have observed that the inalterability effect is produced when both IDENT-IO(μSF) and NOBREAKING are highly ranked. From now on, we will look at various types of anti-inalterability. In this section, we investigate a typical pattern of anti-inalterability which changes the whole geminate under the following ranking predicted in (9b): IDENT-IO(μSF), NOBREAKING, MAX-IO, PAL >> IDENT-IO(F).

This type of anti-inalterability is illustrated by Luganda Velar Palatalization, in which the whole geminate is affected. Specifically, the whole geminate is affected because
of the high ranked constraints NOBREAKING and PAL. It will be also shown that IDENT-IO(COR) must be higher ranked than IDENT-IO(DOR).

4.7.2 Velar Palatalization in Luganda

This section is concerned with a case of anti-inalterability which is due to the fact that the universally high ranked IDENT-IO(μSF) is not effective since palatalization does not alter strong features. Here, the whole geminate is affected partly because NOBREAKING is highly ranked, and partly because the high-ranked PAL enforces palatalization as we have already looked at a similar effect in the analysis of Hausa Palatalization. A comparable case is found in Luganda Velar Palatalization (Clements 1986, Hayes 1986).

According to Clements (1986), in Luganda velar consonants /k g/ are (optionally) palatalized to the corresponding palatals [צ ㅈ], respectively, whenever they precede either the vowel /i/ or the glide /y/.

(41) a. ki:ntu  ~  צ:ntu  thing
    b. bwo:gi  ~  ב:ן:י  ‘sharpness’
    c. oluggi  ~  או:ג’י  ‘dor’
           (‘*oluggi’

(data from Clements 1986: 69)
Luganda allows for geminate stops /kk gg/. As Clements argues, Luganda Palatalization applies uniformly to geminates.\textsuperscript{13}

In Luganda generally, by palatalization velars become [-anterior] coronal consonants before front vocoids /i, y/. As we observed in coronal palatalization in Hausa (section 4.5.2.2), we assume palatalization involves the spreading of the feature complex [coronal, -anterior] from a front vocoid to a preceding [+anterior] coronal or dorsal (cf. Clements 1976, Hume 1992, McCarthy and Prince 1995). In order to capture this point, I proposed the constraint PAL along the lines of Hume (1992) and McCarthy and Prince (1995):

\begin{equation}
\text{(42) PAL:} \quad C[\text{cor}, -\text{ant}]\text{VOC}[\text{cor}, -\text{ant}] \quad \text{(Palatals come before front vocoids) } \quad (\text{cf. Hume 1992, McCarthy and Prince 1995})
\end{equation}

(repeated from (7a))

To be visibly active, PAL must dominate some relevant faithfulness constraint. Here, the constraint is IDENT-IO(DOR), which says that an input [dorsal] segment is also [dorsal] in the output.

\textsuperscript{13}Clements (1986) argues that those geminates are linked to the sequence VC, not CC. However, that is not important to the present analysis. Thus, in this analysis, geminate consonants are understood as having CC sequence. Accordingly, following moraic representation of geminates, they will be represented as a single consonant with a mora.
Output correspondents of an input [dorsal] segment are also [dorsal].

IDENT-IO(DOR) requires that correspondent output segments be featurally identical to the input segment, with regard to [dorsal] feature.

Since PAL requires that [-anterior] coronals come before front vocoids, PAL can capture the general tendency that velar and [+anterior] coronal consonants are palatalized before the front vowels /e,i/ and the glide /y/. Phonological alternations result from the crucial domination of the IDENT-IO(DOR) constraint by PAL, which leads to featural disparity (i.e. palatalization). Tableau (44) shows that IDENT-IO(DOR) is violated when input /k/ becomes output [c], under the compulsion of high ranked PAL:

<table>
<thead>
<tr>
<th>/k i:ntu/</th>
<th>PAL</th>
<th>IDENT-IO(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dor Cor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-ant]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.  k i:ntu</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.  e* i:ntu</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor [-ant]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This ranking is essential to account for velar palatalization in Luganda.

To be complete, however, we need to consider IDENT-IO(COR) with respect to IDENT-IO(DOR).

(45) IDENT-IO(COR): Output correspondents of an input [coronal] segment are also [coronal]

In order to avoid a PAL violation, we can de-coronalize /i/. However, this is not a possible option for Luganda. In this regard, the higher ranked IDENT-IO(COR) prevents decoronalization of front vocoids, so /ki/ will never be realized as something like *[ku]. This suggests that IDENT-IO(COR) must dominate IDENT-IO(DOR).

(46) IDENT-IO(COR) >> IDENT-IO(DOR)

<table>
<thead>
<tr>
<th>/k i:ntu/</th>
<th>IDENT-IO(COR)</th>
<th>IDENT-IO(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dor Cor [-ant]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. k u:ntu \ / Dor

b. ξ i:ntu \ / Cor [-ant]
With regard to the geminate data, we appeal to NOBREAKING in order to account for the palatalization of whole geminates. Because of the highly ranked NOBREAKING, geminates are not broken into two separate segments.

(47) PAL, NOBREAKING >> IDENT-IO(DOR)

<table>
<thead>
<tr>
<th></th>
<th>NOBREAKING</th>
<th>IDENT-IO(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/olug i/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor Cor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-ant]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. !*</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>NOBREAKING</th>
<th>IDENT-IO(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/olug. y i/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor Cor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-ant]</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Note that velar palatalization is explained in the same fashion with coronal palatalization (cf. section 4.5.2.2).
The above ranking can enforce palatalization of the whole geminate (a). If we palatalize only the second half of the geminate, then we crucially violate NOBREAKING, which rules out the form (b) from the optimal output competition.

In summary, IDENT-IO(DOR) is violated to satisfy the higher ranked PAL and IDENT-IO(COR). These are the main constraints inducing velar palatalization. The ranking required to analyze velar palatalization in Luganda is summarized as follows:

(48) (IDENT-IO(\(\mu\)SF)), NOBREAKING, PAL >> IDENT-IO(COR) >> IDENT-IO(DOR)

The constraints and their ranking are now at hand to analyze the data. Consider first non-geminate case. The following tableau shows velar palatalization of non-geminates in Luganda.
As the above tableau shows, candidate (a) is ruled out by the crucial violation of `IDENT-IO(COR)` because of the change [i] → [u]. Candidate (b) is also eliminated by crucially violating `PAL`. Here, a `PAL` violation is incurred because a palatal consonant does not precede the [i] vowel. In (c), to avoid `PAL` violation, velar /k/ is palatalized violating `IDENT-IO(DOR)`. Since `IDENT-IO(DOR)` is lowest ranked, candidate (c) is correctly selected as the optimal output.

Let us turn now to the case of geminate velar consonants. Unlike such weakening cases as Klingenstein’s Law in Hausa and Tiberian Hebrew Spirantization, the constraint `IDENT-IO(μSF)` is not effective since there are no strong features involved in velar
palatalization. Thus, IDENT-IO(µSF) does not play a role at all, thereby allowing palatalization of velar geminates. The following tableau shows how geminate velar consonants are palatalized, manifesting a type of anti-inalterability effect of the geminates. (Because palatalization of the geminate does not incur any IDENT-IO(µSF) violation, the constraint IDENT-IO(µSF) will be disregarded in the analysis of geminate palatalization data—its ranking is irrelevant, though it is universally top-ranked.)
(50) oluggi 'door'

<table>
<thead>
<tr>
<th></th>
<th>NO BREAKING</th>
<th>PAL</th>
<th>IDENT-IO(COR)</th>
<th>IDENT-IO(DOR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o.lug  i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor  Cor</td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o.lugu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o.lug  y  i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dor  Cor</td>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o.luj  y  i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[-ant]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Candidate (a) which is faithful to the input is ruled out by the violation of top-ranked PAL, while (b) loses out because it violates IDENT-IO(COR). The remaining two candidates (c & d) both violate IDENT-IO(DOR) in order to satisfy PAL; the difference between them is the violation of NOBREAKING, earned if only half the geminate is palatalized (c). As a result, (d) is selected as the optimal output form.

4.7.3 Summary

To conclude, in this section we have sketched a case in which both geminate and non-geminate velar consonants are palatalized before the high front vocoids /i/ and /y/ as a type of evidence for the geminate anti-inalterability effect. As predicted by our hypothesis (cf. 9b) and proved by Hausa Coronal Palatalization and Luganda Velar Palatalization, a type of anti-inalterability effect is possible since universally high ranked IDENT-IO(μSF) is not effective in palatalization, and NOBREAKING is high ranked. Because of that, geminates can be freely affected by palatalization unlike weakening cases (thus, /CiCi/ → [CjCj]).

We now turn to the third predicted pattern (9c), in which NOBREAKING is low ranked allowing underlying /pC_i/ to be broken into two segments [pC,Cj] or [pCjC_k] on the surface. For these cases, Korean Post-Obstruent Tensification and Icelandic Preaspiration will be examined.
4.8 Anti-inalterability Effect II: /CiCj/ → [CjCj] and /CiCj/ → [CjCj]

4.8.1 Introduction

In the following two sections, we focus on the cases in which only half of the geminate is changed (Korean Post-Obstruent Tensification) and both elements of the geminate are changed in different ways from palatalization where the whole geminate alters uniformly against the geminate inalterability effect (Icelandic Preaspiration) (see section 4.8.3 for details).

In the beginning of this chapter, we have made predictions that this type of anti-inalterability effect is produced by a low-ranked NOBREAKING and an irrelevant high-ranked IDENT-IO(μSF) (see figure (9c)). First, let us consider Korean Post-Obstruent Tensification.

4.8.2 Korean Post-Obstruent Tensification: A Case of /CiCj/ → [CjCj]

In this section, I present Korean Post-Obstruent Tensification as a counterexample to the geminate inalterability effect. In Korean Post-Obstruent Tensification, only half of the geminate is affected (/CiCj/ → [CjCj]).

(51) Three Types of Stops in Korean

<table>
<thead>
<tr>
<th>Lenis (t)</th>
<th>Aspirate (tʰ)</th>
<th>Tense (t')</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>[SG]</td>
<td>[CG]</td>
<td></td>
</tr>
</tbody>
</table>

A lenis obstruent in the onset position in Korean undergoes tensification immediately after another obstruent (Kim-Renaud 1974, Cho and Inkelas 1994, Lee 1995, etc.).

(52) cokpo [cok.p’o]  | 'genealogy'
maktæ [maktæ]  | 'sick'
kakca [kak.c’a]  | 'ath'  
moksum [moks’um]  |  
kipʰta [kip.t’a]  | 'to be deep'

One interesting point about Korean Post-Obstruent Tensification is that it also applies to geminate clusters as shown in (53), whether derived by place assimilation (a) or given underlyingly (b).

(53) a. tot-ko [tok.k’o]  | 'to rise and'
pat-ki [pak.k’i]  | 'to receive-Noun'
kotpalo [kop.p’alo]  | 'straight'

b. kakkak [kak.k’ak]  |  
tatta [tat.t’a]  | 'to close'
totta [tot.t’a]  | 'to rise'
4.8.2.1 Constraints and their Interactions in Korean Post-Obstruent Tensification

With this background, let us consider relevant constraints for the analysis of Post-Obstruent Tensification in Korean. In addition to the Faithfulness Constraints MAX-IO and DEP-IO, the following constraints are necessary for Korean Post-Obstruent Tensification.

First, from the fact that plain onset obstruents become tensed ones right after coda obstruents as shown in the forms (52) and (53a,b), we propose the constraint *CODA-ONSL.\(^{15}\)

\[(54) \text{*CODA-ONSL: A sequence of coda obstruent-lenis onset obstruent is prohibited (cf. Cho 1995)}\]

Cho (1995) proposes a similar constraint in order to account for Klamath Deglottalization phenomena. In Cho’s analysis, relevant constraint in Klamath is *CC which prohibits a laryngeal (glottalized) consonant followed by another consonant. This constraint plays an important role to explain Deglottalization of obstruent stops in preconsonantal position.

\(^{15}\) It must be noted, however, that this constraint is restricted to obstruent clusters. In sonorant-obstruent sequences, this constraint is not effective. In those sequences, voicing assimilation will occur instead of Post-Obstruent Tensification (e.g. /sìnpal/ ‘shoes’ → [śimbal], *śim[pl]a], /kunt[as] ‘troops’ → [kunda], *[kuntˈa], etc.). However, we will not go into the detail in this thesis to focus on the main issue of the geminate anti-inalterability effect.
Thus, according to this constraint, /q'g'/ becomes [qg'], and /q'l'/ becomes [ql'], etc. The tendency of the appearance of laryngeal (glottalized) consonants in postconsonantal position in Klamath is reminiscent of the postconsonantal laryngeal consonants in Korean, and raises the question of whether this is the preferred position cross-linguistically.

The constraint *CODA-ONS plays a key role in explaining Korean Post-Obstruent Tensification. In connection with Post-Obstruent Tensification, we need IDENT-IO(CG) as well as *CODA-ONS. IDENT-IO(CG) is directly responsible for the laryngeal feature (constricted glottis) changes.

(55) IDENT-IO(CG): Output correspondents of an input [constricted glottis] segment are also [constricted glottis]

With respect to the ranking between *CODA-ONS and IDENT-IO(CG), it is essential that *CODA-ONS should dominate IDENT-IO(CG) to allow Post-Obstruent Tensification. The following tableau illustrates the ranking relation between them.
(56) \(^*\text{CODA-ONS}_L >> \text{IDENT-IO(CG)}\)

<table>
<thead>
<tr>
<th>/mak(\text{ae}/)</th>
<th>(^*\text{CODA-ONS}_L)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\text{mak.\text{ae}})</td>
<td>(^*)</td>
<td></td>
</tr>
<tr>
<td>b. (\text{mak.\text{t\text{'ae}}})</td>
<td></td>
<td>(^*)</td>
</tr>
</tbody>
</table>

The constraint \(^*\text{CODA-ONS}_L\) also dominates \text{NOBREAKING} as shown in the following tableau. Since Korean Post-Obstruent Tensification favors changes of the half of the geminate, I assume \text{NOBREAKING} is ranked below \(^*\text{CODA-ONS}_L\) in Korean.

(57) \(^*\text{CODA-ONS}_L >> \text{NOBREAKING}\)

<table>
<thead>
<tr>
<th>(\mu)</th>
<th>/tata/</th>
<th>Cor</th>
<th>(^*\text{CODA-ONS}_L)</th>
<th>IDENT-IO(CG)</th>
<th>\text{NOBREAKING}</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\mu)</td>
<td>/tata\</td>
<td>Cor</td>
<td>(^*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. (\mu)</td>
<td>/tat.t'a\</td>
<td>(\check{v}) Cor</td>
<td></td>
<td>(^*)</td>
<td>(^*)</td>
</tr>
</tbody>
</table>
In the above tableau, candidate (a) violates \( *\text{CODA-ONSL} \). In (b), underlying \( \text{\textsuperscript{\textprime}}\text{t}' \) is realized on the surface as \( [\text{\textprime}t'] \), violating IDENT-IO(CG) and NOBREAKING. Since (b) is the actual output form in Korean, \( *\text{CODA-ONSL} \) must dominate both IDENT-IO(CG) and NOBREAKING. Thus, in underlying geminate case, Post-Obstruent Tensification occurs to satisfy \( *\text{CODA-ONSL} \), at the cost of violating the low ranked IDENT-IO(CG) and NOBREAKING (b).

Now, let us look at the examples given in (58).

\[
\begin{array}{ccc}
\text{ip}^h & \text{[ip]} & \text{taf} \\
\text{nat}^h & \text{[nat]} & \text{uri} \\
\text{nac}^h & \text{[nat]} & \text{fur} \\
\text{nas} & \text{[nat]} & \text{side'} \\
\text{nah} & \text{[nat]} & \text{give birth'}
\end{array}
\]

In Korean, coda consonants are neutralized, resulting in unreleased sounds. For example, stop obstruents /t\^h/, /t'/ and /t/ are all neutralized into unreleased [t]. In this regard, we need to pay attention to the remarks of Hudson (1995: 655).

"...consonant release yields phonetic burst, a perturbed postconsonantal airstream that clarifies voicing and place of articulation contrasts. Nonrelease naturally leads to neutralization and /or "weakening."..."

Thus, nonrelease is closely related with the process of Neutralization (in the coda).
In order to capture the coda-related phenomena found in the examples in (58), I suggest two constraints \( \star \text{CODAREL} \) and \( \text{IDENT-IO(SG)} \).\(^{16}\)

(59) a. \( \star \text{CODAREL} \): Syllable-final consonants are not released (cf. Iverson and Lee 1994, Hudson 1995)

b. \( \text{IDENT-IO(SG)} \): Output correspondents of an input [spread glottis] segment are also [spread glottis] (cf. McCarthy and Prince 1995)

The following tableau shows that \( \star \text{CODAREL} \) must dominate \( \text{IDENT-IO(SG)} \) and \( \text{IDENT-IO(CG)} \).

(60) \( \star \text{CODAREL} \gg \text{IDENT-IO(SG), IDENT-IO(CG)} \)

<table>
<thead>
<tr>
<th>/kipʰta/</th>
<th>( \star \text{CODAREL} )</th>
<th>( \text{IDENT-IO(SG)} )</th>
<th>( \text{IDENT-IO(CG)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>( \star )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kipʰ.ta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>( \star )</td>
<td>( \star )</td>
<td>( \star )</td>
</tr>
<tr>
<td>kip.t'a</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Between \( \text{IDENT-IO(SG)} \) and \( \text{IDENT-IO(CG)} \), \( \text{IDENT-IO(SG)} \) must dominate \( \text{IDENT-IO(CG)} \) in order to ensure tense segments in the onset, instead of aspirated ones.

\(^{16}\) Here, [released] is used to refer to aspirate/tense stops, fricatives, affricates, and [r] sound. For the detailed discussion of the feature [released], see Chung (1988, 1989), Hudson (1995) and the references cited there (especially, Saussure 1959, Smalley 1973 and Abercrombie 1967 among others).
(61) IDENT-IO(SG) >> IDENT-IO(CG)

<table>
<thead>
<tr>
<th>/mak'tae/</th>
<th>IDENT-IO(SG)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Furthermore, for Korean Post-Obstruent Tensification to be visually active, *CODA-ONS_L and *CODAREL must dominate both IDENT-IO(SG) and IDENT-IO(CG).

(62) *CODA-ONS_L, *CODAREL >> IDENT-IO(SG) >> IDENT-IO(CG)

<table>
<thead>
<tr>
<th>/kip'ta/</th>
<th>*CODA-ONS_L</th>
<th>*CODAREL</th>
<th>IDENT-IO(SG)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>d.</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

The form /kip'ta/ 'to be deep' illustrates the ranking relationship between *CODA-ONS_L, *CODAREL, IDENT-IO(SG) and IDENT-IO(CG). As the above tableau shows, the violations of *CODA-ONS_L and *CODAREL are considered worse than those of IDENT-IO(SG) and IDENT-IO(CG). Thus, candidates (a), (b) and (c) are all eliminated from the optimal output running by crucially violating *CODA-ONS_L and/or *CODAREL. In (a),
*CODA-ONS\textsubscript{L} and *CODAREL are violated because post-obstruent [t] is not tensed and the coda consonant is not unreleased (i.e. [p\textsuperscript{b}]). In (b), the coda consonant is unreleased, but post-obstruent consonant is not tensed, thereby causing a *CODA-ONS\textsubscript{L} violation. By contrast, in (c), post-obstruent consonant is tensed, but the coda consonant is not unreleased, violating *CODAREL. As a result, (d) is chosen as the optimal one because the violations of IDENT-IO(SG) and IDENT-IO(CG) are less than those of *CODA-ONS\textsubscript{L} and *CODAREL.

Going back to the examples in (53a), we can find that coronal consonants are assimilated to non-coronal consonants when there is place assimilation (e.g. /tot-ko/ → [tok.k'o] ‘to rise and’, /kotpalo/ → [kop.p’alo] ‘straight’). Based on this, I propose the constraint *COR → COR:

The effect of the constraint *COR → COR is that coronal consonants are assimilated to the following non-coronal consonants on the surface. To be more precise, in order to ensure place assimilation in Korean, *COR → COR and IDENT-IO(→COR) must dominate IDENT-IO(COR). The ranking is shown in the following tableau.

(64) *COR → COR >> IDENT-IO(→COR) >> IDENT-IO(COR), IDENT-IO(CG)

<table>
<thead>
<tr>
<th>/tot - ko/</th>
<th>*COR → COR</th>
<th>IDENT-IO(→COR)</th>
<th>IDENT-IO(COR)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cor Dor</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| a. tot. ko | *           |                | *             | *            |
| Cor Dor    |             |                |               |              |

| b. tot.'o  | *           | *              | *             | *            |
| V Cor      |             |                |               |              |

| c. tok.'o  | *           | *              | *             | *            |
| V Dor      |             |                |               |              |

*COR → COR is very similar to Iverson and Lee's (1994) PERIPHERALITY which states "Parse peripheral (or marked) specifications", Kenstowicz's (1994b) PARSE-PLACE, Hong and Suh's (1995) *CODA COR, and Cho's (1995) Assimilation Constraint which says that CC sequences have the same place features. As Kenstowicz (1994b) and Iverson and Lee (1994) observe, coronals are different from labials and dorsals, and are reflected on the representation of feature geometry and are interpreted formally in terms of underspecification (Archangeli 1984, 1988). Thus, as in the examples of Korean place assimilation given in (23a), the specified place feature spreads to underspecified coronal segment lacking the place feature specification (Kim 1990, Sohn 1991). That is, given a choice, a language will prefer a more salient consonant along the place dimension. However, we can notice that this matters only when coronal consonants precede non-coronal ones, and not vice versa. Thus, *COR → COR is well borne out to encode this sort of coronal behavior. See also Kim (1973), Yip (1991), Ahn (1994) and Oh (1994) for further discussion of that issue. With respect to Korean Cluster Reduction, in the case in which competing consonants are both coronal, the choice is dependent on such constraints as CODA SON or CONTIGUITY. For the detailed discussion of this issue in connection with Korean Cluster Reduction, refer to Kenstowicz (1994b), Iverson and Lee (1994) and Hong and Suh (1995).
As shown in (64), the high ranked constraints *COR → COR and IDENT-IO(¬COR) rule out candidates (a) and (b), and correctly produces optimal output form (c). Thus, preceding coronal consonants assimilate to the following noncoronal consonants.

The surface effect of the constraint *COR → COR can also be seen in the following pattern as shown in (65), in which coronals are found in the coda before another coronal sound.

(65) kun[tæ] [kun.dæ] 'troops'
into [in.do] 'sidewalk'
insa [in.sa] 'greetings'
incil [in.jil] 'hostage'

(cf. mannata ‘to meet’, innæ ‘patience’, etc.)

The examples given in (65) do not violate *COR → COR, since the obstruents following the coronal nasal are also coronal.¹⁸

Finally, to conclude our discussion of ranking of the constraints for Korean Post-Obstruent Tensification, we assume that MAX-IO and DEP-IO are highly ranked, which means that the violation of these constraints can be fatal. Thus, the candidates which

¹⁸ The effect of *COR → COR can also be seen in Nasal Assimilation of NC structures, in which the coronal nasal gets its place of articulation features from the following onset sound (e.g. /sinpal/ → [simbal] ‘shoes’, /siko/ → [sigo] ‘report’, /panto/ → [pando] ‘peninsula’, etc.).
violate these constraints will be omitted in the following tableaux. Also, as before, since IDENT-IO(μSF) is irrelevant, it will be omitted as well.

4.8.2.2 Summary of the Constraints

Now, we summarize the ranking relations discussed so far.

(66) a. *CODA-ONS_L >> IDENT-IO(CG) (56)
b. *CODA-ONS_L >> NOBREAKING (57)
c. *CODAREL >> IDENT-IO(SG), IDENT-IO(CG) (60)
d. IDENT-IO(SG) >> IDENT-IO(CG) (61)
e. *CODA-ONS_L, *CODAREL >> IDENT-IO(SG) >> IDENT-IO(CG) (62)
f. *COR –COR >> IDENT-IO(–COR) >> IDENT-IO(COR), IDENT-IO(CG) (64)
g. MAX-IO and DEP-IO are high ranked and IDENT-IO(μSF) is irrelevant

If we combine (66a-g), we derive the following ranking of the constraints for Korean Post-Obstruent Tensification.

(67) Ranking of the Constraints in Korean\(^{19}\)


\(^{19}\) I put NOBREAKING higher than the constraints of IDENT-IO(F) family in the ranking hierarchy in accord with the predicted ranking pattern given in (9c).
The following diagram effectively captures overall hierarchy of the constraints in Korean. (Note that the predicted pattern of the key constraints and their ranking (9c) is exactly reflected in the ranking hierarchy in (68)).

(68) \[ \text{CODA-ONS} : \text{CODAREL} : \text{COR-} \rightarrow \text{COR} : \text{MAX-IO} : \text{DEP-IO} \]

\[ \text{NOBREAKING} \]

\[ \text{IDENT-IO}(\neg \text{COR}) : \text{IDENT-IO}(\text{SG}) \]

\[ \text{IDENT-IO(COR)} : \text{IDENT-IO(CG)} \]
4.8.2.3 The Proof

With this background, we can now show how the geminate anti-inalterability effect is accounted for under our framework.

First, let us see why the whole geminate is not altered unlike Hausa and Luganda palatalization. In Korean Post-Obstruent Tensification, underlying geminates are broken into two segments, and only the second segment (i.e. the onset) is tensed against the geminate inalterability hypothesis as illustrated in the following full tableau (cf. 53b). Here, the low ranked NOBREAKING plays a pivotal role in allowing the change of only half of the geminate.
In the above tableau, candidate (a) is first eliminated by violating top ranked *CODA-ONS due to the lenis onset [t]. Candidate (b) is also ruled out by the crucial violation of *CODAREL. Since tense segment [t'] is not unreleased, *CODAREL violation is incurred in this form. On the other hand, candidate (b) violates NOBREAKING and IDENT-IO(CG) which are ranked lower than *CODA-ONS and *CODAREL. Thus, [tat’a] (c) is chosen as the optimal output. Note here that IDENT-IO(µSF) does not play a role at all since Post-Obstruent Tensification in Korean has nothing to do with the strong features.
As we can see in the above tableau, because of the highly ranked constraints *CODA-ONS_L and *CODAREL, we have to change only the second half of the geminate, not the whole geminate. In summary, in underlying geminate case, Post-Obstruent Tensification occurs to satisfy top ranked *CODA-ONS_L and *CODAREL at the cost of violating the low ranked NOBREAKING and IDENT-IO(CG) constraints, resulting in anti-inalterability effect.20

Now, consider the case of derived geminates by place assimilation (cf. 53a). The form /tot-kɔ/ ‘rise-and’, for example, illustrates that the optimal output form [tok-kɔ] is derived from the fact that *COR −COR and IDENT-IO(−COR) dominate IDENT-IO(COR) and IDENT-IO(CG), in particular.

---

20 Another way to deal with the anti-inalterability effect in Korean Post-Obstruent Tensification is to assume μ / phonologically, and to assume that phonetic release occurs in onset only, resulting in [tt'].

Then, NOBREAKING ranking is irrelevant and can be dropped from discussion.
(70) /tot-ko/ ‘to rise-and’

<table>
<thead>
<tr>
<th>/tot-ko/</th>
<th>*CODA-ONS&lt;sub&gt;L&lt;/sub&gt;</th>
<th>*CODA REL</th>
<th>*COR -COR</th>
<th>IDENT-IO(–COR)</th>
<th>IDENT-IO(COR)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cor Dor</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. tot. ko</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. µ / toko</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. µ / tok’o</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>d. tot. k’o</td>
<td>!</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>e. tot.t’o V Cor</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>f. tot.k’o V Dor</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Candidates (a) and (b) are first eliminated by the crucial violation of *CODA-ONS<sub>L</sub>. In both candidates, the violation of *CODA-ONS<sub>L</sub> is incurred because lenis segment [k] is in the onset position preceded by an obstruent in the coda. Candidate (c) is also ruled out.
by the crucial violation of *CODAREL because tense segment [k'] is not unreleased. Candidate (d) crucially violates *COR → COR due to the Cor-Dor consonant sequence. Thus, it is also eliminated from the competition. Between candidates (e) and (f), candidate (e) loses out because it crucially violates IDENT-IO(¬COR). On the other hand, candidate (f) violates IDENT-IO(COR) and IDENT-IO(CG) which are lowest ranked in Korean. Thus, candidate (f) is correctly selected as the optimal output. This shows that place assimilation should occur towards a non-coronal consonants when coronals and non-coronals compete each other. In this way, place assimilated geminates also undergo Post-Obstruent Tensification in Korean.

Non-geminate obstruent sequences, of course, undergo Post-Obstruent Tensification (cf. (52)). I present a simple case in the following tableau.

\[(71) /\text{maktse}/ \text{‘stick’}\]

<table>
<thead>
<tr>
<th></th>
<th>*CODA-ONS\textsubscript{L}</th>
<th>IDENT-IO(SG)</th>
<th>IDENT-IO(CG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. mak.ta'</td>
<td>!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. mak.ta&quot;</td>
<td></td>
<td>!</td>
<td></td>
</tr>
<tr>
<td>c. makt'ae</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

In the above tableau, candidates (a) and (b) are all eliminated because they crucially violate *CODA-ONS\textsubscript{L} and IDENT-IO(SG), respectively. Thus, candidate (c) is chosen as the
optimal output. Because of this ranking, lenis consonants become tense instead of aspirated in obstruent-obstruent sequences in Korean.\textsuperscript{21}

4.8.2.4 Summary

To summarize the results of this section, Korean Post-Obstruent Tensification occurs both in non-geminate and geminate sequences in contradiction to the geminate inalterability hypothesis suggested by the previous rule-based approaches. Under the present approach, this case does not raise any problem. Korean Post-Obstruent Tensification, an anti-inalterability case, is also explained with the interaction of the constraints conforming to the same way of analysis as shown in inalterability cases.

The result of my characterization of Korean Post-Obstruent Tensification is that if NOBREAKING is low ranked with the universally high ranked IDENT-IO(\mu SF) irrelevant, then we get the anti-inalterability effect in geminates, as has been predicted in (9c). Interesting in this regard is the irrelevance of the constraint IDENT-IO(\mu SF) in geminate clusters. Since IDENT-IO(\mu SF) concerns about only weakening cases, it will never take any effect on such non-weakening phenomena as Korean Post-Obstruent Tensification.

Korean Post-Obstruent Tensification is also different from the pattern shown in Hausa and Luganda palatalization. In both cases, IDENT-IO(\mu SF) is irrelevant to the phenomena in question, however, in Hausa and Luganda palatalization, the whole

\textsuperscript{21} A more complicated case is already examined in tableau (62).
geminate is affected under the compulsion of PAL and NOBREAKING. By contrast, in
Korean Post-Obstruent Tensification, only half of the geminate is affected by the high
ranked constraints *CODA-ONSL, *CODAREL and the low ranked NOBREAKING. If the
geminate remains unchanged, then crucial *CODA-ONSL violation will be incurred.
Changing of the whole geminate also crucially induces the violation of *CODAREL.
4.8.3 Icelandic Preaspiration: A Potential Counterexample to Inalterability

\(/C_1C_2/ \rightarrow [C_1C_2]I\)


In this dissertation, I will defend the claim that preaspired consonants in Icelandic (i.e. Icelandic Preaspiration) are the phonetic realization of an aspirated geminate (cf. Thráinsson 1978, Hermans 1985).

(72) Preaspiration Hypothesis:

Preaspiration is the phonetic realization of aspirated stop geminates

This assumption implies that the phonology creates an aspirated geminate, and that the phonetic component then interprets that aspirated geminate as something that sounds like preaspiration followed by a singleton consonant. Under this assumption, then, we need to show how we get aspirated geminates, phonologically. That is, since we make the assumption that preaspiration is the phonetic interpretation of a phonological aspirated geminate, we need to show where the aspirated geminates come from (i.e. underlying and derived). Accordingly, our discussion focuses on geminates. However, for the fuller
understanding of geminate behavior with respect to preaspiration, it is imperative that we should examine the overall pattern of closely related data.

4.8.3.1 Phonetic Aspects of Preaspiration

Aspiration is typically a property of obstruent stops. The term aspiration usually refers to postaspiration in which the aspiration is realized after the stop. The term preaspiration, on the other hand, implies that the aspiration is realized before the stop. Thus, we can say that stops can be preaspirated as well as (post)aspirated. With respect to preaspiration, the following descriptions are quite characteristic:

"Some languages have aspiration, or a short [h] which comes before stops rather than after." (Smalley 1973: 397)

"We must also note that in some languages (e.g. Gaelic and Icelandic) consonants may be pre-aspirated; there may be a period of voicelessness at the end of a vowel before the articulatory stricture is made." (Ladefoged 1973: 77)

In addition to this, Stevens (1975: 19) views preaspiration as timing the laryngeal movements in advance of the supralaryngeal closure. Similarly, Catford (1968: 332) views preaspiration in terms of the offset or cessation of the voicing of the preceding vowel.

\footnote{See Thráinsson (1978) for an elaborate discussion of phonetic description of preaspiration.}
Summarizing all these descriptions, preaspiration seems to be characteristically voiceless and close to [h], and it seems that preaspiration and (post)aspiration are simply differences in the relative timing of laryngeal and supralaryngeal articulatory gestures. Then, we have to ask why Icelandic has preaspiration as well as postaspiration in the same language, and why postaspiration is very common while preaspiration is very rare. Investigation of the phonological aspects of preaspiration in Icelandic will provide some insights into that problem. In the following section, we will undertake such a phonological investigation of Icelandic Preaspiration, in the hope that it will shed some light on the general nature of preaspiration in other languages.

4.8.3.2 Phonological Aspects of Preaspiration in Icelandic

Based on Thráinsson (1978) and Hermans (1985), we assume that modern Icelandic has two contrastive sets of stops: non-aspirated voiceless stops /p, t, k/ and aspirated voiceless stops /pʰ, tʰ, kʰ/. According to Thráinsson (1978) and Hermans (1985), preaspiration (e.g. hp) and postaspiration (pʰ) are quite different. Preaspiration has full segment length, while postaspiration is much shorter and thus does not take any segment length (see also Anderson and Ewen 1987: 194).
Now, consider the examples given below. As shown in (73), preaspiration shows up in singleton aspirated voiceless stops.23

(73) vakʰna [vahk.na] 'wake up'
     vitʰna [viht.na] 'witness (subst.)'

Examples in (74a,b) show that the underlying geminate aspirated stops also undergo preaspiration, whether they are word-internal or word-final.

(74) a. tʰapʰʰi [tʰah.pi] 'ok'
     tʰrapʰʰa [tʰrah.pa] 'stop'
     kʰapʰʰi [kʰah.pi] 'too'
     tóřʰʰir [touh.tir] 'daughter'
     hatʰʰur [hah.tYr] 'hi

     b. upʰʰ [Yhp] 'upstairs'
     nářʰʰ [nauht] 'night'
     tʰakʰʰ [tʰahk] 'thanks'

A sequence of two identical aspirated voiceless stops formed by morpheme concatenation also has preaspiration on the surface as seen in (75).

23 Later, it will be argued that Preaspiration is the surface realization of the geminate aspirated voiceless stops. This suggests that the real source of Preaspiration is the geminates, not the singletons (cf. Thráinsson 1978).
The forms presented above represent the general pattern of preaspiration in Icelandic. In order to understand this pattern, first we need to look at lengthening phenomena, which connects with preaspiration itself.

4.8.3.3 Lengthening and Preaspiration

Examples of the consonant lengthening (i.e. gemination) in Icelandic are shown in (76).24

(76)  

\[
\begin{array}{lll}
\text{rakna} & [\text{rakk.na}] & \text{'curse, swear'} \\
p^\text{h} \text{arna} & [\text{p}^\text{h} \text{att.na}] & \text{'child (gen. plur)'}
\end{array}
\]

In a stressed VC-syllable, a word-internal non-aspirated voiceless consonant is lengthened (i.e., geminated). There is no preaspiration here.

On the other hand, in an open stressed syllable, a vowel is lengthened (77a), and also a vowel is lengthened even in a stressed closed syllable if the syllable is word-final (77b):

\[\text{(77)}\]

\[
\begin{array}{lll}
\text{feit}^\text{h} \text{t}^\text{h} & [\text{feiht}] & \text{'fat (neut. sg.)'} \\
ljört\text{t}^\text{h} & [\text{ljoht}] & \text{'ugly (neut. sg.)'}
\end{array}
\]

\[\text{rakna} & [\text{rakk.na}] & \text{'curse, swear'} \\
p^\text{h} \text{arna} & [\text{p}^\text{h} \text{att.na}] & \text{'child (gen. plur)'}
\]

\[\text{(77)}\]

Following Hermans (1985), I assume that the sequence of stops or 's/ and /r,v,j/ forms a tautosyllabic structure. Else, the cluster is heterosyllabic (cf. Vennemann 1972).
As addressed before in footnote 23, the examples in (73) above are also a case of lengthening, repeated here for convenience.

<table>
<thead>
<tr>
<th>(78)</th>
<th>vak⁴na</th>
<th>[vahk.na]</th>
<th>'wake up'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>vit⁴na</td>
<td>[viht.na]</td>
<td>'witness (subst.)'</td>
</tr>
</tbody>
</table>

Singleton aspirated stops are lengthened (geminated) and this, in turn, is realized as preaspiration (e.g. */vakʰna* → [vakʰkʰna] → [vahkna] 'wake up').

However, there is no lengthening (nor preaspiration) in words with medial or word-final plain geminates.

<table>
<thead>
<tr>
<th>(79) a. flippi</th>
<th>[flippi]</th>
<th>'color'</th>
</tr>
</thead>
<tbody>
<tr>
<td>kʰaffī</td>
<td>[kʰaffī]</td>
<td>'coffee'</td>
</tr>
<tr>
<td>likkja</td>
<td>[likkja]</td>
<td>'tie'</td>
</tr>
<tr>
<td>sattur</td>
<td>[sattYr]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b. flakk</th>
<th>[flakk]</th>
<th>'fig'</th>
</tr>
</thead>
<tbody>
<tr>
<td>kʰrytt</td>
<td>[kʰrît]</td>
<td>'spices'</td>
</tr>
</tbody>
</table>
Finally, the following examples deserve mentioning.

(80) eikn  [eik:n]  'property'
fukl  [fuk:l]  'tid'
kakn  [kak:n]  'advantage'

Unlike (77b), consonant lengthening occurs instead of vowel lengthening if an obstruent is followed by a sonorant word-finally.  

Capturing regularities based on the Icelandic data pattern given above, I hypothesize the following two things: (i) lengthening is motivated to satisfy a bi-moraic requirement on the stressed syllable (ii) only vowels and geminates are moraic. For these purposes, two different strategies are employed in the phonology of Icelandic: (i) vowel lengthening (ii) consonant gemination. Later, according to our hypothesis (72), preaspiration occurs as the phonetic realization of geminate aspirated stops.

Given those hypotheses, aspirated geminates and preaspiration cannot be separated in any way in Icelandic. As a result, consonant lengthening (i.e. gemination) as well as underlying geminates can cause preaspiration in Icelandic.

---

25 The vowel remains short and the consonant is not lengthened if the morpheme [s] is added (e.g. /mein-s/ → [meins] 'gen. sg. of mein (damage)', /baθ-s/ → [baθs] 'gen. sg. of baθ (bath)'). This is not true if [s] is added to a single aspirated stop (e.g. /fat-s/ → [fat's] 'gen. sg. of fat' (piece of clothing)). That is, this time vowel lengthening occurs in the same environment. These examples are out of consideration since they are unpredictable on phonological grounds, but morphologically related in each case.

26 The moraic status of the geminate consonants has been fully discussed in moraic theory of phonology, and thus I do not mention it any more here (see Hayes 1989).
Since the geminate anti-inalterability effect in Icelandic Preaspiration is achieved by phonetic interpretation (cf. Preaspiration Hypothesis (72)), not through the phonological representations, it is safe to call this a potential counterexample to the geminate inalterability. Icelandic Preaspiration is not a counterexample at all.

4.8.3.4 The General Pattern of Lengthening

Having established that Icelandic Preaspiration is sounds like a sequence of [h] followed by a non-aspirated stop on the phonetic level, our next task is (i) to show where we get consonant geminates (underlying and derived), and (ii) to determine how we get consonant geminates (consonant lengthening vs. vowel lengthening) in the phonology. With respect to (i), we will show why consonants must be geminated, and with respect to (ii), we will show how we get consonant lengthening (i.e. derived geminates) and vowel lengthening in a different way.

The detailed discussion will follow later. However, before going on, it will be useful if we summarize the Icelandic examples which are relevant to the lengthening phenomena. Recall that lengthening results in bimoraic stressed syllables. According to our hypothesis, singleton coda consonants are not moraic, thus coda lengthening is required to make the coda moraic. Else, vowels will be lengthened. The following data are given as a summary of general patterns of Icelandic Lengthening.
(81) Vowel Lengthening: /V.CV/ → [V:.CV] (cf. (77))

<table>
<thead>
<tr>
<th></th>
<th>Language</th>
<th>Pronunciation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>próuna</td>
<td>[prü:.na]</td>
<td>'brown'</td>
</tr>
<tr>
<td></td>
<td>tʰakʰa</td>
<td>[tʰa:kʰa]</td>
<td>'tie'</td>
</tr>
<tr>
<td></td>
<td>vitʰja</td>
<td>[vi::tʰja]</td>
<td>'to call on'</td>
</tr>
<tr>
<td>b.</td>
<td>mein</td>
<td>[mei:n]</td>
<td>'damage'</td>
</tr>
<tr>
<td></td>
<td>sem</td>
<td>[se:m]</td>
<td>'as like'</td>
</tr>
<tr>
<td></td>
<td>útʰ</td>
<td>[útʰ]</td>
<td>'of'</td>
</tr>
</tbody>
</table>

(82) Consonant Lengthening: /VC₁.C₂V/ → [VC₁C₁C₂V] (cf. (73), (76) and (80))

<table>
<thead>
<tr>
<th></th>
<th>Language</th>
<th>Pronunciation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>vakʰna</td>
<td>[vahk.na]</td>
<td>'wake-up'</td>
</tr>
<tr>
<td></td>
<td>vitʰna</td>
<td>[viht.na]</td>
<td>'witness (subst.)'</td>
</tr>
<tr>
<td>b.</td>
<td>rakna</td>
<td>[rakk.na]</td>
<td>'curse, swear'</td>
</tr>
<tr>
<td></td>
<td>pʰarna</td>
<td>[pʰatt.na]</td>
<td>'child (gen. plur)'</td>
</tr>
<tr>
<td>c.</td>
<td>eikn</td>
<td>[eik:n]</td>
<td>'property'</td>
</tr>
<tr>
<td></td>
<td>fukl</td>
<td>[flk:l]</td>
<td>'tirf'</td>
</tr>
<tr>
<td></td>
<td>kakn</td>
<td>[kak:n]</td>
<td>'adventure'</td>
</tr>
</tbody>
</table>

(83) No Lengthening (cf. (74), (75) and (79))

<table>
<thead>
<tr>
<th></th>
<th>Language</th>
<th>Pronunciation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>tʰapʰpʰi</td>
<td>[tʰah.pi]</td>
<td>'vak'</td>
</tr>
<tr>
<td></td>
<td>tʰrapʰpʰa</td>
<td>[tʰrah.pa]</td>
<td>'tap'</td>
</tr>
<tr>
<td>b.</td>
<td>upʰpʰ</td>
<td>[Yhp]</td>
<td>'upstairs'</td>
</tr>
<tr>
<td></td>
<td>tʰakʰkʰ</td>
<td>[tʰahk]</td>
<td>'thanks'</td>
</tr>
<tr>
<td>c.</td>
<td>feitʰ-tʰ</td>
<td>[feiht]</td>
<td>'fat (neut. sg.)'</td>
</tr>
<tr>
<td></td>
<td>ljótʰ-tʰ</td>
<td>[ljouht]</td>
<td>'ugly (neut. sg.)'</td>
</tr>
<tr>
<td>d.</td>
<td>flippi</td>
<td>[flippi]</td>
<td>'color'</td>
</tr>
<tr>
<td></td>
<td>likkja</td>
<td>[likkja]</td>
<td>'to lie'</td>
</tr>
<tr>
<td>e.</td>
<td>flakk</td>
<td>[flakk]</td>
<td>'fig'</td>
</tr>
<tr>
<td></td>
<td>kʰrytt</td>
<td>[kʰrít]</td>
<td>'spices'</td>
</tr>
</tbody>
</table>
Thus far, we have looked at the general patterns of lengthening phenomena in connection with Icelandic Preaspiration. In previous rule-based approaches to Icelandic Preaspiration phenomena, no clear suggestions have been made to explain the fundamental reason why consonants and vowels are lengthened mutually exclusively. In the present analysis, however, the same issue will be accounted for through the interaction of universal constraints which are independently motivated. For that purpose, in the following section, we consider the constraints and their interaction proposed for the OT analysis of Icelandic Preaspiration.

4.8.3.5 Constraints and their Interactions in Icelandic Preaspiration

Now, let us turn to the OT analysis of Icelandic Preaspiration. A major claim of this section is that various types of the examples (consonant gemination, vowel lengthening and no lengthening) are accounted for through the interaction of the constraints in a predicted way.

4.8.3.5.1 Bimoraic Requirement for the Stressed Syllable in Icelandic

According to Hayes (1995), Icelandic is a trochaic language. Thus, primary stress falls on the initial syllable and secondary stresses fall on alternating syllables thereafter. In Icelandic, all vowels (and diphthongs) are short underlyingly, and as the lengthening data in (82) show, in Icelandic, non-geminate codas are not moraic. Thus, as Hayes
(1995: 82-85) describes, to make the stressed syllable heavy, either lengthening of the stressed vowel or gemination of the consonant is required. According to Hayes (1989: 257), geminates *almost always* bear a mora. This claim can be extended to the position that a geminate can bear a mora even in the cases where a short consonant is not moraic. From the fact that lengthening is necessary to make the initial stressed syllable bimoraic, I suggest the constraint $[\mu\mu]$. 

\begin{equation}
(84) [\mu\mu]: \text{ Stressed syllables are bimoraic (cf. Hammond 1993)}
\end{equation}

The constraint $[\mu\mu]$ states that two morae are required for the stressed syllable. As we will see later, lengthening phenomena will be governed by the constraint $[\mu\mu]$, and the ranking relation with other constraints will be clearly established once we present the constraints on lengthening.

### 4.8.3.5.2 Vowel Lengthening vs. Consonant Gemination

In Icelandic, insertion of a vocalic mora (i.e. vowel lengthening) and a consonantal mora (i.e. coda gemination) produce different results, so we need to distinguish them under the DEP-IO family. First, let us consider vowel lengthening cases. As shown in the

---

---

\[27\text{ In Icelandic, trochaic lengthening is limited to the main-stressed syllable. Here, lengthening is simply a direct manifestation of stress and not an optimization of foot structure (Hayes 1995: 84).}\]
examples in (81) (and (77)), vowels are lengthened in an open stressed syllable to satisfy the bimoraic requirement of the stressed syllable (e.g. /prúna/ → [prú:na] ‘brown’, /takha → [tʰa:kʰa] ‘takel’). The constraint DEP-IO(²V) is proposed to take care of these examples:

(85) DEP-IO(²V): Every vocalic mora of the output has a correspondent in the input (Prohibits vocalic mora epenthesis) (cf. McCarthy and Prince 1995, Prince and Smolensky 1993)

Now, let us look at the examples of derived geminates (cf. (73), (76), (80) and (82)). In a stressed closed syllable, coda consonants are geminated to satisfy the bimoraic requirement of the stressed syllable (e.g. /rakna/ → [rakk.na] ‘curse, swear’, /vak³na/ → [vakʰkʰna] → [vahk.na] ‘wake up’). According to the Preaspiration Hypothesis (72), it is claimed that preaspiration is the phonetic manifestation of derived or underlying aspirated geminates (cf. Thráinsson 1978, Hermans 1985). Underlying geminate aspirated stops provide the proper environments for the phonetic realization of preaspiration (i.e. /pʰ⁴ → [ʰp]) without any operation in the phonology. However, ³⁴

³⁴ This claim, however, is against the Principle of Equal Weight for Codas (Tranel 1991) which says “Coda portions of geminate consonants behave in the same way as other coda consonants with respect to syllable weight”. For more details, see section 2.3.2 Weight and Length in Moraic Theory.

³⁵ According to the syllabification process proposed by Hermans (1985: 238), geminate [kk] should belong to the same syllable. This says that [kn] cannot be tautosyllabic (cf. Vennemann 1972). We will discuss this issue later when we deal with the data in (80) (also (82)).
derived geminates cause a violation of DEP-IO("C") unlike underlying geminates, due to the
gemination of the singleton consonants. In order to capture coda consonant gemination.
DEP-IO("C") is proposed as shown in (86).

(86) DEP-IO("C"): Every mora of the consonant segment of the output has a
correspondent in the input (Prohibits consonantal moraic
epenthesis) (cf. McCarthy and Prince 1995, Prince and Smolensky
1993)

The motivation for consonant gemination and vowel lengthening is due to the
bimoraic requirement of the stressed syllable in Icelandic. Derived geminates have DEP-
IO("C") violation, while lengthened vowels have DEP-IO("V") violation to satisfy bimoraic
requirement of the stressed syllable. Thus, it is evident that the constraint [µµ] must
dominate both DEP-IO("C") and DEP-IO("V") in Icelandic.

(87) [µµ] >> DEP-IO("C"), DEP-IO("V")

Concerning the ranking of the constraints among the DEP-IO family. DEP-IO("V")
must dominate DEP-IO("C") as the following partial tableau illustrates.
Since DEP-IO(V) dominates DEP-IO(C), coda consonant gemination (a) is preferred to making the stressed syllable bimoraic, instead of vowel lengthening (b). Thus, candidate (a) is selected as the optimal output under this ranking.

In summary, from above discussion we have motivated the following three constraints on the basis of consonant and vowel lengthening phenomena in Icelandic: [μμ].bill, DEP-IO(V) and DEP-IO(C). With respect to the ranking between them, we established that [μμ].bill dominates both DEP-IO(V) and DEP-IO(C), since DEP-IO(V) and DEP-IO(C) can be violated to satisfy [μμ].bill. Also, we showed that DEP-IO(V) must dominate DEP-IO(C), when both vowels and consonants are possible candidates for lengthening. Thus we have the following ranking regarding the three constraints.

(89) [μμ].bill >> DEP-IO(V) >> DEP-IO(C)
This ranking explains coda gemination in a stressed closed syllable. For an illustration, we now turn to tableau analysis.

Consider the form /rakna/ 'curse, swear'. In a stressed VC-syllable the consonant is only lengthened (i.e. geminated) without preaspiration since the consonant is a non-aspirated stop. The following tableau shows that gemination is favored over vowel lengthening.

(90) /rakna/ → [rakka] 'curse, swear'

<table>
<thead>
<tr>
<th>/rakna/</th>
<th>[µµ]σ</th>
<th>DEP-IO(&quot;V&quot;)</th>
<th>DEP-IO(&quot;C&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>µµ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rakna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>µ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rakna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>µµ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rakna</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Candidate (a) violates DEP-IO("C) due to the gemination of coda consonant [k]. However, candidate (a) is chosen as the optimal output because DEP-IO("C) is ranked bottommost among the three constraints. Candidates (b) and (c) are eliminated due to crucial violations of [µµ]σ and DEP-IO("V), respectively. Thus, consonant gemination
(without preaspiration) is produced if the syllable is closed by a non-aspirated stop consonant. By contrast, underlying non-aspirate geminate consonants do not undergo any operations since they are already long and satisfy bimoraic requirement of the stressed syllable (e.g. /flippi/ → [flippi] 'collar').

Now, let us turn to the derived geminates which show preaspiration as well as gemination (e.g. /pʰ/ → [ʰpʰ] → [ʰpʰ]). As the following tableau shows, a singleton aspirated consonant is geminated to meet the bimoraic requirement of the stressed syllable.

(91) /vakʰna/ → [vakʰkʰna] → [vahkna]

<table>
<thead>
<tr>
<th>/vakʰna/</th>
<th>[μμ]ᶜ</th>
<th>DEP-IO(⁵V)</th>
<th>DEP-IO(⁵C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Looking at the above tableau (91), candidates (a) and (b) are eliminated by the crucial violations of [μμ]ᶜ and DEP-IO(⁵V), respectively. The form in (a) has only one mora.
thus it violates $[\mu\mu]\delta$. In (b), DEP-IO($^aV$) is violated due to the lengthening of the vowel, but this form satisfies the higher ranked constraint $[\mu\mu]\delta$. On the other hand, candidate (c) violates DEP-IO($^aC$) due to the lengthening of the coda consonant. In spite of this constraint violation, candidate (c) is chosen as the actual output form because DEP-IO($^aC$) is lower ranked than $[\mu\mu]\delta$ and DEP-IO($^aV$).

Now, let us look at the case in which a vowel is lengthened if it is placed in an open stressed syllable. With those constraints given in (89), we cannot produce correct actual output form. The reason is that we cannot rule out the form in which the onset of the second syllable is geminated, violating DEP-IO($^aC$) because the new moraic coda does not have a moraic coda correspondent in the input. This would incorrectly prefer $[t^hahka]$ to $[t^ha:k^ha]$. Somehow, we need to prevent a pure onset from also becoming a coda.

In order to account for this pattern, we turn to the constraints NOCODA and MAX-IO. Since they were already introduced in previous chapter, I will not mention them any more, here.

First, if we assume the ranking of $[\mu\mu]\delta$. NOCODA $>\text{DEP-IO}($$^aV$$) $>\text{DEP-IO}($$^aC$$), then we can prevent a pure onset from becoming a coda by gemination.
In this tableau, the first candidate (a) is ruled out because of the crucial violation of [μ][i]. Candidate (b) is also ruled out because of the crucial violation of NOCODA. On the other hand, candidate (c) violates only DEP-IO(μV). Thus, between the three candidates (a), (b) and (c), candidate (c) is selected as the optimal output. Consequently, in an open stressed syllable, vowel lengthening is preferred to consonant gemination to satisfy the bimoraic requirement for stressed syllables in Icelandic.

This contrasts sharply with the closed syllable case in which coda consonant gemination is preferred to vowel lengthening as shown in (90) and (91) above. However, in order to ensure the preservation of the input coda consonant, we need to assume that
MAX-IO must dominate NOCODA: MAX-IO >> NOCODA. The following tableau shows this aspect:

\[(93) /\text{rakna/} \rightarrow [\text{rak\textk{a}}] \text{‘curse, swear’}\]

<table>
<thead>
<tr>
<th>/\text{rakna/}</th>
<th>MAX-IO</th>
<th>[\mu\mu]</th>
<th>NOCODA</th>
<th>DEP-IO(\text{‘V’})</th>
<th>DEP-IO(\text{‘C’})</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. \mu</td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rak-na</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. \mu</td>
<td></td>
<td>*!</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ra-na</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. \mu</td>
<td></td>
<td>*</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ra-na</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. rak-na</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

First, candidate (a) crucially violates [\mu\mu] because the initial syllable has just one mora. Thus, it is eliminated. The above tableau shows that we cannot remove the input coda consonant to satisfy NOCODA because that will cause a worse violation of MAX-IO (b). Candidate (c) violates NOCODA and DEP-IO(\text{‘V’}). On the other hand, candidate (d) violates NOCODA and DEP-IO(\text{‘C’}). Between the two candidates (c) and (d), candidate (d)
is correctly selected as the optimal output because $\text{DEP-IO}^{(\text{C})}$ is lower ranked than $\text{DEP-IO}^{(\text{V})}$.

Thus far we have accounted for the complementary distribution of consonant gemination and vowel lengthening through the interaction of the constraints. Especially, we have seen that lengthening is enforced by the compulsion of the high ranked constraint $\mu\mu].$ Also, we have observed that $\text{MAX-IO}$ and $\text{NOCODA}$ play a key role for the precise description of consonant gemination and vowel lengthening.

4.8.3.5.3 An Apparent Counterexample to Vowel Lengthening

The following examples are exceptional to our hypothesis on vowel lengthening in Icelandic (cf. (77) and (81)).

(94) Vowel Lengthening: $/V.CV/ \rightarrow [V:.CV]$

<table>
<thead>
<tr>
<th>mein</th>
<th>[mein]</th>
<th>'damage'</th>
</tr>
</thead>
<tbody>
<tr>
<td>sem</td>
<td>[se:m]</td>
<td>'as, like'</td>
</tr>
<tr>
<td>út$^h$</td>
<td>[ú:t$^h$]</td>
<td>'af'</td>
</tr>
</tbody>
</table>

Here, we need to note that these examples occur in word-final environments. Since alignment comes into play as an additional factor, it is not surprising that we can find some exceptional cases in word-final position. We will show, however, that even these
exceptional cases are not a problem in our system and can be accounted for neatly through constraint interaction.

In general, vowel lengthening occurs in an open stressed syllable in Icelandic. However, the above examples do not have open syllables, and yet vowel lengthening has occurred. In monosyllabic words, vowels are lengthened instead of consonants geminating, even in a closed syllable. In rule-based approaches, these cases were explained with the notion of extrametricality. In this analysis, we use the constraint $\text{ALIGN}(\text{WD-R, M-R})$ to explain word-final exceptional cases without turning to the notion of extrametricality. Originally, $\text{ALIGN}(\text{WD-R, M-R})$ was proposed to have the standard meaning: *The right edge of every word coincides with morpheme-final elements* (McCarthy and Prince 1993a, b and c). Here, however, I extend this to the prosodic structures, so that if a mora is added, then that mora interrupts the satisfaction of $\text{ALIGN}(\text{WD-R, M-R})$. That is, even though singleton consonants and geminates have the same segment in final position, they are not well-aligned with respect to the prosodic structures (i.e. C] vs. "C]). In (95), I show 3 relevant pictures. I assume the input is (95a):

<table>
<thead>
<tr>
<th>(95) a. Input</th>
<th>b. [se:m]</th>
<th>c. [semm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sem/</td>
<td>σ</td>
<td>σ</td>
</tr>
<tr>
<td>μ</td>
<td>/μμ\</td>
<td>/μμ\</td>
</tr>
<tr>
<td>s e m ]Morpheme</td>
<td>s e m ]Word</td>
<td>s e m ]Word</td>
</tr>
</tbody>
</table>

\[
\text{ALIGN(WD-R, M-R)}
\]
(95b) shows that a mora is added to the vowel /e/. Here, there is no ALIGN(WD-R, M-R) violation because the vocalic mora can be added to the left of the input mora. On the other hand, (95c) shows a mora is added to /m/, interrupting satisfaction of ALIGN(WD-R, M-R). Here, the ALIGN(WD-R, M-R) violation is necessarily incurred since the coda mora can only be added to the right of the input mora.

Concerning the ranking of the constraints, we can infer that ALIGN(WD-R, M-R) must dominate DEP-IO(\(^{\text{aV}}\)) since DEP-IO(\(^{\text{aV}}\)) is violated to satisfy ALIGN(WD-R, M-R).

As an illustration, let us consider the following tableau.

(96) /sem/ → [se:m] 'as, like'

<table>
<thead>
<tr>
<th></th>
<th>[(\mu\mu)](\delta)</th>
<th>ALIGN(WD-R, M-R)</th>
<th>DEP-IO((^{\text{aV}}))</th>
<th>DEP-IO((^{\text{aC}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>(\mu)</td>
<td>(\mu)</td>
<td>(\mu)</td>
<td>(\mu)</td>
</tr>
<tr>
<td>b.</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
</tr>
<tr>
<td>c.</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
<td>(\mu\mu)</td>
</tr>
</tbody>
</table>
In the above tableau, candidate (a) violates \([\mu\mu])\ since the stressed syllable has only one mora. Word-final gemination in (b) causes ALIGN(WD-R, M-R) violation as well as DEP-IO("C) violation. Finally, candidate (c) violates DEP-IO("V) due to the lengthening of the vowel to satisfy bimoraic requirement of the stressed syllable. Since \([\mu\mu)])\ and ALIGN(WD-R, M-R) are higher ranked than DEP-IO("V), candidate (c) is selected as the optimal output form. Thus, vowel lengthening occurs in a closed syllable if the word is monosyllabic.

The examples in (80), however, show an obstruent gemination in a closed syllable (e.g. /eikn/ \([\text{eik:n}]\) 'property', /fukl/ \([\text{flk:l}]\) 'im, etc). In this case, sonorants are not geminated. In order to explain this pattern, I treat word-final sonorants as syllabic (cf. Hermans 1985). Resonants can be syllabic in many languages, thereby causing a violation of PEAK which requires a vowel in the syllable (cf. section 3.4.3.1 Ponapean).

Then, in the above examples, obstruents (e.g. [k]) become a syllable-final consonant of the initial syllable, and thus the obstruent will be lengthened to meet bimoraic requirement of the initial stressed syllable (e.g. /eikn/ \([\text{eikk.N}]\)). However, this also causes a violation of ALIGN(WD-R, M-R) because of the new mora ("n) added to the right of the input mora.

Tableau (97) shows this point:
(97) a. Input  

| /\n|  |
|----|
| μ |
| μμμμ |
| eikn| Morpheme |

b. [eikk.N]

<table>
<thead>
<tr>
<th>σ</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>/\</td>
<td></td>
</tr>
<tr>
<td>μμμμ</td>
<td></td>
</tr>
<tr>
<td>eik n</td>
<td>Word</td>
</tr>
</tbody>
</table>

Compare this with the following two forms: [eikkn] and [ei:kn]. In the above, we have established the ranking $\text{ALIGN(WD-R, M-R)} \gg \text{DEP-IO(^V)} \gg \text{DEP-IO(^C)}$ (cf. figure (96)). The form [eikkn] also violates $\text{ALIGN(WD-R, M-R)}$ due to the new mora ("k") added to the right of the input mora. Then, the form [ei:kn] must be chosen as the optimal one against the fact, since it does not violate high ranked $\text{ALIGN(WD-R, M-R)}$ as we have demonstrated in (95b).

In explaining the problem raised above discussion, I turn to the constraint Sonority Sequencing Principle (SSP):

(98) Sonority Sequencing Principle (SSP): Within a syllable, onsets are required to rise in sonority toward the nucleus and codas to fall in sonority from the nucleus (cf. Clements 1990)
It is generally agreed on that syllabification crucially refers to sonority (Vennemann 1972, Selkirk 1982, Clements and Keyser 1983, Clements 1990, among others). Obviously, the word-final resonants of the examples in (80) are more sonorant than the preceding obstruent. Thus, this sequence violates SSP. If we assume that SSP dominates ALIGN(WD-R, M-R), then we can explain why obstruent-resonant sequences are not allowed in syllable final positions and why word-final sonorants are syllabic. (I assume PEAK is low ranked to allow syllabic sonorants in Icelandic). For an illustration, consider the following tableau.

(99) /eikn/ → [eikk.N] ‘property’

<table>
<thead>
<tr>
<th></th>
<th>SSP</th>
<th>[[mu]]</th>
<th>ALIGN(WD-R, M-R)</th>
<th>DEP-IO((\mu)V)</th>
<th>DEP-IO((\mu)C)</th>
<th>PEAK</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>!</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>!</td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>!</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>!</td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>eikn</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>μ</td>
</tr>
<tr>
<td>b.</td>
<td>μμ</td>
</tr>
<tr>
<td>c.</td>
<td>μμ</td>
</tr>
<tr>
<td>d.</td>
<td>μμμ</td>
</tr>
</tbody>
</table>
In the above tableau, candidates (a), (b) and (c) are all eliminated by crucially violating SSP due to the obstruent-sonorant sequence in the coda. By contrast, candidate (d) satisfies SSP because word-final sonorant [n] is not in the coda any more, but forms a new syllable. Thus, candidate (d) is chosen as the optimal output, resulting in obstruent gemination, instead of vowel lengthening.\footnote{We can insert an epenthetic vowel word finally to make the coda [n] an onset of the new syllable (i.e. [eikk.n\textsuperscript{V}]). That will, however, incur worse constrain violations: ALIGN(WD-R, M-R) (**) and DEP-IO. Here, ALIGN(WD-R, M-R) is violated twice since vowel epenthesis causes both segmental and prosodic misalignment. Thus, regardless of the ranking of DEP-IO, this form will be ruled out because the competing form [eikk.N] has less constraint violation. For this reason, we omit this form from the tableau analysis.}

4.8.3.5.4 Fake Geminates

Now, let us see what happens in the case of fake geminates with respect to preaspiration and the geminate inalterability effect. In this case, additionally the OCP and NOFUSION play a role in producing optimal output form. I rank the OCP at the top and NOFUSION at the bottom considering the fact that fake geminates also undergo preaspiration just as in underlying true geminates. Below is the summary of the ranking of the constraints discussed so far.

(100) a. OCP, MAX-IO, SSP \textgreater\textgreater [\textmu\textmu]\textphi, NOCODA, ALIGN(WD-R, M-R), \textgreater\textgreater DEP-IO\textsuperscript{wV}
\textgreater\textgreater DEP-IO\textsuperscript{(C)} \textgreater\textgreater PEAK

b. OCP is top ranked and NOFUSION is low ranked
Thus, the final ranking of the constraints in Icelandic will be like (101):

(101) OCP, MAX-IO, SSP >> [μμ]ο, NOCODA, ALIGN(WD-R, M-R) >> DEP-IO(“V)
      >> DEP-IO(“C), PEAK, NOFUSION

The following diagram easily captures overall hierarchy of the constraints in Icelandic.

(102) OCP : MAX-IO : SSP
      | DEP-IO(“V)
      | DEP-IO(“C) : PEAK : NOFUSION

Now, the following tableau helps to illustrate the behavior of fake geminates with regard to preaspiration.
(103) /feit\(^h\) \(^t\)/ → [feiht] 'fat(neut.sg.)'

<table>
<thead>
<tr>
<th>/feit(^h) (^t)/</th>
<th>OCP</th>
<th>MAX-IO</th>
<th>[(\mu)](^h)</th>
<th>ALIGN (WD-R, M-R)</th>
<th>DEP-IO((\mu)(^V))</th>
<th>NOFUSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\mu)</td>
<td>1</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b. (\mu)</td>
<td>1</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c. (\mu)</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>d. (\mu)(\mu)</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>e. (\mu)(\mu)</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Candidates (a) and (b) are first excluded by crucially violating the top ranked constraint OCP. Here, the OCP violation is incurred because the two identical segments come together side by side without fusing into one segment. Candidate (c) also crucially violates MAX-IO due to the underparsing of the stem-final segment \(t^h\). Between the two candidates (d) and (e), candidate (e) is selected as the optimal output, because candidate (d) has worse violation of DEP-IO(\(\mu\)\(^V\)).
As in the true geminate case, fake geminates also satisfy the bimoraic requirement for the stressed syllable just by fusing the two identical segments into one. Recall that we get a mora by fusion (cf. figure (74) in Chapter 3). This operation is facilitated because the constraint NOFUSION is lowest ranked and the OCP is top ranked. Thus, the form (e) \([\text{feit}^h\text{t}] \rightarrow [\text{feiht}]\) is selected as the optimal output form in fake geminates.

From above discussion, it is shown that there is no difference between true and fake geminates in Icelandic Preaspiration. This partly results from the fact that NOFUSION is lowest ranked, which ensures the fusion of /C-C/ into \([^\text{h}C]\). Because of this, both true geminates and fake geminates are preaspirated by the phonetic manifestation of aspirated geminate stops.

Finally, in Icelandic Preaspiration analysis, I assumed that preaspiration is realized on the phonetic level. And yet, I argued that Icelandic Preaspiration must be represented as an aspirate geminate in the phonology. At this point, we need to make clear how the two assumptions tie to each other towards preaspiration phenomena.

According to Hermans (1985: 260), preaspiration is in complementary distribution with aspiration, thus, at the phonetic level, Icelandic only has short aspirated stops and short preaspirated stops. It does not have any long aspirated stops. On the other hand, Icelandic has both short non-aspirated stops and long ones.

(104) \[\begin{array}{ccc}
[p] & \sim & [pp] & [p^h] & \sim & [hp], *[p^h p^h], *[hphp] \\
[t] & \sim & [tt] & [t^h] & \sim & [ht], *[t^h t^h], *[hht] \\
[k] & \sim & [kk] & [k^h] & \sim & [hk], *[k^h k^h], *[hkhk] \\
\end{array}\]
These phonetic gaps support our assumption that preaspiration phenomena are best analyzed with the interplay of phonetics and phonology. Though aspirated geminates exist in the phonology of Icelandic, they can never show up in the physical world of the phonetic component because of the articulatory mechanism discussed above (see section 4.8.3.1 Phonetic Aspects of Preaspiration). Thus, aspirated geminates will never be attested at the phonetic level. Also, geminated preaspirated stops will never be realized at the phonetic level, because preaspirated stops cannot be lengthened by phonological processes. Various types of phonological processes in Icelandic also support our assumption (for details, see Thráinsson 1978). The way of indicating preaspiration as an aspirated geminate is well borne out since this phonological representation properly reflects the full segment length of preaspiration (i.e. [hp]), unlike postaspiration (i.e. [pʰ]).

4.8.3.6 Summary

In this section, as a potential counterexample to the geminate inalterability effect, we have investigated Icelandic Preaspiration. We have shown that different strategies are employed in Icelandic Preaspiration to meet the bimoraic requirement of the initial stressed syllable: vowel lengthening and consonant gemination. These aspects are shown to be effectively captured by the constraints interaction model of OT.
We have found that phonologically derived aspirated geminates (either underlying or derived by gemination) undergo preaspiration later in the phonetic component, showing no geminate inalterability effect (cf. Preaspiration Hypothesis (72)). We have also demonstrated that looking at preaspiration in this way can also explain other related phonological processes like vowel lengthening and consonant gemination, in a surprisingly simple and systematic way.

4.9 Summary of Chapter 4

In this chapter, I have argued that the inalterability/anti-inalterability effects of geminates are accounted for more effectively if we analyze them under the constraint interaction model OT. First, we have shown that the inalterability effect is essentially achieved through the ranking of the key constraints: both high ranked LDENT-IO(μSF) and NOBREAKING. It has been also suggested that weakening processes show the geminate inalterability effects (Klingenheben's Law in Hausa, Tiberian Hebrew Spirantization, etc.) (cf. Churma 1988). By contrast, anti-inalterability effects result by varying the ranking of the key constraints: (i) high ranked but not effective IDENT-IO(μSF) and high ranked NOBREAKING produces the effect of /C,C/ → [C,C], and (ii) high ranked but not effective IDENT-IO(μSF) and a low ranked NOBREAKING produces the effect of /C,C/ → [C,C]. and (iii) high ranked IDENT-IO(μSF) and low ranked MAX-IO(μ) produces degemination.

For the predicted pattern (i), we have provided evidence from palatalization (Hausa
Coronal Palatalization, Luganda Velar Palatalization). We have examined Korean Post-Obstruent Tensification for the pattern in (ii). The pattern (iii) is the case of degemination. Degemination cases are not dealt with in this dissertation, however, since they do not have a direct bearing on the questions of inalterability and anti-inalterability.

Finally, we examined Icelandic Preaspiration as a potential counterexample to the geminate inalterability effect and I argued that it is not a counterexample because the geminate anti-inalterability effect in Icelandic Preaspiration is achieved by phonetic interpretation, not through the phonological representations (cf. Preaspiration Hypothesis (72)).

Of particular interest in this chapter is that both inalterability and anti-inalterability effects, some of which were recalcitrant or treated as mere exceptions in previous rule-based approaches, can be effectively accounted for under the present OT analysis with great prediction.
5.1 Introduction

In this study, the geminate consonant phenomena known as integrity and inalterability have been examined with an eye toward providing a characterization of geminate behavior in general as well as a deeper understanding of them in a predicted and systematic way under Optimality Theoretic framework.

First, we examined integrity effects of geminates according to the positions in which they occur. Since under the Optimality Theory framework the universal constraint against crossing association lines cannot be responsible for the integrity effects of geminates, we account for them based on the core interaction of the key constraints: MAX-IO, DEP-IO, PLONS, ONS, NOBREAKING, ALIGN(WD-R, M-R) and PROSHIER. By varying the ranking of the key constraints, the OT approach together with moraic theory not only can explain the geminate integrity phenomenon itself but also can explain the other options regarding the distributional patterns of geminates. In other words, the OT account can explain both what languages do not do and what they do with respect to consonant geminates.

Under rule-based approaches, the geminate integrity effect has been understood as a specific surface pattern which derives from the general behaviors of consonant clusters. Since geminate consonant clusters and non-geminate consonant clusters are not different
in calculating the number of segments within the cluster, they both raise impermissible consonant cluster problem. To resolve consonant cluster problem, languages employ vowel epenthesis, thereby impermissible clusters are broken up to fit into permissible well-formed clusters in the syllable structures. The fact that geminates are not broken up by an epenthetic vowel has been explained by the universal No Crossing Constraint, which prohibits vowel insertion across the association lines.

By contrast, under moraic theory, geminates are represented with a singleton consonant associated to a mora, thus, the problem of impermissible consonant cluster is not necessarily raised.

Speaking in terms of OT, *COMPLEX does not trigger vowel insertion, but PLONS is rather responsible for vowel epenthesis, which is attested in such languages as Pero and Ponapean. In previous rule-based approaches, geminate integrity effect is simply considered as a pattern and consequently major concern is "does this pattern (i.e. geminate integrity effect) exist?". When characterizing a geminate integrity pattern, however, we must ask how this pattern interacts with other patterns as well. Otherwise, we will lose a great deal of generalization about consonant cluster behaviors in the syllable structure. Some languages may prefer deletion of the offending element. Some languages will insert a vowel, thereby satisfying high-ranked PLONS, and so forth. When we look at geminate integrity effects as a pattern, then we have to figure out what the nature of the pattern is and provide a formal characterization of the pattern in a principled way. Under
OT approach couched within moraic theory, these patterns are systematically predicted through the interaction of the key constraints. In this dissertation, we have brought out these predictions and addressed which have been borne out and which haven’t been.

5.2 A Review of the Proposals

5.2.1 Integrity Effects in Geminates

In medial geminates, 4 types of different patterns are predicted. Among them, two types of the patterns are attested and exemplified. According to the previous rule-based approaches, in Pero, vowel epenthesis occurs to break up impermissible CCC clusters, that is, to satisfy *COMPLEX (Goldsmith 1990). In the present analysis, however, vowel epenthesis occurs to satisfy top ranked PLONS, instead of *COMPLEX: /C1C1C2/ → [C1C1VC2] and /C1C2C2/ → [C1VC2C2]. I showed that the overall patterns of the Pero data support this analysis. Pero generally allows only geminate consonant clusters and homorganic NC clusters on the surface manifesting dominant PLONS effect.

Ponapean data also support the present line of analysis. In Ponapean, vowel epenthesis occurs to satisfy PLONS in C1C2 clusters word-medially, despite the fact that there is no medial CCC sequence.

Previous rule-based approaches to Palestinian Arabic just stipulate that vowel epenthesis occurs between the first two consonants to resolve impermissible consonant sequence problem (Abu-Salim 1980, Guerssel 1977, Hayes 1986). On the other hand, the
present analysis explains that (i) vowel epenthesis is not required in the C₁C₂ sequence since PLONS is lowest ranked and there is no *COMPLEX violation and (ii) a vowel epenthesis occurs between the first 2 consonants in the CCC sequence to satisfy the higher ranked ALIGN. Vowel epenthesis between the last 2 consonants in the CCC sequence will crucially violate ALIGN since this position coincides with the morpheme boundary in Palestinian Arabic.

Vowel epenthesis does not occur in any case if it would separate the halves of a geminate, which is characterized by the high ranked constraint NOBREAKING.

In the analysis of integrity effects in word-final position,ALIGN(WD-R, M-R) plays a pivotal role. We learned that, in Ponapean, geminates and NC clusters appear on the surface, violating *COMPLEX and PLONS. However, despite these violations they are considered the optimal output forms since other forms have more severe constraint violations. Thus, geminates and NC clusters are realized on the surface in Ponapean.

Palestinian Arabic can also be analyzed in the same manner as shown in Ponapean final consonant clusters. Previous rule-based approaches to Palestinian Arabic describe that a vowel epenthesis occurs between the 2 consonants to resolve impermissible consonant sequence problem (including geminates). By contrast, the present analysis explains that vowel epenthesis is not required in word-final geminates since PLONS is lowest ranked and there is no *COMPLEX violation. We also learned that, unlike true
geminates, fake geminates have two consonant segments, so vowel epenthesis occurs in fake geminates to satisfy \( *\text{COMPLEX} \).

We have also considered geminate integrity and anti-integrity effects in word-initial position. According to the moraic theory, underlying initial geminates are so unstable because of their moraicity in that position that they are realized in several different forms on the surface to fix unstable initial moraic status of geminates. Not surprisingly, the constraints ONS and PROSHIER play pivotal roles to account for general behavior of initial geminates and NOBREAKING plays a key role in explaining anti-integrity effect shown in Ratak dialect of Marshallese.

In Woleaian, geminates are only realized initially on the surface. This pattern is captured by ranking PROSHIER at the bottom \((/C_1C_1V/ \rightarrow [C_1C_1V])\). Fijian and Ponapean show that word-initially only [CV-] syllable structures are allowed on the surface. Basically, this pattern is explained by assuming MAX-IO(\(\mu\)) is low ranked \((/C_1C_1V/ \rightarrow [C_1V])\). Ralik and Ratak dialects in Marshallese show different types of output patterns with respect to word-initial geminates. This dialectal variation shown in Marshallese is also explained with the basic strategy of different ranking of the constraints. In Ralik, underlying \(/C_1C_1V-/\) becomes \([VC_1C_1V-]\) on the surface (e.g. /llu/ \(\rightarrow [yllu]\)). That is, a core syllable is inserted before the geminate to resolve initial geminate cluster problem. This output pattern is produced if we assume DEP-IO is ranked at the bottom. In other words, in Ralik case, integrity effect is achieved by ranking NOBREAKING over DEP-IO.
Because of this ranking, geminate is not split by an epenthetic vowel. On the other hand, in Ratak, underlying /C₁C₁V-/ is realized as [C₁/C₁V-] on the surface. That is, in Ratak case, the situation is reversed. Since DEP-IO dominates NOBREAKING (i.e. DEP-IO >> NOBREAKING) in Ratak, it is easier to put an epenthetic vowel separating the geminates—an apparent case of anti-integrity. Thus, geminate can be split by an epenthetic vowel in Ratak as far as NOBREAKING is lowest ranked.

Furthermore, it is suggested that anti-integrity is only apparent, not real, once we adopt the concept of Lexicon Optimization (Prince and Smolensky 1993, Itō, Mester, and Padgett 1995). According to Lexicon Optimization, we will have the same input form with the actual output form (e.g. Ratak: /lilu/ → [lilu]; Ralik: /yillu/ → [yillu]).

In summary, throughout Chapter 3, we have found that both integrity and anti-integrity effects are uniformly explained depending on the ranking of the constraints. More interestingly, our system can make a clear prediction of possible patterns of the languages which are characterized by the language-specific ranking of the constraints.

Further, Optimality Theory can provide a direct answer to the geminate puzzle: What do the grammars of different languages have in common, and how do they differ? What they have in common is universal constraints (especially, key constraints which are responsible for geminate integrity effect); they differ in how the constraints are ranked. These basic facts lead directly to the characterization of geminate integrity effects and
other options for the unacceptable consonant clusters including geminates. In this way, OT can further encode language universals and markedness which constitute the classic and core issues of linguistic theory (Archangeli 1997, Prince and Smolensky 1997). Narrowing down our discussion into geminate integrity, for instance, the high ranked constraint NOBREAKING indicates the ways in which languages are unmarked with respect to geminates. According to the results of Chapter 3, the higher ranked constraint NOBREAKING is rarely violated throughout the presented languages, and so in the unmarked case geminates are not separated by an epenthetic vowel to satisfy higher ranked constraints like PROSHIER.¹

5.2.2 Inalterability Effects in Geminates

In Chapter 4, geminate inalterability effects are also examined in a systematic and principled way crucially based on the two key constraints, IDENT-IO(μSF) and NOBREAKING. The most striking aspect of inalterability analysis of this study is to explore inalterability effects in conjunction with the theory of "weakening". It is shown that recognizing a distinction between "weakening" and "assimilation" can make the inalterability effects of the geminate even more predictive and explanatory than the rule-based approaches, such as Hayes (1986), and Schein and Steriade (1986), etc.

¹ Archangeli (1997: 15) notes that the potential for being violated is a result of the position of a constraint in a particular language's hierarchy, rather than a property of the constraint itself. This says that the ranking status of the constraints determines the types of markedness/unmarkedness in the language. For further discussion of this issue, see Archangeli (1997).
We have shown that in Hausa geminates behave differently according to the nature of phonological phenomena. In weakening known as Klinghenbein’s Law, geminates are not affected at all showing geminate inalterability effect, while geminates are freely affected by palatalization (i.e. assimilation). This typological difference between weakening and assimilation with regard to geminates is simply accounted for by ranking universally the constraint IDENT-IO(µSF) on the top of the ranking hierarchy. This ranking leads to both inalterability and alterability effects of geminates within a language as shown in Hausa.

As a case for the inalterability effect, Tiberian Hebrew Spirantization was examined, thereby showing that inalterability effects are the result of both high ranked IDENT-IO(µSF) and NOBREAKING. If we change (i.e. spirantize) only half of the geminate, then we crucially violate high ranked IDENT-IO(µ[-cont]) and NOBREAKING. If we change the whole geminate, then we also crucially violate high ranked IDENT-IO(µ[-cont]). For that reason, geminates are not spirantized in Tiberian Hebrew resulting in inalterability effect.

Anti-inalterability effects are produced from three different rankings: (i) irrelevant IDENT-IO(µSF) and NOBREAKING (ii) irrelevant IDENT-IO(µSF) and low ranked NOBREAKING (iii) high ranked IDENT-IO(µSF) and low ranked MAX-IO(µ). The first type of the pattern (i) is attested in palatalization (Hausa Coronal Palatalization, Luganda Velar Palatalization). For the second type of the pattern (ii), we have examined Korean
Post-Obstruent Tensification. For the third type of the pattern (iii), we have predicted degemination cases (e.g. Finnish). Finally, as a potential counterexample to the geminate inalterability effects, we have investigated Icelandic Preaspiration. We have argued that preaspiration is the phonetic realization of the aspirated geminates (underlying or derived) by providing evidence from the phonology of lengthening of Icelandic.

Of particular interest here is that both inalterability and anti-inalterability effects, some of which were recalcitrant or treated as mere exceptions in previous rule-based approaches, can be easily accounted for under the present OT analysis.

In summary, this dissertation shows that geminate integrity and inalterability effects are accounted for more effectively under the Optimality Theory framework. In rule-based approaches, integrity and inalterability are treated as separate phenomena. Thus, they fail to capture the corelation between them.

In this dissertation, however, integrity and inalterability are not two separate phenomena any more, but are closely related phenomena employing closely related constraints. Specifically, MAX-IO(μ) and NOBREAKING play active roles in both integrity and inalterability phenomena. If MAX-IO(μ) is low ranked, then degemination occurs. This degemination resolves PROSHIER problem in integrity cases. Degemination can also be a way of weakening the geminates which is possible when it is low ranked in inalterability cases. As such, both integrity and inalterability are captured with the same constraint concerning geminates. In the same fashion, if NOBREAKING is low ranked, then
both anti-integrity and anti-inalterability are resulted. But, as we have seen in integrity chapter, anti-integrity cases are very rare, or may not exist given the concept of Lexicon Optimization as discussed in Marshallese. However, anti-inalterability cases are found more often than anti-integrity cases due to the fact that in anti-inalterability cases, NOBREAKING alone can be violated without incurring additional DEP-IO violation. On the other hand, in anti-integrity cases, a NOBREAKING violation necessarily causes additional DEP-IO violation.

5.2.3 General Discussions on Predictions and Gaps in Geminates

With respect to the geminate integrity effect, we observed that all the predicted types of languages are not attested. As we can see in the analysis of the geminate integrity effects in each position, however, only the case where MAX-IO is low ranked is found in initial geminates (figure (27b) in Chapter 1). On the other hand, vowel epenthesis is frequently found cross-linguistically. In accounting for the accidental gaps, I turned to the issue of recoverability of the lexical information. Epenthesis tends to preserves the input information, satisfying conflicting constraints (*COMPLEX, PLONS, etc.) by resolving articulatory problems. On the other hand, deletion is likely to cause the loss of the input information, satisfying conflicting constraints. As a result, in the worst case deletion might bring about some communication problems. This suggests then that languages tend to preserve input information, and deletion may occur when it does not
cause any problem in retrieving the input information (i.e. MAX tends to be high ranked).
For that reason, we can find some cases in which deletion does occur in non-geminate
consonant clusters (e.g. Korean, Attic Greek, etc. (Itô 1986, Steriade 1982). However,
this line of reasoning might explain why we find epenthesis more often than deletion
cross-linguistically.

Epenthesis and deletion are both possible surface patterns, thus, they should be
predicted by way of constraint rankings in OT. However, frequency effect is not
encoded in the ranking, thus, the surface realization of the predicted patterns (between
epenthesis and deletion) will be totally subject to empirical verification. As discussed
above, however, we can conjecture that epenthesis will occur more often than deletion
especially in resolving the geminate integrity problem.

Also, we have argued that some of the gaps are systematic, not accidental, due to
the worse constraint violations under our system (e.g. figure (23d) in Chapter 1). Under
normal circumstances, those patterns will not appear, instead other competing patterns
which have less constraint violations will show up on the surface of the languages.

Since ALIGN(WD-R, M-R) comes into play in word-final position as an additional
factor, only one type is attested out of three predicted types of languages in final
geminates. On the other hand, basically, all types of the languages are attested in initial
geminates. However, we need languages which show a real case for the geminate integrity
effect predicted in (27c) in Chapter 1.
5.3 Implications and Remaining Issues for Further Study

In this dissertation, we investigated two major issues concerning consonant geminates: integrity and inalterability. Thus, no discussions were made on the behaviors of long vowels. The remaining question then is whether we can extend this approach to long vowels. Owing to the nature of vowels, the discussion of integrity effects seems to be irrelevant in long vowel cases, and yet the issue of inalterability effects seems to be worthy of studying thoroughly. Therefore, the issue of inalterability effects in long vowels remains for further research.

There are other areas for further study. One of the fundamental proposals made in this dissertation is that integrity (anti-integrity) and inalterability (anti-inalterability) are predicted systematically by varying the key constraints. Some predictions have been exemplified in this study, but some predictions have not been exemplified yet. In this sense, the accidental gaps are needed to be borne out through extensive data analysis. Thus, this issue requires further research, too.

Finally, since this study pursues a unified approach to geminate behaviors including both integrity and inalterability, it will be more desirable if we can find out languages with both inalterability and integrity potential. For example, degemination is a possible area. The characterization of degemination phenomena will even more shed light on understanding of the nature of integrity and inalterability and their interactions.
5.4 Concluding Remarks

The overall goal of this dissertation has been to properly characterize two major issues on consonant geminates known as *integrity* and *inalterability* within the framework of Optimality Theory. Unlike previous rule-based approaches, our theory allows a unified account of integrity and inalterability through the interaction of a set of key constraints.

It is especially interesting to note that recalcitrant or exceptional cases are also naturally accounted for without assuming any ad hoc conditions or procedures. Those *anti-integrity* and *anti-inalterability* effects are produced as a natural consequence of the interaction of the constraints, just as in the cases of *integrity* and *inalterability*.

Specifically, it has been argued that inalterability/anti-inalterability effects must be viewed in the light of the theory of *weakening*. The different behavior of geminates with regard to weakening and assimilation is shown to be essentially the result of the interaction of the universally high ranked IDENT-IO(µSF) and NOBREAKING.
REFERENCES


Levin, J. 1989. The Autonomy of the Skeleton: Evidence from Micronesian. ms.. The University of Texas at Austin.


Myers, S. 1993. OCP Effects in Optimality Theory. ms., University of Texas at Austin.


