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The Effects of the Quadhelix Appliance on the Dentition and Adjacent Buccal Bone

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The Effects of the Quadhelix Appliance on the Dentition and Adjacent Buccal Bone

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree of
Master of Science in Orthodontics and Dentofacial Orthopedics

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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TABLE OF CONTENTS

FIGURES

TABLES

ABBREVIATIONS

App	Type of Appliance
BBT	Buccal Bone Thickness
BBTT1	Initial Buccal Bone Thickness
BMBL	Buccal Marginal Bone Level
BTL	Bone Thickness Level
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
IA	Interdental Angle
ID	Interdental Distance
L	Left
M1	First Molar
P1	First Premolar
P2	Second Premolar
PL	Perpendicular Line
R	Right
Rate	Rate of Appliance Expansion
RL	Reference Line
T1	Pre- Quad Maxillary Expansion
T2	Post- Quad Maxillary Expansion
μSv	Micro-Sieverts
Δ IA	Dental Tipping

Δ ID	Dental Expansion
Δ BBT	Change in Buccal Bone Thickness
Δ BMBL	Change in Buccal Marginal Bone Level

ABSTRACT

The Effects of the Quadhelix Appliance on the Dentition and Adjacent Buccal Bone

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Master of Science, Advanced Education in Orthodontics and Dentofacial Orthopedics
Loma Linda University, December 2007
Dr. Roland Neufeld, Chairperson

Maxillary palatal expansion has long been used in orthodontics as a means of correcting constricted and collapsed dental arches. The quadhelix appliance, developed by Drs. Robert Ricketts and Ruel Bench, expands buccal segments and causes disto-buccal rotation in upper first molars. The objective of this study was to assess the direct effects that the quadhelix appliance on the surrounding dentition and buccal bone in the maxillary premolar and molar areas in a finite, measurable manner. This assessment was made using the NewTom 3G. The pre-quadhelix and post-quadhelix NewTom 3G images of twenty patients treated in the Graduate Orthodontic Clinic at Loma Linda University School of Dentistry were compared. Specifically, the width of expansion, premolar and molar inclination, molar rotation, and the buccal bone levels were evaluated. A statistically significant amount of bone thickness loss was found on the buccal side of the premolar and molar regions while marginal bone level bone loss was found on the buccal side of the first molars. The amount of change in molar rotation was not found to be statistically significant. A considerable amount of buccal crown inclination was created in the first and second premolars while the amount of buccal crown inclination in the molars was not statistically significant at $p<0.05$.

CHAPTER ONE

INTRODUCTION

Posterior cross-bite is a frequently observed malocclusion in deciduous, mixed, and full permanent dentitions. Incidence of this malocclusion is found in up to twenty-three percent of American and European children.[1-5] Posterior cross-bite can be caused by many factors such as: respiratory incompetence, low tongue posture, and digit sucking habits. This malocclusion can be corrected by a combination of orthodontic and orthopedic maxillary expansion.[6,27]

Maxillary palatal expansion has long been used in orthodontics as a means of correcting constricted and collapsed dental arches. The objective of palatal expansion is to produce maximum transverse width in the maxilla while minimizing concomitant negative effects[7] such as dental tipping, bone dehiscence, and reduction of alveolar bone height. Research suggests that buccal crown inclination of adult teeth causes bone destruction with little compensatory bone formation. This destruction can result in root dehiscence.[8]

Palatal expansion can be achieved by the application of an intermittent force over a short period of time or continuous force over a longer period of time. A purported benefit of rapid palatal expansion is that the greater intermittent force can open of the palatal suture with less buccal crown inclination. However, rapid palatal expanders do not allow for as much physiologic sutural adjustment as slow palatal expansion appliances.[6]

Slow palatal expansion appliances apply a constant force over a longer period of time. The quad-helix originally used by Dr. Robert Ricketts[7] and Dr. Ruel Bench is a slow palatal expansion appliance which achieves skeletal and dental expansion within an acceptable time period. Like other expansion appliances, the quadhelix can increase arch length and correct some functional issues.[8] Three to five millimeters of arch length can be gained as molar teeth are disto-buccally rotated.[27]

Originally, the quadhelix or "W" type expansion device was used by Dr. Robert Ricketts and Dr. Ruel Bench to treat cleft palate patients because it can produce more force anteriorly than posteriorly.[9] The quadhelix is a wire appliance which contains four helical loops and releases a slow continuous force. These loops add twenty-five millimeters of arch wire which lightens the force magnitude and increases the range of activation.[27] Dr. Ricketts recommended that the appliance be fabricated from 0.038" Blue Elgiloy™ archwire.[10] He advocated the use of four different prefabricated sizes depending on the arch dimensions of the patient.[11]

In a study of the quad-helix appliance, Urbaniak, Brantley et al., examined the effects of the appliance size, arch wire diameter, and alloy composition on force delivery. They found that when the size of the prefabricated quadhelix is increased, there is a decrease in force delivery unless the arch wire diameter is also increased. When two prefabricated appliances of the same size but different diameter were compared, the appliance with the greater wire diameter produced a more significant increase in force. The force delivery of the quadhelix was found to be independent of whether or not it was fabricated out of stainless steel or Blue Elgiloy wire™.[11]

The quadhelix appliance is fixed to bands which are cemented on the maxillary molars.[7,12] This appliance provides a continuous force until the initial activation force dissipates.[12] The effect of the force from the appliance is an expansion of the buccal segments and rotation of the banded teeth.[11,13] An initial eight millimeters of expansion placed into the appliance before cementation creates approximately fourteen ounces of forces.[14] This activation was found to be enough force to create tooth movement in adults. In children, tooth movement was found with an additional orthopedic effect.[7,15] The benefits of this appliance include increased anchorage, minimal effects on speech, and continuous action over time. Additonally, the quadhelix is activated by the orthodontist, eliminating the need for patient compliance.[15]

The quadhelix is an effective auxiliary appliance in unlocking class II malocclusions in mixed or permanent dentitions because it distally rotates maxillary molars and expands the maxilla.[11] Furthermore, a quadhelix that is activated to de-rotate a maxillary molar on one side of the arch generates a distalizing force on the maxillary molar on the opposite side of the arch.[27] When mesio-palatally rotated molars are corrected, the buccal cusp of the tooth moves distally and buccally which can result in some class II correction.[13,27]

In 1978, Bench et al. described a protocol which, when followed, would optimize the molar rotation and expansion created by the quadhelix appliance. They discussed appliance fabrication, extra oral and intra oral activation, and ways to avoid detrimental effects to the soft tissues.[16]

While the appliance can be activated intraorally, Chaconas and De Alba found that each time the appliance was bent with orthodontic pliers in the mouth, there was a progressive decrease in the original force placed in the appliance.[14] They suggested that to achieve the maximum activation of the appliance, it must be removed from the mouth, re-activated and re-cemented.[14]

The effects produced by the quadhelix are age dependent.[14] In patients less than nine years old, the sutures are still patent and more skeletal expansion can be achieved than in adults. In adults, where intermaxillary sutures are less patent and often fused, orthopedic expansion is difficult and treatment often results in more buccal crown inclination of the posterior teeth.[17]

In 1982, Zachrisson and Greenbaum looked at the iatrogenic effects of palatal expansion devices on the periodontal supporting tissues. They speculated that although it is important to look at reactions in the sutures and the teeth, the response in the buccal periodontium around multi-rooted teeth might have even greater implications for the longevity of the dentition.[18] In their study, thirty-three orthodontic patients underwent orthodontic therapy, which involved a quadhelix appliance. The researchers predicted that both rapid and slow expansion would adversely effect the hard and soft tissues that serve as anchors for the expansion appliance used. However, they found minimal differences in the periodontium among patients who have rapid palatal expansion, slow palatal expansion with the quadhelix or no palatal expansion.[18] They theorized that the supporting tissues adjust to the forces placed on them, minimizing any iatrogenic damage from lateral forces placed on the dentition and sutures.[18]

In past studies, various methods have been used to evaluate the effects of palatal expansion appliances on the bone, the periodontium and the adjacent dentition. These methods involved clinical examinations, model analysis, and measurements of two-dimensional radiographs and intra-oral pictures.[6,7,12,13,15,16,19,20]

Currently, three-dimensional imaging technology provides better visualization and evaluation of the effects of palatal expansion appliances. The NewTom 3G (NewTom 3G, AFP Imaging Corporation, Elmsford, NY) is a low-dose computed tomography that allows direct measurements on accurately scaled images.[21]

Using the NewTom 3G, the practitioner can easily visualize hard tissues in the maxillo-mandibular region.[21] It provides sub-millimeter (0.125 - 0.4 mm) resolution in images of high diagnostic quality and short scanning times (10 -70 seconds).[21] The radiation dose (13-100 μSv) is fifteen times lower than those of a conventional computed tomography scan and is capable of providing a three-dimensional representation of the maxillofacial skeleton with minimal distortion.[21] Cone beam computed tomography (CBCT) images result in a low level of metal artifact, especially when viewing the teeth and jaws in a secondary reconstruction. The data can be compiled and visualized on proprietary software.[21]

The objective of this study was to assess the direct effect that the quadhelix appliance has on the surrounding dentition and buccal bone in the maxillary premolar and molar areas in a finite, measurable manner. Using the NewTom 3G, buccal bone dehiscence, buccal marginal bone levels, and the amount of molar rotation were measured.

CHAPTER TWO

MATERIALS AND METHODS

Patient Selection

The pre- and post-quadhelix NewTom 3G images of twenty patients who were treated with the quadhelix appliance were assessed. These qualifying patients, were taken from the general population of patients who came to the Graduate Orthodontic Clinic at Loma Linda University, School of Dentistry for treatment. For each of these patients, the quadhelix appliance was treatment planned due to the need for palatal expansion, dental expansion and/or molar rotation. The Ricketts "W" type quadhelix was used. The appliance was fabricated from 0.036-inch stainless steel wire and contained four helical loops [Fig. 2]. The appliances were fabricated either by Par (Laguna Niguel, California) or Prowire (Montrose, California) Orthodontic Laboratories. It is the standard protocol of the Graduate Orthodontic clinic at Loma Linda University, School of Dentistry, that the pre-quad NewTom 3G images are taken at the time of patient enrollment, and post-quad NewTom 3G images are taken after expansion is complete. There was no record of the expansive force placed on the appliance. However, clinicians did note when the appliance was activated, whether it was activated intra or extra-orally and whether it was activated for rotation and /or expansion.

The patient Dicom (Digital Imaging and Communications in Medicine) files were imported from the NewTom 3G machine into OsiriX Medical Imaging Software program (Open-Source™) for reconstruction and measurement. To keep measurements consistent, only one experimenter performed the reconstruction and assessment. The Institutional Review Board of Loma Linda University, Loma Linda, California, USA has approved this study.

Data Collections

The charts of twenty patients who have been treated since June 2006 and have the pre- and post-quadhelix NewTom 3G images were reviewed and the following data recorded:

1. Chart Number
2. Sex (male or female)
3. Age at beginning of treatment
4. Race (White, Black, Hispanic, Asian and others)
5. Total length of time between quadhelix delivery and completion of quadhelix activation.
6. Details regarding the types of appliance activation.

The NewTom 3G data of each patient were reconstructed at 0.5 mm increments and the DICOM (Digital Imaging and Communications in Medicine) images were assessed using OsiriX Medical Imaging Software program (Open-Source™). The following parameters were evaluated on first premolar (P1), second premolar (P2) and first molar (M1) and recorded:

Buccal Marginal Bone Level (BMBL) and Bone Thickness (BBT)[22]

From the axial section of the pre-quadhelix (T1) images, an opened-polygon cut was made bucco-lingually at the level of root of tooth of interest (P1, P2 or M1), so that it bisected the root bilaterally (Fig. 2). Reference lines (RL) were constructed from the buccal cusp tips to the buccal root tips bilaterally, on the coronal image derived from the opened-polygon cut (Fig. 3). A straight line connecting the buccal cusp tips was then drawn and a perpendicular line (PL1) to the RL was made at the most coronal point where the bone was in contact with the tooth. The distance on the RL from PL1 to the cusp tip was defined as the buccal marginal bone level (BMBL). At the level where the buccal bone deflected, a second perpendicular line (PL2) was made. The distance from the root surface to the most buccal bone surface on PL2 was labeled as the buccal bone thickness (BBT). The bone thickness level (BTL) was the distance on RL from PL2 to the cusp tip. The buccal bone thickness of the post-quadhelix (T2) image was measured at this location. The procedure was repeated for post-quad measurements, at the same cut and location, except that on PL2, the post-quadhelix image was determined by the pre-quad BTL (Fig. 4). The change in buccal bone thickness (ΔBBT) was defined by subtracting pre-quadhelix value from post-quadhelix value (BBTT2 – BBTT1); whereas the change in buccal marginal bone level (ΔBMBL) was obtained by subtracting post-quadhelix value from pre-quadhelix value (BMBLT1 – BMBLT2). If the ΔBBT and ΔBMBL were negative values, bone loss was noted.

The percentage of the buccal bone thickness loss was calculated by dividing the BBTT2 by BBTT1 (BBTT2/BBTT1). To find the percentage of the buccal marginal bone level loss, the distances from the pre-treatment and post-treatment BMBL to the mesio-buccal root apex were compared. The percentage of BMBL loss was calculated by dividing the difference between the pre-quadhelix and post-quadhelix buccal marginal bone levels by the pre-treatment distance from the BMBL to the mesiobuccal root apex.

[Figure 5]. This percentage value represents the amount of bone height loss that occurred from the pretreatment buccal marginal bone level to the apex of the mesiobuccal root tip.

Maxillary Molar Rotation (MR)

Using an axial cut, parallel to the occlusal plane, at the level of the root of the first molars, two points were placed on the pre-quad image. One point is placed over the mesio-buccal canals of the right and left first molars and another over the lingual canals of the right and left first molars. The mesio-buccal and lingual canals were marked with a point at the first axial cut that both canals could be easily visualized. A line was then drawn over the midpalatal suture (between the right and left maxillary bones). A line was placed which ran through the mesiobuccal canal point and the lingual canal point ending at the intersection with the midpalatal suture line. This was done on both right and left sides [Figure 5]. The molar rotation (MR) is the angle formed by the intersection of these two independent lines with the midpalatal suture. Using the angle measurement tool, the angle at which the right and left canal lines intersected the midpalatal suture line was measured. This measurement was taken on the pre- and post-quadhelix images. The pre-quad measurement was subtracted from the post-quad measurement to get the change in molar rotation value (ΔMR). A positive ΔMR signified disto-buccal molar rotation. In this study, it is expected that molar rotation and expansion are two independent actions. Any rotation that occurs is assumed to have occurred because the appliance was activated accordingly [Figure 6].

Interdental Distance (ID)[22]

From the axial section of the pre-quad images, at the level of the crown of the tooth of interest (P1, P2 or M1), an opened-polygon cut was made bucco-lingually so that it passed through the central fossae bilaterally (Fig. 7). On the coronal image derived from the opened-polygon cut, an inter-fossal measurement was made and was defined as interdental distance (Fig. 8). The procedure was repeated for post-quad measurements and their difference (IDT2 – IDT1) was the amount of dental expansion (Δ ID).

Interdental Angle (IA)[22]

From the axial section of the pre-quad images, at the level of cusp tips of tooth of interest (P1, P2 or M1), an opened-polygon cut was made bucco-lingually so that it passed through the buccal and lingual (for M1, mesiobuccal and mesiolingual) cusp tips bilaterally (Fig. 2). Lines were drawn across the buccal and lingual cusp tips of both left and right teeth on the coronal image derived from the opened-polygon cut. The interdental angle was the angle formed by their intersection (Fig. 9) and was defined as the interdental angle (IA). The procedure was repeated for post-quad measurements and their difference (IAT1 – IAT2) signified the amount of dental tipping (Δ IA). Buccal crown tipping was indicated by a negative Δ IA value.

Statistical Analysis

For each parameter of interest, means and standard deviations were calculated. The Kruscal Wallis ranks test and Mann-Whitney U-test were used to evaluate the pre-quad and post-quad data. A Pearson correlation analysis was performed to determine associations between the variables. Statistical significance was denoted as $p<0.05$.

Intraclass correlation coefficients were not performed in this study, because previous studies found correlations to be higher than 0.97.[22] This would indicate that the measurement methods used when assessing each NewTom image were highly reproducible and reliable. Furthermore, this finding indicates that CBCT images contain sufficiently high resolution for accurate measuring.[22]

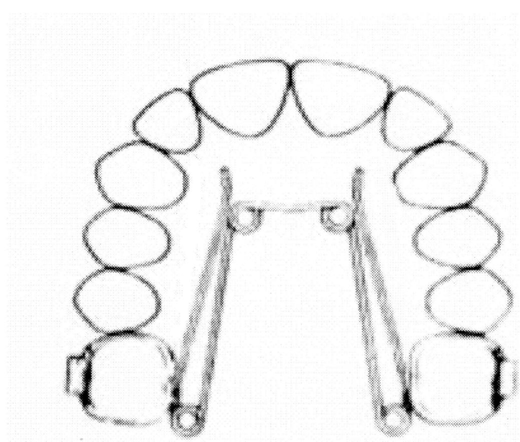

Figure 1. Occlusal diagram of an activated quadhelix appliance using 0.036 stainless steel wire. Note: the palatal arms of the appliance are moved away from the lingual aspect of the canines and premolars to allow molar rotation to occur prior to expansion in the areas.

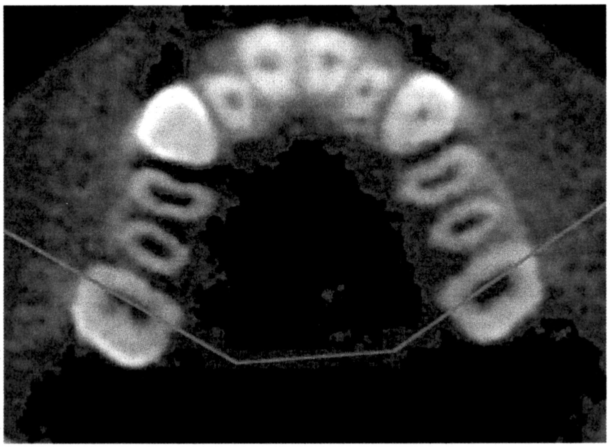

Figure 2. An opened-polygon cut was made bucco-lingually so that it bisected the mesio-buccal root of first molars bilaterally.

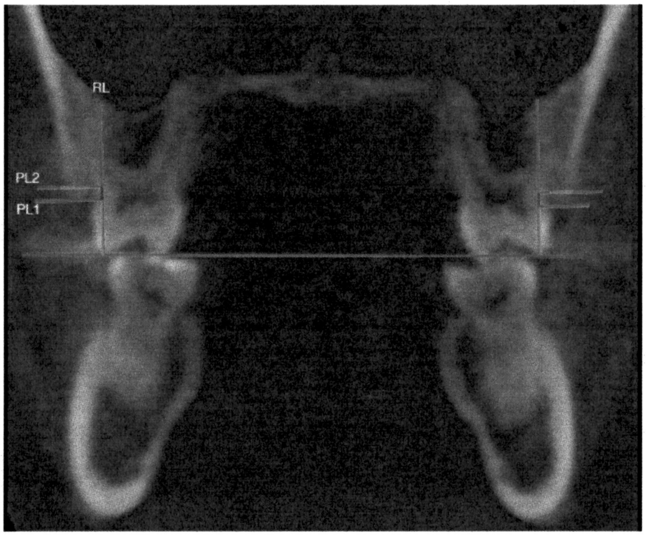

Figure 3. Pre-quad coronal image derived from the opened-polygon cut (Fig 2). RL = Reference line; PL1 = Perpendicular line 1; PL2 = Perpendicular line 2; BMBL = Buccal marginal bone level depicted in yellow; BBT = buccal bone thickness depicted in pink; BTL = Bone thickness level depicted in red.

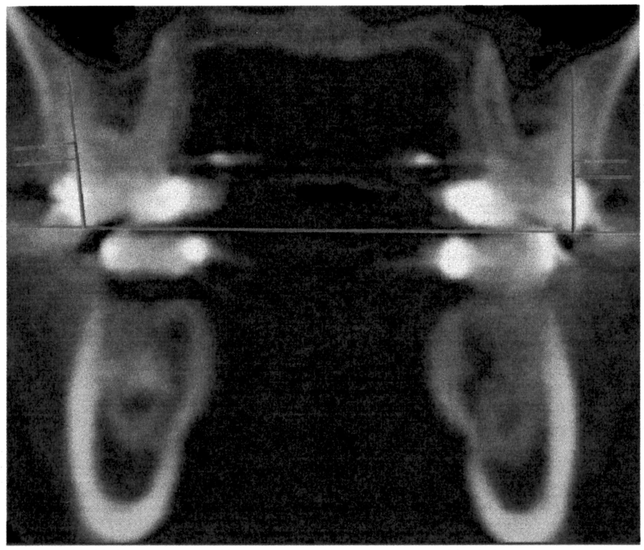

Figure 4. Post-quad image. Note significant change in BMBL (yellow) and the use of BTL (red) to determine the level BBT would be measured.

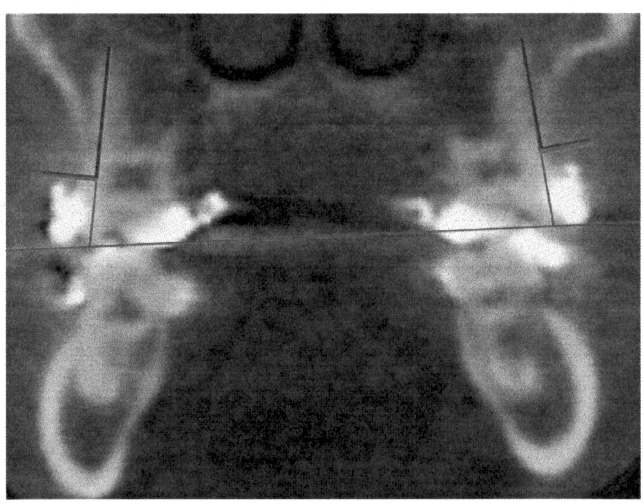

Figure 5. Percentage of buccal marginal bone level loss. Pre-treatment BMBL (horizontal yellow line). Post-treatment BMBL (horizontal red line, signifying apical movement of the BMBL). The difference between pre-treatment and post-treatment BMBL (buccal bone level loss) divided by the pretreatment BMBL is the percentage of buccal marginal bone level loss. Note: the buccal root apices are used as a static measurement reference.

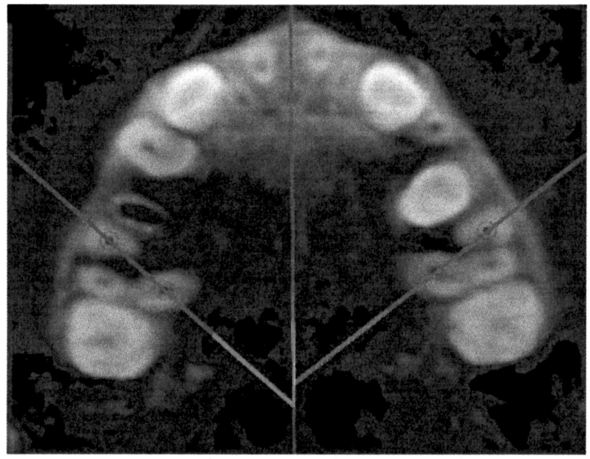

Figure 6. Molar rotation. Points representing the mesiobuccal and lingual root canals are connected by a line which intersects a second line drawn along mid-palatal suture. The angle of this intersection is measured and compared with post-quad image.

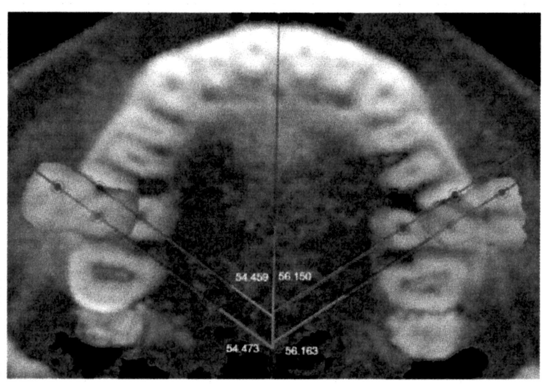

Figure 7: No rotational change is present when pure expansion occurs using the quad helix appliance.

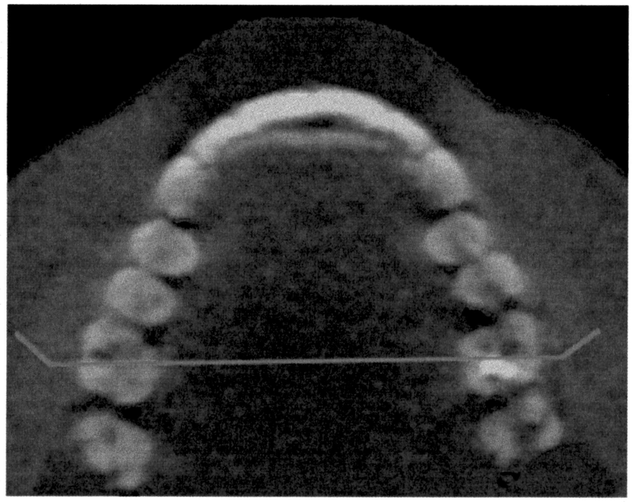

Figure 8. An opened-polygon cut was made bucco-lingually so that it passed through the central fossa of the first molars bilaterally.

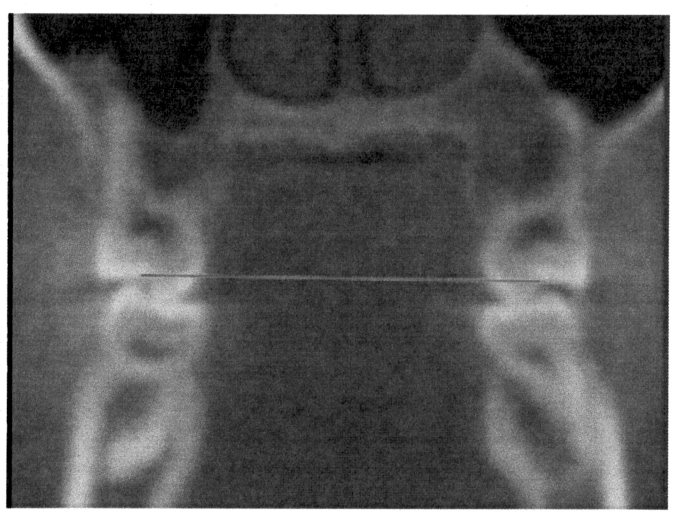

Figure 9. Coronal image derived from the opened-polygon cut (Fig 8). Inter-fossal measurement was made (green line), which signified inter-molar distance.

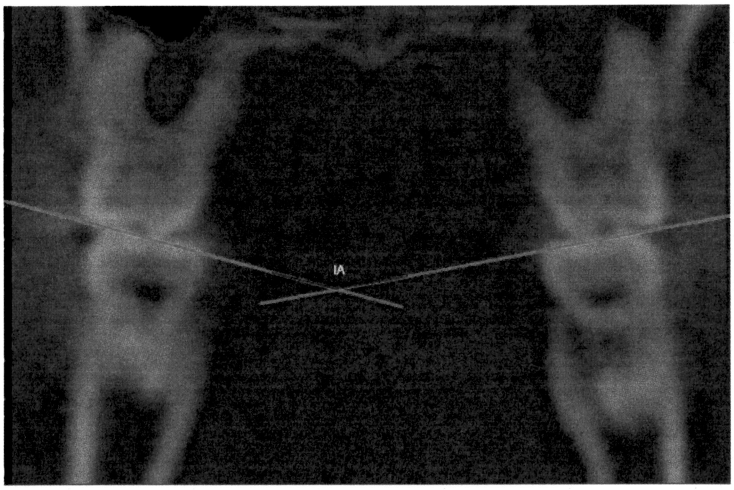

Figure 10. Coronal image derived from the opened-polygon cut (Fig 2). Inter-molar angle (IA), depicted in blue, is the angle formed by the intersection of the lines drawn across the mesiobuccal and mesiolingual cusp tips of 1st molars bilaterally.

CHAPTER THREE

RESULTS

Nine males and eleven females with the mean age of 15.12 (range = 9.8 – 27.8) years old were included in this study. The mean length of quad helix wear was 20.95± 7.57 (range= 9.00- 37.00) weeks. In six patients, 1st and 2nd premolars and in three patients only 2nd premolars were not erupted before the pre-quad images were obtained [Table #1]. Measurements could not be taken at these areas. All of these teeth were bilaterally missing. Five of the twenty patients had edgewise brackets with light orthodontic wires (.014 nickel titanium) placed during active expansion with the quadhelix appliance.

Table 1. Average patient age (years) at the beginning of treatment and average length of quadhelix wear (weeks).

	Mean ± SD	Range
Age (yr)	15.12± 5.4	9.8 – 27.8
Active Quad Wear (wks)	20.95± 7.57	9.00- 37.00

In this study, twenty quad helix appliances were activated for expansion prior to cementation. Of those twenty, twelve were also activated for molar rotation. Nine of the appliances were activated intra-orally for expansion and seven were activated intra-orally for rotation. Three of the appliances were removed and activated for expansion and then re-cemented while only two were removed, activated for rotation, and re-cemented [Table 2].

Table 2. Types of adjustments performed during treatment with quadhelix appliance.

	Pre-activated at appliance delivery	Intra-orally adjusted for additional activation	Extra-orally adjusted for additional activation
Expansion	20/20= 100%	9/20= 45%	3/20= 15%
Rotation	12/20= 60%	7/20= 35%	2/20= 10%

Tables 3 – 5 display the means and standard deviations of all pre-quad and post-quad measured parameters, their differences and the result of the statistical evaluation.

Using the Mann-Whitney U-test at the significance level of α=.05, the pre- and post-quad interdental distance, buccal bone thickness, buccal marginal bone level and interdental angle for P1, P2, and M1 were compared. Molar rotation was compared for only M1. Statistically significant differences were found in all parameters ($p < .05$) except for the interdental angle of M1 ($p = 0.121$), the BMBL of P1 and P2 ($p= 0.069$, $p= 0.364$, respectively), and molar rotation of M1 ($p=0.096$) [Table 3].

Table 3. Comparison of pre- and post-quad measurements using Mann-Whitney U-test at the significant level of $\alpha = 0.05$.

	Pre-Quad (Mean ± SD)	Post-Quad (Mean ± SD)	Average Difference T2-T1 (Mean)	% Bone Loss	p-value
ID P1 (mm)	34.57±3.32	39.29±4.04	4.71±3.63		.003
ID P2 (mm)	39.29±2.90	44.59±3.23	5.30±3.85		< .0001
ID M1 (mm)	44.75±2.98	50.90±3.90	6.15±3.53		< .0001
IA P1 (deg)	209.16±14.19	189.07±27.18	-20.08± 21.45		.035
IA P2 (deg)	189.93±12.45	169.57±13.85	-20.35± 9.27		.003
IA M1 (deg)	171.94±8.62	166.42±14.13	-5.52± 12.50		.121
BBT P1 (mm)	2.29±0.74	1.74±0.89	-0.55± 0.70	33.9	.044
BBT P2 (mm)	2.90±0.94	1.85±0.69	-1.03± 2.10	31.4	.005
BBT M1 (mm)	2.27±0.62	0.97±0.91	-1.31± 2.2	56.8	< .0001
BMBL P1 (mm)	9.67±1.18	12.50±5.18	-2.80± 4.86	12.3	.069
BMBL P2 (mm)	7.86±2.43	9.60±4.15	-1.74± 0.20	14.6	.346
BMBL M1(mm)	8.17±0.94	11.72±2.82	-3.55± 2.64	29.8	< .0001
MR (deg)	42.71±8.73	47.87±8.70	5.17±9.93		.096

ID = Interdental distance; IA = Interdental angle; BBT = Buccal bone thickness; BMBL = Buccal marginal bone level; P1 = 1st premolar; P2 = 2nd premolar; M1 = Mesial1st molar, MR= 1st molar rotation.

When comparing the effect of the quadhelix on P1, P2, and M1 using Kruskal-Wallis ranks test at the significance level of $\alpha = 0.05$, no statistically significant differences were found in the amount of interdental distance (ID), the amount of buccal bone thickness (BBT) or the buccal marginal bone level (BMBL). However, the changes in intradental angulation were statistically significantly greater in the P1 and P2 than in the M1 ($p = .027$ and $.002$ respectively). Using Mann-Whitney U-test at the significance level of $\alpha = 0.05$, no statistically significant differences were found in the changes in buccal bone thickness and marginal bone level between P1, P2, and M1 ($p > .05$) [Table 4].

Table 4. Comparison of quadhelix effect on 1st premolar (P1), 2nd premolar (P2) and 1st molar (M1) using Kruscal-Wallis ranks test and Mann-Whitney U-test at the significant level of $\alpha = 0.05$

	P1 (Mean ± SD)	P2 (Mean ± SD)	MM1 (Mean ± SD)	p-value
Δ ID (mm)	4.71±3.63	5.30±3.85	6.15±3.53	.452
ΔMR (deg)			5.17±8.93	.096
Δ IA (deg)	-20.08±21.45	-20.35±9.27	-5.52±12.50	.008*
ΔBBT (mm)	-0.55±0.70	-1.03±2.10	-1.31±2.2	.075
ΔBMBL (mm)	-2.80±4.86	-1.74±0.20	-3.55±2.64	.119

* Statistically significant, p<.05
Δ ID = Dental expansion; Δ IA = Dental tipping; Δ BBT = Change in buccal bone thickness; Δ BMBL = Change in buccal marginal bone level; ΔMR= Change in molar rotation.

Using the Mann-Whitney U-test at a significance level of $\alpha = 0.05$, the right and left sides were compared for changes in buccal bone thickness (ΔBBT) and buccal marginal bone level (Δ BMBL) for P1, P2, and M1. The change in molar rotation between the right and left sides (Δ MR) was also compared. No statistically significant differences were found between the right and left sides for any of these parameters ($p>0.05$)[Table 5].

In addition, since there were no statistically significant differences in the changes in buccal bone thickness, marginal bone level and molar rotation between the right and left P1, P2 and M1 [Table 5], only the measurements on the right side were used for correlation analyses.

Table 5. Comparison of buccal bone changes between right (R) and left (L) 1st premolar (P1), 2nd premolar (P2) and 1st molar (M1) and rotation changes between the right (R) and left (L) molars using Mann-Whitney U-test at the significant level of $\alpha = 0.05$

	P1 (Mean ± SD)		P2 (Mean ± SD)		MM1 (Mean ± SD)	
	R	L	R	L	R	L
Δ BBT (mm)	-0.55±0.70	-0.56±0.93	-1.02±1.07	-1.12±0.80	-1.31±.94	-1.55±1.30
p-value	.982		.519		.583	
ΔBMBL (mm)	-2.85±4.86	-2.20±4.47	-1.74±2.84	-2.11±1.50	-3.54±2.50	-2.59±1.80
p-value	.603		.898		.134	
Δ MR (deg)					5.17±8.93	5.63±9.61
p-value					.904	

Δ BBT = Change in buccal bone thickness; Δ BMBL = Change in buccal marginal bone level; Δ MR= Change in molar rotation

Tables 6-8 shows the matrix of Pearson correlation coefficients (r) for changes in the P1, P2, and M1 groups. For the P1 group, five of the thirty-six correlations were found to be statistically significant ($p<0.05$). For the P2 group, three of the thirty-six correlations were found to be statistically significant (p<0.05). Finally, three of the forty-five correlations were found to be statistically significant (p<0.05) in the M1 group.

More specifically, a strong correlation was found between ΔIA and ΔBMBL (r= -.670, p= 0.009) and ΔIA and ΔID (r= 0.711, p=0.004) for P1. The length of quadhelix wear was also strongly correlated with the ΔBT for P1 (r= .785, p=0.001). For P2, the ΔBT was strongly correlated with the BTT1 (r=-0.770, p<0.006). For M1, correlations were found between BH1 and age (r= -.449, p= 0.047), length of wear and ΔBT (r= -.470, p= 0.037) and ΔIA and ΔMR (r= -0.564, p=0.036).

Table 6: Pearson Correlation Coefficients for the 1st premolar.

	Age	Length	ΔID	ΔIA	ΔMBL	ΔBT	BTT1	BH1
Age	1							
Length	.028	1						
ΔID	-.092	.439	1					
ΔIA	-.123	.337	.711**	1				
ΔMBL	-.138	-.201	-.527	-.670**	1			
ΔBT	-.257	-.785**	-.420	-.188	.355	1		
BTT1	.357	.365	-.098	-.552*	.615*	-.236	1	
BH1	.229	.110	-.328	.067	-.156	-.158	-.175	1

*p<.05, **p<.001

Table 7: Pearson Correlation Coefficients for the 2nd premolar.

	Age	Length	ΔID	ΔIA	ΔMBL	ΔBT	BTT1	BH1
Age	1							
Length	.028	1						
ΔID	-.118	.236	1					
ΔIA	-.503	-.286	.386	1				
ΔMBL	.131	.079	-.104	-.098	1			
ΔBT	-.198	-.223	.218	-.204	.369	1		
BTT1	.422	.323	-.285	.049	.236	-.770**	1	
BH1	.181	-.210	-.633*	-.291	-.234	-.161	.120	1

*p<.05, **p<.001

Table 8: Pearson Correlation Coefficients for first molar.

	Age	Length	ΔID	ΔIA	ΔMBL	ΔBT	BTT1	BH1	ΔMR
Age	1								
Length	.028	1							
ΔID	-.208	.428	1						
ΔIA	.127	-.170	.296	1					
ΔMBL	-.105	-.202	-.010	.070	1				
ΔBT	-.113	-.470*	-.011	-.144	.215	1			
BTT1	.047	.239	-.230	-.284	.333	-.383	1		
BH1	.449*	-.280	.057	.226	-.019	.011	-.413	1	
ΔMR	.231	-.007	-.261	-.564*	-.341	.093	.107	-.088	1

*p<.05, **p<.001

CHAPTER FOUR

DISCUSSION

In this study, twenty patients requiring maxillary palatal expansion were treated using the quadhelix appliance. Pre-treatment images were taken with the NewTom 3G prior to appliance cementation. Post-treatment images were taken with the NewTom 3G on each patient at the end of active expansion. The pre- and post-quadhelix images were then compared by looking at five areas of change: Interdental distance (ID), buccal bone thickness (BBT), buccal marginal bone level (BMBL), buccal crown inclination (IA) and rotation (MR).

Interdental Distance

A statistically significant change in interdental distance was found at the first premolar, second premolar, and first molar after active expansion with the quadhelix appliance (4.71± 3.60, 5.30± 3.85, 6.15± 3.53 mm, respectively). However, when the change in interdental distance was compared among the first premolar, second premolar and molar regions, no statistically significant difference was found. In other words, there was no more expansion in the first and second premolars than in the first molars. This lack of differential expansion between the premolars and molars may be caused by improper differential activation of the quadhelix appliances. When activated correctly, the sweeping action of the quadhelix arms should begin to exert force on the palatal surfaces of the canines and premolars after molar rotation and expansion has been accomplished.

The interdental distance was comparable to that found by Haas et al. In their study of the quadhelix appliance, an average of 5.88 mm of expansion was found between the maxillary first molars.[28]

Buccal Bone Thickness

The use of the quad helix appliance caused statistically significant buccal marginal bone loss in the premolars and molars of the maxilla. A decrease in buccal bone thickness (BBT) after active treatment with the quadhelix was found at the first premolar, second premolar and first molar regions [Table 3; $p < .05$ for P1 and P2, $p < .0001$ for M1]. The change in buccal bone thickness (ΔBBT) around the first premolar, second premolar, and first molar (-0.55± 0.70 (33.9%), -1.03± 2.10 (31.4 %), -1.31± 2.20 mm (56.8%), respectively) was not significantly different when these different areas were compared ($p = 0.075$). It should be noted that these percentages of buccal bone thickness loss in the premolar and molar regions are clinically significant. However, it is postulated that the bone may remodel after active expansion is completed. Future studies would need to be done to further assess whether bone is re-established on the buccal surfaces of the premolar and molar regions.

Before cone beam computed technology (CBCT), visualization of changes in bone thickness was difficult. Although bone height can be measured with periodontal probing (2D), bone thickness is virtually impossible to assess without cone beam computed technology (3D).

In 2006 Rungcharassaeng et al., examined the change in buccal bone thickness associated with the use of a rapid maxillary expansion appliance. Using cone beam computer technology (CBCT) scans and the same methods as this study, statistically significant amounts of bone thickness loss at the first premolar, second premolar and first molar regions (-1.14 mm, -.84 mm, -1.24 mm respectively) were found.[22]

Buccal Marginal Bone Level

Buccal marginal bone loss (BMBL) was only found to be statistically significant around the first molar (-3.55mm (29.8%), $p<.0001$). No statistical significance was found when the buccal marginal bone levels of the first premolar, second premolar, and the first molar were compared ($p= 0.119$). A strong Pearson correlation was found between the buccal marginal bone level (ΔBMBL) and the interdental angle (ΔIA). As the interdental angle decreases, more buccal crown inclination occurs. As buccal crown inclination increases, the buccal marginal bone level decreases, demonstrating more buccal marginal bone loss (-.670, $p<.001$). As the teeth tip more, buccal bone loss increases.

Zachrisson and Greenbaum evaluated the crestal bone level at the mesial, central and distal aspects of the first molar through transgingival probing by the sounding technique.[18] Bone height was measured from the cemento-enamel junction (CEJ) on patients treated with a rapid palatal expansion appliance, a slow palatal expansion appliance and no treatment. No significant bone loss was found in any of these groups. However, variations were found when the mean attachment levels at the central and distal aspects were compared.[18] These variations were attributed to the ability of the quadhelix to rotate the molars. Upon distobuccal rotation of the molars with the quadhelix appliance, less lateral force is exerted against the buccal tissues.[18] In contrast, the rapid palatal expansion appliances do not rotate the first molars and considerable stress is placed on the distobuccal aspects of the periodontium.

In the current study, the amount of disto-buccal molar rotation was not statistically significant but a significant amount of buccal marginal bone loss was found. With only slight disto-buccal rotation, more lateral force may have been placed on the buccal tissues eliciting more bone loss as described by Zachrisson and Greenbaum.

When examining changes in the buccal marginal bone level (BMBL) and buccal bone thickness (BT), no difference was found between the right and left sides. The right and left side measurements taken were statistically insignificant, indicating that changes in each of the variables measured occurred symmetrically. This differs from the findings of Greenbaum and Zachrisson which found that one side of the mouth displayed more periodontal change than the other. They suspected that this asymmetry was due to brushing habits of the patients. More change was found on the left side of the patients' mouth because more of the patients in the study brushed with their right hand.[18]

Interdental Angle

More buccal crown inclination change was found in the first and second premolar regions than in the first molar region. The change in intradental angle (ΔIA) was found to be statistically significant at first premolar (P1) and second premolar (P2) (P1=-20.08° p= 0.035, P2=-20.35°, p= 0.003) but not at the first molar (M1)(-5.52°, p= 0.121). Furthermore, when the axial inclination changes were compared among the first premolar

(P1), second premolar (P2) and first molar (M1) using the Kruscal Wallis ranks test and Mann Whitney U test, both the first premolar and second premolar were not significantly different from each other ($p= 0.767$). However, both the first premolar and second premolar displayed a significantly greater amount of change in buccal crown inclination than the first molar (P1; $p=0.027$, P2; $p=0.002$). A strong correlation was found between the change in interdental angle and the change in interdental distance at the first premolar ($r= 0.711$, $p= 0.004$). Essentially, as more crown inclination occurred, greater arch width was achieved.

Most of the expansion gained by use of the quadhelix appliance has been found to be dentoalveolar.[23] The quadhelix appliance has been shown to demonstrate greater molar buccal crown inclination when compared to other types of expansion.[23,24] In a patient with a reversed (negative) curve of Wilson, buccal crown inclination can be a desired effect of the quadhelix appliance.[27] The amount of molar buccal crown inclination found in this study (-5.52 ± 12.50 degrees) is comparable to that found in similar studies. Hicks found two to twenty degrees of buccal crown inclination in the maxillary molars with use of slow expansion appliances.[10] The average molar buccal crown inclination found by Herold when examining the casts of patients after the use of the quad helix was two degrees in the canine and three degrees in the molars.[25]

When compared to the molars, the premolars displayed a significantly greater buccal crown inclination. This is attributed to the way that the appliance is attached to the dentition. The molars are attached to the appliance with bands which creates more torque control in these teeth. In contrast, the premolars are not attached to the appliance, and any expansive or rotational force is transferred to the palatal surface of the premolars by the lingual bar. This force creates a buccal moment that results in greater buccal crown inclination of the premolars.[25,26]

It should be noted that a large range was found in the interdental angulation values for the first premolar, second premolar and first molar (-17.0- 54.9, 6.6- 31.5, -27.4- 34.5, respectively). Lingual crown inclination was found in two of the first premolars, none of the second premolars and four of the first molars of the subjects after treatment with the quadhelix appliance. This lingual crown inclination is not conducive to cross-bite correction and may have occurred because the appliances were not activated properly.

Molar Rotation

The quadhelix is as an expansion appliance that has the ability to distally rotate maxillary first molars in an effort to correct a class II malocclusion.[18] However, the findings of this study show an insignificant amount of molar rotation (5.17±8.93°, p= 0.096).

The small change in molar rotation and the large degree of premolar buccal crown inclination can best be explained by looking at how the appliances were activated before placement in the mouth. Bench et al., stated that where extreme mesial rotation of the upper molars exists, it is beneficial to allow for distal molar rotation to occur prior to anterior buccal segment expansion.[16] This is accomplished by keeping the lingual arms away from the deciduous buccal segments. As the upper molars rotate distally, the lingual arm will swing across to pick up the buccal segments and start to expand these teeth.[16] The canine, first premolar, second premolar, and first molar are expanded in a differential manner which helps create the ovoid arch form that is often desired in a patient's final occlusion.[27] If the lingual arms were not properly moved away from the buccal segments, all of the energy that was placed into the appliance for molar rotation would instead be placed directly against the palatal surface of the upper premolars.[16] The buccal crown inclination would be greater than expected with less force available for molar rotation. This contention would be more accurately demonstrated with intra-oral photographs taken at the placement of the appliance.

Negative molar rotation was found in four of the twenty patients whose appliances were activated intra-orally for expansion by the clinician during active treatment. Intra-oral activation for expansion can cause the molar to move into mesial rotation. In order to maintain distobuccal rotation on the maxillary first molars, an activation bend for rotation must also be placed into the appliance.

In conclusion, the quadhelix is a technique sensitive appliance. Care must be taken during activation to ensure that an adequate amount of expansion and rotation are placed and that the palatal arms of the appliance are kept away from the lingual cusps of the buccal segments at initial cementation so that molar rotation can occur. Furthermore, if the appliance is intraorally activated for expansion, the appliance must also be activated for mesial molar rotation. If this "counter" adjustment is not made, a negative molar rotation may be found.

This was retrospective study aimed at evaluating the use of the quad helix appliance in a clinical setting. Limitations should be acknowledged since many of the variables were not controlled. Data was collected on consecutively treated patients and the standardized rotation/expansion protocol was followed by clinicians with varying level of experience. Future studies would benefit from the use of a larger sample size and a more controlled standardized expansion/rotation protocol. The activation, cementation, and adjustments of the quadhelix appliance should be done by only one orthodontist. Additionally, the long-term effects of the quadhelix appliance on maxillary molars, premolars and the adjacent buccal bone should be determined.

CHAPTER FIVE

CONCLUSIONS

1. A statistically significant amount of bone thickness loss was found at the premolar and molar regions while bone height loss was only found buccal to the first molars.
2. Considerably more tipping was found at P1 and P2 than at M1 after active expansion with the quadhelix appliance.
3. The amount of molar rotation ($5.17 \pm 8.93°$, $p=0.096$) that occurred at the maxillary molars was not statistically significant and was judged to be clinically significant.
4. The quadhelix is technique sensitive appliance.

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