Marginal Ridge Thickness (MRT) of Maxillary Incisors

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MARGINAL RIDGE THICKNESS (MRT) OF MAXILLARY INCISORS IN ORTHODONTIC PATIENTS

By

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ABSTRACT

MARGINAL RIDGE THICKNESS (MRT) OF MAXILLARY INCISORS IN ORTHODONTIC PATIENTS

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Aim: To determine the marginal ridge thickness (MRT) of maxillary incisors in orthodontic patients and the possible correlation between MRT and Bolton Index.

Methods: 120 pre-orthodontic treatment dental casts were collected, following the inclusion criteria: Quality pretreatment upper and lower casts, age 10-16, full permanent dentition (except 2nd and 3rd molars), no obvious wear/attrition/abrasion, no proximal restorations or crowns. For each cast, the mesio-distal (M-D) widths of the upper and lower teeth from left 1st molar to right 1st molar were measured to calculate Bolton Index. The MRTs of the maxillary incisors were measured in the following method. Along the long axis of clinical crown mark a circumferential line for the maxillary incisors at the incisal one-third level, followed by the measurement of the labial-lingual thickness at the mesial and distal marginal ridges as well as at the center of the crown, perpendicular to the long axis of the crown. Descriptive analysis was applied to show the distribution of the MRTs of each upper incisor. Independent sample *t*-test or one-way ANOVA was used to test the significance of the differences of the MRT between genders, races, and among Class I, II and III malocclusions, respectively. Pearson correlation analysis was used to test the possible correlation between MRT index and Bolton index. Significance was considered when *p* value was less than 0.05.

Results: MRT discrepancy (>2SD) exists in 4-6% of orthodontic patients. MRTs are smaller in Caucasian than non-Caucasians, and larger in males than in females (except distal #9). MRT scores (from small to large): Class II > Class I > Class III (except mesial #9, between Class I and Class II). MRT and Bolton Index are highly correlated (R=0.652, p=0.000).

Conclusions: The MRT established in this study may be used as a tool in treatment planning and finishing orthodontic cases.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

When diagnosing and treatment planning orthodontic cases, space problems (both intra-arch and inter-arch) are one of the key factors to be considered in order to achieve a normal occlusion with proper overbite (OB) and overjet (OJ). For years, the Bolton Index has been used to judge the mesio-distal (M-D) tooth size discrepancy between the maxillary and mandibular dental arches. However the MRT (labio-palatal or bucco-lingual tooth size) discrepancy has been overlooked, leaving the treatment planning and clinical management of the MRT discrepancy totally on an empirical basis. The aim of this study was to establish the MRT (average ± standard deviation) in 120 pre-orthodontic casts, and test the possible differences of the MRT between genders (male vs. female), races (Caucasian vs. non-Caucasian), and classifications of malocclusion (Class I vs. II vs. III). In addition, a correlation between the Bolton Index and MRT was sought. The findings from this study will provide orthodontists a tool – MRT Index to help judge the marginal thickness discrepancy, which will ultimately help treatment plan and finish orthodontic patients to a better quality of results.

Literature Review

Morphogenesis and Morphology of Maxillary Permanent Incisors

Central incisors

The crowns of permanent incisors develop from lobes or primary growth centers. Physiologically incisors develop from four lobes; three facial lobes and one lingual lobe, which form the cingulum area. The three facial lobes; mesial, middle and distal, of newly erupted incisors form the incisal mamelons (**Figure**

1), which are divided by two straight, shallow depressions which extend from the incisal edge toward the gingiva.[1] These depressions are known as the mesiolabial and distolabial developmental depressions (**Figure 1**).[2]

When viewed from the incisal, the crowns of incisors are noticeably wider mesiodistally than faciolingually.[1] They have concave lingual fossa located just incisal to the cingulum. The lingual fossa is located in the incisal half to two-thirds of the surface and is bound by four convexities; on the mesial and distal by the mesial and distal marginal ridges, on the incisal by the incisal edge, and on the cervical by the cingulum.[2] The marginal ridges vary in prominence from tooth to tooth and from person to person. Due to the variation in prominence of the marginal ridges the lingual fossa may be shallow or deep. Teeth with deep lingual fossa and prominent mesial and distal marginal ridges have been described as "shovel-shaped incisors".[1] (**Figure 2**) Dr. Woelfel examined the maxillary incisors on casts of 715 dental hygiene students and found that 32% of the central incisors and 27% of the lateral incisors have some degree of shoveling. The rest had smooth concave lingual surfaces without prominent marginal ridges or deep fossae.[1]

The lingual anatomy of the maxillary central incisor is quite variable. Accessory lingual ridges, if present, are small or narrow and extend vertically from the cingulum through the lingual fossa and toward the incisal edge. The number of ridges may vary in number from one to four.[1] Inspection of 506 maxillary central incisors by Dr. Woelfel revealed 36% with none of these ridges, 27% with one small ridge, 28% with two accessory ridges, 9% with three ridges, and only three teeth with four small ridges.[1]

Figure 1: Developmental Depressions and Mamelons

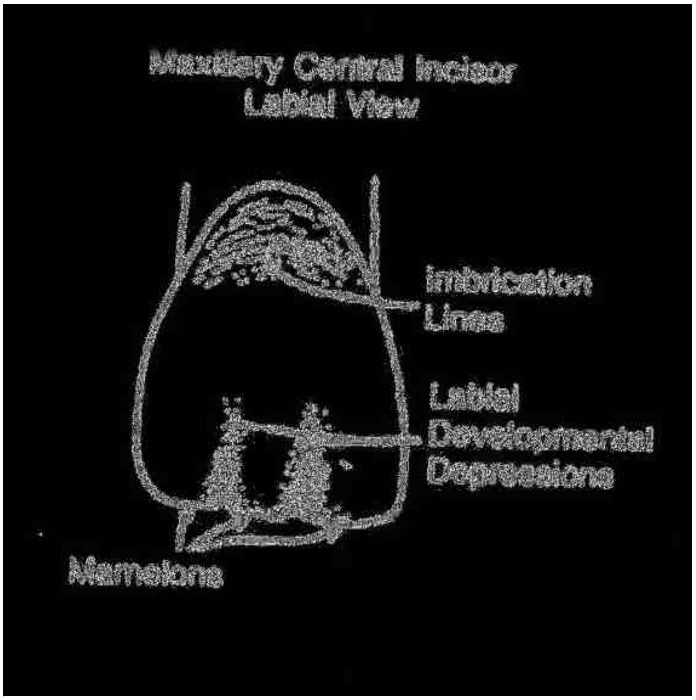


Figure 2: Shovel Shaped Incisors

Lateral incisors

There is great morphologic variation in the maxillary lateral incisor. It may be missing, it may resemble a small slender version of a maxillary central incisor; it may be quite asymmetrical; or may be peg shaped (**Figure 3**).[1] Most frequently the maxillary lateral incisor resembles the maxillary central incisor in all aspects, but on a smaller scale. It is relatively longer incisocervically and narrower mesiodistally. It is also generally more rounded than the central incisor.[2] Mamelons, and the labial depressions of the lateral incisor are less prominent and less common than on the central incisor. When viewed from the incisal the mesiodistal measurement of the lateral incisor crown is greater than the labiolingual measurement but less so than the central incisor.[1]

When viewed from the lingual, the fossa of the maxillary lateral incisor although smaller in area, is often even more pronounced than on the maxillary central incisor. The mesial and distal marginal ridges, as well as the cingulum, are relatively more prominent. [2] The cingulum of the lateral incisor is also narrower than that of the central and is almost centered on the root axis line.[1]

Figure 3: Peg Shaped Laterals

Shape and Size Variations in Maxillary Incisors among Races

Racial differences in the shape and morphology of maxillary incisor teeth have been documented in the dental literature. For example, Mongoloid peoples including many groups of American Indians have been observed to have a high incidence of shovel-shaped incisors. Labial "shoveling" has also been reported in some Eskimo people. Caucasian and Black people are reported to have less frequent occurrences of this characteristic.[3, 4, 5, 6]

Along with varying tooth morphology, ethnicity has also been documented to have an association with tooth size. Notably it has been written that people of African descent have larger mesiodistal tooth dimensions than those of European descent.[7-12] Also, studies including Hispanic populations reported significant differences in relation to Caucasians but similarities to African-Americans.[13]

When comparing tooth-size ratios as a function of ethnicity, the literature is limited, yet most authors agree that ethnicities differ in tooth-size ratios. However, Johe found no significant differences among African-American, Caucasian, and Hispanic groups in a study involving 306 subjects of varying sex, ethnicity, and malocclusion.[14] This same study did find that when comparing the prevalence of anterior clinically significant tooth-size discrepancies there was a statistically significant difference between ethnicities. This statistic contradicts a study by Sameshima, who concluded that the frequency of subjects with greater than 2 standard deviations of tooth-size discrepancy was not significantly different among ethnic groups.[15] However; little has been documented as to the role of ethnicity and the size of teeth in the buccal-lingual dimension.

Malocclusion and Tooth Size

A correlation among tooth-size discrepancies and malocclusion groups has been documented. Lavelle studied subjects for anterior tooth sizes and showed a tendency for Angle Class III patients to have smaller maxillary teeth compared with those classified as Class I or Class II. The study indicated that mandibular teeth were larger in Class III than in Class I and Class II subjects, with the inference that a Bolton discrepancy is greater in Class III patients than in the other malocclusion groups.[16] Sperry et al, found similar results, with Class III subjects showing greater mandibular tooth-size excess than Class I and Class II groups.[17] In contrast, Xia and Wu found no significant difference for tooth-size ratios between malocclusion groups when compared to a normal occlusion group.[18] Nie and Lin compared 5 malocclusion groups and noted no statistical differences among the groups, but did report a tendency toward Bolton discrepancy in the Class II and Class III malocclusions. [19]

Gender and Tooth Size

Tooth size has been shown to have a strong association with gender. Males have consistently larger teeth than females.[20] That being said Sameshima found that the frequency of subjects with greater than 2 standard deviations of tooth-size discrepancy was not significantly different among ethnic groups or sexes.[15] This was also noted in a study completed by Johe et al in which they found no significant differences between the sexes as a function of tooth-size ratios and, hence no sexual dimorphism.[14] Johe stated that “Most authors recognize that men’s teeth are generally larger than women’s, yet the ratio of tooth sizes between both arches remains constant.”[14] This finding was backed by studies from Araujo and Souki, Akyalcin et al, Basaran et al and Nie and Lin who all found no significance when relating sex to tooth-size ratios.[21, 22, 23, 24]

Bolton Discrepancy

The importance of tooth-size discrepancies in orthodontic diagnosis has been recognized since Bolton’s original research was carried out on 55 cases with normal occlusions. Following Bolton others have widely reported on tooth-size discrepancies in the literature, and the orthodontic community has come to acknowledge the importance of this diagnostic factor in relating the maxillary and mandibular dentitions. Bolton reported tooth-size discrepancies greater than 1 standard deviation in 29% of the patients in his private practice.[25] Richardson and Malhotra found similar discrepancies in 33.7% of their patients.[26] Crosby and Alexander found 22.9% of the subjects in their study showed anterior ratios that significantly deviated from the Bolton analysis means by greater than 2 standard deviations. [27] Similarly Freeman et al found that 30% of their 157 subjects had an anterior tooth-size discrepancy ratio greater than 2 standard deviations from the Bolton means and Santoro et al reinforced these findings when they observed that 28% of Dominican Americans had a discrepancy greater than 2 standard deviations.[28, 29]

CHAPTER 2

MATERIALS AND METHODS

Pretreatment orthodontic record plaster models from (year 2001-2010) the Department of Orthodontics at Marquette University School of Dentistry were screened and 120 sets of dental casts were collected following the inclusion criteria: (1) quality pretreatment upper and lower dental casts; (2) patient chronological age 10-16; (3) full permanent dentition (except 2nd and 3rd molars); (4) no obvious wear/attrition/abrasion; (5) no proximal restorations or crowns.

For each of the casts, a digital caliper with a resolution of 1/100mm was used to measure the mesio-distal (M-D) width of the upper and lower teeth from left 1st molar to right 1st molar. These data were entered into an Excel spreadsheet from which the Bolton Index was calculated.

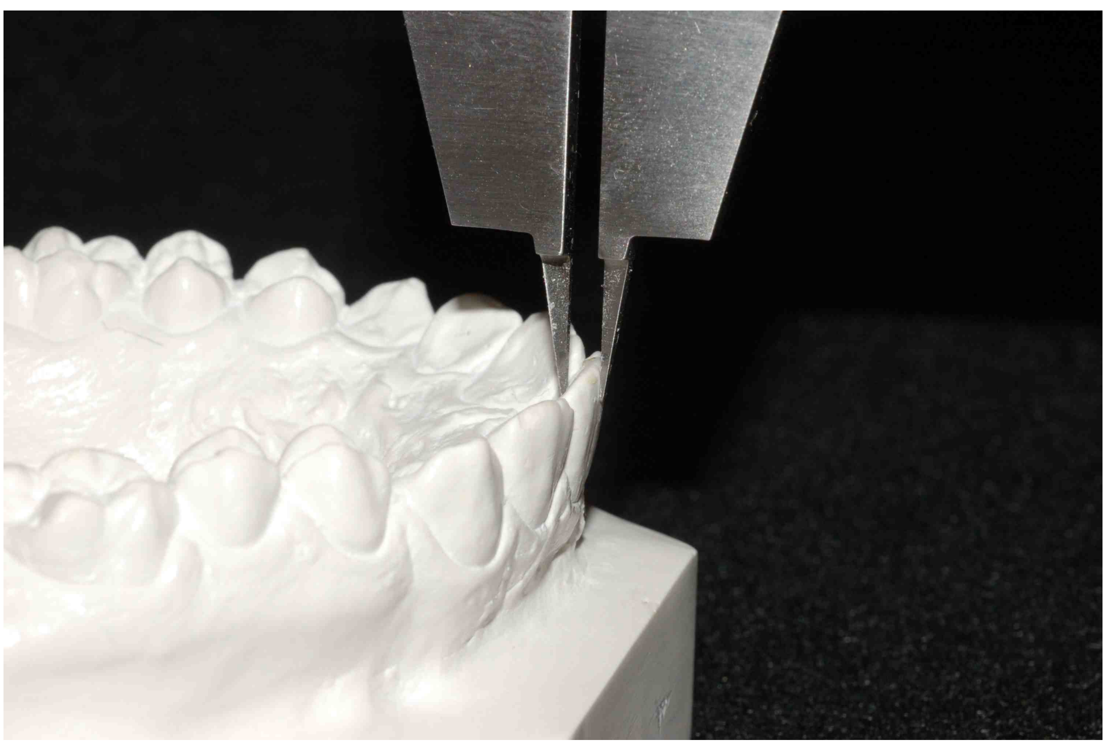
Using the same digital caliper the MRTs of the maxillary incisors were measured in the following method. Along the long axis of clinical crown, mark a circumferential line for the maxillary incisors at incisal one-third level (**Figure 4**). Next, the digital caliber was used to measure labial-lingual thickness at the mesial and distal marginal ridges as well as at the center of the crown, perpendicular to the long axis of the crown (**Figure 5**). This measurement was made at the circumferential line marked at the incisal one-third level. The measurements were recorded into an Excel spreadsheet. The measuring process took place over a three week period.

Intra-examiner reliability was verified on five randomly selected sets of casts that were measured on three separate occasions, each one week apart.

Intra-examiner reliability measurements were completed one week before the measurements of the 120 sets of casts were initiated.

Figure 4: Incisal One-Third Demarcation

Figure 5: MRT measurement



To determine the “working” thickness of the marginal ridges the value measured at the center of each tooth was subtracted from the measurements made at both the mesial and distal marginal ridges. This value gave the thickness of the mesial and distal marginal ridges in excess of the central measurement. If the marginal ridge thickness (MRT) was greater than the thickness measured at the center of the tooth a positive value was given, if however, the measurement of thickness in the center of the tooth was greater than a measurement of a mesial or distal marginal ridge measurement, that MRT was given a negative value. To be noticed, the MRT mentioned hereafter in this thesis specifically indicates the “working” thickness of the marginal ridges.

Descriptive analysis was applied to show the distribution of the MRT(s) of each upper incisor in the study sample. Independent sample t test or one-way ANOVA was used to test the significance of the differences of the MRT by each maxillary incisor edges between males and females, between Caucasian and non-Caucasian, and among Class I, II and III malocclusions, respectively. Correlation between MRT index and Bolton index was sought by using Pearson correlation analysis. Significance was considered when *p* value was less than 0.05. (SPSS Version 17. Chicago USA)

CHAPTER 3

RESULTS

Marginal Ridge Thickness (MRT) Measurements

Central incisors

The mean mesial and distal MRT values can be seen in **Table 1**. The mean distal MRT of tooth #8 was 0.586mm with a standard deviation of 0.34mm. The mesial MRT of tooth #8 was 0.362mm with a standard deviation of 0.378mm. For tooth #9 the mean distal MRT was 0.493mm with a standard deviation of 0.366mm and the mean mesial MRT was 0.378mm with a standard deviation of 0.378mm. The range for the distal MRT of tooth #8 was from -0.06mm to 1.81mm and from -0.04mm to 2.0mm for the mesial. The range for the distal MRT of tooth #9 was from -0.42mm to 1.69mm and -0.74mm to 1.95mm for the mesial. For tooth #8, 77% of the measured teeth were within one standard deviation on both the mesial and distal MRTs and 98% within two standard deviations. For tooth #9, 73% of the teeth measured were within one standard deviation on both the mesial and distal MRTs. While 97% of the mesial MRT measurements and 95% of the distal MRT measurements were within two standard deviations.

Table 1. Values and distribution of MRT (mesial "m" and distal "d") of tooth # 8 and #9 (mean ± SD)

MRT	#8d	#8m	#9m	#9d
Mean (SD)	0.586 (0.34)	0.362 (0.378)	0.378 (0.378)	0.493 (0.366)
Range	-0.06 ~ 1.81	-0.4 ~ 2.0	-0.74 ~ 1.95	-0.42 ~ 1.69
± 1SD	77%	77%	73%	73%
> 2SD	19%	19%	22%	21%
> 3SD	2%	2%	3%	5%

Lateral incisors

The mean mesial and distal MRT values can be seen in **Table 2**. The mean distal MRT of tooth #7 was 0.232mm with a standard deviation of 0.367mm. The mesial MRT of tooth #7 was 0.117mm with a standard deviation of 0.33mm. For tooth #10 the mean distal MRT was 0.139mm with a standard deviation of 0.375mm and the mesial MRT mean was 0.158mm with a standard deviation of 0.303mm. The range for the distal MRT of tooth #7 was from -1.06mm to 1.62mm and from -0.56mm to 1.4mm for the mesial MRT. The range for the distal MRT of tooth #10 was from -0.60mm to 1.67mm and from -0.61mm to 1.1mm for the mesial MRT. For tooth #7, 77% of the measured teeth were within one standard deviation on both the mesial and distal marginal ridges and 98% within two standard deviations. For tooth #10, 73% of the teeth measured were within one standard deviation on both the mesial and distal MRTs. 97% of the mesial MRT measurements and 95% of the distal MRT measurements were within two standard deviations.

Table 2. Values and distribution of MRT (mesial "m" and distal "d") of tooth # 7 and #10 (mean ± SD)

MRT	#7d	#7m	#10m	#10d
Mean (SD)	0.232 (0.367)	0.117 (0.33)	0.158 (0.303)	0.139 (0.375)
Range	-1.06 ~ 1.62	-0.56 ~ 1.4	-0.61 ~ 1.1	-0.60 ~ 1.67
± 1SD	77%	77%	73%	73%
> 2SD	19%	19%	22%	21%
> 3SD	2%	2%	3%	5%

Gender Measurements

Central incisors

Of the 120 cases included in the study, 70 were females and the remaining 50 were males. For the males, the mean distal MRT of tooth #8 was 0.615mm while the mesial MRT was 0.395mm. The females had a mean distal MRT of 0.564mm while the mesial MRT of 0.339mm. For the male group, tooth #9 was measured to have a mean distal MRT of 0.484mm and mesial MRT of 0.378mm; while the female group had a mean distal MRT on tooth #9 of 0.50mm and mesial MRT of 0.377mm. These data can be seen in **Table 3**. Of statistical significance, the mesial MRT of #8 is larger in males than that in females (p=0.004). Although not statistically significant, it can also be noted that on average the MRT of males was greater at each marginal ridge except the distal of tooth #9.

Figure 6. Patient Gender Frequency

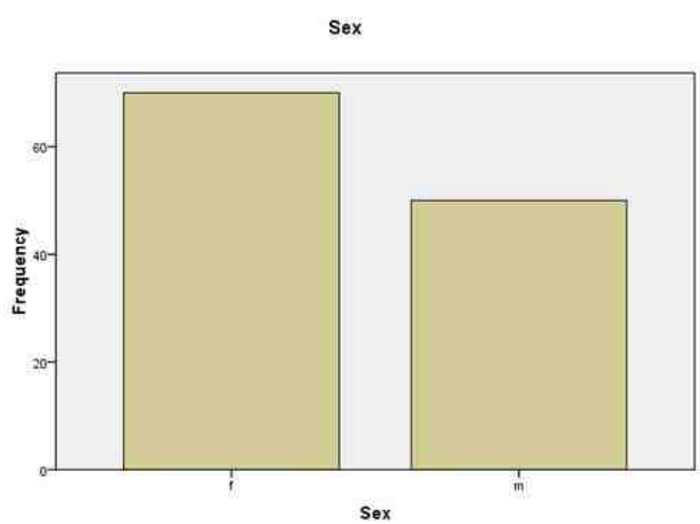


Table 3. Differences of MRT of tooth # 8 and #9 between Males vs. Females (mean ± SD)

Gender	#8d	#8m**	#9m	#9d
Male (50)	0.615 (0.388)	0.395 (0.482)	0.378 (0.423)	0.484 (0.391)
Female (70)	0.564 (0.303)	0.339 (0.283)	0.377 (0.338)	0.5 (0.35)

Note: * $p<0.05$, ** $p<0.01$

Lateral incisors

For males the mean distal MRT of tooth #7 was 0.282mm while the mesial MRT was 0.15mm. The females had a mean distal MRT of 0.197mm while the mesial MRT was 0.093mm. For the males tooth #10 was measured to have a mean distal MRT of 0.226mm and mesial MRT of 0.219mm. The females had a mean distal MRT on tooth #10 of 0.078mm and mesial MRT of 0.115mm. These data can be seen in **Table 4**. Of statistical significance, the distal MRT of #7 is larger in males than that in females (p=0.035). Although not statistically significant, it can also be noted that on average the MRT of males was greater at each MRT on both teeth #7 and #10.

Table 4. Differences of MRT of tooth # 7 and #10 between Males vs. Females (mean ± SD)

Gender	#7d*	#7m	#10m	#10d
Male (50)	0.282 (0.407)	0.15 (0.366)	0.219 (0.3)	0.226 (0.44)
Female (70)	0.197 (0.335)	0.093 (0.302)	0.115 (0.3)	0.078 (0.309)

Note: * $p<0.05$

Race Measurements

Central incisors

Of the 120 cases included in the study, 98 of the patients were Caucasian while 22 were non-Caucasian (**Figure 7**). Race was determined by the information on patient's records. For the Caucasians, the mean distal MRT of tooth #8 was 0.538mm while the mesial MRT was 0.302mm. The non-Caucasian group had a mean distal MRT of 0.801mm while the mesial MRT of 0.639mm. For the Caucasian group, tooth #9 was measured to have a mean distal MRT of 0.436mm and mesial MRT of 0.31mm. The non-Caucasian group had a mean distal MRT on tooth #9 of 0.751mm and mesial MRT of 0.694mm. These data can be seen in **Table 5**. The mesial MRTs for both teeth #8 and #9 in the Caucasian group were statistically smaller than those in the non-Caucasian group ($p<0.01$ and 0.05). Although not statistically significant for all, non-Caucasian MRTs on both teeth #8 and #9 were generally greater than those in the Caucasian group.

Figure 7. Patient Race Frequency

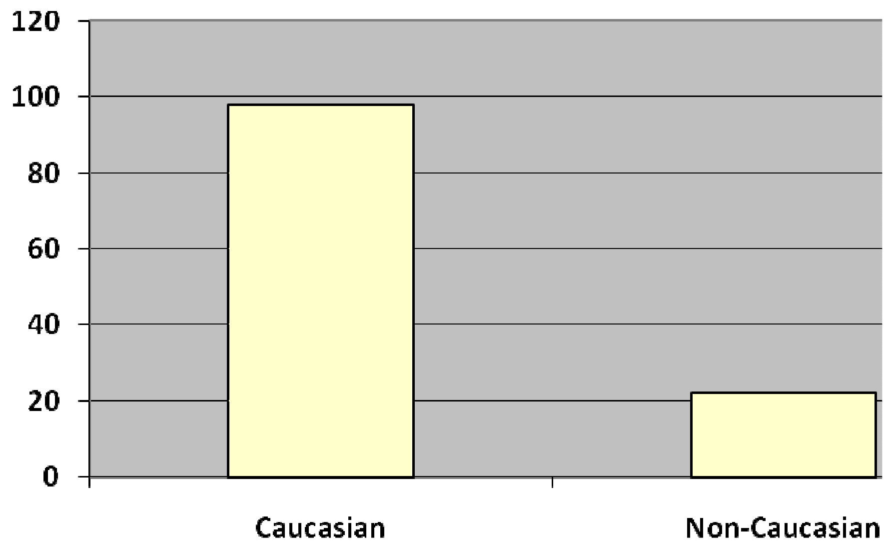


Table 5. Differences of MRT of tooth # 8 and #9 between Caucasian vs. non-Caucasians (mean ± SD)

Race	#8d	#8m**	#9m*	#9d
Caucasian (98)	0.538 (0.309)	0.302 (0.324)	0.31 (0.323)	0.436 (0.339)
Non-Caucasian (22)	0.801 (0.404)	0.639 (0.49)	0.694 (0.468)	0.751 (0.392)

Note: * $p<0.05$, ** $p<0.01$

Lateral incisors

For the Caucasians, the mean distal MRT of tooth #7 was 0.203mm while the mesial MRT was 0.055mm. The non-Caucasian group had a mean distal

MRT of 0.357mm while the mesial MRT of 0.41mm. For the Caucasian group, tooth #10 was measured to have a mean distal MRT of 0.111mm and mesial MRT of 0.109mm. The non-Caucasian group had a mean distal MRT on tooth #10 of 0.271mm and mesial MRT of 0.408mm. These data can be seen in **Table 6**. The mesial MRTs in the Caucasian group, on both teeth #7 and #10, were statistically smaller than those in the non-Caucasian group ($p<0.01$). Although not statistically significant for all, it can also be seen that in general the non-Caucasian group had greater mean values in all MRT measurements for teeth #7 and #10.

Table 6. Differences of MRT of tooth # 7 and #10 between Caucasian vs. non-Caucasians (mean ± SD)

Race	#7d	#7m**	#10m**	#10d
Caucasian (98)	0.203 (0.292)	0.055 (0.267)	0.109 (0.25)	0.111 (0.316)
Non-Caucasian (22)	0.357 (0.607)	0.41 (0.438)	0.408 (0.398)	0.271 (0.547)

Note: * $p<0.05$, ** $p<0.01$

Malocclusion Class Measurements

Central incisors

Of the 120 cases included in the study, 54 of the patients had Angle Class I , 58 had Class II and 8 had Class III molar relationships (**Figure 8**). For Class I patients, the mean distal MRT of tooth #8 was 0.577mm while the mesial MRT was 0.366mm. The Class II group had a mean distal MRT for tooth #8 of 0.568mm while the mesial MRT was 0.331mm. The Class III group had a mean distal MRT on tooth #8 of 0.769mm and a mean mesial MRT of 0.565mm. For the Class I group tooth #9 was measured to have a mean distal MRT of 0.491mm and mesial MRT of 0.355mm. The Class II group had a mean distal MRT on tooth #9 of 0.467mm and mesial MRT of 0.369mm. Lastly the Class III group had a mean distal MRT for tooth #9 of 0.696mm and mesial of 0.594mm. These data can be seen in **Table 7**. When comparing the MRTs among different malocclusion classifications, the difference between the Class III and Class II groups was statistically significant for the mesial MRT of tooth #9 only.

Figure 8. Patient Malocclusion Frequency

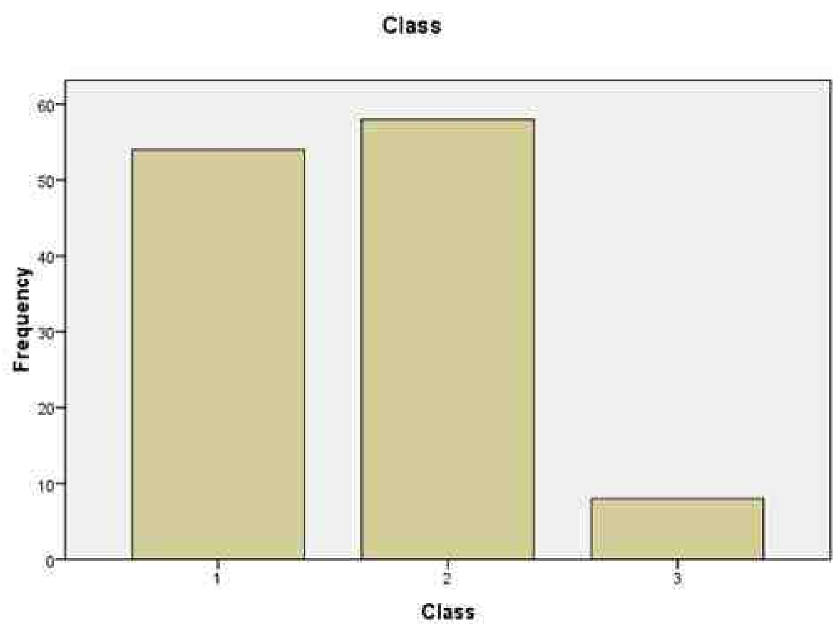


Table 7. Differences of MRT of tooth # 8 and #9 among Class I, II, III malocclusions (mean ± SD)

Class	#8d	#8m	#9m	#9d
I (54)	0.577 (0.335)	0.366 (0.411)	0.355 (0.423)	0.491 (0.382)
II (58)	0.568 (0.345)	0.331 (0.343)	0.369 (0.311)	0.467 (0.328)
III (8)	0.769 (0.324)	0.565 (0.371)	0.594* (0.481)	0.696 (0.493)

Note: * $p<0.05$ between groups II vs. III only

Lateral incisors

For Class I patients, the mean distal MRT of tooth #7 was 0.298mm while the mesial MRT was 0.193mm. The Class II group had a mean distal MRT for tooth #7 of 0.137mm while the mesial MRT was 0.02mm. The Class III group had a mean distal MRT on tooth #7 of 0.479mm and a mean mesial MRT of 0.308mm. For the Class I group, tooth #10 was measured to have a mean distal MRT of 0.176mm and mesial MRT of 0.191mm. The Class II group had a mean distal MRT on tooth #10 of 0.094mm and mesial MRT of 0.119mm. Lastly the Class III group had a mean distal MRT for tooth #10 of 0.224mm and mesial MRT of 0.224mm. These data can be seen in **Table 8**. Addressing the distal of tooth #7, when comparing the MRTs of different malocclusions the difference between the Class I and Class II groups was statistically significant (p=0.049), as was the difference between the Class II and Class III groups (p=0.033). Regarding the mesial MRT of tooth #7, the difference between the Class I and Class II groups was statistically significant (p=0.013). There was also a statistically significant difference between the mesial MRT for tooth #7 between the Class II and Class III groups (p=0.047). Overall it can be seen that there is a tendency of the MRTs of the lateral incisors following the order of Class III > Class I > Class II malocclusions (from bigger to smaller).

Table 8. Differences of MRT of tooth # 7 and #10 among Class I, II, III malocclusions (mean ± SD)

Class	#7d**	#7m**	#10m	#10d
I (54)	0.298 (0.394)	0.193 (0.409)	0.191 (0.354)	0.176 (0.432)
II (58)	0.137 (0.312)	0.02 (0.17)	0.119 (0.216)	0.094 (0.3)
III (8)	0.479 (0.395)	0.308 (0.432)	0.224 (0.454)	0.224 (0.459)

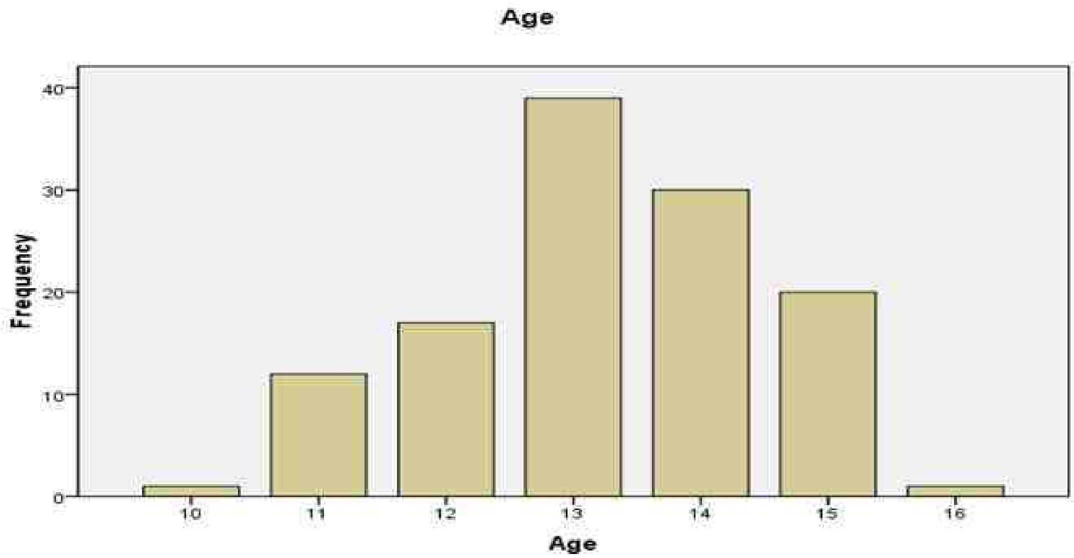
Note: * $p<0.05$, ** $p<0.01$. Significance between group:
I-II (* p=0.013 for #7m and p=0.049 for #7d),
II-III (* p=0.047 for #7m and p=0.033 for #7d) and
I-III (p=0.609 for #7m and p=0.376 for #7d).

CHAPTER 4

DISCUSSION

This study evaluated the MRT of orthodontic patients prior to orthodontic treatment. The 120 patients included in this study had an average age of 13.2 years old. The breakdown for patient ages can be seen in **Figure 9**. The inclusion criteria of patients between the ages of 10 and 16 were used to reflect the common age range at which people are being treated orthodontically. The goal was also to select patients who were in the early stages of permanent dentition to minimize the probability of wear, attrition, abrasion and other possible alterations to the natural dentition. Patients with missing teeth, unerupted teeth or restored teeth were excluded from the study, again with the goal of producing a quality study sample with a full and unaltered dentition. Ideally final records would have been used to eliminate potential measurement errors caused by crowding. In a study by Shellhart et al in 1995 they noted that clinically significant measurement errors could occur when the Bolton tooth-size analysis is performed on casts that had at least 3 mm of crowding. They suggested clinicians undertake a tooth size discrepancy analysis in substantially crowded cases only when the teeth have been aligned.[31] However, the treatment plan needs to be placed before the initiation of treatment, and often in the process of orthodontic treatment teeth may incur wear, abrasion, attrition or be modified by the clinician in order to achieve a more ideal result.

Figure 9. Patient Age Frequency



Plaster models were used for this study as opposed to emodels because we wished to gain a large sample size. At the time of data collection the amount of emodels in the Marquette University Orthodontic pool would not have been enough for a large sample size. Future research measuring these parameters may be completed using emodels. A study testing the accuracy and speed of measuring the overall arch length and the Bolton ratio, and the time to perform a Bolton analysis for each patient by using software (emodel, version 6.0, GeoDigm Corp, Chanhassen, Minn) compared with hand-held plaster models was completed by Mullen et al. Their results suggest that, when performing a Bolton analysis, the emodel can be as accurate as, and significantly faster than, the traditional method of using digital calipers and plaster models. A clinician who has switched to using emodel software can be confident in his or her diagnoses using it. However, currently it may be difficult to complete the marginal ridge measurements as cross-sectional measurements would need to be completed, which is not readily available in today's e-model software.

Five sets of models were randomly selected for the intra-examiner error evaluation and measured at weekly intervals for three weeks prior to the completion of data collection. This was done to determine the reliability of the measurements taken. Intra-examiner reliability coefficient was calculated for 3 random parameters using the Shrout-Fleiss measure of reliability. The overall reliability score was measured to be 0.99491, meaning that the measurements are approximately 99.5% reliable.

The goal of the study was to establish a Marginal Ridge Thickness (MRT) Index to help judge the marginal thickness discrepancy in orthodontic patients. Ideally this index will aid in the treatment planning process as well as enable orthodontic patients to be finished to a higher quality result. Interproximal enamel reduction (IPR), also referred to as inderdental stripping, enamel approximation or slenderizing, is a well-known technique that is frequently applied during orthodontic treatment. It is used to achieve better alignment and occlusion of the teeth and also simplifies the long-term maintenance of tooth alignment.[32] IPR addresses the issue of tooth size discrepancy in the mesial-distal dimension, but in order to complete a patient's orthodontic treatment to an ideal occlusion with proper overbite and overjet not only must there be no tooth size discrepancy in the mesial-distal dimension, there must also be no discrepancy in labial-lingual dimension of the maxillary anterior incisors.

If for instance there is no tooth size discrepancy in the mesial-distal dimension but the maxillary anterior incisors have thick marginal ridges there will be difficulty finishing the case to a proper OB and OJ while having no spacing in the maxillary dentition. In such a situation the clinician may choose to compensate for this labial-lingual discrepancy in the following ways; interproximal reduction of the mandibular incisors to account for the thickness of the maxillary anterior marginal ridge thickness', finish with spacing in the maxillary anteriors, intrude the maxillary or mandibular incisors reducing the overbite and thus allowing the upper spacing to be closed, or lastly reduce the thickness of the maxillary anterior marginal ridges. Reducing the MRT would be the ideal option assuming that the enamel of the marginal ridges is thick enough to not expose dentin. Reducing the MRT would allow for proper overbite and overjet as well as complete space closure between the maxillary anterior teeth. Again this scenario would only exist in a patient with no mesial-distal tooth size discrepancy.

Another scenario where MRT of maxillary incisors could be problematic is an incisor with a discrepancy of one marginal ridge, either mesial or distal. An example of this situation can be seen in **Figures 10 and 11**. Tooth #9 has a distal MRT that is visibly greater than the mesial MRT of the same tooth. This difference in thicknesses has resulted in the distal marginal ridge contacting prematurely with the incisal edge of the mandibular lateral incisor. When viewed from the incisal in **Figure 11**, it can be noted that distal aspect of tooth #9 is not aligned well with tooth #10. The distal MRT discrepancy has required tooth #9 to be rotated in order to achieve proper contact on both the mesial and distal marginal ridges. A view of the mandibular incisors of the same patient (**Figure 12**) reveals that they are properly aligned. In order to achieve proper alignment of tooth #9 it should be rotated distally. However, simply adding distal rotation to tooth #9 without first reducing the distal MRT would compromise the mesial contact and further diminish the esthetics of the dentition. Therefore, enamel reduction must be completed to the distal MRT of tooth #9. This reduction and rotational correction would allow even contact of tooth #9 on both the mesial and distal marginal ridges as well as proper alignment.

Figure 10: Distal MRT Discrepancy in Occlusion

Figure 11: MRT Discrepancy Maxillary Incisal View

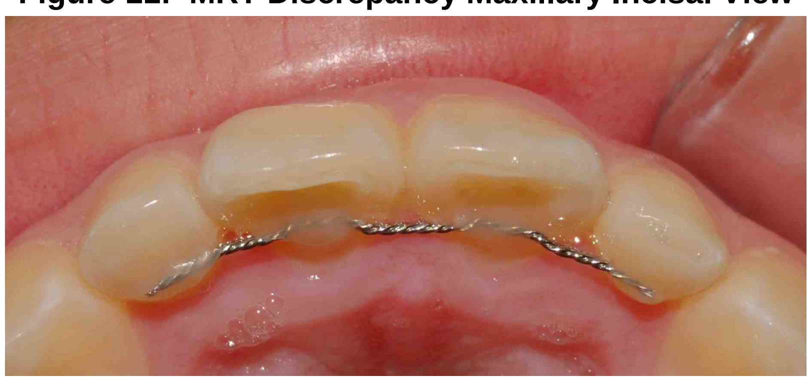


Figure 12: Mandibular Incisal View

Another example of MRT of maxillary posing an issue in the finishing stages of orthodontic treatment can be seen in **Figures 13 and 14**. Tooth #10 has a mesial MRT discrepancy when compared to the distal MRT of the same tooth. This difference in thicknesses has resulted in the mesial marginal ridge contacting prematurely with the incisal edge of the mandibular lateral incisor. Meanwhile, the distal marginal ridge currently has no contact with the mandibular canine. When viewed from the incisal in **Figures 14 and 15**, it can be noted that tooth #10 is aligned well with both tooth #9 and #11. Thus, in order to achieve contact on the distal marginal ridge with the lower canine, tooth #10 could be rotated distally. However, adding distal rotation to tooth #10 would compromise the alignment and esthetics of the dentition. Therefore, another option would be to reduce the mesial MRT of tooth #10. This reduction would allow contact of tooth #10 on both the mesial and distal marginal ridges and the overall overjet in this case to be decreased.

Figure 13: Mesial MRT Discrepancy in Occlusion

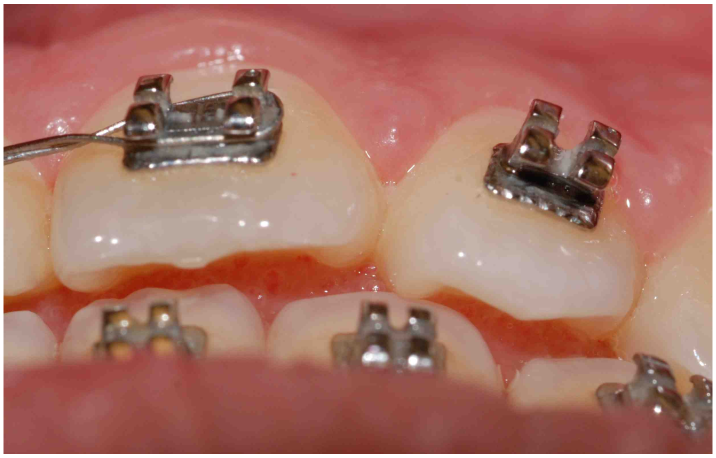


Figure 14: MRT Discrepancy Incisal View 1

Figure 15: MRT Discrepancy Incisal View 2

Our study found that a MRT discrepancy (>2SD) exists in approximately 4-6% of orthodontic patients. It could be argued that these results although statistically significant are not clinically significant. Reports of statistically significant differences that may not be clinically significant are much more frequently encountered in the literature than clinically significant differences missed statistically.[33] Tests of statistical significance usually ask the question "Is it probable that the difference between these groups is due only to chance?"[33] Clinical significance, however, usually asks the question "Does that make any difference in treatment outcomes?"[33] A study on overjet and class II correction completed by Kevin O'Brien and others noted that a 2mm change or greater in overjet was considered to be clinically significant.[34] Further research would need to be completed on our results to if the marginal ridge discrepancies found in our sample would equate to a clinically significant increase in either overjet or malocclusion.

Following statistical analysis we found that MRTs are smaller in Caucasian than non-Caucasians and MRTs are also smaller in females than in males (except distal #9). MRT scores were lowest in the Class II group, followed by the Class I group. On average the group with the largest MRT values was the Class III group. This data is similar to that discussed previously in the introduction.

Our study also found a correlation between those patients with a MRT discrepancy and those with a Bolton discrepancy. Following Pearson correlation analysis it was noted that approximately 65% (R=0.652, p=0.000) of patients found to have a MRT discrepancy also had a Bolton discrepancy. This suggests to the practicing clinician that if a MRT is suspected it is also likely that a Bolton discrepancy may exist. This information is also useful for the clinician if they have completed a tooth size analysis and found a Bolton discrepancy, the clinician then must be wary of a possible MRT discrepancy as well.

Limitations and Future Directions

In order for the results of this study to become clinically applicable, further research must be conducted that measures the labial-lingual enamel thickness of maxillary incisors at the same incisal-gingival level used for this study. This proposed study is needed to determine the amount of enamel that could be safely removed before reaching dentin. Many authors have suggested that approximately 50% of the interproximal enamel can be safely removed.[35, 36, 37, 38] These estimates of the amount of tooth structure that can be removed depend on accurate reference data for enamel thickness which is currently available. So far, reduction of the interproximal surfaces for the anterior teeth has not been shown to result in increased susceptibility to caries or periodontal disease.[36, 37, 39, 40, 41, 42, 43] Again these data are focused on the mesial-distal dimension of teeth and offers little prospective on enamel reduction in the labial-lingual dimension. Although each individual tooth varies in anatomy and thus enamel thickness, this study could act as a guideline for enamel reduction. Also, the severity of crowding was not included in the exclusion criteria. As stated earlier crowding of at least 3mm may lead to measurement errors.[31]

CHAPTER 5

SUMMARY AND CONCLUSIONS

The aim of this study was to determine the marginal ridge thickness (MRT) of maxillary incisors in orthodontic patients and how that relates to Bolton tooth size discrepancy. The MRT of maxillary incisors and the Bolton index of 120 pre-orthodontic dental casts were measured for the frequency and the magnitude (means ± standard deviation). These data were analyzed to depict the distribution of MRT in orthodontic patients, and to test the possible correlation between MRT and Bolton Index. Through the completion of this study the following conclusions have been reached.

- MRT discrepancy (>2SD) exists in about 4-6% of orthodontic patients.
- MRTs are smaller in Caucasian than non-Caucasians.
- MRTs are larger in males than in females (except distal #9).
- MRT scores (from small to large): Class II > Class I > Class III (except mesial #9, between Class I and Class II)
- MRT and Bolton Index are highly correlated (R=0.652, p=0.000)
- The MRT established in this study may be used as a tool in treatment planning and finishing orthodontic cases.

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