CORTICOTOMY-FACILITATED ORTHODONTICS

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Clinical Dentistry

by

Dr Berna Young-Eun Kim

BDSc (Hons)

Orthodontics

School of Dentistry

Faculty of Health Sciences

The University of Adelaide

2013
1. CONTENTS

1. CONTENTS ................................................................................................................. 1

   Literature Review List of Figures ............................................................................ 3

   Literature Review List of Tables ............................................................................. 3

   Article 1 List of Figures ......................................................................................... 4

   Article 2 List of Figures ......................................................................................... 5

   Article 2 List of Tables ......................................................................................... 5

2. ACKNOWLEDGEMENTS ...................................................................................... 6

3. SIGNED STATEMENT ............................................................................................ 7

4. SUMMARY ................................................................................................................ 8

5. LITERATURE REVIEW .......................................................................................... 11

   Introduction ............................................................................................................ 11

   Orthodontic Tooth Movement .............................................................................. 12

      Early Pioneers .................................................................................................. 12

      Theories of OTM ............................................................................................... 13

      The Present and the Future .............................................................................. 15

   Phases of Tooth Movement .................................................................................. 15

   Hyalinisation ......................................................................................................... 16

   Variation of tooth movement between individuals .............................................. 17

   Accelerating OTM ............................................................................................... 18

   Non-Surgical ........................................................................................................ 19
Literature Review List of Figures

Figure 1: Hypothetical model of the role of bioelectric potentials .......................... 14
Figure 2: Four phases of OTM ................................................................. 16
Figure 3: Model of factors affecting phenotype .............................................. 17
Figure 4: Liou’s dental distraction - no cuts are performed on buccal and lingual plates .................................................. 26
Figure 5: PAOO technique as described by Wilcko et al ............................... 33
Figure 6: CBCT post grafting demonstrating 2.4mm of additional labial bone and 3.6mm of lingual bone at B point .................................................. 31
Figure 7: Evolving secondary osteon in the longitudinal dimension .............. 35
Figure 8: Hwang’s Corticotomy for Intrusion ............................................. 37
Figure 9: Intrusion of tooth 16 by corticotomy and magnetic appliance .......... 37
Figure 10: Custom made hook and TAD used in conjunction with corticotomy to intrude 26 and 27 ................................................................. 38
Figure 11: Corticotomy cuts ................................................................. 40
Figure 12: Ankylosed 11, corticotomy surgery and final result ..................... 42
Figure 13: Study Design and animal numbers in each group .......................... 44

Literature Review List of Table

Table 1: Candidate bone active substances with heritable polymorphisms ........ 18
Article 1 List of Figures

Figure 1: Have you heard about this procedure? ................................................................. 64
Figure 2: Where did you first hear about the procedure? ..................................................... 64
Figure 3: For what reasons would you decide against recommending the corticotomy procedure? .................................................................................................................. 65
Figure 4: What would make you feel more likely to recommend this procedure to your patients? ............................................................................................................................ 65
Figure 5: How many cases have you undertaken (per year)? .............................................. 66
Figure 6: Would you recommend this procedure to your patients? ....................................... 67
Figure 7: What type of cases would you limit the corticotomy procedure to? ...................... 68
Figure 8: How important do you believe that the reduction in treatment time is for patients? 68
Figure 9: Are you using other methods to reduce treatment time? ....................................... 69
Figure 10: Distributions of how comfortable periodontists are in conducting the procedure. The box plot shows the median, first and third quartiles, while the black dots represent the jittered raw data.................................................................................................................. 69
Article 2 List of Figures

Figure 1: Bone Label Timeline ..............................................................................................83
Figure 2: Appliance Design ....................................................................................................85
Figure 3: Appliance being placed in the oral cavity ...............................................................85
Figure 4: Corticotomy Cut .....................................................................................................86
Figure 5: Histomorphometric slide showing the double labelling of calcein (green) and alizarin red (orange) ..............................................................................................88
Figure 6: Mineral Apposition Rate. Error bars represent ±1 standard deviation ...............90
Figure 7: Differences between groups. Red colour represents that the differences were statistically significant at the 5% significance level. The p values are also included for each pair. ......................................................................................................................................91

Article 2 List of Tables

Table 1: Rat groups and their adjusted means of mineral apposition rate ..........................89
2. ACKNOWLEDGEMENTS

I wish to express my appreciation and thanks to my supervisors: Professor Wayne Sampson, Dr Ian Parkinson, Associate Professor Craig Dreyer and Professor Mark Bartold, for their expert advice, encouragement and editorial opinion throughout this project.

Thanks to Dr Mun Jong who initiated this project and carried out the animal experiment component. Without his effort the project would not have been possible. Thanks also to Drs Cherry Zaw and Nida Khan for their input with the animal experiment and the preparation of materials.

I also wish to express my thanks to the following people and organisations:

- The Australian Society Research Foundation for their funding support.
- Mr Tom Sullivan for his statistical expertise.
- Drs Boram Park, Arlene Khaw, Brian Chee and Catherine Doyle for their help with the survey at the Australian and New-Zealand Academy of Periodontists’ scientific conference in Hobart.
- The staff of Bone and Joint Research Laboratory Staff at the Institute of Medical and Veterinary Science – Ms Helen Tsangari, Ms Yolandi Starczak, Ms Lena Truong, Dr Julia Kuliwaba and Dr Paul Anderson who were all so generous with their time.
- Mrs Marjorie Quinn and Mrs Sandie Hughes who guided me in the preparation of the histological slides.
- Associate Professor Karen Peres of Australian Research Centre for Population Oral Health (ARCPOH) for her expertise in formulating the questionnaires.
- Gunz, GAC and 3M for their generous donation of materials used in the study.
- Mr Eddie Sziller and Mr Jon Cor-Udy for laboratory technical assistance, including appliance fabrication.
- The staff of the Animal House for their assistance and support.
- My colleagues Drs Vandana Katyal and Ed Karim for their friendship and collegiality during my time as a post-graduate student.
- My dear friends, near and far who have provided continuous encouragement and support during the last three years.

Finally, this thesis is dedicated to my family – who have always been supportive of all that I do and to a special member who left us in my final year of studies.
3. SIGNED STATEMENT

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

I also give permission for the digital version of my thesis to be made available on the web, via the University’s digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Berna Kim
4. SUMMARY

The duration of orthodontic treatment is an important determinant of patient satisfaction, and the demand for shorter-duration treatment options appears to be increasing. Prolonged orthodontic treatment can become an obstacle to certain social interactions – especially in adults. From a biological point of view, disadvantages of prolonged treatment time include white spot lesions and root resorption. Therefore there has recently been a renewed interest in investigating options to reduce orthodontic treatment time.

Corticotomy-facilitated orthodontic tooth movement (OTM) has been reported to reduce treatment time by two thirds, and involves surgical intervention to the cortical bone. The insult to the bone induces the regional acceleratory phenomenon whereby OTM is increased via up-regulation of bone remodelling and transient osteopenia. Contrary to popular belief, the method dates back to 1959 and results are well documented with one author in 1991 publishing the outcome of 395 treated cases. Nevertheless, despite its long standing history in the study of orthodontics, the method has still not been widely adopted by orthodontists.

The reasons behind this lack of adoption were examined in the first study “Accelerating orthodontic tooth movement with the aid of periodontal surgery – what the practitioners are thinking”. Two separate questionnaires were developed for specialist periodontists and orthodontists. For the periodontists, a survey questionnaire was handed out by the primary investigator at the Australian and New Zealand Academy of Periodontists’ 16th scientific conference, which was held in Hobart, Australia, from 6-9th of March 2013. For the orthodontists, a survey questionnaire was handed out by the principal investigator at the Australian Society of Orthodontists’ Foundation Meeting which was held in Canberra Australia from 15-17th of March 2013.

The results showed that a majority of orthodontists and periodontists believe more research is required on the topic of corticotomy-facilitated orthodontic tooth movement before they would be willing to recommend it to patients. More than half of the orthodontists would never recommend corticotomy-facilitated orthodontics to their patients, while the minority who would recommend the procedure would limit it to adult patients, ankylosed teeth, impacted canines and patients susceptible to root resorption. Over 90% of periodontists believe that there are side effects associated with the corticotomy procedure. Finally, the proportion of practitioners who have undertaken at least one case per annum was quite low,
with few orthodontists (11.5%) and periodontists (18.2%) reporting experience with the procedure.

Despite the perceived lack of research on the topic by the professional community, numerous studies have already attempted to validate the biological mechanism behind corticotomy-facilitated OTM. For example utilising radiographic, tomographic, molecular biology techniques along with histology, studies have investigated the possible mechanism behind corticotomy-facilitated OTM using the rat. Incapable of demonstrating the dynamic remodelling of the bone in the region pertaining to the corticotomy, the methods described above only quantify the static effects of the corticotomy surgery. Furthermore, these studies use a mesially-directed force to the upper first molar; this may be applicable to the closing of an extraction space, but the direction of this force does not represent the clinical scenario of expansion-based, non-extraction treatment plans.

For these reasons, the second study in this thesis titled “Dynamic response of the alveolar bone to corticotomy-facilitated orthodontic tooth movement” aimed to augment the research evidence on the mechanism by which corticotomy accelerates OTM. Using double fluorescent bone labelling to quantify the mineral apposition rate, the changes that take place in bone over a period of time – rather than at a specific time-point – add another dimension to the understanding of corticotomy-facilitated OTM.

To conduct this analysis, thirty-six male Sprague Dawley rats were obtained from Laboratory Animal Services (University of Adelaide), and for comparison a control group without any intervention was included. A bone label, calcein was administered three days prior to appliance insertion and a second label, alizarin red, was administered five days after appliance placement. The rats were randomly assigned to one of six groups:

<table>
<thead>
<tr>
<th>Group</th>
<th>Appliance</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>Flap</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Corticotomy</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Flap</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Corticotomy</td>
</tr>
</tbody>
</table>
For the groups undergoing orthodontic tooth movement, buccally directed force (100g) was delivered to the maxillary right first molar. The activated appliance remained *in situ* for seven days. The animals were sacrificed at the end of the observation period, and the maxilla was dissected and embedded in polymethylmethacrylate. Coronal sections of 5μm thickness were then chosen to study the effects of corticotomy along the length of the root of the first molar tooth in the buccal aspect. Histomorphometric analysis of the mineral apposition rate (MAR) was performed by selecting five random slides.

There was a statistically significant difference in mean average values between the six groups (p < 0.0001). From the six groups tested, the OTM+corticotomy group had the highest MAR. This was followed by OTM only, OTM+flap, corticotomy only, flap only and control. The MAR for the OTM+corticotomy group was approximately 1.19 times higher than for the OTM-only group and 2.37 times higher than the control group. When the groups were compared to each other, there was no significant difference in the MAR of OTM and OTM+flap.

Based on these results it is concluded that when no OTM is involved, there is a trend towards increasing MAR accompanying both the raising of a mucoperiosteal flap and a corticotomy procedure. In contrast when OTM is involved, raising a flap does not significantly increase the MAR beyond the levels of OTM; therefore, it is concluded that injury to the cortical bone is essential to increase MAR, and thus the rate of OTM. OTM itself increases MAR and it is postulated that this is a result of micro-damage to the alveolar bone in the vicinity of the tooth undergoing OTM.