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DIVISION OF ORTHODONTICS

COMPARISON OF SECOND MOLAR DEVELOPMENT IN SUBJECTS WITH CLASS I, CLASS II-1, CLASS II-2, AND CLASS III SKELETAL GROWTH PATTERNS

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BY

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DECLARATION

I, Etienne Pitout, declare that this research report is my own work. It is being submitted in partial fulfilment of the requirements for the degree of Master of Dentistry in the branch of Orthodontics at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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I dedicate this report to my dear wife Nelmarie, my son James, and my daughter Caroli. They endured long hours of my absence while this research project was underway. Their support and love was invaluable to me throughout.

To my mother, Bertha, thank you for always believing in me and supporting me in the pursuit of my dreams.

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ABSTRACT

Class II-2 is a difficult malocclusion to treat. Early treatment is recommended, entailing distal movement of the maxillary first molars, which can result in impaction of the second molars. This could be avoided if the developmental stage of the maxillary second molar were known. **Objectives:** To compare the ages at which the maxillary second molars reach specific developmental stages for subjects with Class I, Class II-1, Class II-2, and Class III skeletal growth patterns. **Methods:** Records from the Michigan Growth Study, which contains longitudinal data for over 300 Caucasian subjects of Northern European descent, were searched for subjects having Class I, II-1, II-2 or Class III occlusal patterns, based on their last available plaster casts and cephalometric radiographs. ANB of ≥ 5° was regarded as Class II while that ≤ 0° was considered Class III. An attempt was made to match the Class II–1 and Class I to the Class II-2 and Class III subjects.. All available records for Class II-2 and Class III subjects were included in the study as those were rare. The age at which each of the second molars of each patient reached the development stages described by Demirjian (1973) were established using the serial lateral oblique radiographs which were available. The GLM procedure in SAS was used to compare the data among and within the skeletal patterns. **Results**: There were no significant differences among the four skeletal patterns as related to the developmental stages of the second molars. However, the developmental stages were reached at significantly different ages. **Conclusion:** There were no statistically significant differences in the stages of development of the second molars among Class I, Class II-1, Class II-2 and Class III subjects.

CHAPTER I

INTRODUCTION

In many instances it is beneficial to do early treatment for orthodontic patients as early intervention could reduce the treatment time required to correct the malocclusion as well as the severity of the malocclusion. Such treatment often entails maintenance of the arch length in order for the canines and premolars to be accommodated in the arch. In cases where arch length has been lost due to premature loss of teeth, or in cases with severe space shortage, it may even be necessary to move the first molars distally in order to accommodate the succedaneous canines and premolars (Rubin*, et al.*, 2012).

Several appliances are available for the correction of Class II or Class III malocclusions. These include the use of a lip bumper to augment Class III elastics or a Schwartz appliance in the mandibular arch, face-bow headgear in the maxillary arch or molar distalization appliances such as the distal jet, pendulum, Jones jig, or Keles slider appliance (McSherry and Bradley, 2000). All of these appliances have been reported to lead to satisfactory results, but certain unwanted effects can occur which include impaction of second molars (Rubin*, et al.*, 2012).

The timing of space maintenance or molar distalization often precedes the full eruption of the second molar. The management of the second molar may better be achieved if the age at which the second molar develops were more precisely known. During normal development of the second molar the space available for eruption is created by growth of the body of the mandible and the tuberosity of the maxilla, as well as a mesial shift of the first molar allowed by the E-space. First molar distalization negates the effect of the E-space. Space maintenance takes maximum advantage of the E-space in those patients where there is potential crowding in the middle and anterior segments of the arch. If distal molar movement were initiated prior to eruption of the second molar, impaction of that tooth might be the result (Kinzinger*, et al.*, 2004).

Valmaseda-Castellon *et al*.(1999) found that when the third molars were excluded, the mandibular second molar was the most commonly impacted molar tooth, followed by the maxillary second molar. The Schwartz appliance as well as the fixed lingual holding arch have been associated with an increase in second molar eruption difficulties, (Rubin*, et al.*, 2012, Shapira*, et al.*, 2011) while lip bumper treatment is associated with a nine fold increase in the prevalence of second molar impaction (Ferro*, et al.*, 2011).

The Class II division 2 (Class II-2) skeletal growth pattern is not as common as the Class II division 1 (Class II-1) or Class III growth patterns. However it often presents as a more complex malocclusion to treat (Millett*, et al.*, 2012). The Class II-2 patient usually presents with a strong pterygomasseteric sling, retroclined upper and lower incisors, a deep bite and a Class II molar relationship. In many instances it is preferable to treat the Class II-2 patient during the transitional dentition, prior to eruption of the second permanent molar. Such treatment could include the use of extra-oral traction, such as a headgear; a functional or a pendulum appliance (Kinzinger*, et al.*, 2004).

The pendulum appliance has been reported to move the maxillary first molar distally by 5mm in 4 months (Bussick and McNamara Jr, 2000). Tipping of the first molar as it is being distalized is much more pronounced if the second molar is still at the budding stage (Kinzinger*, et al.*, 2004). The distal movement of the first permanent molar may lead to delayed or halted eruption of the second molar, as observed by Nanda and Dandajena (2006), who described eruption of the maxillary second molar to be delayed to as much as 22 years of age after prolonged headgear wear. Abed and Brin (2010) compared the upper first and second molar positions of patients who had undergone headgear treatment for 15 months with those of a control group. They found that the first molar was positioned 3.8mm more distal in the headgear group while the second molar was positioned 2.7mm more distal than those that had not received similar treatment. The eruption of the second molar was also delayed in the headgear group, although they reported only one impaction and commented that that was most probably of pathological origin (Abed and Brin, 2010).

While the treatment protocol followed to correct the Class II pattern might lead to non-eruption of the second maxillary molar, the patient's skeletal growth pattern can also influence eruption times. It has been suggested that altered development and eruption times of the second molars may be associated with skeletal Class II and III growth patterns (Anderson and Popovich, 1981, Haruki*, et al.*, 1997, Lo and Moyers, 1953). Brin *et al*. (2006) found no difference in the eruption status of second molars between Class I and Class II skeletal subjects in a cross sectional study. However, Vedtofte *et al.* (1999) found an association between arrested eruption of the mandibular second molar and a Class II skeletal pattern. Early detection of the arrested emergence of the second molar is imperative, as correct measures might eliminate its potential impaction and reduce the need for complicated orthodontic treatment (Shapira*, et al.*, 2011). Premature or delayed tooth eruption is assumed if the eruption time lies outside two standard deviations of the population mean for chronological age (Rasmussen and Kotsaki, 1997).

The second maxillary molar generally emerges into the oral cavity during the twelfth to thirteenth year of life. It is the seventh tooth in each dental quadrant to erupt following the first permanent molar, the central incisor, lateral incisor, first and second premolar and the canine. Some variations exist in the eruption patterns, usually associated with the maxillary arch. In these variations, the maxillary canines emerge prior to the premolars in girls or the second molars erupt prior to the canines in boys (Lunt and Law, 1974)**.** None of these variations should influence the possible impaction of the maxillary second molar.

Three classification systems are commonly used to describe the stages of development of the second and third molar teeth discernible on radiographs (Nolla, 1960, Moorrees, 1963, and Dimerjian, 1973). These systems are commonly used for age determination in forensic dentistry when the true age of the subject is usually unknown and the developmental stage seen on an x-ray suggests an age range within which the subject is likely to fall. These classification systems can also be used to determine the developmental stage of a second molar of a subject whose age is known. All three classification systems use illustrations of different morphological characteristics of teeth that become radiologically visible as development takes place. These morphological features are used to describe the different stages of development. There is a division between single and multi-rooted teeth in all three classification systems as there are considerable differences in the developmental patterns of these teeth. Nolla described 10 stages, while Moorrees divided his classification into stages of crown and root development. Dimerjian has only eight stages of tooth development which are easily discernible.

Dimerjian's classification system for molar development has been suggested for the classification of third molar development (Olze*, et al.*, 2005). The stages are clearly defined with excellent reproducibility (Dhanjal*, et al.*, 2006) and the system has also been used in studies evaluating second molar development (Balaraj and Nithin, 2010). When Dimerjian's classification system is used for the purposes of forensic dentistry, seven teeth are evaluated and probability charts are then used in order to determine the age of the subject. This is referenced against the data derived from the 1446 boys and 1482 girls of known chronological ages who were examined at the St-Justine Hospital and the Growth Centre, Montreal. For the purposes of this project the Dimerjian classification was used to evaluate the development of the second molars of subjects of known chronological age.

CHAPTER II

STATEMENT OF PURPOSE

Early orthodontic treatment is an effective method of eliminating possible future problems in the dentition of the growing human. However, a possible consequence of early treatment that involves distal movement of the first molars is impaction of the second molar. This could possibly be avoided if the developmental stages of the second molar in the various occlusions of Class I, II-1, II-2 and Class III were known. The objective of this study was to compare the ages at which the second maxillary molars reach specific developmental stages for patients with Class I, Class II-1, Class II-2, and Class III skeletal growth patterns, and to assess whether the eight developmental stages of tooth development described by Dimerjian (1973) were reached at distinct ages which could predictably be separated. The hypothesis was that there is a difference in second molar eruption patterns among the different occlusions and that the developmental stages are different among the different occlusions. A secondary assumption was that there may be gender differences as well.

CHAPTER III

MATERIAL AND METHODS

DATA SOURCE

Records from the Michigan Elementary and Secondary School Growth Study, housed at the University of Michigan, Ann Arbor, were investigated in this project. There are four growth centres in North America where comprehensive longitudinal records of growing subjects have been collected. These are available for research purposes at the University of Michigan, the University of Oklahoma, Case Western University and the University of Toronto (AAOFLegacycollection, 2012). The Michigan growth study contains annual records of 721 students enrolled in the University School from 1953 to 1970, as well as recall records of the same cohort of participants up to 2007. These records include plaster models, lateral and postero-anterior cephalograms, lateral oblique, and hand/wrist films. The participants were Caucasian subjects of Northern European descent (Waldo, 1936).

INCLUSION and EXCLUSION CRITERIA

The collection was hand searched for records of subjects who satisfied the following criteria:

1. Adequate records available in order to establish the second molar developmental stages to within six months.
2. No known craniofacial anomalies.
3. No history of orthodontic treatment or orthognathic surgery.

4. While gender was not a criterion for inclusion/exclusion in the study, the data were assessed for possible gender differences.

SKELETAL PATTERN CLASSIFICATION

Subjects were classified according to Angle's classification, using the relationships of the mesio-buccal cusp of the maxillary first molar to the mesio-buccal groove of the mandibular first molar as visualised on the last available plaster casts taken for each subject. Subjects were classified as:

1. Class I
2. Class II-1
3. Class II-2
4. Class III.

The dental classification was compared with the skeletal classification which was based on measurements taken on the lateral cephalogram which had been recorded at the same time point. Skeletal classification was determined on the angle ANB which is formed between A-point and B-point with its vertex at nasion (N). These classifications were:

1. Class I: $0<ANB<5$
2. Class II: $5\leq ANB$
3. Class III: $0\geq ANB$.

The three landmarks used to derive the angle ANB are shown in Fig 1.

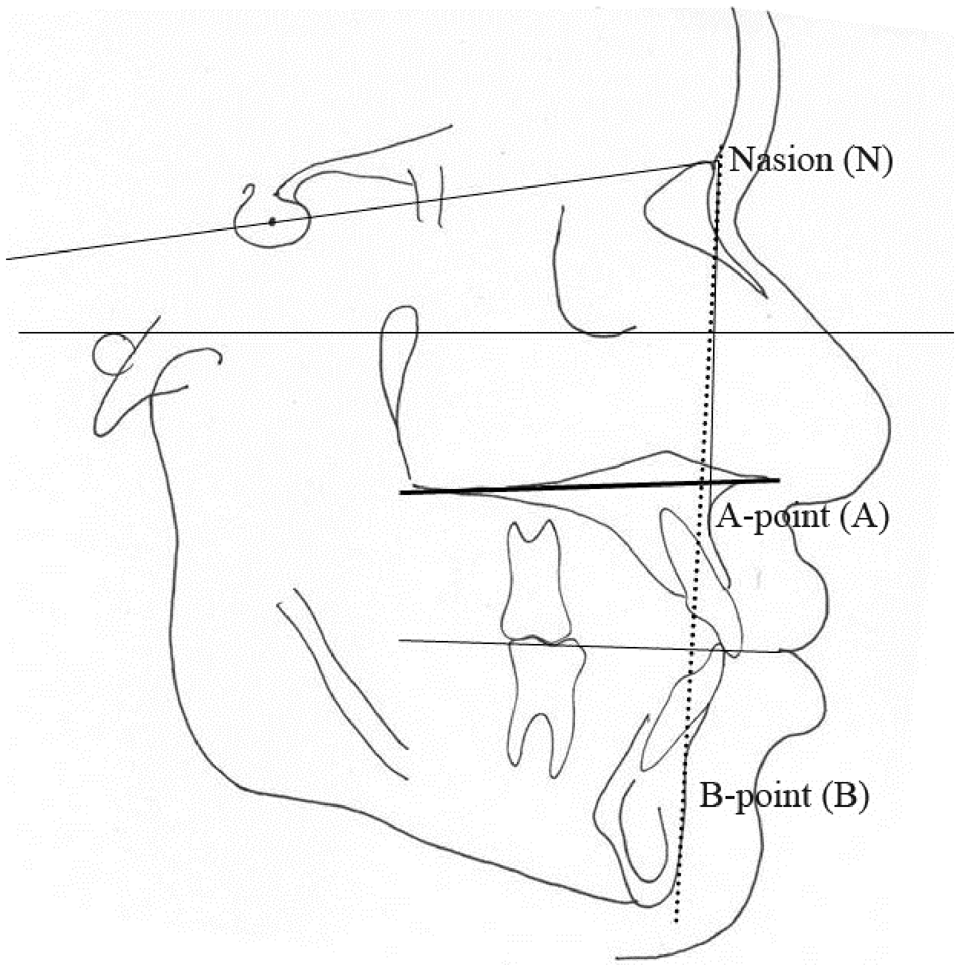


Fig. 1 Cephalometric tracing showing the landmarks used in the study.

DEMIRJIAN CLASSIFICATION SYSTEM

The ages at which each of the upper second molars of each patient reached the developmental stages described by Demirjian (1973) were established by examining all the serial lateral oblique radiographs that were available for each subject. The developmental stages of the teeth as described by Demirjian are shown in Fig. 2 below.

ERROR OF METHOD

All recordings were made by two examiners. Where assessments differed, consensus was reached through discussion. All the records were evaluated during a two week period. Once the entire sample had been processed, ten subjects were randomly selected and their records re-evaluated to enable testing for agreement between the two examiners.

STATISTICAL ANALYSIS

The data were first archived in a Microsoft ©Excel spreadsheet and subsequently imported into SAS statistical software (SAS Institute, Carrey, NC). The data were longitudinally assessed, in SAS, using the Generalized Linear Model (GLM). The data were assessed for interaction among three main effects: stage of development (StageDev), gender (Gender) and skeletal pattern (Occlude). There were four variations of Occlude which were Class I (A), II-1 (B), II-2 (C) and Class III (D).

Stage Description

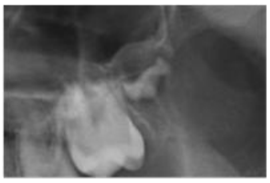
A

In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the occlusal level of the crypt in the form of a cone or cones.

B

Fusion of the calcified points forms one or several cusps which unite to give a regularly outlined occlusal surface.

C

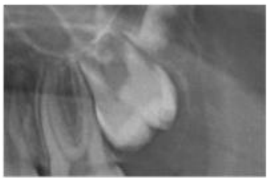


Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen. The beginning of dentinal deposit is seen. The outline of the pulp chamber has a curved shape at the occlusal border.

D

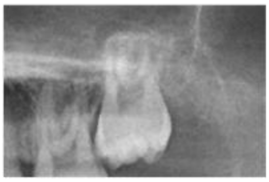
The crown formation is completed down to the cementoenamel junction. In molars, the pulp chamber has a trapezoidal form. Beginning of root formation is seen in the form of a spicule.

E



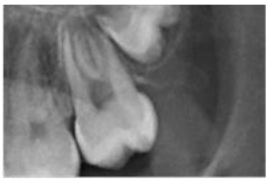
Initial formation of the radicular bifurcation is seen in the form of a calcified point or a semi-lunar shape. The root length is still less than crown height.

F



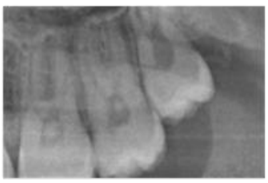
The calcified region of the bifurcation has developed further down from its semi-lunar stage to give the roots a more definite and distinct outline with funnel shaped endings. The root length is equal to or greater than crown height.

G



The walls of the root canal are now parallel and its apical end is still partially open (distal root in molars).

H



The apical end of the root canal is completely closed (distal root in molars). The periodontal membrane has a uniform width around the root and apex.

Fig. 2 The stages of dental development as described by Demirjian. The examples are copies of original images selected from the sample.

STATISTICAL ANALYSIS (continued)

As per Demirjian's classification, there were eight developmental stages from A to H. The response variable was the chronological age (CAGEY), in years, at which the maxillary second molar reached a specific developmental stage. Hence the data were assessed for differences, if any, in the chronological ages at which developmental stages had been achieved among the four skeletal occlusal schemes as related to any interaction among the skeletal pattern, gender and the stage of development.

CHAPTER IV

RESULTS

The total number of subjects included in the study was 109 with 51 females and 58 males. The sample distribution, by gender and skeletal pattern, is shown in Table I. The number of subjects in each skeletal pattern at each stage of development is shown in Table II. Due to incomplete records for many of the subjects the sample sizes vary considerably.

There were uneven distributions related to gender in the various skeletal patterns at the different developmental stages which did not allow for the assessment of gender differences. The main effects considered, then, were only the skeletal pattern and stage of development. The mean age (in years) at which the second molars of each skeletal pattern reached the eight stages of development is summarised in Table III. Analysis of variance by way of the GLM procedure in SAS showed no interaction between skeletal pattern and stage of development of the maxillary second molar ($p=0.9719$) and neither were there significant differences among the skeletal patterns ($p=0.3867$).

The mean ages at which the entire cohort of subjects reached the eight stages of development are shown in Table IV. There were statistically significant differences in the times at which each developmental stage was reached. The Tukey-Kramer test showed that the timing of each developmental stage was significantly different from the preceding or following stage (Table V). No specific pattern of transition could be established among the various stages.

Table I. Sample distribution by skeletal pattern and gender.

	Gender		
Skeletal Pattern	Male	Female	**Total**
Class I	21	15	**36**
Class II – 1	19	17	**36**
Class II – 2	11	8	**19**
Class III	7	11	**18**
Total	**58**	**51**	**109**

Table II. Sample distribution at the various stages of development stratified by skeletal pattern (data includes both second molars in each instance).

	Stage of development							
Skeletal Pattern	A	B	C	D	E	F	G	H
Class I	12	15	56	72	72	65	64	54
Class II – 1	16	22	60	72	66	62	62	46
Class II – 2	6	12	34	38	38	32	34	28
Class III	4	8	30	36	34	32	32	34
TOTAL	**38**	**57**	**180**	**218**	**210**	**191**	**192**	**162**

Table III. Mean age at which the second molar of each skeletal pattern reached each of Dimerjian's eight stages of development. There were no significant differences among the occlusal schemes within each stage of development (p=0.3867).

StageDev	Occlude	N	Mean age	Std Dev
A	A	12	4.01	0.28
	B	16	4.26	0.38
	C	6	4.28	0.50
	D	4	4.00	0.10
B	A	15	4.88	0.63
	B	22	5.01	0.75
	C	12	4.51	0.57
	D	8	4.79	0.55
C	A	56	5.87	0.82
	B	60	5.86	0.79
	C	34	5.77	0.55
	D	30	5.80	0.63
D	A	72	7.47	0.87
	B	72	7.21	0.88
	C	38	7.32	0.77
	D	36	7.34	0.74
E	A	72	9.94	1.03
	B	66	9.69	0.97
	C	38	9.75	0.93
	D	34	9.86	1.00
F	A	65	11.02	0.97
	B	62	10.88	0.96
	C	32	11.04	0.73
	D	32	10.91	0.95
G	A	64	12.23	1.02
	B	62	11.93	1.02
	C	34	12.19	0.77
	D	32	12.07	1.06
H	A	54	13.65	0.96
	B	46	13.25	1.09
	C	28	13.52	0.75
	D	34	13.38	1.01

Table IV. Least Squares mean age (in years) at which the second molar of the entire cohort of patients reached each of Dimerjian's eight stages of development.
These stages of development were significantly different from each other at every stage (p<0001). The last column of the table is to be read with Table V. StageDev = stage of development. CAGEY = chronological age in years. LSMEAN = least squares mean.

StageDev.	CAGEY LSMEAN	LSMEAN Number (i, j)
A	4.16	1
B	4.85	2
C	5.83	3
D	7.33	4
E	9.81	5
F	10.96	6
G	12.10	7
H	13.45	8

Table V. Cross comparison using Least Squares Means for the stage of development. Pr > |t| for H0: LSMean(i)=LSMean(j), with dependant variable chronological age in years (CAGEY). See Table IV for explanation of LSMean number.

Least Square Means Comparison								
	1	2	3	4	5	6	7	8
1	-	0.0061	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
2	0.0061	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
3	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
4	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001
5	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001	<0.0001
6	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001	<0.0001
7	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.0001
8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	-

CHAPTER V

DISCUSSION

Impaction of second molars emanating from early treatment has been considered to be a serious reality. This is of major concern in patients with Class II malocclusion, be it Class II-1 or Class II-2. Hence the aim of this project, for knowledge of the precise stage of development of the second molar may be a valuable guide in deciding if and when to embark upon treatment directed at distalizing the upper buccal segment.

Tooth development is related to physical development as shown by Nanda and Chawla (1966) and Chertkow (1980). However, the current study provides the first clear assessment of maxillary second molar development as it relates to the different occlusal schemes of Class I, Class II-1, II-2, and Class III. This study demonstrated no significant difference among the four skeletal patterns in terms of the timing and pace of maxillary second molar development. This is in agreement with the results of Brin *et al.* (2006), who found no difference in the developmental stages of either the maxillary or mandibular second molars between patients with either Class I or Class II occlusion. Brin *et al.* did find that the second maxillary molars were more advanced in their eruption status in Class II subjects where the maxilla was seen to be over-developed. The study by Brin *et al.* was however cross sectional, rendering the results less apposite than longitudinal data.

According to the cross-sectional study undertaken by Vedtofte *et al*. (1999), an association exists between arrested eruption of the mandibular second molar and a Class II skeletal pattern. While the current longitudinal study was limited to the maxillary second molars only, no association was found between the four occlusal schemes and developmental stages of the second molars in the maxillary arch. A consideration and possible limitation is that this study was limited to a Caucasian population of northern European descent. It however has been reported that while other physical changes have undergone cyclic changes, tooth development has not (Ferguson *et al*., 2011).

Whilst impaction of the maxillary second molar has been reported, that problem is almost always due to treatment. Natural impaction has been reported mostly for the mandibular second molar and only rarely for the maxillary molars. It has been found that the angulation of the lower second molar is the most pertinent indicator of possible impaction, while treatment timing is of lesser importance (Sonis and Ackerman, 2011). The mandibular molars are orientated along a mesially directed force during eruption while eruption imperative in the maxilla is distally directed (van der Linden and Duterloo, 1976). This would imply that the angulation of the maxillary second molar would be a poor predictor of maxillary second molar impaction, while factors such as treatment timing could play a greater role.

One of the dominant theories of eruption attributes the eruptive force of teeth to elements of the periodontal ligament, a structure which is first established when root formation starts. Stage D of Dimerjian's classification system signifies the end of crown formation of a tooth, while stage E indicates that root formation has commenced, as seen by the appearance of the radicular bifurcation. Eruption of the second maxillary molar could therefore be expected to commence at or around stage E according to Dimerjian’s classification, although Steedle and Proffit (1985) observed that several millimetres of root formation were required before movement. As the volume of the periodontal ligament increases with the lengthening root, the rate of tooth eruption will increase (Carlson, 1944).

This study clearly demonstrated that the maxillary second molars reached certain developmental stages at reasonably defined and specific times. It is relevant that no difference were found in the developmental times of these teeth among the four occlusal patterns, making prediction feasible. This is clinically relevant as it may be possible for a practitioner to evaluate any radiograph taken at an early age that shows the presence of the maxillary second molar and predict accurately when that molar will reach each stage of development. Raghoebar *et al*. (1991) stated that impaction of permanent molars is the result of a physical barrier in the path of eruption in the majority of cases. Furthermore Kinzinger *et al*. (2004) showed that tipping of the first maxillary molar over the unerupted second maxillary molar occurs when molar distalization is initiated too early. It can therefore be surmised that molar distalization should not commence prior to the second molar reaching stage E of Dimerjian's classification, in order to reduce the likelihood of second maxillary molar impaction. For the sample investigated in this study this would imply that molar distalization could commence at the age of 9 years and 10 months. The impact of this study would be that a single x-ray taken any time prior to the second molar reaching stage E of Dimerjian's classification system would enable the practitioner to accurately calculate when that particular patient's second maxillary molar would reach stage E of Dimerjian's classification system and molar distalization could then commence with the least likelihood of second maxillary molar impaction.

CHAPTER VI

SUMMARY AND CONCLUSION

The purpose of this study was to compare the ages at which the second maxillary molars reach specific developmental stages for patients with Class I, Class II-1, Class II-2, and Class III skeletal growth patterns. The study also aimed to assess whether the eight developmental stages of tooth development described by Dimerjian (1973) were reached at distinct ages and could therefore be predictably separated.

Based on the findings of this study, it was possible to conclude the following:

1. There was no difference in the timing of development among the four different skeletal patterns evaluated in this study.
2. The ages at which the second maxillary molar reaches each of the developmental stages are distinctly different.
3. The intervals between developmental stages are predictable, thus allowing for proper timing of early treatment that aims to distalize the maxillary molars.

LIMITATIONS

This study was not without limitations. These included a sample that was biased to the occlusions more commonly found in the sample population, uneven sample sizes, and a sample limited to subjects of northern European descent.

The collections of longitudinal growth data, such as the Michigan study are invaluable, as the collection of similar data will never again be possible. While examining these records gives us valuable insight into the growth and development of individuals the overall sample displays a bias toward Class II-1 malocclusion and increased lower anterior facial height, with very few individuals presenting with Class II-2, and Class III malocclusions. Therefore all the available records for Class II-2 and Class III subjects were included in the study. The entire collection was hand searched and all Class II-2 and Class III subjects were included regardless of the completeness of records for these individuals. In addition Class I and Class II-1 subjects were randomly selected in order to compile an equivalent sample of subjects with Class II-1 and Class I to match to the Class II-2 and Class III subjects.

The collection of data for this study was reliant on subjects being enrolled as learners in the University of Michigan Elementary and Secondary School. Subjects would often enrol at an advanced age, transfer to or from other schools, or leave the school early. This led to the records of several subjects missing data at the two ends of the age spectrum, and uneven sample sizes were unavoidable in this study. However this was adequately dealt with in the statistical calculation by way of the GLM procedure.

All the subjects that formed the sample were Caucasians of Northern European descent. It would be remiss to assume the same developmental patterns exist across all racial groups. While it has been shown that certain racial norms in terms of aesthetics may be attributed more to social background than physical makeup (Johnson, 1992), this cannot be applied to the skeletal structure and development of subjects from differing ethnic groups. The development of different cephalometric norms for various ethnic groups is, therefore, indicated to reflect these variations in skeletal patterns. Differences in molar development may well be present also.

This study excluded all patients who had undergone orthodontic treatment, and in doing so was limited to mild skeletal discrepancies, as all subjects with severe malocclusions enrolled in the University School did receive orthodontic treatment. However, in a clinical trial Kinzinger (2010) demonstrated that the root development of teeth used for orthodontic anchorage continued unimpeded. One could thus expect that orthodontic treatment would have no effect on the rate of development of unerupted second molar teeth. It should therefore be possible to include subjects undergoing orthodontic treatment in a study of second molar development. This should serve to include more subjects with severe malocclusions and lead to a study with higher sensitivity and specificity.

RECOMMENDATIONS FOR FURTHER RESEARCH

With the implementation of digital radiography at most dental schools and private practices today, vast resources of information are being compiled, with many orthodontic patients being imaged daily. In theory it should be possible to compile an enormous sample of cross sectional and longitudinal data using panoramic radiographs of orthodontic patients with known skeletal patterns who are followed up regularly. A more complete comparison of second molar development between different skeletal patterns would then be possible.

Bibliography

1. AAOFLegacycollection (2012) *www.aaoflegacycollection.org* American Association of Orthodontists Foundation

2. Abed, Y. and Brin, I. (2010) Early headgear effect on the eruption pattern of maxillary second molars. *Angle Orthod*, 80:642-8

3. Anderson, D. L. and Popovich, F. (1981) Association of relatively delayed emergence of mandibular molars with molar reduction and position. *Am J Phys Anthropol*, 54:369-76

4. Balaraj, B. M. and Nithin, M. D. (2010) Determination of adolescent ages 14 - 16 years by radiological study of permanent mandibular second molars. *J Forensic Leg Med,* 17:329-32

5. Brin, I., Camasuvi, S., Dali, N. and Aizenbud, D. (2006) Comparison of second molar eruption patterns in patients with skeletal Class II and skeletal Class I malocclusions. *Am J of Orthod Dentofacial Orthop,* 130: 746 - 51

6. Bussick, T. J. and McNamara Jr, J. A. (2000) Dentoalveolar and skeletal changes associated with the pendulum appliance. *Am J Orthod Dentofacial Orthop*, 117:333-43

7. Carlson, H. (1944) Studies on the rate and amount of eruption of certain human teeth. *Am J Orthod*, 30:575-88

8. Chertkow, S. (1980) Tooth mineralization as an indicator of the pubertal growth spurt. *Am J Orthod*, 77:79-91

9. Dhanjal, K. S., Bhardwaj, M. K. and Liversidge, H. M. (2006) Reproducibility of radiographic stage assessment of third molars. *Forensic Sci Int*, 159:S74-7

10. Demirjian, A., Goldstein, H. and Tanner, J. M. (1973) A New System of Dental Age Assessment. *Hum Biol*, 45: 211 - 27

11. Ferguson, D. J. Growth of the Face and Dental Arches. Dean, J. A., Avery, D. R. and McDonald, R. E. Editors.(2011) *McDonald and Avery's Dentistry for the Child and Adolescent*. 9th ed. Mosby - Elsevier. St. Louis. 510-24

12. Ferro, F., Funiciello, G., Perillo, L. and Chiodini, P. (2011) Mandibular lip bumper treatment and second molar eruption disturbances. *Am J Orthod Dentofacial Orthop*, 139:622-7

13. Haruki, T., Kanomi, R. and Shimono, T. (1997) The differences in the chronology and calcification of second molars between Angle Class III and Class II occlusions in Japanese children. *ASDC J Dent Child*, 64:400-4

14. Johnson, P. F. (1992) Racial norms: Esthetic and prosthodontic implications. *J Prosthet Dent*, 67:502-8

15. Kinzinger, G. S. M., Fritz, U. B., Doz, P., Sander, F. G. and Diedrich, P. R. (2004) Efficiency of a pendulum appliance for molar distalization related to second molar eruption stage. *Am J Orthod Dentofacial Orthop*, 125:8-23

16. Kinziger, G. S. M., Pantel, C., Ludwig, B., Gülden, N., Glasl, B., Lisson, J. (2010) Effects of conventional anchorage on premolar root development during treatment with a pendulum appliance. *J Orofac Orthop,* 71:281-9

17. Lo, R. T. and Moyers, R. E. (1953) Studies in the etiology and prevention of malocclusion. I. The sequence of eruption of the permanent dentition. *Am J Orthod*, 39:460-7

18. Lunt, R. C. and Law, D. B. (1974) A review of the chronology of eruption of deciduous teeth. *J Am Dent Assoc*, 89:872-9

19. McSherry, P. F. and Bradley, H. (2000) Class II correction-reducing patient compliance: a review of the available techniques. *J Orthod*, 27:219-25

20. Millett, D. T., Cunningham, S. J., O'Brien, K. D., Benson, P. E. and de Oliveira, C. M. (2012) Treatment and stability of Class II Division 2 malocclusion in children and adolescents: A systematic review. *Am J Orthod Dentofacial Orthop*, 142:159-69

21. Moorrees, C. F. A., Fanning, E. A. and Hunt, E. E. (1963) Age Variation of Formation Stages for Ten Permanent Teeth *J Dent Res*, 42: 1490 - 502

22. Nanda, R. S. and Chawla, T. N. (1966) Growth and development of dentitions in Indian children. I. Development of the permanent teeth. *Am J Orthod*, 52:837-53

23. Nanda, R. S. and Dandajena, T. C. (2006) The role of the headgear in growth modification. *Semin Orthod*, 12:25-33

24. Nolla, C. M. (1960) The Development of the Permanent Teeth. *J Dent Child*, 27: 254 - 66

25. Olze, A., Schmidt, S., Wernecke, K. D., Geserick, G. and Schmeling, A. (2005) Validation of common classification systems for assessing the mineralization of third molars. *Int J Legal Med*, 119:22-6

26. Raghoebar, G. M., Boering, G., Vissink, A., Stegenga, B. (1991) Eruption disturbances of permanent molars: a review. *J Oral Pathol Med*, 20:159-66

27. Rasmussen, P. and Kotsaki, A. (1997) Inherited retarded eruption in the permanent dentition. *J Clin Pediatr Dent*, 21:205-11

28. Rubin, R. L., Baccetti, T. and McNamara Jr, J. A. (2012) Mandibular second molar eruption difficulties related to the maintenance of arch perimeter in the mixed dentition. *Am J Orthod Dentofacial Orthop*, 141:146-52

29. Shapira, Y., Finkelstein, T., Shpack, N., Lai, Y. H., Kuftinec, M. M. and Vardimon, A. (2011) Mandibular second molar impaction. Part 1: Genetic traits and characteristics. *Am J Orthod Dentofacial Orthop*, 140:32-7

30. Sonis, A. and Ackerman, M. (2011) E-space preservation. Is there a relationship to mandibular second molar impaction? *Angle Orthod*, 81:1045-49

31. Steedle, J. R. and Proffit, W. R. (1985) The pattern and control of eruptive tooth movements *Am J Orthod*, 87:56-66

32. Valmaseda-Castellon, E., De-La-Rosa-Gay, C. and Gay-Escoda, C. (1999) Eruption disturbances of the first and second permanent molars: Results of treatment in 43 cases. *Am J Orthod Dentofacial Orthop*, 116:651-8

33. van der Linden, F. P. G. M. and Duterloo, H. S. (1976) *Development of the Human Dentition: an Atlas*. Harper & Row. New York

34. Vedtofte, H., Andreasen, J. O., Kjaer, I. (1999) Arrested eruption of the permanent lower second molar. *Eur J Orthod*, 21:31-40

35. Waldo, C. M. (1936) Orthodontic research as a component of a balanced longitudinal study of 100 children. *Int J Orthodontia*, 22:659-73