Maxillary first molar extraction in Class II malocclusion

Livas, Christos

MAXILLARY FIRST MOLAR EXTRACTION IN CLASS II MALOCCLUSION

Follow-up studies on treatment effects

Thesis

Christos Livas

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Door Christos Livas

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CONTENTS

To the memory of my mother

CHAPTER 1

GENERAL INTRODUCTION

1.1. NORMAL OCCLUSION AND MALOCCLUSION

Occlusion refers to the relationship of maxillary and mandibular teeth as they are brought into functional contact.[1] The current perception of normal occlusion has been strongly influenced by the work of Angle, Andrews and Roth. The original Angle's classification[2] was regulated by the articulation of the mesiobuccal cusp of the maxillary first molar in the buccal groove of the mandibular first molar and the arrangement of teeth in a smoothly curving line of occlusion. Decades later, based on the occlusion characteristics consistently observed in 120 study casts of non-orthodontic patients, Andrews[3] described the 'six keys to normal occlusion'; Angle's occlusion of first molars, correct crown angulation and inclination, absence of rotations, tight proximal contacts and flat occlusal plane. Roth added further prerequisite features for normal occlusion regarding the coincidence of centric relationship and centric occlusion, the guidance during protrusion and lateral excursions of the mandible, and the even posterior contacts in centric occlusion.[4]

Malocclusion is defined as any appreciable deviation from the normal occlusion that may be perceived aesthetically unsatisfactory, thus implying imbalance in the relative size and position of teeth, facial bones and surrounding soft tissues.[5] It represents neither a normal nor a healthy condition.[6] The World Health Organization (WHO) included malocclusion under the heading of dental diseases and conditions that constitute worldwide major public health problems. The term used by WHO instead, Handicapping Dentofacial Anomaly, describes the dental condition that 'causes disfigurement or impedes function'. Such 'anomaly should be regarded as requiring treatment if the disfigurement or functional defect is or likely to be an obstacle to the patient's physical and emotional well-being'.[7]

1.2 DEFINITION OF ANGLE CLASS II MALOCCLUSION

According to Angle's occlusal classification of malocclusion,[2] the permanent maxillary first molar is presumed reference point. In normal occlusion, maxillary and mandibular molars should be so related that the mesiobuccal cusp of the maxillary molar occludes in the buccal groove of the antagonist. Deviating inter-arch relationships are identified as Class I, Class II division 1, Class II division 2 and Class III malocclusion. In Class II malocclusion, the mandibular first molar occludes distal to the normal position as defined above. Angle Class II is further categorized to Class II Division 1, characterized by labial inclination of maxillary incisors and increased overjet, and Class II Division 2, characterized by lingually inclined maxillary central incisors combined or not with labially tipped maxillary lateral incisors, reduced overjet, and partial or complete deep bite. Each of the divisions presents a subdivision, in which only one of the lateral halves is in distal occlusion, while the other half is in normal occlusion.

Therefore, Angle Class II subdivision malocclusions possess characteristics of both Class I and Class II malocclusions resulting in asymmetry between the right and the left sides of the dentition.

1.3 EPIDEMIOLOGY OF MALOCCLUSION

Class II malocclusion is a dentofacial deformity, commonly diagnosed in the general population. Differences in prevalence of malocclusion among countries may arise due to differences in racial and ethnic composition.[8] According to the National Health and Nutrition Estimates Survey III data, an overjet of 5 mm or greater, indicative of Angle's Class II malocclusion appears in 23.0% of the children, 15.0% of youths, and 13.0% of the adults in the United States.[6] Relatively higher prevalence rates of 21.3-24.0% have been observed in child and adolescent groups in northern European countries.[9] A nationwide survey in the Netherlands reported a 28.0% prevalence of Class II malocclusion among 14-74 year-olds.[10] Limited epidemiologic data regarding asymmetric Class II malocclusion is available. Class II subdivisions are estimated to account for up to 50% of all Class II malocclusions.[11]

1.4 NEED FOR ORTHODONTIC TREATMENT OF CLASS II MALOCCLUSION – IMPACT ON THE ORAL HEALTH-RELATED QUALITY OF LIFE (OHRQOL)

Although not life-threatening, malocclusion is the third most prevalent oral pathology, after tooth decay and periodontal disease.[12] Research on the physical, psychological, and social consequences of malocclusion has been so far inconclusive. Certain types of malocclusion including Class II malocclusion with a large overjet and deep bite may contribute to development of temporomandibular disorder (TMD) in the long term.[13-15] However, the evidence of the correlation between TMD and different types of malocclusion is generally weak, and this does not imply under any circumstances a cause-and-effect relationship.[16] Malocclusion has been found to be associated with increased likelihood of dental trauma, especially in children with untreated Class II Division 1 malocclusions.[17-19] A meta-analysis on the relationship between overjet size and dental trauma concluded that children with an overjet greater than 3 mm ran an almost two-fold risk of incisor injury compared to children with an overjet less than 3 mm.[20] The relationship between gingival inflammation and malocclusion remains also controversial. Patients with large overjets and deep overbites are more prone to experience periodontal disease associated with incisal contact. In extreme deep bite cases, direct trauma to gingival tissues from the incisal edges may induce palatal recession in the maxillary incisor region.[21] Longitudinal research findings indicate a significant but rather weak association between the type of speech disorder and dentofacial abnormality. [22,23] There might be a tendency in Class II patients to pronounce differently sibilants such as /s/, /z/, /j/ and /ch/.[24-26] Furthermore, an anterior open bite combined with a Class II occlusion may cause pronunciation disorders.[27] Negative effects of malocclusions on OHRQOL, predominantly in emotional and social wellbeing have been lately confirmed by studies with high level of quality.[28] Bullying has been significantly associated with Class II Division 1 incisor relationship, increased overbite, increased overjet and high need for orthodontic treatment need.[29] Patients with dentofacial deformities had a more negative oral health-related quality of life and a lower self-esteem compared with controls.[30] On the other hand, the self-concept of children with Class II malocclusion neither appeared low before treatment nor benefited from a brief period of early orthodontic treatment.[31] Children that had received early treatment with a Twin-Block appliance reported higher self-concepts and more positive social experiences.[32]

1.5 TREATMENT OPTIONS OF CLASS II MALOCCLUSION

Treatment decision making in Class II cases relies heavily on the patient's skeletal age, facial aesthetics, arch length discrepancy, and motivation. Growth modification with either functional appliances or headgear may be the standard treatment of choice in prepubertal patients with a favourable growth pattern. Nowadays, maxillary molar distalization mechanics or appliances supported by Temporary Anchorage Devices are widely used in the management of Class II malocclusion. Orthognathic surgery to alter the underlying jaw relationship may be reserved for individuals seeking treatment beyond the growth spurt. In crowded dentitions, orthodontic extractions of teeth in the maxillary arch alone or both maxillary and mandibular arches, may serve as treatment alternative. Without doubt, premolars are the teeth most frequently removed in such extraction protocols. However, less traditional Class II therapeutic approaches involving extraction of first or second molars have been also advocated by a number of authors.[33-36]

1.5.1 MAXILLARY FIRST MOLAR EXTRACTION TREATMENT: THE TECHNIQUE

The first permanent molar is often significantly compromised by caries or endodontic complications, or from developmental anomalies such as hypoplasia.[37] Depending on the eruption prognosis of maxillary third molars and the severity of malocclusion, removal of any compromised teeth in conjunction with orthodontic treatment may be considered in selected cases. Bilateral extraction of maxillary first permanent molars with Begg fixed appliances has been recently reintroduced in the treatment of Class II Division 1 malocclusion.[38] Prior to molar extractions, bands with 6-mm single 0.018-in round buccal tubes and palatal sheaths are placed on the maxillary second molars. Premolars are not directly bonded with Begg brackets to facilitate sliding mechanics. Anchor bends on an individually made archwire constructed of 0.016-in premium plus pull-straightened Australian wire (Wilcock, Whittlesea, Australia) mesial of the molar tubes are utilized to prevent mesial tipping of the molars. Light horizontal elastics (5/16 inch) are prescribed for 24 hours a day, and replaced once per week. Anchor and v-bends between mandibular canines and molars are added to achieve bite opening. Anchorage required for canine retraction is reinforced by insertion of a transpalatal arch. At the time that Class I canine and premolar relationship is established, the premolars are bonded and Class II elastics are used instead of Class I elastics. After alignment of the maxillary premolars, the 0.016-inch starting wire is replaced by a 0.018-inch premium plus archwire (Wilcock, Whittlesea, Australia). During space closure and when indicated, torque auxiliaries may be inserted. In the final sessions, archwire adjustments are made for detailed finishing.

1.5.2 MAXILLARY FIRST MOLAR EXTRACTION TREATMENT OUTCOMES

A prospective longitudinal study of one hundred patients with Class II division 1 malocclusion consecutively treated with extraction of maxillary first molars and 1-stage full fixed appliances confirmed high treatment standards.[39] These authors demonstrated an 89.9% mean reduction of weighted PAR score and a minor effect on the soft tissue profile. In particular, the lower lip retruded 1.6 mm in relation to the aesthetic line, while the nasolabial angle became 2.1° more obtuse after treatment. Contrary to one of the prevailing orthodontic dogmas, a bite-closing effect of extracting the maxillary first molars was not observed. In other words, divergent patients did not seem to benefit more than deepbite patients when treated with this treatment modality. Nevertheless, the clinical relevance of this finding was deemed limited.

Analysis of overjet correction and space closure mechanisms on the same group of patients revealed a mean overjet reduction of 5.2 mm, on average accomplished by means of 1.7 mm skeletal and 3.5 mm dental changes.[40] Overjet reduction was mostly achieved by retrusion of the maxillary incisors and to a lesser extent by protrusion of the mandibular incisors and forward growth of the mandible. Interestingly, a pronounced mesialization of 9.9 mm of the maxillary second molars took place, whereas the maxillary premolars were distalized merely by 1.4 mm.

A recent comparative study on Class II treatment effects of extraction of maxillary first molars and Herbst appliance verified the predominantly dental contribution (65% dental and 35% skeletal changes) in the extraction group, while the Herbst group exhibited mainly skeletal in origin effects (58% skeletal and 42% dental changes).[41] There was a significant increase in the nasolabial angle by 2.33° in the extracted subjects compared to the Herbst controls. The soft tissue profile convexity decreased in both treatment groups, which was 0.78° more evident in the Herbst group, though not statistically significant. Overall, the authors concluded that both Class II treatment methods produced high standard outcomes.

1.5.3 UNILATERAL MAXILLARY FIRST MOLAR EXTRACTION IN CLASS II SUBDIVISION

Asymmetric mechanics in the affected side by means of various orthodontic accessories,[42-44] as well as asymmetric extraction patterns[45,46] and orthognathic surgery[47] may be each considered treatment of choice for Class II subdivision malocclusion. Modification of the aforementioned technique including unilateral extraction of a maxillary first molar on the Class II side has been suggested for treatment of asymmetric Class II malocclusion.[48] As far as we are aware, no clinical study has been carried out so far to provide insight into the treatment outcomes of this therapeutic modality.

1.5.4 MAXILLARY MOLAR ERUPTION AFTER EXTRACTION OF MAXILLARY POSTERIOR TEETH

Third molar inclination changes have been investigated in patients orthodontically treated or not with either second molar,[49-53] first premolar extractions[54-58] or unilateral extraction of the mandibular first molar.[59] Improved positions of maxillary third molars have been substantiated after orthodontic therapy with extraction of all first permanent molars.[60] Theoretically, the relative location of the extracted tooth to the maxillary third molar may determine the prognosis of third molar eruption.[61] In this sense, molar extraction protocols may be proved more beneficial than premolar extractions. The effect on second and third molar inclination of either unilateral or bilateral extraction of maxillary first molars followed by orthodontic treatment remains to be determined.

1.5.5 ORTHODONTIC SPACE CLOSURE AND MAXILLARY SINUS INTERFERENCE

In almost half of the adults, the maxillary sinus penetrates the maxillary alveolar process, expanding between the periapical areas of the second premolar and second permanent molar.[62] Experimental and clinical research has found modest apical root

resorption and variable tipping of teeth being intruded and bodily moved across the maxillary sinus floor.[63-65] Given the amount and the location of space resulting from maxillary first molar extraction, tipping of the neighbouring teeth against the sinus walls may also be expected during closing mechanics.

1.5.6 OVERERUPTION OF THE UNOPPOSED MANDIBULAR SECOND MOLARS

Lack of antagonist contact has been identified to cause movement of the unopposed tooth in occlusal direction, i.e. overeruption.[66] The authors of a systematic review on the treatment need for posterior bounded edentulous spaces,[67] found an up to 2 mm overeruption for the most studies analyzed. According to the step-by-step description of the maxillary first molar extraction technique,[38] following appliance removal, segmental retention wires are bonded on mandibular first and second molars are to counteract overeruption of the second molars. These sectionals are maintained until occlusal contact of the maxillary third molars and antagonists occurs. But is this fixed retention adequate to inhibit vertical movement of the mandibular second molars?

1.6 AIMS OF THIS THESIS

The overall aim of this thesis was to evaluate posttreatment effects of unilateral and bilateral extraction of maxillary first molars in Class II malocclusion cases.

The specific aims of this research project were determined as follows:

1. To evaluate the stability of occlusal and soft tissue profile outcomes of Class II subdivision treatment with unilateral maxillary first molar extraction in the retention stage.
2. To investigate the influence of orthodontic treatment of Class II subdivision treatment with unilateral maxillary first molar extraction on the maxillary second and third molar inclination.
3. To assess the maxillary second and third molar inclination changes following bilateral maxillary first molar extraction in Class II Division 1 malocclusion subjects.
4. To investigate potential associations between maxillary sinus floor extension and inclination of maxillary second premolars and second molars in patients with Class II Division 1 malocclusion whose orthodontic treatment included bilateral maxillary first molar extraction.
5. To evaluate the effectiveness of fixed retention in preventing overeruption of mandibular second molars lacking antagonist contact in Class II Division 1 cases treated with bilateral extraction of maxillary first molars.

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CHAPTER 2

LONG-TERM EVALUATION OF CLASS II SUBDIVISION TREATMENT WITH UNILATERAL MAXILLARY FIRST MOLAR EXTRACTION

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SUMMARY

Introduction: To evaluate the long-term effects of asymmetrical maxillary first molar (M1) extraction in Class II subdivision treatment.

Materials and Methods: Records of 20 Class II subdivision whites (7 boys, 13 girls; mean age,13.0 years; SD, 1.7 years) consecutively treated with the Begg technique and M1 extraction, and 15 untreated asymmetrical Class II adolescents (4 boys, 11 girls; mean age, 12.2 years; SD, 1.3 years) were examined in this study. Cephalometric analysis and PAR assessment were carried out before treatment (T1), after treatment (T2), and on average 2.5 years posttreatment (T3) for the treatment group, and at similar time points and average follow-up of 1.8 years for the controls.

Results: The adjusted analysis indicated that the maxillary incisors were 2.3 mm more retracted in relation to A-Pog between T1 and T3 (β, 2.31; 95% CI, 0.76, 3.87), whereas the mandibular incisors were 1.3 mm more protracted (β, 1.34; 95% CI, 0.09, 2.59), and 5.9° more proclined to the mandibular plane (β, 5.92; 95% CI, 1.43, 10.41) compared with controls. The lower lip appeared 1.4 mm more protrusive relative to the subnasale-soft tissue-Pog line throughout the observation period in the treated adolescents (β, 1.43; 95% CI, 0.18, 2.67). There was a significant PAR score reduction over the entire follow-up period in the molar extraction group (β, -6.73; 95% CI, -10.73, -2.73). At T2, 65% of the subjects had maxillary midlines perfectly aligned with the face.

Conclusions: Unilateral M1 extraction in asymmetrical Class II cases may lead to favourable occlusal outcomes in the long term without harming the midline aesthetics and soft tissue profile.

2.1 INTRODUCTION

Correction of Class II subdivision malocclusion has long been a challenge for clinicians. Through the years, a wide variety of treatment modalities have been implemented, such as use of asymmetrical headgear,[1] unilateral Class II elastics coupled with a coil spring, sliding jigs, or tip-back mechanics on the affected side,[2] one, three, or four premolar extractions,[3,4] bimaxillary surgical procedures,[5] TADs-supported unilateral molar distalization,[6] and a fixed functional appliance.[7]

Despite strong clinical interest, few studies on Class II subdivision treatment have been published. Janson et al observed slightly better treatment success rates in asymmetric extraction of 3 premolars compared with extraction of 4 premolars.[3] Smile attractiveness and buccal corridors did not differ in Class II subdivision subjects treated with 1, 3, or 4 premolar extractions.[4]

A retrospective study of varying treatment strategies, ie, intermaxillary elastics, extractions, asymmetrical headgear, fixed functional appliance, and orthognathic surgery, demonstrated comparable occlusal outcomes.[8] Finally, whereas Herbst treatment was similarly successful in various Class II malocclusions, a Class III tendency was more frequently evident in the subdivision group.[7]

Recently, unilateral extraction of a maxillary first molar (M1) followed by fixed appliance treatment has also been advocated in a case report with a favourable result.[9] However, no case series or long-term follow-up studies have yet been published on the treatment of unilateral M1 extraction in Class II subdivision malocclusion. Therefore, the objective of this study was to assess long-term treatment changes in a sample of Class II subdivision patients treated with one M1 extraction and fixed appliances.

2.2 MATERIALS AND METHODS

This retrospective study included 20 Class II subdivision subjects (7 boys, 13 girls; mean age, 13.0 years; SD, 1.7 years) all consecutively treated by 1 orthodontist (J.W.B.) with the Begg light-wire appliance in his private practice (Table I). The inclusion criteria were white race, Class II subdivision (defined as a unilateral Class II ≥1/2 premolar width and Class I on the other side), no missing teeth or tooth agenesis including third molars, permanent dentition, no or mild crowding in the mandibular arch, and unilateral M1 extraction on the Class II side. Clinical records were obtained before treatment (T1), after treatment (T2), and 2.5 years posttreatment on average (T3 range, 1.8 years-4.3 years).

According to the technique,[9] prior to molar extraction, bands with 6-mm single 0.018-inch round buccal tubes and palatal sheaths were placed on the maxillary second molar of the extraction side and the contralateral maxillary first molar. Premolars were not directly bonded with Begg brackets to facilitate sliding mechanics. Anchor bends on an individually made archwire constructed of 0.016-inch premium plus pullstraightened Australian wire (Wilcock, Whittlesea, Australia) mesial of the molar tubes prevented mesial tipping of the molars. Light horizontal elastics (5/16 inch) were worn for 24 hours on the Class II buccal segment and replaced once per week. Anchor and v-bends between mandibular canines and molars were added to achieve bite opening. Anchorage required for canine retraction was reinforced by means of a transpalatal arch. When a Class I canine and premolar interocclusal relationship had been established, the premolars were bonded and Class II elastics were used instead. After alignment of the maxillary premolars, the 0.016-inch starting wire was replaced by a 0.018-inch premium plus archwire (Wilcock). During space closure, and when indicated, torque auxiliaries were inserted. In the final treatment stage, adjustments were made in the archwires for detailed finishing.

The control subjects were untreated Class II subdivision adolescents (4 boys, 11 girls; mean age, 12.2 years; SD, 1.3 years at the start of the observation period) selected and matched by age from the archives of the Groningen Longitudinal Growth Study (Table I).[10–12] This study material derived from a sample of elementary school children residing in the Northern Netherlands, which had been clinically examined and documented on annual basis between the ages 6-18 years. The sample composition was representative of the prevalence of Class I and Class II malocclusion in the general Dutch population.

	Treatment (n=20)	*Control (n=15)*
Gender		
Boys	7	4
Girls	13	11
Age (y)		
T1	13.0 (1.7)	12.2 (1.3)
T2	15.3 (1.9)	14.0 (1.6)
T3	17.7 (1.9)	15.0 (1.8)

Table I. Summary statistics (means, SDs in parentheses) of the treatment and control groups.

All lateral headfilms were scanned (Epson Expression 1680 Pro, Suwa, Nagano, Japan) and subsequently digitized by the first author using cephalometric software (Viewbox 3.0; dHAL Software, Kifissia, Greece). The landmarks and reference lines used for the analysis are displayed in Figure 1. The same calibrated examiner scored all study casts using the peer assessment rating (PAR). Twelve tracings and PAR scores were randomly selected and repeated at least 2 weeks after the initial series of measurements to evaluate intraobserver reliability. Joint Photographic Experts Group images of pa-

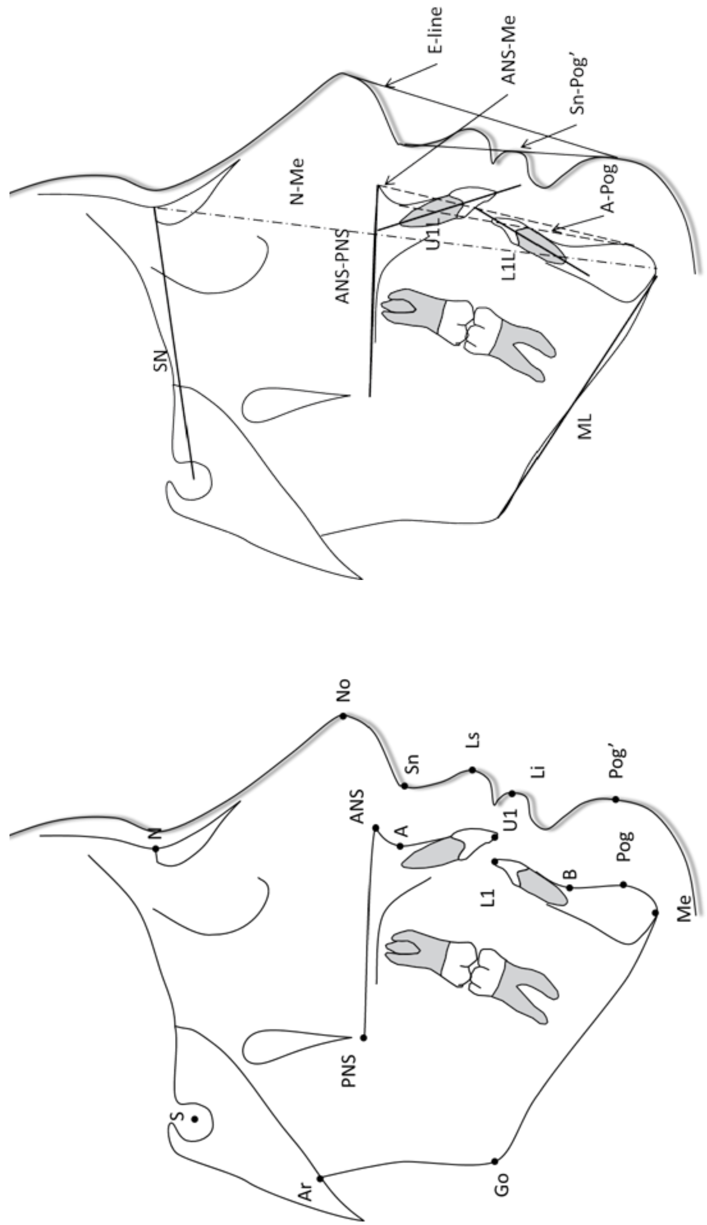

Figure 1. Landmarks (left) and reference lines (right) included in the cephalometric analysis of the study.

tient smiles were imported into image processing software (Image J version 1.48v, US National Institutes of Health, Bethesda, Md) to assess midline asymmetry. Image J was set to define facial and dental midlines and calculate the linear distance between the midlines.

Statistical analysis

Descriptive statistics (means, standard deviations) were calculated for all cephalometric and PAR measurements. Intraobserver reliability was assessed using the intracluster correlation coefficient (ICC). The effect of the intervention on the parameters of interest was assessed by fitting a mixed linear model in which each outcome of interest was regressed on treatment, time point, patient age and outcome baseline value. The mixed model accounts for the correlated nature of data arising from the fact that there are multiple observations within patients; the patient was used as the random effect. The level of statistical significance was set at 5%. Statistical analysis was performed with Stata version 13 software (Stata Corporation, College Station, Tx, US).

2.3 RESULTS

The ICC ranged from 0.75 to 0.99, indicating excellent intraobserver reliability. Demographics and summary values (means, standard deviations) for the study and control groups are presented in Tables I and II. The results from the adjusted analyses for the effects of therapy on the parameters of interest are shown in Table III.

Cephalometric analysis

Superimposition of the mean tracings at all 3 time points illustrates the overall treatment and growth effects (Figure 2). Six cephalometric variables (U1 to A-Pog, L1/ML, L1 to A-Pog, Li to Sn-Pog', N-No, ANS-Me/N-Me) showed a statistical significant association with treatment (Table III).

The adjusted analysis indicated that during therapy, the maxillary incisors were retracted 2.3 mm more than the control teeth in relation to A-Pog (β, 2.31; 95% CI: 0.76, 3.87). At T3, the maxillary incisors relapsed in both groups but remained retracted compared with pretreatment standards in the treated adolescents (mean, 6.0 mm; SD, 2.5 mm). Treatment also had a significant effect on the mandibular incisor position relative to A-Pog (β, 1.34; 95% CI, 0.09, 2.59). In the treatment group, the mandibular incisors were protracted 0.9 mm between T1 and T2 (at T2; mean, 2.4; SD, 2.1) and 0.4 mm at T3 (mean, 2.8; SD; 2.1). In the growth study sample, the mandibular incisors were slightly retracted at T2 (mean, 0.4 mm; SD, 1.7 mm) and moved in the opposite direction at follow-up (mean, 0.8 mm; SD, 1.7 mm). In the extraction group, the mandibular incisor to mandibular plane angle increased significantly from T1 to

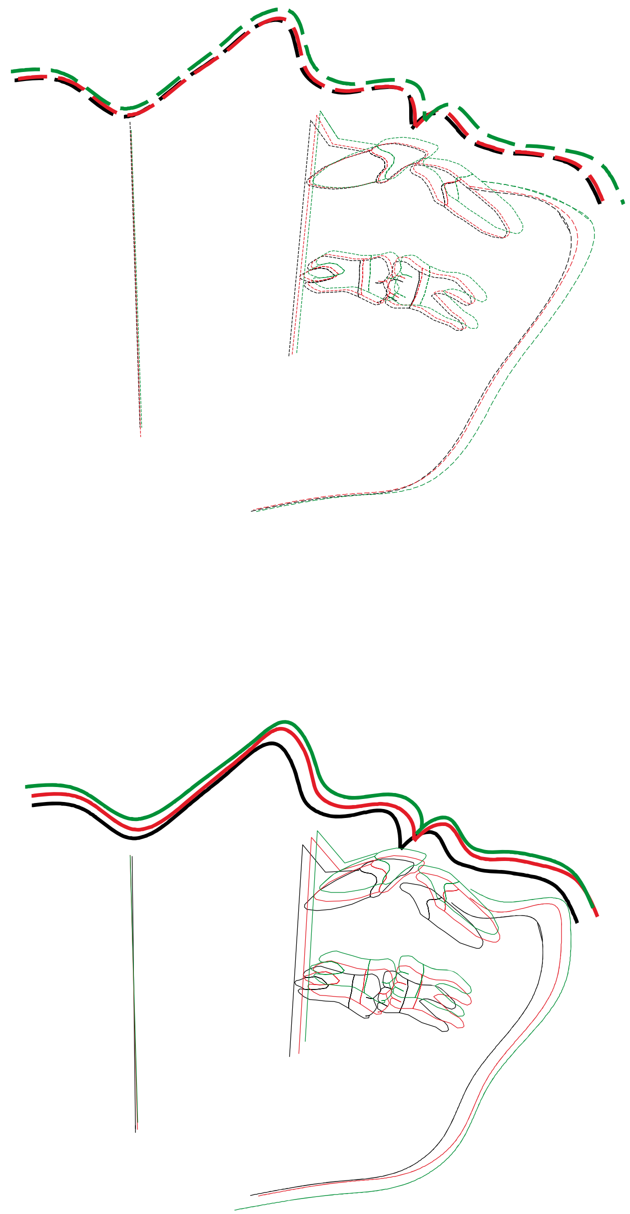

Figure 2. Mean tracings of the treatment (left) and control group (right): black, T1; red, T2; green, T3.

	T1		T2		T3	
Variable	Control	Treatment	Control	Treatment	Control	Treatment
PAR	15.6 (7.1)	22.1 (7.2)	16.3 (7.3)	2.0 (2.5)	16.9 (9.1)	2.3 (2.5)
SNA (°)	81.9 (4.0)	84.8 (4.1)	81.7 (3.3)	83.1 (4.8)	81.5 (3.8)	83.2 (5.4)
SNB (°)	77.8 (3.3)	79.7 (3.8)	77.8 (3.1)	79.2 (3.9)	77.8 (3.7)	79.5 (4.6)
ANB (°)	4.0 (1.9)	5.1 (1.7)	4.0 (1.9)	3.9 (2.5)	3.7 (2.1)	3.6 (2.5)
SN/ANS-PNS (°)	7.7 (2.9)	4.8 (4.2)	8.2 (3.4)	5.1 (4.3)	7.6 (2.3)	5.2 (4.8)
SN/ML (°)	32.2 (5.8)	29.1 (6.2)	32.0 (5.4)	29.5 (6.4)	31.8 (5.7)	28.7 (7.0)
ANS-PNS/ML (°)	24.5 (5.1)	24.4 (5.0)	23.7 (5.2)	24.4 (5.0)	24.2 (5.5)	23.6 (5.4)
ANS-Me/N-Me (ratio)	55.7 (2.0)	57.0 (2.6)	55.6 (1.7)	57.5 (2.4)	56.0 (1.8)	57.6 (2.2)
U1L/ANS-PNS (°)	108.1 (8.0)	112.1 (6.7)	108.7 (8.4)	110.2 (5.5)	109.6 (6.5)	109.8 (6.3)
U1 to A-Pog (mm)	4.4 (2.2)	7.7 (3.1)	4.1 (2.1)	5.7 (2.4)	4.6 (1.7)	6.0 (2.5)
L1L/ML (°)	94.2 (6.7)	98.5 (8.2)	94.9 (7.2)	100.5 (7.4)	94.9 (6.5)	102.1 (6.4)
L1 to A-Pog (mm)	0.5 (1.8)	1.5 (2.4)	0.4 (1.7)	2.4 (2.1)	0.8 (1.7)	2.8 (2.1)
Overbite (mm)	2.9 (1.3)	2.3 (2.4)	2.7 (1.3)	1.3 (1.5)	2.6 (1.8)	1.3 (1.2)
Overjet (mm)	4.0 (1.3)	6.4 (2.0)	3.9 (1.5)	3.4 (1.5)	3.9 (1.6)	3.3 (1.1)
Nasolabial angle (°)	124.8 (5.9)	126.9 (9.4)	124.5 (7.2)	129.8 (7.5)	125.5 (6.4)	128.9 (7.9)
Ls to Sn-Pog' (mm)	3.4 (1.7)	4.4 (1.9)	3.3 (1.8)	3.0 (2.1)	3.3 (1.5)	3.1 (1.7)
Li to Sn-Pog' (mm)	1.5 (2.1)	3.3 (2.1)	1.7 (2.4)	2.8 (2.2)	1.9 (2.0)	2.6 (1.9)
Ls to E-line (mm)	-2.6 (2.2)	-1.8 (2.1)	-2.8 (2.4)	-4.2 (3.0)	-2.8 (1.8)	-4.3 (2.5)
Li to E-line	-2.2 (2.3)	-0.4 (2.3)	-2.0 (2.8)	-1.7 (2.5)	-2.0 (2.0)	-1.9 (2.6)
N-No (mm)	46.7 (6.0)	49.3 (7.4)	46.4 (2.9)	51.9 (7.3)	47.0 (2.0)	52.5 (9.9)
Ls-U1 (mm)	15.0 (2.6)	14.9 (2.7)	15.0 (2.3)	16.0 (3.1)	14.2 (2.6)	16.2 (3.4)
Li-L1 (mm)	14.5 (2.6)	16.5 (3.3)	14.5 (1.9)	15.2 (3.0)	14.6 (1.4)	15.3 (2.5)

Table II. Means and SDs in parentheses of PAR scores and cephalometric measurements.

T3 (β, 5.92; 95% CI, 1.43, 10.41) compared with control, namely, from 98.5° (SD, 8.2) to 102.1° (SD, 6.4). The mandibular incisors in the untreated controls proclined after treatment (mean, 94.9°; SD, 7.2°) and remained stable during the posttreatment period (mean, 94.9°, SD, 6.5°).

Regarding soft tissue measurements, the significant maxillary incisor retraction was not accompanied by equivalent changes either in the upper lip position or the nasolabial angle (Table III). Following the significant treatment effects on L1/ML and L1 to A-Pog, the lower lip appeared significantly more protrusive relative to Sn-Pog' throughout the observation period in the treatment group (β, 1.43; 95% CI, 0.18, 2.67). On the contrary, projection of the labrale inferius was decreased in the matched controls by 0.2 mm from T1 to T2 (at T2, mean, 1.7; SD, 2.4) and from T2 to T3 (at T3, mean, 1.9; SD; 2.0).

Variable	β-coefficient	95 % CI	P value
PAR	-6.73	-10.73, -2.73	0.001*
SNA (°)	1.68	-1.05, 4.40	0.29
SNB (°)	1.10	-1.31, 3.52	0.37
ANB (°)	0.52	-0.77, 1.82	0.43
SN/ANS-PNS (°)	-2.78	-5.18, 0.38	0.02
SN/ML (°)	-2.61	-6.60, 1.39	0.20
ANS-PNS/ML (°)	-0.03	-3.32, 3.26	0.99
ANS-Me/N-Me (ratio)	1.63	0.26, 3.01	0.02*
U1L/ANS-PNS (°)	2.32	-1.87, 6.52	0.28
U1 to A-Pog (mm)	2.31	0.76, 3.87	0.004*
L1L/ML (°)	5.92	1.43, 10.41	0.01*
L1 to A-Pog (mm)	1.34	0.09, 2.59	0.04*
Overbite (mm)	-0.85	-1.76, 0.05	0.06
Overjet (mm)	0.68	-0.21, 1.57	0.14
Nasolabial angle (°)	3.87	-0.42, 8.16	0.08
Ls to Sn-Pog' (mm)	0.23	-0.80, 1.25	0.66
Li to Sn-Pog' (mm)	1.43	0.18, 2.67	0.02*
Ls to E-line (mm)	-0.45	-1.81, 0.91	0.52
Li to E-line (mm)	1.01	-0.41, 2.43	0.16
N-No (mm)	3.97	0.62, 7.33	0.02*
Ls-U1 (mm)	1.12	-0.41, 2.65	0.15
Li-L1 (mm)	1.28	-0.08, 2.64	0.06

Table III. Results of the mixed model analysis (*: P values<0.05).

The ratio ANS-Me/N-Me was significantly increased from T1 to T3 in the treatment group (β, 1.63; 95% CI, 0.26, 3.01) indicating an increase in lower face height that we did not consider clinically significant. Not related to treatment, the nose became significantly more prominent in the treated subjects (β, 3.97; 95% CI, 0.62, 7.33).

Dental Cast Analysis

According to the adjusted model (Figure 3), PAR exhibited a significant decrease with treatment compared with the control group (β, 6.73; 95% CI, -10.73, -2.73). The average PAR score in the treatment group at T1 was 22.1 (SD, 7.2), which was reduced to 2.0 (SD, 2.5) at the end of treatment. PAR reduction for the unilateral molar extraction group exceeded 90%. All but three cases exhibited PAR scores lower than 6 at the follow-up examination. In contrast, there was a mean absolute increase of 1.3 points in the PAR score of the untreated subjects from T1 to T3 (Figure 2).

A

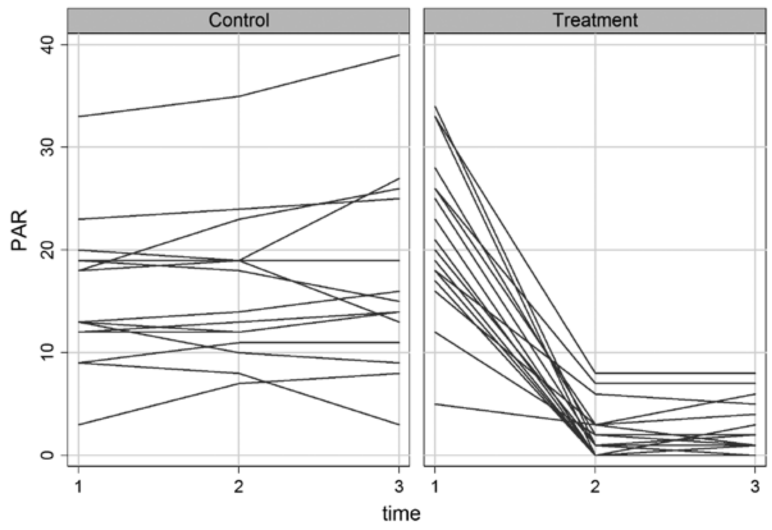

Figure 3A. PAR changes for the treatment and control groups by time point and per individual.

B

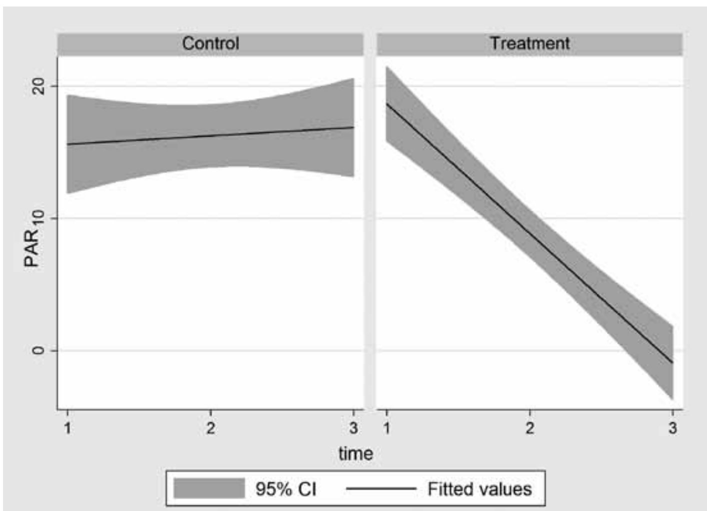

Figure 3B. Fitted PAR changes and associated 95% confidence intervals calculated from the linear mixed model per treatment and control groups.

Midline Asymmetry

Initially, in 13 out of 20 adolescents (65%) from the treatment group, the mandibular midline did not correspond with the facial midline. Both dental midlines deviated in five cases (25%), while the remaining subjects (10%) had a shift of the maxillary midline in relation to the facial midline. After removal of appliances, facial and dental midlines were coincident in nine patients (45%). The maxillary-to-facial midline discrepancy was fully addressed by the therapy in thirteen subjects (65%).

Deviation between maxillary midline to face and between dental midlines ranged between 0.3–2.1 mm and 0.5–1.2 mm, respectively, after treatment. At T2, nine individuals appeared to have midlines perfectly aligned with the face. Midline characteristics of the study group are summarized in Table IV.

	T1		*T2*		*T3*	
Variables	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Maxillary midline to face (mm)	0.4	0.7	0.4	0.7	0.4	0.7
Maxillary to mandibular midline (mm)	1.7	0.9	0.3	0.4	0.4	0.5

Table IV. Summary values (means, SDs) of maxillary midline-face and maxillary-mandibular midline discrepancies.

2.4 DISCUSSION

This is the first clinical study to evaluate long-term changes in Class II subdivision orthodontic patients undergoing unilateral M1 extraction. During the observation period, the maxillary incisors were significantly retracted in the treatment group, whereas comparable changes in lip projection and nasolabial angle did not take place. In contrast, the only previous study on extraction treatment of asymmetrical Class II malocclusion[13] that cephalometrically compared three-premolar with four-premolar extraction protocols showed no significant changes in maxillary incisor displacement between groups immediately after treatment. The great variability in the amount of retraction in the abovementioned study, probably resulting from varying premolar extraction patterns within the groups, might have contributed to the lack of significant differences. Nevertheless, retraction of the upper lip was significantly greater in cases wherein four premolars had been extracted. As pointed out in our results, proper axial inclination of maxillary incisors was maintained during an average retraction of 2.1 mm relative to the A-Pog line, while the upper lip followed on average 66% of the maxillary incisor movement. In contrast, Stalpers and colleagues[14] found that the upper lip moved half the distance in the same direction as the maxillary incisors in cases of bilateral M1 extractions.

In Class II therapy with extraction of two maxillary first premolars, patients exhibited significantly more retruded maxillary central incisors after treatment than those with premolar extractions in both jaws or nonextraction therapy.[15] Yet, the distance between upper and lower lips to the aesthetic line increased highly significantly in all groups regardless of extraction patterns. These investigators noted slight but insignificant increase in the nasolabial angle between the start and end of treatment in all groups. In another two-maxillary-premolar-extraction study, correction of a mean overjet of 8.6 mm was accompanied by significant retraction of the maxillary incisors and labrale superius and an increase in the nasolabial angle.[16] Nonetheless, these authors concluded that the upper lip did not respond uniformly to the distal movement of the maxillary incisors, and therefore potential decrease of lip projection should not be a matter of concern in less severe Class II division 1 malocclusions. In this context, Katsaros,[17,18] based on relatively small changes in the sagittal position of the lips in both extraction and nonextraction patients, claimed that the influence of growth of the chin and nose on the facial profile might be more important than the extractions themselves.

Leveling of the curve of Spee and tooth alignment in treated subjects were accompanied by a significant proclination and protrusion of the mandibular incisors relative to A-Pog and a similar forward movement of the lower lip as measured by the vertical distance from the subnasale-soft tissue-Pog line. These findings are consistent with the changes observed in dental and soft tissue parameters after the extraction of two M1s.[14] Moreover, the resulting forward movement of the mandibular incisors reduced the required amount of maxillary incisor retraction and apparently enhanced aesthetics. Previous analysis of overjet correction with the same low-friction appliances in bilateral M1 extraction cases showed that approximately one-third of the anteroposterior correction was achieved by protrusion of the mandibular incisors.[19]

With reference to the skeletal measurements, we found a statistically significant increase in lower-face vertical dimension in the treated subjects. However, the 0.1%–0.5% increase in the ratio of lower anterior facial height to total anterior facial height between time points can be considered clinically irrelevant. Given that such vertical skeletal increase was not apparent in the controls, it can be assumed that it most likely resulted from orthodontic extrusive mechanics during incisor retraction and use of Class II elastics rather than normal craniofacial growth and development. In line with our results, lower face height increased in camouflage therapy of Class II Division 1 whites having two maxillary first premolars extracted[16,20] and two M1s extracted in the horizontal- and normal-vertical-face height patients.[14]

The statistically significant increase in nose length in the treated subjects may be due to the inclusion of older patients and more males than in the control group. It has been previously demonstrated that essential changes in facial convexity, primarily resulting from an increase in nasal prominence relative to the rest of the soft tissue profile, occur earlier in females (at 10–15 years) than in males (15–25 years).[21]

The M1 extraction cases underwent an average reduction of more than 20 PAR points, whereas the malocclusion was slightly increased in untreated controls. According to PAR conventions, a minimum change in the weighted PAR score of 22 points is required for a case to be classified as 'greatly improved.'[22] Owing to the asymmetrical Class II malocclusion, our study group initially presented only moderate overjet, which diminished the severity of the malocclusion, and did not allow a potentially greater PAR reduction after treatment. Nevertheless, as indicated by the improved occlusal outcomes after treatment, the patients benefited substantially from treatment with M1 extraction.

Similar to past studies on classification of Class II subdivision malocclusion,[13,23] midline asymmetry was most commonly located in the mandibular arch. At T2, maxillary and mandibular midlines were harmonized with the midline of the face in approximately half the subjects. Recent research on smile aesthetics has demonstrated maximum acceptable maxillary midline-to-face discrepancies ranging from 2.9 mm to 3.3 mm.[24–26] Additionally, the limit of acceptability for the maxillary-mandibular midline deviation has been estimated to be between 2.1 mm and 3.6 mm.[24–26] In view of these results, it can be postulated that midline aesthetics was promoted in the treatment group.

Our investigation presents certain shortcomings, mainly related to the sample characteristics. First, it may be argued that the study group included a relatively small number of subjects, which resulted, in some cases, in imprecise estimates as the associated confidence intervals range from clinically significant to nonsignificant effects. Second, to enable discrimination of the treatment outcome from normal growth, we used historical control data representative of the general Dutch population; however, use of historical controls can be problematic. As factors such as living standards, lifestyles, and nutrition change across time periods, the comparability between the historical and contemporary samples might be questionable. For example, differences in the general level of nutrition, texture of foods, frequency of eating events,[27] and infant feeding methods[28] may affect dental arch development. On the other hand, it would have been unethical to recruit controls by deferring treatment until a later time. Prospective comparative studies of M1 extraction with other Class II subdivision treatment approaches may increase our understanding of the management of asymmetrical Class II malocclusion.

2.5 CONCLUSIONS

Unilateral M1 extraction in Class II subdivision malocclusion may yield favourable long-term occlusal outcomes. Posttreatment changes in midline aesthetics and soft tissue profile are considered acceptable.

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CHAPTER 3

INFLUENCE OF UNILATERAL MAXILLARY FIRST MOLAR EXTRACTION ON SECOND AND THIRD MOLAR INCLINATION IN CLASS II SUBDIVISION PATIENTS

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SUMMARY

Introduction: To assess the maxillary second molar (M2) and third molar (M3) inclination following orthodontic treatment of Class II subdivision malocclusion with unilateral maxillary first molar (M1) extraction.

Materials and Methods: Panoramic radiographs of 21 Class II subdivision adolescents (8 boys, 13 girls; mean age, 12.8 years; standard deviation, 1.7 years) before treatment, after treatment with extraction of one maxillary first molar and Begg appliances and after at least 1.8 years in retention were retrospectively collected from a private practice. M2 and M3 inclination angles (M2/ITP, M2/IOP, M3/ITP, M3/IOP), constructed by intertuberosity (ITP) and interorbital planes (IOP), were calculated for the extracted and nonextracted segments. Random effects regression analysis was performed to evaluate the effect on the molar angulation of extraction, time, and gender after adjusting for baseline measurements.

Results: Time and extraction status were significant predictors for M2 angulation. M2/ITP and M2/IOP decreased by 4.04° (95% confidence interval [CI]: -6.93, -1.16; P = 0.001) and 3.67° (95% CI: -6.76, -0.58; P = 0.020) in the extraction group compared to the nonextraction group after adjusting for time and gender. The adjusted analysis showed that extraction was the only predictor for M3 angulation that reached statistical significance. M3 mesial inclination increased by 7.38° (95% CI: -11.2, -3.54; P < 0.001) and 7.33° (95% CI: -11.48, -3.19; P = 0.001).

Conclusions: M2 and M3 uprighting significantly improved in the extraction side after orthodontic treatment with unilateral maxillary M1 extraction. There was a significant increase in mesial tipping of maxillary second molar crowns over time.

3.1 INTRODUCTION

The prognosis of the third molar (M3) eruption is one of the clinical issues encountered by orthodontists while treating adolescents. M3 impaction represents the most common tooth impaction in contemporary populations.[1] Controversies have been reported with regard to the incidence of M3 impaction related to gender, ethnicity, and location.[2] There is evidence that factors such as vertical growth pattern, reduced mandibular length, molar axial inclination, and delayed maturation may influence the likelihood of M3 eruption.[3,4] Overall, impacted maxillary third molars do not remain static; however, their position over time may be considered unpredictable, as indicated by the limited longitudinal data.[5]

In theory, extraction of posterior teeth followed by orthodontic mesialization of the buccal segments may enhance the mesioangular inclination, and therefore the eruption status, of M3s. Orthodontic treatment involving extraction of two maxillary first premolars,[6] four first premolars,[7] or four first molars[8] resulted in significant improvement in the developing M3 position compared to nonextraction therapy. Other researchers observed no significant differences on the final M3 angulation between subjects orthodontically treated with either first premolar extraction and nonextraction[1,9] or first premolar and second molar (M2) extractions.[10]

To date, M3 mesiodistal angulation after asymmetric extraction has been scarcely subjected to investigation.[11,12] A retrospective study[12] of spontaneous positional changes in mandibular M3s after unilateral mandibular first molar (M1) extraction for non-orthodontic purposes demonstrated improved positions of the M3s. Furthermore, in an asymmetric extraction subgroup of orthodontic patients undergoing maxillary M2 extractions, the eruption rate of third molars was accelerated on the extraction side.[11]

The objective of this study was to determine the posttreatment angulation changes of maxillary second and third molars in a sample of Class II subdivision adolescents treated with unilateral maxillary M1 extraction and fixed orthodontic appliances.

3.2 MATERIALS AND METHODS

A sample of 21 Class II subdivision adolescents (8 boys, 13 girls; mean age, 12.8 years; SD, 1.7 years) consecutively treated with unilateral extraction of a maxillary M1 and Begg technique was retrospectively collected from the archives of a private practice in Gorinchem, The Netherlands.[13-15] The rest of the inclusion criteria were as follows: whites; Class II ≥ 1/2 premolar width molar occlusion on one buccal segment and Class I on the contralateral segment; up to mild crowding in the mandibular arch; full complement of permanent teeth; and panoramic radiographs of good quality obtained pretreatment (T1), posttreatment (T2), and at a minimum follow-up period (T3) of 1.8 years (mean follow-up, 2.6 years; SD, 1.0 years) (Table I). The right maxillary M1 was extracted in 14 subjects, whereas the left M1 was extracted in seven of the cases. The nonextraction side served as the control.

	Males (n=8)	*Females (n=13)*
Age T1	13.2 (0.8)	12.6 (2.0)
Age T2	15.5 (1.0)	14.8 (2.1)
Age T3	17.5 (1.0)	17.8 (2.4)
T2-T1	2.2 (0.4)	
T3-T2	2.6 (1.0)	

Table I. Age of subjects and time intervals in years (means, SDs in parentheses), T1 indicates pretreatment; T2, posttreatment; and T3, minimum follow-up period.

Scanning of the panoramic radiographs (Epson Expression 1680 Pro, Suwa, Nagano, Japan; resolution of 600 dpi) and digitization of landmarks by means of specialized software (Viewbox 3.0; dHAL Software, Kifissia, Greece) were performed by the first author. The landmarks, reference planes, and angular measurements[6] used for the study are displayed in Figure 1. Molar inclination was estimated using the following angles: M2/IOP, the angle between the M2 long axis and the interorbital plane (IOP); M3/IOP, the angle between the M3 long axis and the IOP; M2/ITP, the angle between the M2 long axis and the inter-tuberosity plane (ITP); M3/ITP, the angle between the M3 long axis and the ITP (Figure 1). Given the stage of the root development, the most apical point visible on the panoramic radiograph was selected as the midpoint of the root apex. To determine intraobserver agreement, 14 randomly selected sets of variables were remeasured 2 weeks after the initial assessment.

Statistical Analysis

Means and SDs were estimated for all four molar angular measurements. The intraclass correlation coefficient (ICC) was calculated to assess intraobserver reliability. The Pearson's correlation coefficient (r) was calculated between the two different plane-defined measurements. Random effects regression analysis was implemented in order to assess the effect on the molar angulation of extraction, time, and gender after adjusting for baseline measurements. A 0.05 level of significance was used to determine statistically significant effects. Statistical analysis was carried out with the STATA statistical software package (STATA® 13, Stata Corporation, College Station, Tx, US).

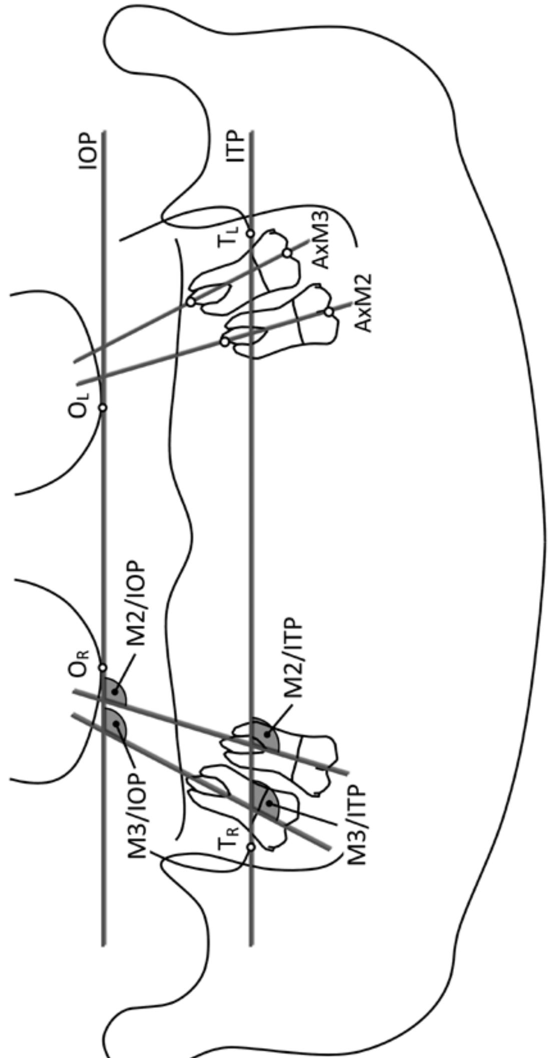

Figure 1. Landmarks: Right orbital (OR) indicates most inferior point of the right orbital cavity; left orbital (OL), most inferior point of the left orbital cavity; right tuberosity (TR), most inferior point of the right maxillary tuberosity; and left tuberosity (TL), most inferior point of the left maxillary tuberosity. Reference planes: interorbital plane (IOP), plane defined by OR and OL; intertuberosity plane (ITP), plane defined by TR and TL; AxM2, AxM3: M2 and M3 long axes constructed by the midpoints of the occlusal surfaces and root apexes of the molars. M2 and M3 inclination angles: M2/IOP, M3/IOP, M2/ITP, and M3/ITP.

3.3 RESULTS

The ICC values ranged from 0.95 to 0.97 for all angular variables, reflecting excellent intraobserver reliability. All measurements conducted using both planes were highly correlated (r = 0.99–1.00).

Descriptive statistics (means, SDs) are summarized in Table I. Means and SDs of the measured angular variables are presented for the extraction and nonextraction sides in Table II.

All molar measurements exhibited increasingly improved mesial inclination (ie, smaller angular values between T1–T2) regardless of whether teeth had been extracted or not. This tendency for an increase in the mesial tipping of the molar crowns was more evident in the segments in which the M1 had been extracted (Figure 2).

The statistical analysis (Table III) indicated that for M2 angulations both extraction and time were significant predictors of the final outcome, whereas gender was not. In more detail, for M2/ITP and M2/IOP there was a decrease of 4.04° in the extraction group (95% CI: -6.93,-1.16; P = 0.001) and of 3.67° (95% CI: -6.76, -0.58; P = 0.020), respectively, compared to the nonextraction group, after adjusting for time and gender.

The adjusted analysis also showed that extraction was the only predictor for the angulation of maxillary third molars related to the intertuberosity and interorbital planes that reached statistical significance. M3 mesial inclination increased by 7.38° (95% CI: -11.22, -3.54; P < 0.001) and 7.33° (95% CI: -11.48, -3.19; P = 0.001). There was evi-

	T1		*T2*		*T3*	
Variable	*Extraction*	*Nonextraction*	*Extraction*	*Nonextraction*	*Extraction*	*Nonextraction*
M2/IOP (°)	113.3 (7.3)	114.3 (7.3)	105.2 (8.4)	108.5 (8.0)	101.1 (7.9)	105.9 (10.0)
M3/IOP (°)	126.5 (13.7)	123.2 (11.1)	107.7 (11.3)	117.2 (11.9)	107.3 (8.6)	112.7 (13.5)
M2/ITP (°)	113.6 (7.4)	114.0 (7.1)	105.2 (8.3)	108.7 (7.7)	101.0 (7.6)	105.9 (9.6)
M3/ITP (°)	126.8 (13.8)	122.9 (10.9)	107.6 (10.5)	117.3 (11.5)	107.2 (8.8)	112.7 (12.9)
	T2-T1		T3-T2		T3-T1	
M2/IOP (°)	-8.1 (12.0)	-5.7 (7.4)	-4.1 (8.5)	-2.7 (6.4)	-12.3 (9.9)	-8.4 (8.0)
M3/IOP (°)	-18.8 (17.3)	-6.0 (16.5)	-0.4 (11.3)	-4.5 (10.2)	-19.3 (16.0)	-10.5 (15.0)
M2/ITP (°)	-8.4 (11.5)	-5.4 (7.7)	-4.1 (8.2)	-2.7 (6.8)	-12.6 (9.4)	-8.1 (7.8)
M3/ITP (°)	-19.2 (16.9)	-5.6 (16.3)	-0.4 (10.6)	-4.6 (10.2)	-19.6 (16.6)	-10.2 (14.6)

Table II. Means and SDs of the angular measurements for the extraction (n=21) and nonextraction (n=21) sides, T1 indicates pretreatment; T2, posttreatment; T3, minimum follow-up period; M2, second molar; M3, third molar; ITP, intertuberosity; and IOP, interorbital planes.

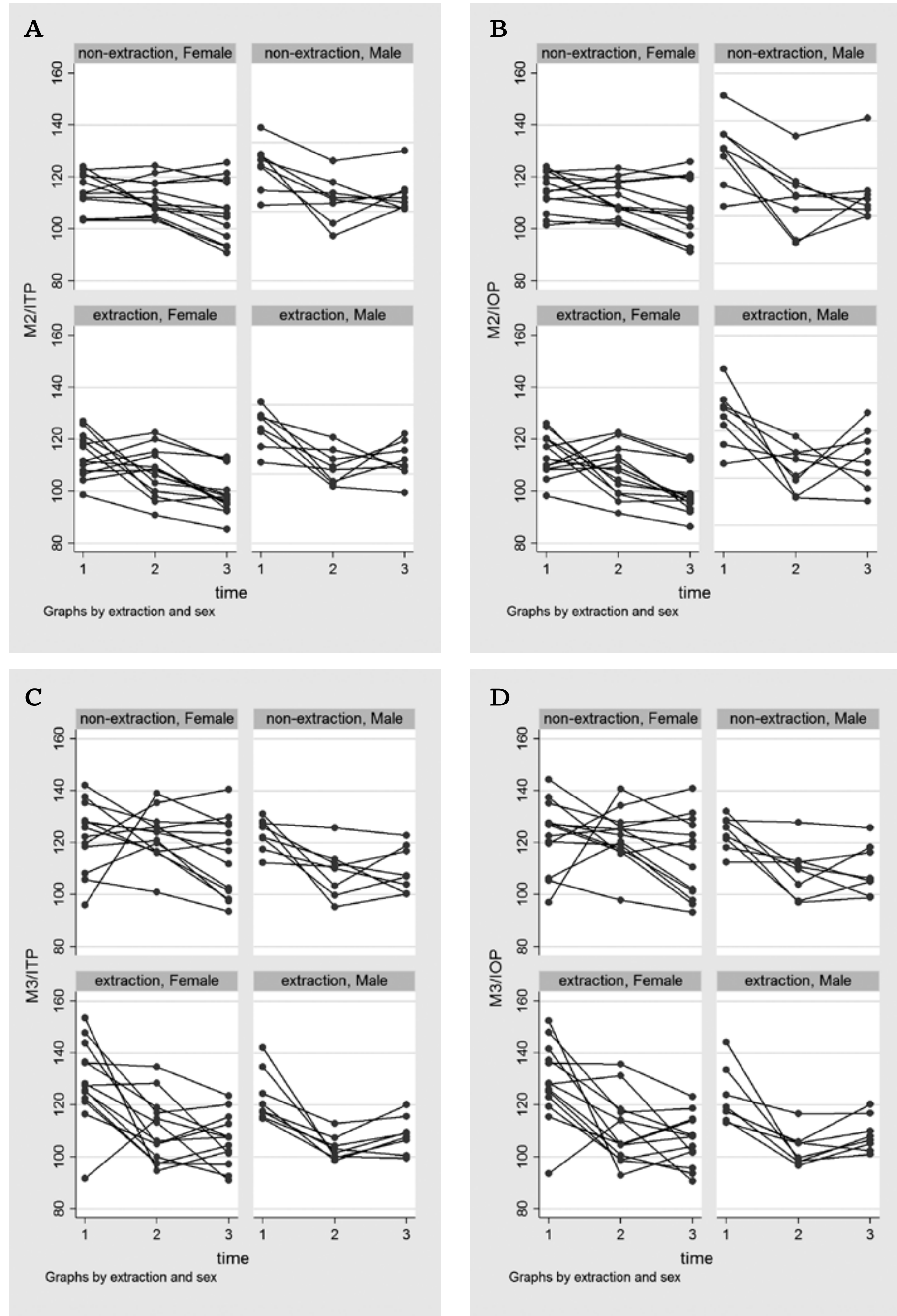

Figure 2. Angulation changes of second and third molars by extraction-nonextraction group, sex, and time point per patient (A: M2/ITP; B: M2/IOP; C: M3/ITP; and D: M3/IOP).

dence that gender was associated with third molar angulations; however, this difference did not reach statistical significance at the 5% level. Age appeared similar among treatment groups and was not found to be a significant predictor, and, therefore, it was not included in the final analysis.

3.4 DISCUSSION

Our study shows that maxillary second and third molars moved to more favourable positions after treatment regardless of the M1 extraction. These M3 angulation findings are in line with comparative studies[1,9] of samples treated with first premolar extraction and nonextraction approaches. However, maxillary second molars in the extraction side became 1.4–1.6 times more upright than the contralateral teeth at T2, whereas the mesial inclination of maxillary third molars increased by 3.1–3.4 times. Likewise, bilateral M1 extraction and fixed orthodontic treatment with Begg appliances in Class II Division 1 patients led to a fourfold uprighting of maxillary third molars in comparison to nonextraction controls.[16] On the other hand, Class II individuals treated with two maxillary first premolar extractions demonstrated a double increase in the mesial inclination of maxillary third molars compared with those treated via the nonextraction route.[6] In extraction treatment planning (premolars or molars), differences in the intra-arch location of the extraction site and in the amount of tooth mass removed should be considered.[6] The closer the position of the extracted tooth to the maxillary third molar, the more influential will be the extraction on the M3 development.[17] In this context, molar extraction protocols may produce more favourable conditions for M3 uprighting than do premolar extractions. Nevertheless, the available eruption space may be drastically reduced during orthodontic management of severe Class II malocclusion and crowded cases.

Based on the regression analysis results, improved inclinations of maxillary second and third molars may be expected after Class II subdivision treatment with a single M1 extraction. In addition to this, time was a significant predictor for second molar angulation. Thus, maxillary second molars involved in fixed orthodontic treatment of asymmetric Class II malocclusion are likely to present smaller inclination angles over time, notwithstanding whether or not the maxillary first molars are extracted in one segment.

Direct comparison of published studies on the effect of orthodontic extractions on M3 eruption may not be feasible as a result of methodological issues such as lack of control groups,[11,18–21] unclear definition of malocclusion, discrepancies in anchorage requirements, mixed extraction protocols,[11,21,22] examination of radiographic records other than panoramic radiographs, [11,15,21] or inclusion of linear rather than angular measurements.[8,11,21]

M2/ITP		*Coefficient*	*P value*	*95% CI*
Time		-3.42	0.020	-6.30, -0.54
M2/ITP (T1)		0.42	0.002	0.15, 0.69
Gender				
	Female	Reference		
	Male	-2.20	0.330	-6.63, 2.23
Extraction				
	No	Reference		
	Yes	-4.04	0.006	-6.93, -1.16
M2/IOP		*Coefficient*	*P value*	*95% CI*
Time		-3.42	0.029	-6.50, -0.35
M2/IOP (T1)		0.40	0.004	0.13, 0.68
Gender				
	Female	Reference		
	Male	-2.20	0.328	-6.61, 2.21
Extraction				
	No	Reference		
	Yes	-3.67	0.020	-6.76, -0.58
M3/ITP		*Coefficient*	*P value*	*95% CI*
Time		-2.48	0.197	-6.25, 1.28
M3/ITP (T1)		-0.06	0.535	-0.26, 0.13
Gender				
	Female	Reference		
	Male	-6.03	0.063	-12.39, 0.34
Extraction				
	No	Reference		
	Yes	-7.38	<0.001	-11.22, -3.54
M3/IOP		*Coefficient*	*P value*	*95% CI*
Time		-2.47	0.237	-6.55, 1.62
M3/IOP (T1)		-0.04	0.733	-0.24, 0.17
Gender				
	Female	Reference		
	Male	-5.96	0.063	-12.24, 0.32
Extraction				
	No	Reference		
	Yes	-7.33	0.001	-11.48, -3.19

Table III. Coefficients, associated confidence intervals (95% CIs), and P values from the random effects analysis for second and third molars; M2/ITP (T1), M2/IOP (T1), M3/ITP (T1), M3/IOP (T1), baseline values of M2 and M3 Inclination, T1 indicates pretreatment; M2, second molar; M3, third molar; ITP, intertuberosity; and IOP, interorbital planes.

Use of consistently identifiable reference landmarks is a matter of concern in consecutive measurements. Jain and Valiathan[7] defined angulation of mandibular second and third molars in relation to a horizontal palatal plane constructed from the anterior nasal spine and the nasal spectrum. However, these authors omitted assessment of the reproducibility in terms of locating the definition landmarks. Others[1,8–10,12,20] used the occlusal plane to measure tooth inclination changes, in spite of its reliance on treatment mechanics. In our study, we selected instead two horizontal references planes based on skeletal structures, of which the repeatability had been validated by previous research.[6] Despite the high correlation between the measurements defined by the two planes, we decided to use both types to increase measurement validity.

We aimed to measure on orthopantomograms molar angular changes in the sagittal plane following extraction of a maxillary M1 and orthodontics. However, variations of the molar position in the buccolingual direction or rotations around the tooth long axis could not be considered because of the inherent panoramic image distortions.[23–26] Increased buccal root may resemble distal tipping, while increased lingual root torque may appear as more mesial tipping on panoramic radiographs.[26] Therefore, the use of panoramic images to assess root angulation should be approached with extreme caution and understanding of the technical limitations. In this sense, rotated, buccally or lingually displaced molars may need to undergo a second short fixed appliance treatment to obtain proper occlusal contacts.

Another point of discussion may be related to the length of the observation period. Our follow-up did not extend beyond the expected eruption time of maxillary third molars, and, thus, the actual improvement in M3 position might have been underestimated. A second follow-up study may yield more useful conclusions on the treatment effect on the eruption success of maxillary third molars.

To our knowledge, this is the first study of split-mouth design to examine the influence of asymmetric maxillary M1 extraction on the axial inclination of adjacent molars. The split-mouth design reduces interindividual variability from estimates of the treatment effect, and therefore may be considered advantageous.[27]

3.5 CONCLUSIONS

- Orthodontic treatment with unilateral maxillary M1 extraction resulted in a significant increase in the mesial inclination of maxillary second and third molars.
- Maxillary second molar crowns significantly tipped over time on both extraction and nonextraction sides.

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CHAPTER 4

EXTRACTION OF MAXILLARY FIRST MOLARS IMPROVES SECOND AND THIRD MOLAR INCLINATIONS

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SUMMARY

Introduction: The aim of this study was to assess the changes in inclination of the maxillary second (M2s) and third (M3s) molars after orthodontic treatment of Class II Division 1 malocclusion with extraction of maxillary first molars.

Methods: Two groups of subjects were studied. The experimental group consisted of 37 subjects, 18 boys and 19 girls (mean age, 13.2 ± 1.62 years). The inclusion criteria were white origin, Class II Division 1 malocclusion, overjet ≥4 mm, no missing teeth or agenesis, and maxillary M3s present. All patients were treated with extraction of the maxillary first molars and the Begg technique. Standardized lateral cephalometric radiographs were taken at the start of active treatment (T1) and at least 3.7 years posttreatment (T2). The control group was drawn from the archives of the Nittedal Growth Material (Oslo University, Oslo, Norway) and included 54 untreated Class I and Class II subjects,18 boys and 36 girls (mean age, 13.4 ± 1.99 years) followed up for a minimum of 3.6 years. M2 and M3 inclinations relative to the palatal plane (PP) and functional occlusal plane (FOP) were measured and compared between groups and time periods.

Results: M2 to PP inclination improved significantly in both the control group (M2-PP at T1, 17.7° ± 5.81°, and at T2, 11.9° ± 4.61°) and the experimental group (M2-PP at T1, 26.7° ± 5.75°, and at T2, 6.9° ± 6.76°). There were also significant increases of the mesial inclination of M3s in the control group (M3-PP at T1, 30.1° ± 8.54°, and at T2, 19.6° ± 9.01°) and extraction group (M3-PP at T1, 32.2° ± 7.90°, and at T2, 12.8° ± 7.36°). By using the FOP as the reference system, no significant change in the inclination of M2s was observed in the control group, whereas, in the extraction group, although more distally inclined at T1, M2s ended up mesially inclined at T2 (M2-FOP at T1, 14.2° ± 4.62°, and at T2, -6.2° ± 6.10°; $P<0.0001$). M3 inclinations were similar between the groups at T1 (M3-FOP control, 17.3° ± 9.35°; M3-FOP experimental, 19.6° ± 7.37°), and these improved significantly in both groups. However, M3 uprighting was almost 4 times greater in the extraction group (M3-FOP from T2-T1, 5.6° vs 19.3°). The greatest distal inclination of M3s at T2 in the extraction group was 9.4°, a value attained by only 43% of the control group.

Conclusions: Extraction of the maxillary first molars in Class II Division 1 patients results in significant uprighting of M2s and M3s and facilitates the normal eruption of M3s.

4.1 INTRODUCTION

Extraction of maxillary first permanent molars (M1s) is an available treatment option for patients with Class II malocclusion with an increased overjet and a fairly well-aligned mandibular arch. Indications may include teeth affected by caries or periodontitis, with extensive restorations and questionable long-term prognosis. It is still controversial whether high-angle individuals would benefit from extractions in the posterior part of the buccal segments.[1-3] It is also argued that the particular extraction pattern will have a less flattening effect on the facial profile.[4] In addition to this, extracting posterior teeth can be advantageous with regard to the inclination of the third molars.[5]

A recent study in Class II Division 1 patients treated with extraction of maxillary first molars and fixed appliances demonstrated good treatment outcomes with a minor retrusive effect on the facial profiles[6]. These investigators could not attribute to this treatment method a clinically significant bite-closing effect. Booij et al[7] termed this treatment modality a 'less-compliance therapy' data underlying the relatively diminished dependence on patient cooperation.

So far, few authors have investigated third molar changes after tooth extractions, solely or combined with orthodontic treatment. Most of them dealt with second molar extractions,[8-12] first premolar extractions (in the maxillary arch,[13] or the maxillary and mandibular arches[14-17]), or unilateral extractions of the mandibular first molar.[18] In the single study that evaluated the extraction of all 4 first permanent molars, a favourable effect on the inclination of third molars was documented.[5] The aim of this study was to assess the change of inclination of maxillary second (M2s) and third (M3s) molars after orthodontic treatment of Class II Division I malocclusion with extraction of the M1s.

4.2 MATERIALS AND METHODS

The study group consisted of 37 subjects (18 boys, 19 girls; mean age, 13.2 years; SD, 1.62 years) consecutively with the Begg technique by 1 orthodontist (J.W.B.). The inclusion criteria for the initial enrollment were white patients, Class II Division 1 malocclusion, sagittal overjet of ≥4 mm, treatment plan including extraction of the M1s, no missing teeth or agenesis, M3s present, and 1-stage full fixed appliance treatment. Standardized lateral cephalometric radiographs on the same radiographic unit (Trophy OL 100, Trophy Radiologie, Vincennes, France) were available at the start of active treatment (T1) and at least 3.7 years posttreatment (T2).

The control group consisted of untreated Class I and Class II subjects (18 boys, 36 girls; mean age, 13.4 years; SD, 1.99 years) followed for a minimum of 3.6 years. The subjects were drawn from the archives of the Nittedal Growth Material, a longitudinal study conducted by the Department of Orthodontics, University of Oslo, and described in detail in previous articles.[19, 20] The data was collected within a 20-year period from children called for dental examination at 6 years, and afterwards every three years till the age of 21. Radiographic records of poor quality were excluded from the study material. Table I shows the means and standard deviations for ages and observation periods for all groups.

		Age (y)		*Observation period T2-T1 (y)*	
Group	*n*	*Mean*	*SD*	*Mean*	*SD*
Experimental (boys)	18	13.2	1.27	5.0	1.00
Experimental (girls)	19	13.1	1.93	4.9	1.18
Control (boys)	18	13.4	2.11	5.9	2.32
Control (girls)	36	13.4	1.96	5.4	1.80

Table I. Descriptive statistics of the experimental and control groups.

All lateral headfilms were scanned and digitized by one investigator (C.L.) using cephalometric analysis software (Viewbox 3.0; dHAL Software, Kifissia, Greece).

The landmarks traced on each lateral headfilm are summarized in Figure 1.

A number of skeletal and dental points were digitized for the definition of measurements necessary to evaluate the subjects' molar inclinations and craniofacial patterns.

Molar inclination was assessed by the following angles (Figure 2): M2-PP, the angle between the occlusal surface of M2 (M2OS) and the palatal plane; M2-FOP, the angle between the M2OS and the functional occlusal plane; M3-PP: the angle between the occlusal surface of M3 (M3OS) and the PP; and M3-FOP: the angle between the M3OS and the FOP.

Statistical analysis

The data was analyzed with the StatsDirect statistical software (version 2.7.2; StatsDirect, Cheshire, UK). Nonparametric tests were performed to evaluate the changes between T1 and T2. The reproducibility of the measurements was assessed by statistical analyses of the differences between double measurements of 20 randomly selected and traced radiographs by the same investigator 2 weeks after the initial series of measurements.

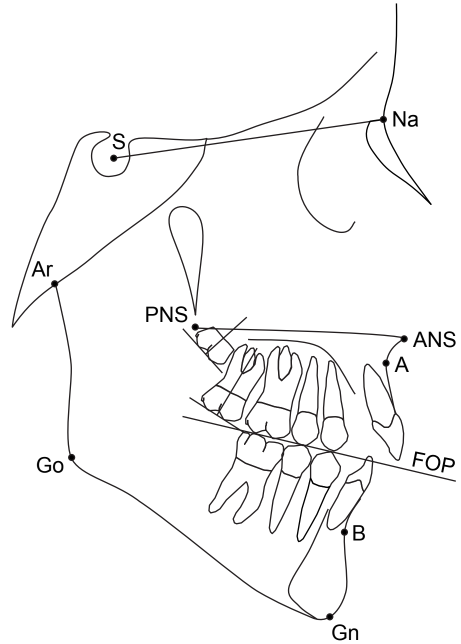

Figure 1. Cephalometric points and reference planes used in the study.

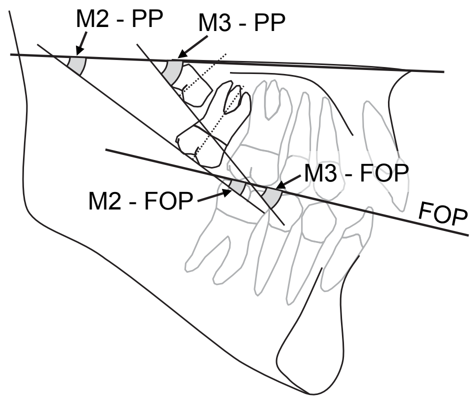

Figure 2. Angular measurements used for evaluation of inclination of M2s and M3s.

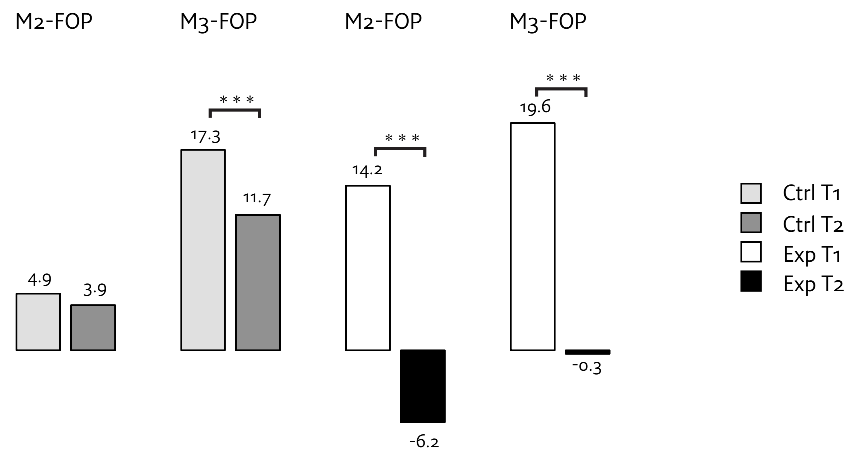

Figure 3. Inclination measurements in relation to the FOP (*Exp*, Experimental; *Ctrl*, Control). *Asterisk bars* denote statistically significant changes at $P<0.001$.

4.3 RESULTS

Random error was calculated according to Houston.[21] Errors ranged from 3.21° (M2-PP) to 4.78° (M3-PP). Paired t-tests did not show any systematic error between the 2 measurements ($P>0.05$).

The measurements were tested for normality of distribution and equality of variance (F test). For some variables, the F test was significant; therefore, it was decided to apply more robust nonparametric methods (Mann-Whitney and Wilcoxon signed ranks) for intergroup comparisons.

Comparison of T1 skeletal values of control and experimental boys revealed significant differences for the angles SNB, ANB, PP-MP. The female groups displayed significant differences in the angular measurements ANB, PP-SN, PP-MP, Ar-Go-Gn. It generally seemed that the experimental subjects were more retrognathic and hyperdivergent than were the controls (Table II).

The average molar angular values and standard deviations of the experimental and control groups are presented in Table III. There were statistically significant differences in the angles M2-PP, M2-FOP between experimental and control groups for both males and females at T1. The measurements for the M3s between groups at T1 did not differ significantly. However, all groups showed significant differences in all measurements at T2.

	Boys			Girls		
Measurement	*Ctrl (n=18)*	*Exp (n=18)*	*95% CI*	*Ctrl (n=19)*	*Exp (n=36)*	*95% CI*
SNA (°)	83.7 (2.53)	81.1 (4.47)	-6.29 to -2.14	82.2 (3.47)	83.6 (4.47)	83.6 (4.47)
SNB (°)	80.3 (2.54)	76.0 (3.84)	-4.97 to 0.21 ***	78.2 (2.53)	77.2 (4.17)	77.2 (4.17)
ANB (°)	3.3 (3.02)	5.2 (1.94)	0.03 to 3.66 *	4.0 (2.04)	6.3 (2.11)	6.3 (2.11)
PP-SN (°)	8.2 (3.70)	6.7 (4.13)	4.67 to 1.01	8.1 (3.01)	5.9 (3.52)	5.9 (3.52)
PP-MP (°)	19.8 (6.39)	26.2 (2.81)	3.53 to 10.27 **	20.7 (4.11)	26.9 (4.80)	26.9 (4.80)
Ar-Go-Gn (°)	125.6 (5.90)	124.5 (6.26)	-4.99 to 2.69	124.1 (5.36)	125.4 (4.03)	125.4 (4.03)

Ctrl, Control group; *Exp*, experimental group

*$P<0.05$; **$P<0.01$; ***$P<0.001$

Table II. Means (SDs) of skeletal measurement at T1 and 95% CI of intergroup differences (Mann-Whitney U test).

Measurement	Boys			Girls		
T1	*Ctrl (n=18)*	*Exp (n=18)*	*95% CI*	*Ctrl (n=36)*	*Exp (n=19)*	*95% CI*
M2-PP	17.1 (7.13)	26.5 (5.15)	4.33 to 13.67 ***	18.1 (5.12)	27.0 (6.40)	5.62 to 12.68 ***
M2-FOP	4.4 (5.99)	14.4 (4.77)	6.37 to 13.57 ***	5.2 (5.96)	13.9 (4.58)	5.66 to 12.34 ***
M3-PP	29.6 (7.87)	32.5 (8.57)	-2.27 to 8.92	30.3 (8.94)	31.8 (7.42)	3.09 to 6.37
M3-FOP	16.9 (7.13)	20.5 (8.31)	-2.76 to 9.64	17.5 (9.94)	18.8 (6.48)	-2.46 to 5.18
Measurement	*Boys*			*Girls*		
T2	*Ctrl (n=18)*	*Exp (n=18)*	*95% CI*	*Ctrl (n=36)*	*Exp (n=19)*	*95% CI*
M2-PP	11.4 (5.16)	6.2 (5.99)	-8.75 to -1.87 **	12.1 (4.37)	7.6 (7.51)	-7.20 to -0.87 *
M2-FOP	2.7 (4.35)	-5.2 (5.06)	-10.90 to -4.22 ***	4.5 (4.71)	-7.1 (6.96)	-14.12 to -8.30 ***
M3-PP	19.6 (9.70)	11.2 (6.73)	-13.16 to -2.38 **	19.7 (8.79)	14.3 (7.79)	-10.66 to-0.83 *
M3-FOP	10.9 (11.28)	-0.2 (6.54)	-16.13 to -4.88 ***	12.1 (10.01)	-0.4 (7.19)	-17.87 to -7.99 ***

Ctrl, Control group; *Exp*, experimental group

*P<0.05; **P<0.01; ***P<0.001

Table III. Means (SDs) of dental measurement at T1 and T2, and 95% CI of intergroup differences (Mann-Whitney U test).

Measurement	*T1*	*T2*	*95% CI*
	Ctrl (n=54)		
M2-PP	17.7 (5.81)	11.9 (4.61)	4.21 to 7.39 ***
M2-FOP	4.9 (5.94)	3.9 (4.63)	-0.83 to 2.76
M3-PP	30.1 (8.54)	19.6 (9.01)	7.93 to 13.00 ***
M3-FOP	17.3 (9.35)	11.7 (10.36)	3.15 to 8.13 ***
	Exp (n=37)		
M2-PP	26.7 (5.75)	6.9 (6.76)	17.37 to 22.72 ***
M2-FOP	14.2 (4.62)	-6.2 (6.10)	17.68 to 22.98 ***
M3-PP	32.2 (7.90)	12.8 (7.36)	16.62 to 22.30 ***
M3-FOP	19.6 (7.37)	0.3 (6.79)	16.68 to 23.23 ***

Ctrl, Control group; *Exp*, Experimental group

***P<0.001

Table IV. Means (SDs) of dental measurements and 95% CI of intergroup differences (Mann-Whitney U-test) in the pooled groups.

No significant differences were found between the sexes for any of the dental measurements. To prevent clutter, we compared the molar inclinations at T1 and T2 by combing the sexes, presenting the results in Table IV. Despite the more upright positions of M2s and M3s in the control group, there were greater improvements in the molar angulations in the experimental group.

Regarding the measurements based on the PP, M2 and M3 inclinations improved significantly in both control and extraction groups (Table IV). However, the increase of mesial inclination of M2s and M3s was 3.4 and 1.8 times greater, respectively, in the extraction group (M2-PP from T2-T1: 5.8° vs 19.8°; M3-PP from T2-T1: 10.5° vs 19.4°).

The results for the measurements related to the FOP are shown in Figure 3. In the control group, there was no significant change in the initial distal inclination of M2s, whereas, in the extraction group, although more distally inclined at T1, M2s ended up mesially inclined at T2 (M2-FOP: T1: 14.2 ± 4.62°, T2: -6.2 ± 6.10°; P<0.0001). M3 inclinations were similar between groups at T1, (M3-FOP control, 17.3 ± 9.35°; M3-FOP experimental, 19.6 ± 7.37°) and improved significantly in both groups; however M3 uprighting was almost 4 times larger in the extraction group (M3-FOP from T2-T1, 5.6° vs 19.3°).

4.4 DISCUSSION

This is, to our knowledge, the first study to investigate the effect of M1 extractions on the inclinations of M2s and M3s in orthodontically treated patients, in comparison to non-orthodontic patients.

We decided not to use panoramic images because of the inbuilt distortion effect of the rotational panoramic radiography[22] and the less reliable angular measurements when compared with those on lateral cephalograms.[23] The use of cephalometric films also enables evaluation of the axial inclination of teeth in relation to skeletal planes that are regularly used for cephalometric analysis. The superimposition of bilateral structures was addressed by drawing the average outline of the right and left images.

The potential change of the FOP angulation during treatment was considered, and that was the reason for additionally using the PP for evaluation of molar inclination. Results from both reference systems are presented and led to similar conclusions. However, we have stressed the FOP-related results because the functional significance of molar inclination pertains to the occlusal plane rather than to the PP.

The shortcomings of our investigation basically derive from the characteristics of the selected controls. The ideal control group would include subjects of similar age, sex, origin, nationality and craniofacial pattern. Because of the retrospective nature of the study, we had to compromise with radiographic data collected for past research purposes, and consequently apply less strict criteria for group selection. However, we were able to closely match the control to the experimental group by age. We did our best to match groups by sex, and this is reflected by the number of participants in each group. For the control girls, the availability of age-matched subjects permitted the inclusion of double the number of participants in relation to treated girls.

Statistical tests confirmed differences in the skeletal measurements between the experimental and control groups at T1. Our experimental group was similar to study groups of German and Icelandic origin presented in other studies.[24-26] Although our experimental group comprised more high-angle subjects than did the control group, there was greater improvement in molar inclination. This outcome was contrary to what might have been expected from the findings of Breik and Grubor,[27] whose hypodivergent subjects demonstrated an almost 2 times lower incidence of mandibular third molar impaction compared with hyperdivergent subjects.

Unpredictable changes in the position and angulation of third molars tend to occur over the years. In a panoramic radiographic study of the positional changes of unerupted third molars in nonorthodontic patients (young adults), Sandhu and Kaur[28] recorded a 24% percentage of molars erupted to the occlusal plane. Interestingly enough, 20% of our control and 54% of the experimental M3s erupted good inclinations relative to the FOP (-6°<M3-FOP<6°).

Dachi and Howell[29] on a survey of 3,874 full-mouth radiographs, reported a 29.9% incidence of M3 impaction in the general population. In orthodontic patient samples managed with extraction of M1s[5] or M2s[9, 11] and fixed appliances, the percentage of 'successful' M3 eruptions were between 96% and 100%. All M3s from our experimental group erupted to a good position. Still, direct comparison with the aforementioned eruption rates cannot be made because of differences in the definition of 'success' and use of panoramic rather than cephalometric images.

When it is necessary to extract teeth in the orthodontic treatment of patients with Class II maloclussion, it is common practice to choose either the 2- or 4-premolar extraction regimen and under special circumstances the maxillary molar extraction. In such cases, our investigation confirms the positive influence of first molar extraction on the angulation of M2s and M3s.

4.5 CONCLUSION

The findings of this study suggest that orthodontic treatment with extraction of M1s results in significant improvement of the position of the M2s and M3s. In this case, normal eruption of the M3s can be expected to be highly likely.

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CHAPTER 5

MAXILLARY SINUS FLOOR EXTENSION AND POSTERIOR TOOTH INCLINATION IN ADOLESCENT PATIENTS WITH CLASS II DIVISION 1 MALOCCLUSION TREATED WITH MAXILLARY FIRST MOLAR EXTRACTIONS

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SUMMARY

Introduction: Our objective was to investigate potential associations between maxillary sinus floor extension and inclination of maxillary second premolars and second molars in patients with Class II Division 1 malocclusion whose orthodontic treatment included maxillary first molar extractions.

Materials and Methods: The records of 37 patients (18 boys, 19 girls; mean age, 13.2 years; SD, 1.62 years), treated between 1998 and 2004 by 1 orthodontist with full Begg appliances were used in this study. Inclusion criteria were: white patients with Class II Division 1 malocclusion, sagittal overjet of ≥4 mm, treatment plan including extraction of the maxillary first permanent molars, no missing teeth, and no agenesis. Maxillary posterior tooth inclination and lower maxillary sinus area in relation to the palatal plane were measured on lateral cephalograms at 3 time points: at the start and end of treatment, and on average 2.5 years posttreatment. Data was analyzed for the second premolar and second molar inclinations by using mixed linear models.

Results: The analysis showed that the second molar inclination angle decreased by 7° after orthodontic treatment, compared with pretreatment values, and by 11.5° at the latest follow-up, compared with pretreatment. There was evidence that maxillary sinus volume was negatively correlated with second molar inclination angle; the greater the volume, the smaller the inclination angle. For premolars, inclination increased by 15.4° after orthodontic treatment compared with pretreatment, and by 8.1° at the latest follow-up compared with baseline. The volume of maxillary sinus was not associated with premolar inclination.

Conclusions: We found evidence of an association between maxillary second molar inclination and surface area of the lower sinus in patients treated with maxillary first molar extractions. Clinicians who undertake such an extraction scheme in Class II patients should be aware of this potential association, and consider appropriate biomechanics to control root uprighting.

5.1 INTRODUCTION

The maxillary sinus, the largest of the paranasal sinuses, begins to develop at the ethmoidal infundibulum in the third month of fetal life.[1] After birth, it undergoes rapid growth, extending both laterally and inferiorly, during the first 3 years and from 7 to 12 years of age.[2] In approximately 50% of the adult population, the sinus invades the maxillary alveolar process, coming in close proximity to the roots of the second premolar and the first and second permanent molars. Occasionally, the sinus floor can extend as far as the region of the canine root.[3] Tooth roots that protrude into the maxillary sinus may induce complications in extractions, implantation, endondontic procedures and orthodontic mechanics.[4]

Orthodontic intrusion and bodily movement of teeth across the sinus floor have been found to cause moderate apical root resorption and variable degrees of tipping in experimental and clinical studies.[5-7] Up to date the interaction of maxillary sinus development and posterior tooth axial inclinations has not been assessed longitudinally in orthodontic patients. Therefore, the aim of this cephalometric study was to investigate the possible association between maxillary sinus extent and inclination of maxillary second molars and second premolars, in Class II adolescents before and after active orthodontic treatment with extraction of maxillary first molars.

5.2 MATERIALS AND METHODS

The records of 37 patients (18 boys, 19 girls; mean age, 13.2 years; SD, 1.62 years), treated between 1998 and 2004 with extraction of maxillary first permanent molars and full Begg appliances in 1 orthodontist practice were collected.[8] They represented a subsample from a prospective clinical study with the following inclusion criteria: Caucasians, Class II Division 1 malocclusion, sagittal overjet ≥ 4 mm, no missing teeth, or no agenesis, including maxillary third molars.[10] Standardized lateral cephalograms before and after treatment, and for an average follow-up period of 2.5 years were evaluated by 1 author (C.L.).

The scanning and digitization of all available lateral headfilms were carried out with cephalometric analysis software (Viewbox 3.0; dHAL Software, Kifissia, Greece). Preselected anatomic and dental landmarks were digitized to enable the calculation of the maxillary second premolar (P2) and second molar (M2) inclinations, and lower sinus area (LSA) in relation to the palatal plane (PP). These measurements were defined as follows (Figure 1):

P2-PP, the angle between P2 long axis and PP; M2-PP, the average of the angles constructed by lines crossing the mesiobuccal and distobuccal root apexes and the re-

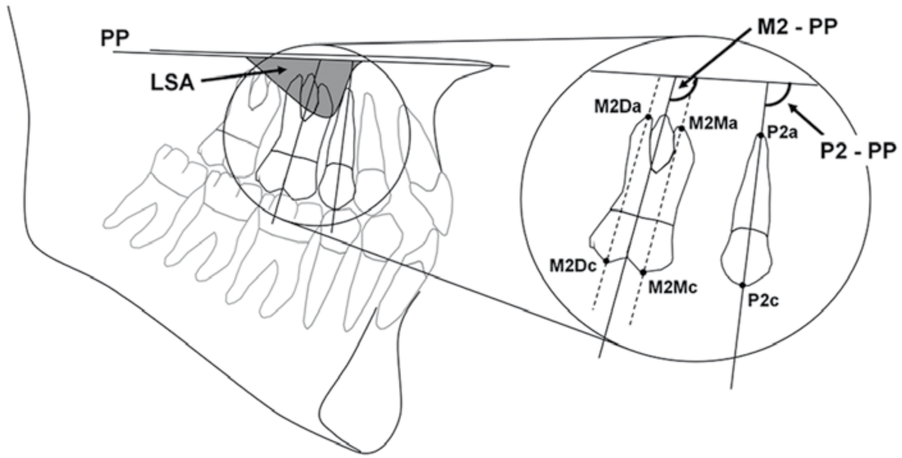

Figure 1. Representation of cephalometric points and measurements (P2-PP, M2-PP, LSA) used in the study (in magnified image: M2Mc, mesial cusp of the maxillary second molar; M2Ma, mesiobuccal root apex of the maxillary second molar; M2Dc, distal cusp of the maxillary second molar; M2Da, distobuccal root apex of the maxillary second molar; P2c, midpoint of the cusp of the maxillary second premolar; P2a, Root apex of the maxillary second premolar). This figure shows the situation after treatment.

spective occlusal cusps, and PP; and LSA, the area established by the outline of the inferior wall of the sinus and PP.

To assess intraexaminer reliability, 30 randomly selected cephalograms were retraced and remeasured by the same investigator after a 2-week interval.

Statistical analysis

Summary values (means, standard deviations) were calculated for age, M2-PP, P2-PP, and LSA for the 3 time points. The effects on tooth inclination, age and lower sinus size on the 3 points (before and after treatment, and at follow-up) were investigated using multilevel modeling, where level 1 was the 3 time points and level 2 was the patients. Multilevel modeling allows for the correlated nature of the data resulting from multiple measurements in the same patients to be considered during the analysis. Statistical significance was set at 5%. All analyses were undertaken by using a statistical software package (version 12.1; StataCorp, College Station, Tx, US).

5.3 RESULTS

Random errors, calculated according to the method of Houston,[10] were 1.08°, 1.48°, and 21.69 mm^2 for P2, M2, and LSA respectively. Paired t tests on the repeated tracings showed no systematic errors ($P>0.05$).

Table I displays mean values and standard deviations for age, M2-PP, P2-PP, and LSA by sex and for the 3 time points.

Table II shows the results of the statistical analyses for M2 and P2. Figure 2 displays individual trends for M2 and P2 inclinations at the 3 time points (T0-T2).

Specifically for molars, the inclination angles decreased by 7° from before to after treatment, and by 11.5° at the latest follow-up. The difference in baseline angles between boys and girls was very small (0.22°, P=0.83). Age had a negative relation to the inclination angles: ie, older children tended to have smaller inclination angles. The volume of maxillary sinus had a negative association with the inclination angles at each time point, and those associations were statistically significant before and after treatment. This suggests that the greater the volume, the smaller the inclination angles.

	T0 mean (SD)	*T1 mean (SD)*	*T2 mean (SD)*	*T1-T0 mean (SD)*	*T2-T1 mean (SD)*
Boys (n=18)					
Age (y)	13.2 (1.3)	16.1 (1.5)	18.6 (1.5)		
M2-PP (°)	112.3 (5.1)	101.1 (5.4)	96.5 (3.5)	-11.2 (4.7)	-4.6 (3.3)
P2-PP (°)	98.4 (5.0)	106.2 (4.0)	103.8 (3.8)	7.8 (4.0)	-2.4 (3.0)
LSA (mm^2)	48.7 (38.6)	91.6 (33.3)	108.4 (40.1)	42.9 (35.1)	16.8 (14.3)
Girls (n=19)					
Age (y)	13.2 (1.9)	15.6 (2.1)	18.1 (2.2)		
M2-PP (°)	112.4 (4.5)	101.0 (5.5)	97.1 (5.6)	-11.4 (5.8)	-3.9 (4.3)
P2-PP (°)	97.4 (5.1)	106.9 (6.1)	103.7 (5.4)	9.5 (6.5)	-3.2 (3.3)
LSA (mm^2)	62.0 (43.7)	100.5 (43.5)	123.0 (47.3)	38.5 (26.6)	22.5 (18.5)

T0, Pretreatment; T1, posttreatment; T2, follow-up.

Table I. Means and SDs in parentheses of age, tooth inclinations, and lower sinus area at 3 time points.

For premolars, the inclination angles increased by 15.4° after active treatment compared with baseline angles, and by 8.1° at posttreatment. The difference in baseline angles between boys and girls was very small (0.3°, P=0.82).

Age also had a negative relationship to premolar inclination angles, meaning that older patients had smaller premolar angles. However, none of these associations were statistically significant. The volume of maxillary sinus did not seem to be associated with premolar axial inclination.

The higher level in the multilevel models was patients whose number was 37, and each patient had 3 repeated observations (the lower level). These are usually sufficient to estimate the random effects at both levels, and Table II shows that the standard errors for the random effects in both models are relatively small, indicating the random-effects estimation is robust.

	M2			*P2*		
	β	*95% CI*	*P value*	β	*95% CI*	*P value*
Fixed effects						
Time						
T0-T1	-7.02	-19.64 to 5.59	0.28	15.43	2.45 to 28.41	0.02
T1-T2	-11.52	-25.46 to 2.42	0.11	8.09	-6.32 to 22.49	0.27
Male	0.22	-1.85 to 2.29	0.83	0.30	-2.27 to 2.87	0.82
Age_T0	-0.94	-1.73 to -0.15	0.02	-0.27	-1.15 to 0.61	0.54
Age_T1	-0.69	-1.41 to 0.03	0.06	-0.70	-1.50 to 0.10	0.09
Age_T2	-0.62	-1.30 to 0.07	0.08	-0.39	-1.15 to 0.37	0.32
LSA_T0	-0.01	-0.03 to 0.01	0.54	0.00	-0.02 to 0.03	0.84
LSA_T1	-0.05	-0.08 to -0.03	0.00	0.01	-0.02 to 0.03	0.55
LSA_T2	-0.04	-0.07 to -0.02	0.00	0.01	-0.02 to 0.04	0.43
_cons*	125.12	114.66 to 135.58	0.00	101.16	89.53 to 112.79	0.00
Random effects						
Level 2 (subjects)	2.62	0.47		3.50	0.54	
Level 1 (residuals)	3.16	0.26		3.24	0.27	

T0, Pretreatment; *T2*, posttreatment; *T3*, follow-up; _cons*, constant.

Table II. Multilevel analysis-derived coefficients (Đ) and 95% confidence intervals (CIs) for the adjusted effect of LSA on second molar and second premolar inclinations (coefficients correspond to degrees).

5.4 DISCUSSION

This study aimed to document potential changes in the location of the lower surface of the maxillary sinus and the inclinations of the posterior teeth during treatment with maxillary first molar extractions. It is known that a close relationship between the dental roots and the inferior wall of the sinus can impede orthodontic tooth movement.[5,11]

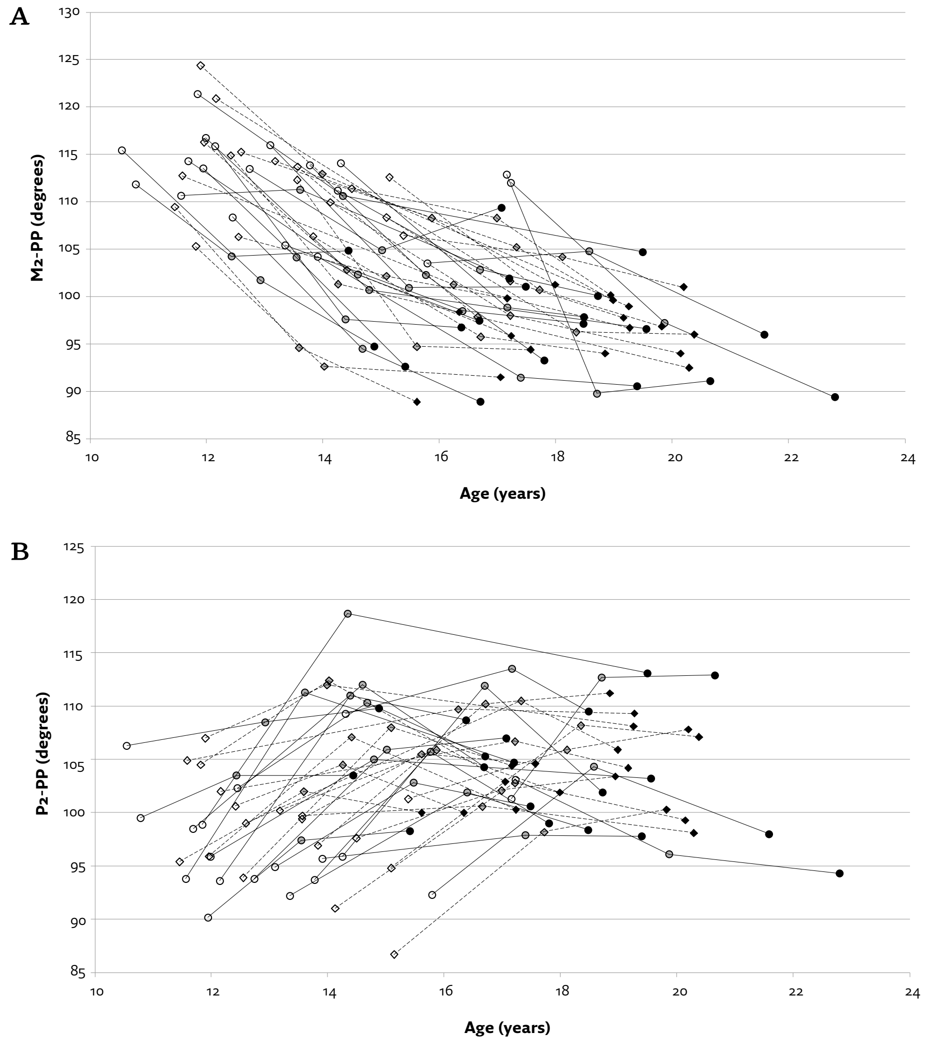

Figure 2. The trends observed in **A**, second molar; **B**, second premolar inclination angles with time (circles and solid lines: females; diamonds and broken lines: males; lighter to darker color signifies treatment stage, T0 to T2; lines connect data of the same patient).

Despite the increasing popularity of 3-dimensional radiographic techniques, such as computed tomography and cone-beam computed tomography in orthodontic research, the systematic use of 3-dimensional imaging for diagnostic procedures and treatment planning is still not considered standard care, and it is limited to selected clinical conditions.[12] On the other hand, lateral cephalograms are prescribed for most orthodontic patients on a routine basis. At the time this study was conducted, a limited number of cephalometric studies on maxillary sinuses were indexed in electronic databases. Robinson et al,[13] by measuring the maxillary sinus on cephalometric radiographs of patients with cleft palate and normal subjects, found no significant differences with respect to size, shape and rate of development. Similarly, a recent cephalometric study in adolescents with different malocclusion classes reported no significant association between maxillary sinus size and sagittal skeletal jaw relationship.[14]

However, cephalograms present inherent disadvantages for measuring 3-dimensional structures; distortion, superimposition and differential magnification can lead to misidentification of the sinus outline and measurement errors.[15] Measurement accuracy can also be compromised by volumetric differences between the right and left sides.[16] To minimize such errors, we chose to consider only the sinus outline that extended below the palatal plane. This lower sinus component is closely related to the periapical region of maxillary posterior teeth, and therefore, was considered to be most related to orthodontic intervention. If we had selected the total sinus area, we would not have been able to differentiate between potentially relevant area changes close to the teeth and changes at other distant locations, not related to the dentition.

Statistical analysis showed no evidence of an association between sex and second premolar inclination and molar inclination. The lack of sexual dimorphism on sinus size is consistent with the results of previous cephalometric studies,[14,17,18] but computed tomography volumetric evaluation has shown sex-specific differences.[19,20] LSA exhibited expansion between treatment stages, continuing up to the follow-up period, which extended beyond 18 years for most subjects. The age of termination of sinus growth is debatable; some studies have shown cessation by 15 years of age,[21,22] and others have shown continuing growth in volume during the second decade of life in both sexes.[19,23] As expected from the aims and biomechanics of treatment, statistically significant changes were identified for posterior tooth inclinations.[24] During treatment, P2 inclined distally and M2 mesially; the premolar showed partial relapse during the follow-up period, whereas the molar continued its mesial inclination.

The available literature on orthodontic tooth movement in the region of the maxillary sinus has so far been scarce and comprises mainly case reports[25-28] and histological analyses of the side effects on bone and dental tissues.[29,30] Wehrbein et al[6] found a correlation between the depth of maxillary sinus recess and the degree of tipping of the teeth adjacent to the extraction site; ie, the more vertically extended the sinus, the larger the tooth inclination. We could not establish a correlation between maxillary lower sinus area and second premolar inclination during our observation period. This outcome might have been expected because the maxillary sinus in our sample appeared not to extend exceptionally to the periapical area distal to the second premolar, a finding that is generally reported in the literature.[31,32]

On the other hand, the statistical analysis demonstrated that LSA was a significant predictor of molar inclination. Of course, this association is indeterminate for a cause-and-effect sequence of events; whether the descent of the sinus was exaggerated because of incomplete molar uprighting or the inferior antral extension inhibited mesial bodily molar movement remains unclear. Nonetheless, given the potential effect of dentition on maxillary sinus development, the second scenario might be more applicable. In particular, tooth extraction seems to result in increase of sinus size[33-37] even though opposite views do exist.[23,38] Extraction studies with[34] or without treatment[37] have concluded that inferior sinus expansion is greater in first and second maxillary molar extraction cases, in comparison to premolars. The explanation may lie in the large residual osseous defect in the extraction site, and the subsequent reduced bone resistance because of the long healing period of the alveolar socket that allows the sinus to expand.[37] Wehrbein and Diedrich[34] proposed space closure to be initiated during the healing phase of the alveolar socket in order to restrain further maxillary sinus extension. Our study group experienced a significant increase of maxillary sinus size even during the follow-up phase long after space closure.

The sample of this investigation was unique in that it involved extractions of first molars and longitudinal data was available, covering a considerable posttreatment period. Unfortunately, the retrospective and cross-sectional nature of the records and the lack of control group impose important limitations on this study. Due to the lack of a control group, variability in root inclination might be attributed to factors other than treatment objectives, such as inadvertent differences in mechanotherapy, variability in biological response, and anatomical variations, including sinus development. Nevertheless, the value of this study lies with the unique sample and the fact that allows hypotheses generation that can be tested in a prospective manner in the future. In forthcoming studies, it would also be advantageous to utilize 3-dimensional cone-beam computed tomography data for volumetric evaluation, and a wider age range for assessing sinus development.

5.5 CONCLUSION

Our study demonstrated a significant correlation between extension of the maxillary sinus floor and posttreatment second molar inclination. Diagnosis of a vertically extended maxillary sinus in patients having maxillary first molar extractions should prompt clinicians to plan appropriate space closure and uprighting mechanics.

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CHAPTER 6

DOES FIXED RETENTION PREVENT OVERERUPTION OF UNOPPOSED MANDIBULAR SECOND MOLARS IN MAXILLARY FIRST MOLAR EXTRACTION CASES?

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SUMMARY

Introduction: To investigate whether multistranded fixed retainers prevented overeruption of unopposed mandibular second molars in maxillary first molar extraction cases.

Materials and Methods: The panoramic radiographs of 65 Class II Division 1 whites (28 females, 37 males) consecutively treated with bilateral maxillary first molar extraction and the Begg technique, and with records taken after treatment (T1) and in retention (T2), were withdrawn from private practice records. According to the treatment protocol, mandibular second molars were retained with sectional wires in case of lack of occlusal contact with the antagonist. The subjects were assigned to study and control groups based on the use of fixed retainers. Radiographic analysis was carried out to determine inclination of mandibular molars in relation to the mandibular plane and the resulting movement of second molar centroids as a percentage of its mesiodistal dimension. Parametric and nonparametric tests were performed to assess the changes between T1 and T2.

Results: No statistically significant differences in molar inclination were observed between groups and time points ($P>0.05$). There were no statistically significant differences in molar movement percentages ($P>0.05$) irrespective of whether fixed retention had been used or not.

Conclusions: Within its limitations, this study suggests that no significant eruption occurred in unopposed mandibular second molars bonded with fixed sectional retainers compared to molars partially occluded with the antagonists. Fixed retention may be considered in preventing tooth overeruption in unopposed molars.

6.1 INTRODUCTION

A plethora of terms including overeruption,[1] hypereruption,[2] supraeruption,[3] supereruption,[4] and continuous eruption,[5,6] have been used to describe the tendency of tooth movement in an occlusal direction following loss of antagonist contact. This phenomenon has been claimed to induce occlusal interferences and changes in the dental equilibrium.[2,7]

A 12-year study in females with missing opposed and/or adjacent molars showed 4.9 times higher risk of overeruption of ≥ 2 mm in unopposed molars.[8] Not all teeth without antagonist will necessarily overerupt, not even in a long-term perspective. Examination of the position of molars that had been unopposed for a long period showed that 18% of teeth exhibited no signs of overeruption.[1] Maxillary unopposed teeth appear to migrate vertically more than mandibular[4,8] with the eruption being most pronounced during the first years after the loss of the opposed tooth.[9] Age and periodontal condition may be associated with the severity of changes. A higher incidence of severe overeruption has been observed in studies with younger age and periodontally affected groups.[10] Unlike young age, compromised periodontal condition was not associated with the severity of changes in animal experiments.[11,12] A recent systematic review on the treatment need for posterior bounded edentulous spaces[10] demonstrated that overeruption was limited to 2 mm for most studies reviewed. However, the authors classified the quality of evidence as very low, and concluded that tooth replacement should not be considered as the mainstay of therapy.

Placement of etched metal splints on the lingual surfaces of unopposed molars has been recommended to counteract tooth extrusion.[13,14] According to the retention protocol of a Class II Division 1 malocclusion treatment technique involving extraction of maxillary first molars, multistranded sectional wires are bonded on mandibular first and second molars to prevent vertical displacement of the out-of-occlusion second molars as a result of the late eruption of maxillary third molars.[15,16] To the authors' knowledge, no clinical study has been published so far aiming to explore the potential overeruption of nonoccluding teeth retained with sectional wires.

The objective of this study was to investigate whether overeruption occurred in unopposed mandibular second molars with multistranded fixed retainers in patients treated with orthodontic extraction of maxillary first molars.

6.2 MATERIALS AND METHODS

A total of 65 consecutively treated Class II Division 1 cases (28 females, 37 males) were retrieved from the archives of a private practice. Inclusion criteria were whites, overjet

≥4 mm, no missing tooth or agenesis including maxillary third molars, permanent dentition, available panoramic radiographs after treatment (T1) and at a follow-up (T2), and treatment with 2-maxillary first molar extraction and Begg fixed appliances. The treatment approach has been described in detail in the literature.[15,16] In case that mandibular second molar had not occluded with the antagonists at the time of appliance removal, 0.195-inch buccal retention wires (Wildcat, GAC, Central Islip, NY, US) were placed on the mandibular first and second molars to inhibit unwanted vertical tooth movement of the teeth without occlusal contacts. These sectionals are removed as soon as the maxillary third molars are coming into occlusion with the mandibular second molars. Based on the presence of bonded buccal retainers on the mandibular first and second molars at 2 posttreatment time points (T1, T2), the subjects were allocated to the study-retention group (12 females, 18 males; mean age at T1, 15.2 years; SD, 1.6 years), and the control-nonretention group (16 females, 19 males; mean age at T1, 16.2 years; SD, 1.7 years) (Table I).

	Ret (n=30)	*Non (n=35)*
Gender		
Male	18	19
Female	12	16
Age (y)		
T1	15.2 (1.6)	16.2 (1.7)
T2	17.6 (1.7)	18.6 (2.0)
T2-T1 interval (y)	2.4 (0.8)	2.4 (0.9)

Table I. Summary statistics (means, SDs in parentheses) of the retention and nonretention groups: *Ret*, retention group; *Non*, nonretention.

All panoramic radiographs were scanned (Epson Expression 1680 Pro, Suwa, Nagano, Japan; resolution of 600 dpi) and traced by the first author using a cephalometric analysis software (Viewbox 3.0; dHAL Software, Kifissia, Greece). The centroids of the mandibular right and left second molars were selected to represent the molar teeth. A set of 77 points lying on the outline of the teeth were digitized, 11 points on the occlusal surface of premolars and 33 points on each molar; 11 points on the mesial outline, 11 points on the distal outline, 4 points on the occlusal surface and 7 points between the molar roots. The centroid was computed as the average of second molar points and subsequently transferred from the T2 to the T1 dataset by means of Procrustes and best fist superimpositions. By applying the first superimposition on the 2 molars and the occlusal surfaces of the 2 premolars, the size between the 2 panoramic ra-

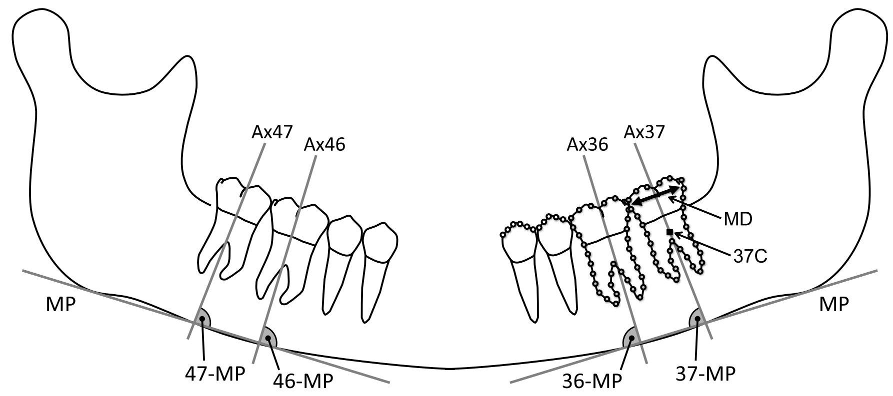

Figure 1A. Reference points and planes: Mandibular plane (MP); Ax36, Ax37, Ax46, Ax47: first and second molar long axes constructed by the midpoints of the occlusal surfaces and root apexes of the molars; Mesiodistal dimension of second molar crown (MD); Centroid of the mandibular second molar (37C); Molar inclination angles: 36-MP, 37-MP, 46-MP, and 47-MP.

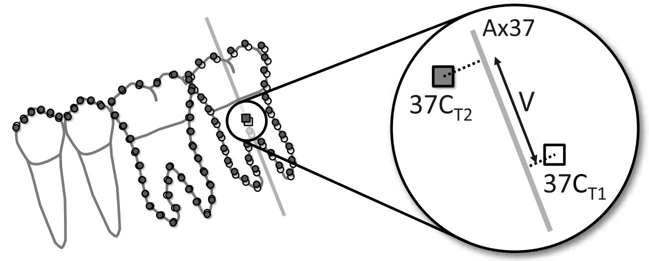

Figure 1B. Superimposition of panoramic radiographs taken at T1, T2: Centroids of mandibular second molar at T1, T2 ($37C_{T1}$, $37C_{T2}$); Movement of centroids along the molar long axis (V); White circles: Digitization points at T1; Grey circles: Digitization points at T2.

diographs was adjusted. The second superimposition was carried out on the first molar and the occlusal surfaces of the premolars to measure the distance between the second molar centroids along the direction of the long axis of the tooth (distance V in Figure 1). Given the limitations of panoramic radiography in providing absolute linear measurements,[17] we decided to express the molar movement as a percentage of its mesiodistal size. Therefore, the software was set to calculate the ratio of this distance (V) to the mesiodistal dimension of the mandibular second molar crown (MD) providing a percentage value for the occurring molar movement between T1 and T2; 37V/MD, 47V/MD. Assuming an average molar width value of 11 mm, 1% of tooth movement corresponds to 0.11 mm. Molar inclination was determined in relation to the mandibular plane (MP) by the angles between the molar long axes and MP; 36-MP, 37-MP, 46-MP, 47-MP (Figure 1).

Statistical analysis

Data analysis was carried out using a statistical software package (version 2.7.2; StatsDirect, Cheshire, UK). The measurements were tested for normality of distribution and equality of variance (F test). If the F test was significant, nonparametric alternatives (Mann-Whitney U and Wilcoxon signed-rank tests) instead of parametric methods (paired and unpaired t-tests) were applied for intergroup comparisons between T1 and T2. Statistical significance was set at 5%. To estimate reproducibility of measurements, 25 randomly selected pairs of tracings were replicated by the same examiner 2 weeks after the first series of tracings.[18]

6.3 RESULTS

Reproducibility was assessed using the method of Bland and Altman.[19] The mean difference values for the repeated 37V/MD and 47V/MD measurements were 0.19±4.24% (95% CI, - 8.12 to 8.51) and 0.92±3.40% (95% CI, -7.58 to 5.75).

Descriptive statistics for 36-MP, 37-MP, 46-MP, 47-MP, 37V/MD and 47V/MD are summarized in Table II.

Comparison of T1 molar inclination values showed no significant differences between the retention and nonretention groups (P>0.05) (Table II). The mandibular left molars with fixed retention appeared at T1 slightly more mesially inclined than nonretention controls. The contralateral molars were slightly more upright in the retention than in the nonretention group. These trends in molar inclination persisted at T2 without reaching statistical significance (P>0.05).

No significant differences were found between T1-T2 for either molar inclination angles or movement percentages (P>0.05) (Table III). Retained molars exhibited slightly increased mesial inclination whereas no clear patterns could be seen in the axial inclination changes of the counterparts without retention wires. On average, all molars overerupted during the observation period with this tendency being more prominent though not statistically significant in the nonretention molars.

T1				
Measurement	Ret (n=30)	Non (n=35)	P value	95% CI
36-MP (°)	90.8 (4.9)	92.2 (6.9)	0.34	-1.54 to 4.40
37-MP (°)	91.1 (6.1)	91.2 (7.9)	0.97	3.49 to 3.62
46-MP (°)	89.4 (5.2)	86.9 (5.5)	0.07	-5.11 to 0.22
47-MP (°)	89.0 (7.4)	85.7 (10.0)	0.13	-7.77 to 1.06
T2				
Measurement	Ret (n=30)	Non (n=35)	P value	95% CI
36-MP (°)*	89.9 (4.4)	91.9 (7.1)	0.09	-1.00 to 4.98
37-MP (°)*	90.7 (4.8)	91.4 (7.2)	0.62	-2.38 to 3.76
46-MP (°)	88.3 (6.5)	86.7 (7.2)	0.32	-4.72 to 1.56
47-MP (°)	87.5 (7.2)	86.1 (10.1)	0.53	-5.80 to 2.99
37V/MD (%)	1.0 (4.4)	1.2 (5.2)	0.87	-2.22 to 2.62
47V/MD (%)	0.5 (5.5)	1.1 (5.7)	0.67	-2.19 to 3.38

Table II. Means, SDs in parentheses of the molar inclination angles and movement percentages at T1 and T2, and P values, 95% CI of intergroup differences (unpaired t-test): Ret, retention group; Non, nonretention group; *, Mann-Whitney U test.

T2-T1

Measurement	Ret (n=30)	P value	95% CI	Non (n=35)	P value	95% CI
36-MP (°)*	-0.9 (3.6)	0.18	-0.45 to 2.24	-0.3 (3.5)	0.58	-0.88 to 1.55
37-MP (°)*	-0.4 (4.4)	0.60	-1.21 to 2.05	0.2 (3.6)	0.73	-1.44 to 1.02
46-MP (°)	-1.1 (4.1)	0.16	-0.46 to 2.60	-0.2 (4.3)	0.77	-1.26 to 1.67
47-MP (°)	-1.5 (4.6)	0.09	-0.25 to 3.22	0.5 (5.2)	0.59	-2.27 to 1.32
37 V/MD (%)	1.0 (4.4)	0.23	-0.66 to 2.65	1.2 (5.2)	0.19	-0.60 to 2.98
47 V/MD (%)	0.5 (5.5)	0.61	-1.54 to 2.57	1.1 (5.7)	0.26	-0.84 to 3.06

Table III. Means, SDs in parentheses of the molar inclination angles and movement percentages between T1 and T2, and P values, 95% CI of intragroup differences (paired t-test): Ret, retention group; Non, nonretention group; *, Wilcoxon signed-rank test

6.4 DISCUSSION

A common belief among dental professionals is that molars without antagonists tend to overerupt leading to dental problems in the long-term perspective. A questionnaire survey among dentists on the perception of potential risks for molars without antagonists revealed that 85% of the respondents believed that overeruption of the nonoccluding molars would occur. Interestingly, more than half of the dentists considered necessary to perform prosthodontics in the opposing arch to fill the edentulous space.[20]

The influence of one-arch orthodontic extractions on the position of antagonists has been scarcely investigated in the past. Smith[21]observed that the distal aspect of the mandibular second molars overerupted significantly in subjects orthodontically treated with extraction of maxillary second molars compared to nonextraction controls. Crown tilting was likely to occur if partial occlusal contact had been established mesially with the distal portion of the occlusal surface of the opposing first molar.

Our study demonstrated statistically nonsignifant changes in molar positions determined by the mandibular plane and the movement of molar centroid along the tooth long axis regardless of whether sectional bonded retainers had been used or not. On average, slightly lower but not statistically significant overeruption rates were observed for the molars in the retention group compared to the control molars. Analyzing the results, the overeruption percentages between T1-T2 ranged between 0.5-1.0% and 1.1-1.2% in the retention and nonretention mandibular second molars, which are translated into clinically insignificant changes of a tenth of mm.

Strictly speaking in clinical terms, the multistranded retention wires on mandibular first and second molars restrained the eruptive movement of unopposed second molars. Stated differently, the partial tooth contact with the antagonists in the control group appeared to be as efficient in preventing overeruption as the application of fixed retention in the opposing segment. In contrast to these findings, previous research has suggested that maintenance of vertical tooth position should not be clinically relied on partial tooth contact. In particular, Craddock found that teeth with partial tooth contact of 30% or less occlusal overlap displayed a similar degree of overeruption to those without occlusal contact in adults missing teeth for over 5 years.[22]

This study presents certain shortcomings, mainly related to the retrospective nature and the measurement method. No sample size calculation was performed prior to initiation of the study. All subjects with eligible radiographic records were included instead. Study cast measurements could have supplemented our radiographic methods to determine the overeruption rates. However, the lack of complete documentation made this option not feasible. On the other hand, model casting, i.e. impression and

settling of casts may hide potentially errors, and such likelihood should not be underestimated.[23] The inclusion of dental casts might have been more favourable in case of upper arch measurements where palatal rugae could serve as reliable landmarks for longitudinal cast analysis.[24,25] Regarding the use of panoramic analysis, accuracy in overeruption and molar inclination measurements of the study might have been jeopardized by the inherent panoramic image distortions.[26-28] Registration of the relative vertical position of out-of-occlusion teeth on the panoramic radiographs was based on the assumption that the adjacent teeth had not moved during the observation period. To strengthen the tracing technique, we defined a wide list of digitization points extending from the distal outline of the mandibular second molar to the occlusal surface of the mandibular first premolar. However, the probability of tooth movement in the surrounding teeth cannot be neglected and may have partly contributed to the negative values in the vertical displacement of mandibular second molars. Moreover, the resulting growth of molar roots between observations in younger subjects should be also considered when interpreting the results. Finally, mechanical deformation of the retention wires during T1-T2 induced by biting on hard food,[29] especially due to the rather increased intermolar wire span, might have also been involved.

6.5 CONCLUSIONS

Within the limitations of this study, it is concluded that significant changes in the eruptive movement of unopposed mandibular second molars bonded with fixed sectional retainers did not occur during the observation period compared to counterparts with partial contact with the antagonists. In light of these findings, use of fixed retainers as a measure to prevent tooth overeruption may be useful in nonoccluding molars.

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CHAPTER 7

SUMMARY AND GENERAL DISCUSSION

SUMMARY

In this thesis, we ran case series studies to investigate postorthodontic changes in patient groups treated with unilateral and bilateral extraction of maxillary first molars (M1s) and Begg appliances. In **Chapter 1**, a short introduction to basic orthodontic terms such as occlusion, malocclusion, and Class II Angle classification is provided. Class II malocclusion is commonly diagnosed in the general population, and represents a public health priority. Individuals with Class II malocclusion are seeking therapy on the grounds of physical, psychological, and social benefits. Treatment planning is driven by the patient's growth potential, dental crowding, aesthetics and appliance preferences. While extraction of premolars is commonplace in orthodontics, molars with questionable long-term prognosis may be chosen instead. A treatment approach combining bilateral M1 extraction and Begg fixed appliances has shown good treatment outcomes in Class II Division 1 malocclusion subjects. Modification of this technique with extraction of one M1 on the Class II side has also been described for treating Class II subdivision cases. The overall and specific aims of this thesis are presented.

Chapter 2 deals with a follow-up assessment of a Class II subdivision sample treated with unilateral M1 extraction in terms of occlusion, facial profile and midline aesthetics. Twenty Class II subdivision subjects consecutively treated by one orthodontist with the Begg technique and unilateral M1 extraction were selected from the records of a private practice. Inclusion in the study was based on the following criteria: white subjects, unilateral Class II molar relationship ≥1/2 premolar width, no tooth agenesis including third molars, fairly aligned mandibular arch, unilateral M1 extraction, and available records before treatment (T1), after treatment (T2), and 2.5 years in retention, on average. The control subjects were 15 untreated asymmetrical Class II adolescents closely matched by age, with complete T1-T3 documentation, retrieved from the archives of the Groningen Longitudinal Growth Study. PAR scoring and cephalometric analysis was carried out for both groups, while midline correction was evaluated on patient smile photographs. We observed significant changes in maxillary incisor retraction, mandibular incisor protraction, and lower lip protrusion, which promoted patients' facial profiles. The M1 extraction cases exhibited an average reduction of more than 20 PAR points, whereas the severity of malocclusion was slightly increased in untreated controls. At T2, facial and dental midlines were coincident in 45% of the treated subjects. Therefore, we concluded that asymmetrical M1 extraction in Class II subdivision patients may yield stable occlusal and aesthetic results from a long-term perspective.

A retrospective split-mouth study on the changes of maxillary second (M2) and third molar (M3) inclination following Class II subdivision treatment with unilateral M1 extraction and Begg appliances is presented in **Chapter 3**. Orthopantomograms of 21 Class II subdivision adolescents treated with the abovementioned protocol in one orthodontist-practice obtained at T1, T2, and T3 (at least 1.8 years after treatment) were traced. M2 and M3 axial inclination on the extraction and nonextraction sides was measured using the intertuberosity (ITP) and interorbital planes (IOP). According to the random effects regression analysis, time and extraction status were significant predictors for M2 angulation, whereas extraction was the only significant predictor for M3 angulation. On the basis of these results, it was concluded that unilateral maxillary M1 extraction led to a significant increase in M2 and M3 mesial inclination. There was a significant tilting of M2s over time irrespective of M1 extraction.

Chapter 4 desribes a cephalometric study aiming to investigate the changes in the inclination of M2s and M3s after orthodontic treatment of Class II Division 1 malocclusion with extraction of the M1s. The study group included 37 subjects meeting the following criteria: white origin, Class II Division 1 malocclusion, overjet ≥ 4mm, full complement of permanent teeth, treatment with extraction of the maxillary first molars and the Begg technique. Lateral cephalograms had been taken at T1, T2 and T3 (at least 3.7 years after treatment). Fifty-four untreated Class I and Class II subjects, followed up for a minimum of 3.6 years, were selected from the archives of the Nittedal Growth Material as controls. M2 and M3 inclination was defined relative to the palatal plane (PP) and functional occlusal plane (FOP). Mesial inclination of M2s and M3s in relation to PP was significantly increased in both groups. With reference to FOP, significant changes in M2 inclination were observed only in the extraction group, with the initially more distally tilted M2s reaching a mesial inclination at T2. M3 inclinations improved significantly in either group, but M3s became 4 times more upright in the extraction subjects. In light of these findings, we concluded that M1 extraction in Class II Division 1 patients results in significant uprighting of M2s and M3s and increases the chances for normal eruption of M3s.

The same sample of Class II adolescents was enrolled in the study described in **Chapter 5** to explore the possible association between the maxillary sinus extent and the inclinations of the maxillary second molars and second premolars before and after orthodontic treatment with bilateral M1 extractions. Maxillary posterior tooth inclination and lower maxillary sinus outline in relation to the palatal plane was determined on available lateral cephalograms at T1, T2 and T3 (on average 2.5 years after treatment). The results showed that second molar inclination achieved increasingly smaller angular values from T1 to T3. We found evidence for a negative correlation of maxillary sinus area and second molar inclination angle; the greater the sinus extent (area), the smaller the inclination angle. For premolars, inclination angles increased between T1-T2, but unlike molars, partially relapsed at T3. The maxillary sinus area was not associated with premolar inclination. To conclude, our study demonstrated a significant correlation between extension of the maxillary sinus floor and posttreatment second molar inclination. When a vertically extended maxillary sinus in patients undergoing M1 extractions is diagnosed, this possible association should be considered in space closure mechanics.

The potential of fixed sectional retainers in preventing overeruption of unopposed mandibular second molars was investigated in **Chapter 6**. Private practice records were screened for Class II Division 1 subjects who had received orthodontic treatment with M1 extraction and Begg fixed appliances and met the abovementioned criteria. 30 subjects with bonded buccal retention wires on the mandibular first and second molars lacking occlusion with antagonists at T1 and T2 were allocated to the study group. Twenty-five nonretention subjects with intra-arch occlusion in the posterior segments were assigned as controls. Analysis of panoramic radiographs was carried out to determine changes in the inclination of mandibular molars in relation to the mandibular plane and the resulting overeruption was expressed as movement of the second molar centroids between T1 and T2. No statistically significant changes occurred in either molar inclination or overeruption between retention and nonretention groups. This study concluded that fixed retention of nonoccluding mandibular second molar may be an effective means to inhibit tooth overeruption.

7.2 STRENGTHS AND LIMITATIONS

All studies examined unique patient samples with reference to the unconventional extraction decision and the extensive experience of the treating orthodontist in the Begg technique. Extraction of permanent first molars was found to be prescribed by US orthodontists in less than 0.5% of the extraction cases, whereas premolar extraction pattens accounted for 82%.[1] Because of the very low incidence of M1 extractions in orthodontic practice, it has not been earlier possible to conduct clinical trials with sufficient power to investigate aspects of this treatment modality. Previous research on the impact of maxillary first molar extraction on third molar position, angulation and/or eruption focused on different extraction protocols[2-5] and non-orthodontic patient groups,[3,5] in contrast to the studies presented here. Additionally, the inclusion of clinical records obtained at a minimum range follow-up of 1.8-3.7 years enabled us to evaluate the treatment effects from a longer-term perspective. Regarding Class II subdivision treatment, a single study assessing the occlusal stability of cases treated with asymmetrical premolar extractions 6.9 years on average after the end of treatment was found in the literature.[6] Therefore, our follow-up studies described in **Chapters 2 and 3** provided more insight into the maintenance of treatment outcome of asymmetric Class II malocclusion in the retention stage.

The methodological limitations of these studies are primarily related to the retrospective type of design, as retrospective data collection may induce selection and detection bias. To reduce selection bias, all patients meeting the inclusion criteria were enrolled.[7] 'Blinding (or masking) of outcome assessors may diminish the risk that knowledge of which intervention was received, rather than the intervention itself, affects outcome measurement'.[8] In the current studies, blinding of examiners or masking of records could not have been possible due to the obvious intervention of M1 extraction and its comparison with untreated subjects. Deliberate delay of treatment or nontreatment would have been inappropriate owing to ethical concerns of recruiting untreated participants in clinical trials.[9] To compensate for the lack of untreated Class II malocclusion subjects in **Chapters 2** and **4**, we selected historical controls closely matched by race, age, and if applicable by sex, and further increased the ratio of controls to cases in **Chapter 4**. The limited control over data collection did not allow outcome ascertainment on complete clinical records including dental casts in **Chapter 6**. Nevertheless, we struggled to apply robust radiographic analyses that integrated multiple reference planes (**Chapters 3 and 4**) and digitization points (**Chapter 6**) to strengthen measurement validity. One observer was engaged in all measurements, thus ensuring consistency of the results. On the other hand, this is a limitation of the studies because the extent of interobserver differences could not be assessed. However, it was attempted by the crafting of the computer-aided measurements to reduce observer error and increase objectivity. For example, the long axis of the molars in **Chapter 6** was computed automatically, based on the drawn outline of the whole tooth; therefore, significant interobserver differences in drawing the tooth outlines would be required for an appreciable change in the computed long axis, whereas large differences might be observed if the long axis was based on the manual identification of just two points. The impact of this design is evident by the lack of significant differences between repeated measurements. In addition to this, the involvement of more examiners, though theoretically ideal, might have caused interobserver differences due to observer variations in experience and training.[10] Despite the inherent technical discrepancies,[11,12] axial inclination of molars was determined on panoramic radiographs (**Chapter 3**) rather than lateral cephalograms (**Chapter 4**) due to superimposition of bilateral structures on cephalometric films. Finally, we need to recognize that all studies were not designed to test the involved questions in post hoc analyses. As a consequence, our studies may be, at best, used as indicators of potentially new information, and viewed as hypothesis-generating.

7.3 CLINICAL IMPLICATIONS

A decision to electively extract healthy premolar teeth for orthodontic purposes may not be justifiable in cases with compromised M1s. As a general rule, presence of extensive caries lesions, large fillings, endodontic or periodontal problems, or hypoplastic enamel should be taken into account when extraction treatment has been chosen. The first permanent molar has the shortest caries-free survival under the age of 8 years.[13] It also represents the most caries prone tooth in children older than 11 years.[14] First molars can suffer from developmental enamel hypomineralisation of unknown aetiology often involving permanent incisors. Lately published rates vary between 4.2-

21.4% depending on the child population and examination method.[15-17] In the Netherlands, an increase in the prevalence of molar incisor hypomineralisation was recorded between 1999 and 2003 with 12.7% of children having at least 2 defective molars.[18,19] Prognosis of endodontic treatment in multirooted teeth may be also problematic. Previous research showed that the most commonly extracted tooth due to endodontic complications was the M1.[20] In this scope, and of cource in the presence of healthy and well-formed M2s and M3s, M1 extraction may be a viable option.

Favourable and stable treatment outcomes in terms of occlusion, facial profile and midline aesthetics may be expected in management of Class II subdivision malocclusion with one M1 extraction (**Chapter 2**). Given the longer treatment duration of the premolar-extraction protocols (3 extractions, 3.5 years; 4 extractions; 4.0 years)[6] compared to the mean treatment time of 2.3 years in the M1 extraction group, the latter Class II subdivision treatment alternative appears more attractive. As soon as 6 months after treatment commences, a Class I canine and premolar relationship can be established.[21] Furthermore, patient cooperation is restricted to oral hygiene measures and once-per-week replacement of elastics, which may render this method suitable for patients with poor compliance. An additional benefit of orthodontic treatment with unilateral or bilateral M1 extraction may be the improved eruption status of M3s, even when unfavourably positioned before treatment (**Chapters 3 and 4**). Our studies also underpinned the interference of a vertically extended maxillary sinus in achieving proper tooth axial inclination during space closure (**Chapter 5**), and the capacity of multistranded retention wires to prevent overeruption of unopposed mandibular second molars (**Chapter 6**). Clinicians treating with M1 extractions should meticulously plan and apply mechanotherapy and retention to counteract unwanted posterior tooth movement.

7.4 FUTURE PERSPECTIVES

This PhD thesis generated research hypotheses that can be tested in new, specifically designed studies. The appliance of choice, the Begg light-wire appliance delivers only a single contact point between the bracket and the archwire, which reduces friction between the bracket and the archwire, and virtually eliminates the binding of the archwire in the bracket slot, as is seen in all horizontal slot brackets.[22] Given the low friction levels of as-received self-ligating brackets[23,24] and the popularity of these systems,[1] future research may focus on coupling maxillary first molar extraction(s) with self-ligating and conventional appliances in prospective randomized clinical trials.

Given the exceptional maxillary second molar protraction achieved by space closure mechanics[25] and the predisposing role of the distance of tooth movement in root resorption,[26] it would be interesting and methodologically challenging to investigate the

incidence of the associated molar root resorption. Nonetheless, the use of light elastic forces throughout the course of treatment may be expected to keep the extent of such potential complication limited.

The minimum length of the observation period in the treatment groups ranged between 1.8-3.7 years. In view of the late emergence of third molars, i.e. 17-21 years,[27] studies not covering this period might fail to accurately depict the rate of molar eruption. From a clinical perspective, more useful conclusions about the maxillary first molar extraction effects in the treatment of Class II malocclusion and outcome stability can be drawn if studies with longer follow-ups will be undertaken.

7.5 CONCLUSIONS

The studies of this thesis demonstrated:

1. Favourable occlusal and aesthetic outcomes on average 2.5 years posttreatment in Class II subdivision patients treated with unilateral M1 extraction.
2. A positive influence of ulilateral and bilateral M1 extraction on M2 and M3 inclination after treatment and in retention.
3. An association between maxillary sinus extension and mesial inclination of M2s in bilateral M1 extraction cases.
4. The effectiveness of multistranded retainers to inhibit overeruption of nonoccluding mandibular second molars.

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CHAPTER 8

DUTCH SUMMARY

In dit proefschrift worden patiëntenseries beschreven waarbij onderzoek werd gedaan naar de postorthodontische veranderingen bij groepen patiënten die behandeld zijn met eenzijdige of tweezijdige extractie van de eerste molaren uit de bovenkaak (M1s) in combinatie met Begg apparatuur. In **hoofdstuk 1** wordt eerst kort ingegaan op de orthodontische terminologie zoals occlusie, malocclusie en Angle klasse II classificatie. Deze klasse II malocclusie komt vaak voor in de Nederlandse populatie. Er zijn verschillende redenen zoals lichamelijke, psychologische en sociale verbeteringen waarom personen bij wie sprake is van een klasse II malocclusie willen orthodontisch behandeld worden. Bij de planning van de behandeling wordt rekening gehouden met de potentiële groei, dentale crowding, esthetiek en voorkeur voor bepaalde apparatuur van de patiënt. Hoewel extractie van de premolaren gemeengoed is in de orthodontie kan ook worden gekozen voor extractie van molaren met een dubieuze lange termijn prognose. Een behandeloptie waarbij tweezijdige M1 extractie wordt gecombineerd met vaste Begg apparatuur heeft goede resultaten laten zien bij patiënten met een klasse II-1 malocclusie. Aanpassing van deze techniek met extractie van één M1 aan de kant van de klasse II wordt ook beschreven bij behandeling van patiënten met een klasse II afwijking. In dit hoofdstuk worden eveneens de algemene en specifieke doelstellingen van dit proefschrift beschreven.

Hoofdstuk 2 gaat over een vervolgonderzoek bij een groep patiënten met een klasse II afwijking die behandeld werden met eenzijdige extractie. Bij de follow-up wordt aandacht geschonken aan aspecten zoals occlusie, gezichtsprofiel en esthetiek van de mediaanlijn. Twintig klasse II patiënten, allemaal behandeld door één orthodontist met de Begg techniek en éénzijdige M1 extractie, zijn hiervoor geselecteerd uit het bestand van één zelfstandige orthodontiepraktijk. De inclusiecriteria waren als volgt: blanke personen, éénzijdige klasse II molaar relatie ≥1/2 premolaarbreedte, geen agenesieën (inclusief derde molaren), redelijk opgelijnde tandboog in de onderkaak, éénzijdige M1 extractie en aanwezigheid van documentatie voorafgaand aan de behandeling (T1), na afloop van de behandeling (T2) en (gemiddeld) 2,5 jaar in retentie (T3). De controle groep bestond uit 15 onbehandelde adolescenten, nauw gematched op leeftijd, met asymmetrische klasse II met volledige T1-T3 documentatie. Deze data is afkomstig van de gegevensbestanden van de Groningen Longitudinale Groei Studie. Bij beide groepen zijn PAR scores en cephalometrische analyses gedaan en evaluatie van de mediaanlijn verschuiving vond plaats op basis van foto's van lachende patiënten. De resultaten lieten significante veranderingen zien van retractie van de incisieven in de bovenkaak, protractie van de incisieven in de onderkaak en protrusie van de onderlip, resulterend in een verbetering van het profiel van de patiënten. De PAR score liet een gemiddelde afname van 20 punten in de groep met extractie van de M1s zien, terwijl de ernst van de malocclusie licht toenam in de onbehandelde controle groep. Bij T2 waren de mediaanlijnen van gezicht en dentitie gelijk bij 45% van de behandelde groep patiënten. De conclusie is dan ook dat asymmetrische M1 extractie bij patiënten met een klasse II afwijking tot een stabiel resultaat voor wat betreft occlusie en esthetiek op de lange termijn kan leiden.

Een retrospectief split-mouth onderzoek naar de veranderingen van de inclinatie van tweede en derde molaren (respectievelijk M2 en M3) na behandeling van klasse II afwijkingen waarbij de M1s zijn geëxtraheerd en Begg apparatuur is gebruikt, wordt in **hoofdstuk 3** beschreven. Bij 21 adolescenten van één zelfstadige orthodontiepraktijk die zijn behandeld volgens bovengenoemd protocol, zijn orthopantomogrammen, verkregen op T1, T2 en T3 (minimaal 1.8 jaar na behandeling), getraced. De axiale inclinatie van M2s en M3s zijn met behulp van twee skelettale vlakken zowel, aan de zijde van de extractie als aan de niet geëxtraheerde zijde, gemeten. Random effects regressie analyse liet zien dat tijd en (wel/geen) M1 extractie significante voorspellers waren van angulatie van de M2s, terwijl extractie de enige significante voorspeller was van angulatie van de M3s. Op basis van deze resultaten werd geconcludeerd dat unilaterale M1 extractie in de bovenkaak resulteerde in een significante toename van mesiale inclinatie van de M2s en M3s. Er was sprake van een significante kanteling van de M2s in de tijd ongeacht M1 extractie.

In **hoofdstuk 4** wordt een cefalometrisch onderzoek beschreven met als doel veranderingen van inclinatie van M2s en M3s te onderzoeken na orthodontische behandeling van patiënten met een klasse II-1 afwijking bij wie de M1s zijn geëxtraheerd. De onderzoekspopulatie bestond uit 37 patiënten die voldeden aan de volgende criteria: blank, klasse II-1 malocclusie, sagittale overbeet ≥ 4 mm, volledig blijvende dentitie, behandeling met extractie van de M1s in de bovenkaak en met behulp van de Begg techniek. Laterale schedelfoto's zijn gemaakt op T1, T2 en T3 (minimaal 3.7 jaar na behandeling). De controle groep bestond uit 54 onbehandelde patiënten met een klasse I of klasse II afwijking (minimale follow up van 3.6 jaar), geselecteerd uit de gegevensbestanden van het Nittedal Growth Material onderzoek. Inclinatie van de M2s en M3s werd gedefinieerd ten opzichte van het palatinale vlak (PV) en het functionele occlusale vlak (FOV). Mesiale inclinatie van de M2s en M3s ten opzichte van PV liet bij beide groepen een significante toename zien. Ten opzichte van FOV werden alleen significante veranderingen gevonden van inclinatie van M2s bij de extractie groep. Daarbij bereikten de initieel meer naar distaal gekantelde M2s een mesiale inclinatie op T2. Hoewel in beide groepen een significante verbetering van de inclinatie van de M3s werd gevonden, richten de M3s zich in de extractie groep 4 keer zoveel op. Op basis van deze resultaten kan worden geconcludeerd dat extractie van de M1s bij klasse II-I patiënten resulteert in het significant oprichten van de M2s en M3s en dat het de kansen van normale eruptie van de M3s vergroot.

Het mogelijke verband tussen de omvang van de sinus maxillaris en de inclinaties van de tweede molaren en tweede premolaren in de bovenkaak voor en na orthodontische behandeling met tweezijdige extractie van de M1s wordt onderzocht in **hoofdstuk 5**. De studiepopulatie betreft de groep patiënten met klasse II zoals in hoofdstuk 4 beschreven. Inclinatie van de zijdelingse delen in de bovenkaak en de onderste begrenzing van de sinus maxillaris ten opzichte van het palatinale vlak werd bepaald met behulp van laterale schedelfoto's op T1, T2 en T3 (gemiddeld 2.5 jaar na de behandeling). De resultaten lieten een afname in de tijd (van T1 tot T3) in de grootte van de hoeken van de inclinatie van de M2s zien. Daarnaast bleek het sinus maxillaris gebied negatief gerelateerd te zijn aan de hoek van de inclinatie van de M2: hoe groter de omvang van de sinus maxillaris, des te kleiner de hoek van de inclinatie. De hoeken van inclinatie van de premolaren namen op T2 toe ten opzichte van T1, maar in tegenstelling tot de molaren, trad op T3 een gedeeltelijke relaps op. Er werd geen relatie gevonden tussen de sinus maxillaris en de inclinatie van de premolaren. De conclusie van dit onderzoek is dat er een significante relatie bestaat tussen de omvang van de bodem van de sinus maxillaris en inclinatie van de M2 na de behandeling. Bij patiënten, gediagnosticeerd met een vertikaal vergrote sinus maxillaris, die M1 extractie ondergaan, dient rekening gehouden te worden met dit mogelijke verband bij de toe te passen mechanica om diastemen te sluiten.

De mogelijkheid van een vaste sectionele spalk om overeruptie van tweede molaren in de onderkaak zonder antagonisten te voorkomen, is in **hoofdstuk 6** onderzocht. Hiervoor is gebruik gemaakt van gegevensbestanden van één zelfstandige orthodontiepraktijk. Deze bestanden zijn gescreend op patiënten met klasse II-1 die orthodontische behandeling met M1 extractie en vaste Begg apparatuur hebben gehad en voldeden aan de eerder genoemde criteria. In totaal bestond de onderzoeksgroep uit 30 patiënten met vaste buccale retentie draden op de eerste en tweede molaren in de onderkaak zonder occlusie met antagonisten op T1 en T2. De controle groep bestond uit 25 patiënten met occlusie in de zijdelingse delen zonder retentie. Orthopantomogrammen zijn geanalyseerd om veranderingen in de inclinatie van molaren in de onderkaak ten opzichte van het mandibulaire vlak te bepalen en de resulterende overeruptie werd uitgedrukt als beweging van het zwaartepunt van de tweede molaren tussen T1 en T2. De resultaten lieten geen significante veranderingen tussen beide (retentie versus non-retentie) groepen zien in inclinatie en overeruptie van molaren. Op basis van deze resultaten wordt geconcludeerd dat vaste retentie van tweede molaren in de onderkaak zonder occlusie mogelijk een effectieve methode is om overeruptie van gebitselementen tegen te gaan.

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CURRICULUM VITAE

Christos Livas graduated from the Faculty of Dentistry, Aristotle University - Military School of Officers Corps, Thessaloniki, Greece in 1998. Besides serving in the Greek Armed Forces as dental officer and before his orthodontic training, he practiced general dentistry in his own practice in Athens, Greece. He obtained his specialty certificate from the Department of Orthodontics and Craniofacial Biology, Radboud University Medical Center, Nijmegen, The Netherlands in 2007. For the coming 5 years, he was assigned as Associate Director in the Department of Orthodontics, 251 Hellenic Air Force VA General Hospital in Athens. In 2012, he received his doctoral degree from the Department of Orthodontics and Dentofacial Orthopedics, University of Bern, Bern, Switzerland. Since December 2012, he has joined the Department of Orthodontics, University Medical Center Groningen as full-time staff member.

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