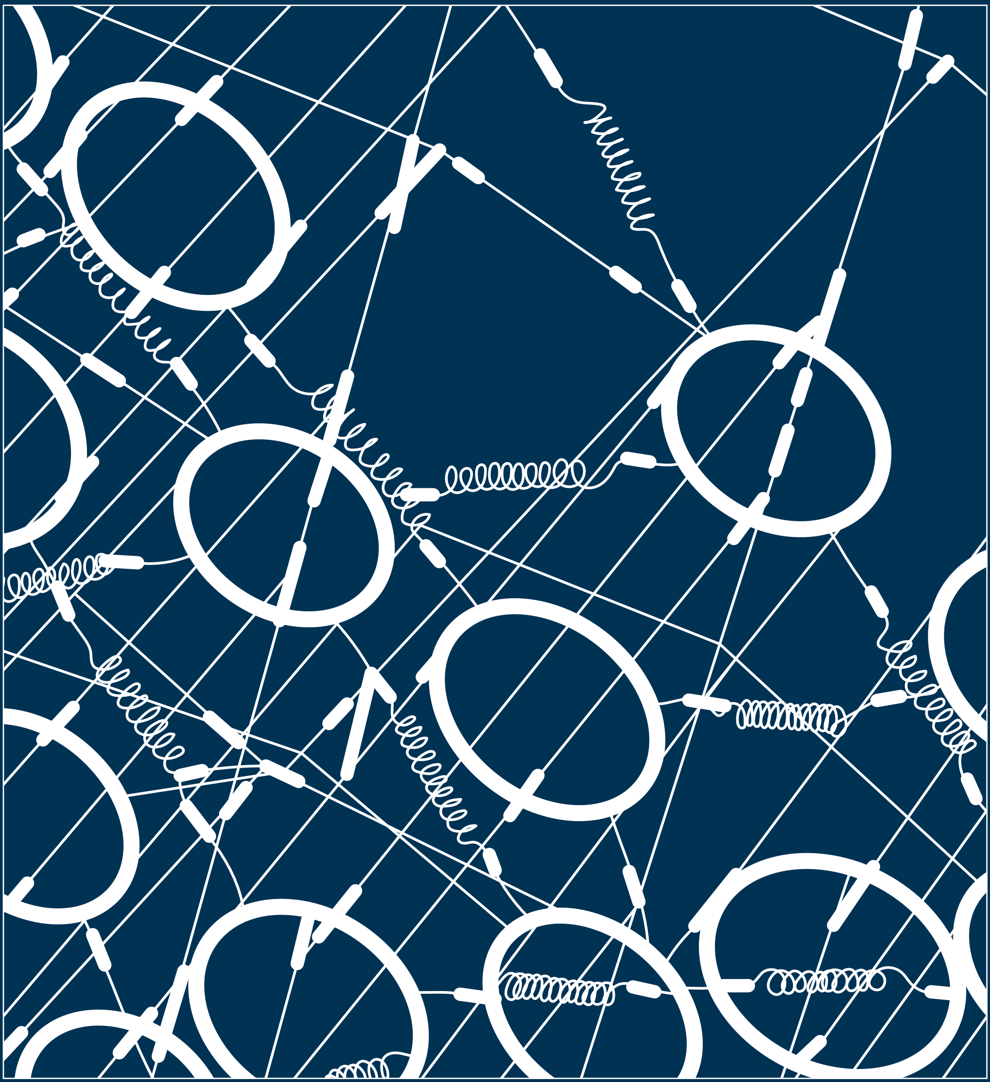

TREATMENT OF CLASS II DIVISION 1 MALOCCLUSION AFTER MAXILLARY FIRST PERMANENT MOLAR EXTRACTIONS

JOHAN WILLEM BOOIJ

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TREATMENT OF CLASS II DIVISION 1 MALOCCLUSION AFTER MAXILLARY FIRST PERMANENT MOLAR EXTRACTIONS

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ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. dr. J.H.J.M. van Krieken,
volgens besluit van het college van decanen
in het openbaar te verdedigen op maandag 15 maart 2021
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door

Johan Willem Booij

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Promotoren:

Prof. dr. A.M. Kuijpers-Jagtman
Prof. dr. C. Katsaros, Universität Bern, Zwitserland

Manuscriptcommissie:

Prof. dr. G.J. Meijer (voorzitter)
Prof. dr. G. de Pauw, Universiteit Gent, België
Dr. A.C Jongsma, Universitair Medisch Centrum Groningen

Paranimfen:

K.A. Dijk
Drs. F.J. Hordijk

TREATMENT OF CLASS II DIVISION 1 MALOCCLUSION AFTER MAXILLARY FIRST PERMANENT MOLAR EXTRACTIONS

D O C T O R A L   T H E S I S

to obtain the degree of doctor
from Radboud University Nijmegen
on the authority of the rector magnificus prof. dr. J.H.J.M. van Krieken,
according to the decision of the Council of Deans
to be defended in public on Monday the 15th of March 2021
at 14:30 hours

by

Johan Willem Booij

born on March 19 1954
Groningen

Supervisors:

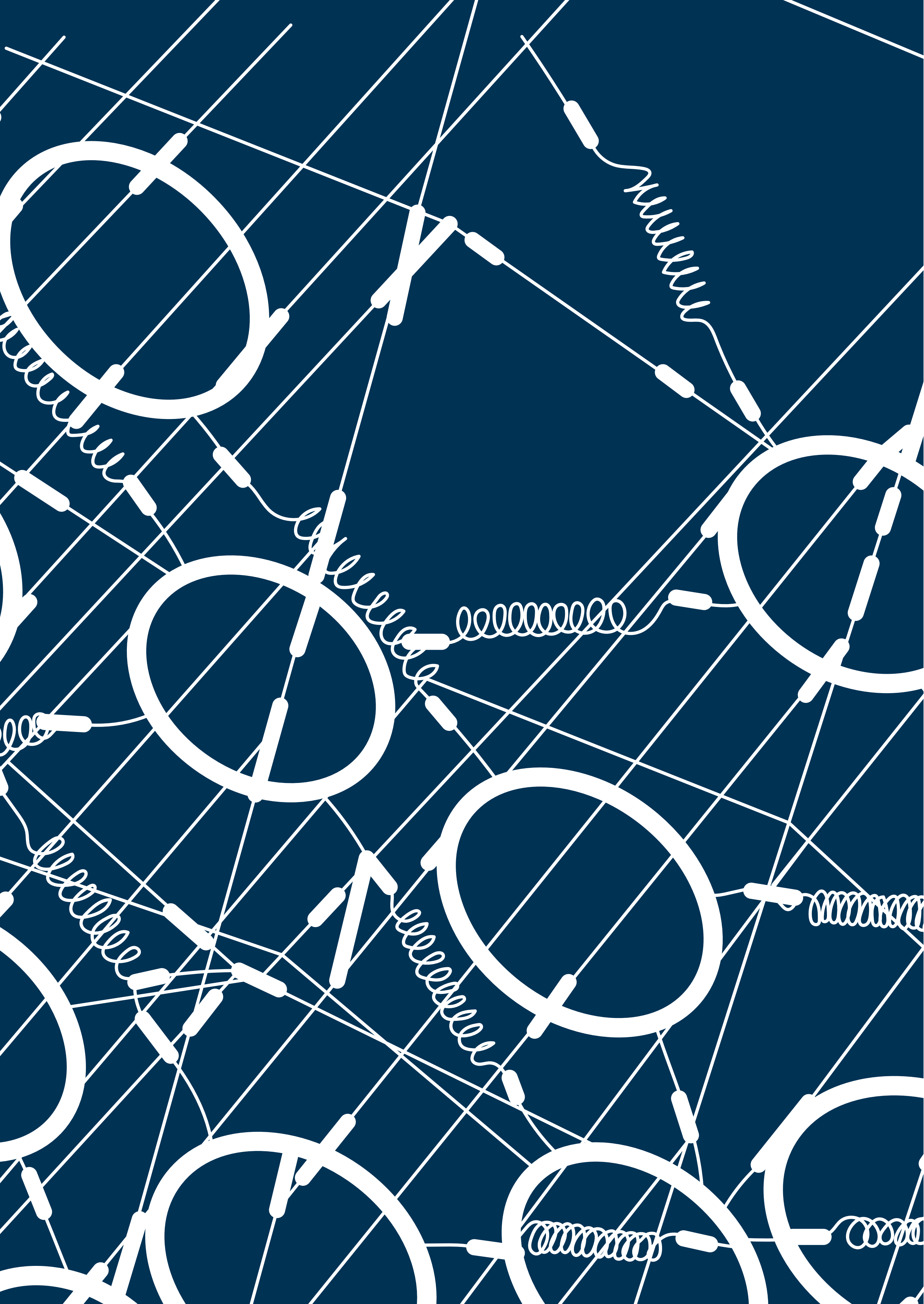
Prof. dr. A.M. Kuijpers-Jagtman
Prof. dr. C. Katsaros, University of Bern, Switzerland

Doctoral thesis committee:

Prof. dr. G.J. Meijer (chair)
Prof. dr. G. de Pauw, University of Gent, Belgium
Dr. A.C. Jongsma, University Medical Center Groningen

Paranymphs:

K.A. Dijk
F.F. Hordijk, DDS



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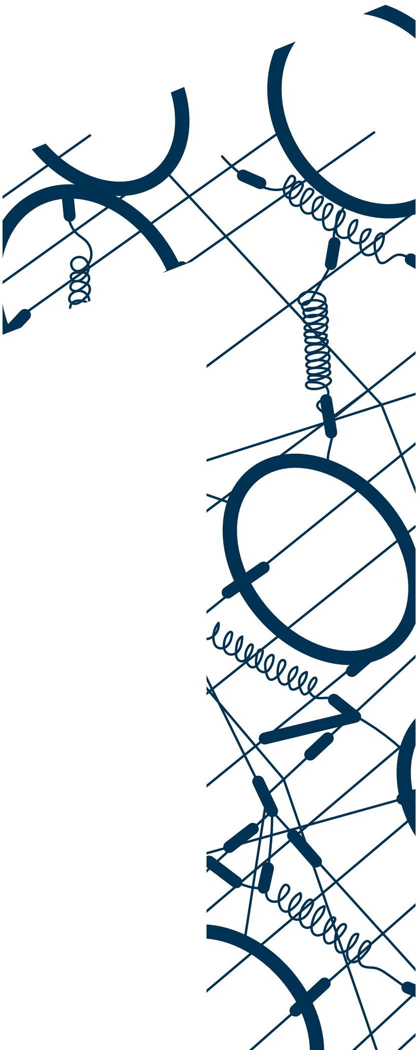

CHAPTER 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Epidemiology and etiology of class II malocclusion

Class II division 1 malocclusion is the most frequent orthodontic deformity seen in the orthodontic office. In a retrospective study on the prevalence of dentofacial characteristics in a Belgian orthodontic population, the prevalences of Angle Class I, Class II division 1, Class II division 2, and Class III malocclusions were 31%, 52%, 11%, and 6%, respectively [1]. In a large epidemiological study in the Dutch population in 1989, the percentages for Class I, II, and III malocclusions were 69%, 28%, and 2%, respectively [2]. In a later study involving 11-year-old Dutch children, 36% had a Class II malocclusion [3].

As part of a large-scale national survey (NHANES III) of health care problems and needs in the US population, the overjet was measured, and an overjet of 5 mm or more was interpreted as a Class II division 1 malocclusion. This level of overjet was identified in 23% of whites with northern European ancestry [4, 5]. In a Cochrane review of orthodontic treatment for prominent upper front teeth (Class II malocclusion) in children and adolescents, about a quarter of the 12-year-old children in the UK were affected with this condition [6].

Class II malocclusions show a large range of soft tissue, skeletal, and dental variations. Soft tissue variations and skeletal components such as mandibular retrognathia, maxillary protrusion, and vertical variations have a strong genetic basis [7]. The dental alveolar components are more influenced by functional and environmental factors such as thumb suckling, lip biting, lip suckling, tongue interposition, infantile swallow, mouth breathing, and the composition of food [8]. Superimposition of these functional factors on the original genetic background will result in the final dentofacial pattern [9].

Present research findings have yielded no simple explanations for the etiology of malocclusions in terms of function and heredity [10]. The complexity of the interactions between genetic and environmental factors may explain why, at the present state of the art in orthodontics, treatment modalities for malocclusions are more directed to the symptoms rather than to etiology [11].

Definition and dentoskeletal characteristics of Class II malocclusion

In 1907, Edward H. Angle had already introduced his classification of orthodontic malocclusions based on the relationship of the upper and lower first permanent molars, and he called the upper first molars “the key to occlusion” [12]. In the last century, many other classifications were developed, based on skeletal and/or dental structures [13, 14, 15, 16].

Although Angle's classification relies only on the occlusion of the first permanent molars, and the vertical dimension and the soft tissues are not involved, this classification remains in common use, despite its shortcomings.

In the textbook *Glossary of Orthodontic Terms* [17], Class II malocclusion is defined as: "A malocclusion in which the buccal groove of the mandibular first molar occludes posterior (distal) to the mesial buccal cusp of the maxillary first molar. The severity of the deviation from the Class I molar relationship usually is indicated in fractions (or multiples) of the mesiodistal width of a premolar crown ('cusp' or 'unit')."

Class II division 1 malocclusion can be associated with all of the vertical growth patterns (brachyfacial, normofacial, and dolichofacial), while Class II division 2 malocclusion is most often found in brachyfacial patterns [14]. Different vertical growth patterns result in different facial rotations [18]. In brachyfacial patterns, the mandible tends to rotate forward, and in dolichofacial patterns the mandible tends to rotate backward during growth. This rotation also affects the eruption pattern of the lower incisors. The brachyfacial pattern is mostly combined with a deep incisal overbite, whereas with dolichofacial patterns, an open bite tendency is seen more often. In general, Class II malocclusions can be separated into skeletal components and upper and lower dental components with a large range of variation [19].

One-phase versus two-phase treatment

Prominent upper front teeth can cause functional, esthetic, and social problems for the child and carry a greater risk for damage by trauma [6]. A wide variety of treatment options are available, and correction can be performed with different orthodontic appliances at different ages.

With a child at age 7 to 11 years, the orthodontist has to decide whether to start the correction of the upper prominent front teeth or to wait until adolescence. The choice then must be made between early treatment (two phases), later treatment (one phase), or a combined treatment after completion of growth. In a two-phase treatment, the Class II malocclusion is first corrected with a functional appliance or extra-oral traction, followed by a treatment with fixed appliances at the age of 12 to 16 years. In the one-phase treatment, orthodontics is more efficient.

A recently published Cochrane review assessed the effects of orthodontic treatment for Class II malocclusions started when children were age 7 to 11 years ("early treatment" in two phases) compared to treatment at around age 12 to 16 years ("late treatment" in one phase) [6]. The authors included 27 randomized controlled trials (RCTs) with 1251 participants, all children under age 16 years. The following variables were studied: overjet, ANB angle, self-esteem, patient satisfaction, any injury to the upper front teeth, temporomandibular joint problems, gingival harm, damage to the teeth, and Peer Assessment Rating Index (PAR) scores. For only one variable was a difference found between early and late treatment: the incidence of new incisal trauma [6]. The overall conclusion of this Cochrane review was that any benefit of early treatment, such as reduction in overjet and possible increase in self-esteem, is limited. The quality of the evidence for this outcome was low to moderate, and the findings did not suggest that any appliance was better than any other to decrease overjet and ANB angle.

Skeletal anchorage with TADs and fixed intermaxillary springs are currently gaining in popularity, which makes treatment outcome less dependent on patient adherence. These so-called non-compliance treatments likely will have a positive effect on outcomes of Class II division 1 treatment.

Skeletal, dento-alveolar, and soft tissue changes during treatment

Class II therapy aims at reducing the jaw discrepancy and/or diminishing the prominence of the upper anterior teeth [6]. Soft tissue changes are the result of the underlying skeletal and dento-alveolar changes and growth. There is a long-lasting controversy about the influence of extraction treatment versus non-extraction treatment on the soft tissues of the face. Among orthodontists, it is a common belief that tooth extractions affect the facial profile. However, a recent systematic review on this subject indicated that with current understanding, it is impossible to predict with precision the profile response of different types of orthodontic treatment [20]. The design and results of existing studies are too heterogeneous to allow for reliable conclusions. Well-designed randomized controlled trials (RCTs), advanced uniform cephalometric analysis, and possibly the use of 3D-imaging techniques such as CBCT and 3D-stereophotogrammetry are needed to obtain more detailed information about growth, treatment effects, and post-treatment changes that can support accurate prognosis.

The question of whether we really can increase mandibular length and the mandibular ramus in the long term remains difficult to answer. Precise timing of the start of functional treatment in relation to pubertal growth also could have an effect [21, 22].

Stability and change after Class II treatment

To cite George Northcroft [23] in 1914*:* "As long as etiological problems remain unsolved, so long will our retention of cases involving these problems remain guesswork." Even 100 years later, little is known about post-treatment changes and the individual predictability of treatment. Bondemark et al. [24] published a systematic review on long-term stability up to at least 5 years post retention. Their search resulted in 38 articles that met the inclusion criteria.

With respect to Class II treatment, they found some evidence only for treatment of Class II division 1 malocclusion with the Herbst appliance, which normalized the occlusion, but changes after treatment did occur and could not be predicted at the individual level.

Recently, Maniewicz et al. [25] published a systematic review on predictive factors of sagittal stability after extraction or non-extraction treatment of Class II malocclusions, with functional or fixed appliances. Inclusion criteria were longitudinal studies with at least 10 patients looking at associations between at least one factor and change after treatment. The minimum follow-up period was 2 years. A total of 17 of 1372 articles met these inclusion criteria. These authors found only limited evidence for two factors as being positively associated with relapse. A large change in the sagittal molar relationship and the sagittal canine relationship during active treatment was associated with more post-treatment change. Many other factors, including treatment characteristics, pretreatment patient characteristics, and final posttreatment characteristics were not predictive for post-treatment change [25].

Class II treatment with extraction of maxillary permanent first molars

Patients and orthodontists prefer efficient and fast treatment. Earlier studies have shown that a two-phase treatment of Class II division 1 malocclusion has no real benefit [6]. For this reason, the author of this thesis prefers to employ a one-phase approach. Williams, in 1979, was among the first to publish a treatment concept involving extraction of maxillary first molars using the Begg technique [26]. In 2009, this method was described in detail by Booij et al. [27].

Thin, round, custom-made arch wires, low-friction light wire brackets, light horizontal elastics, and limited Class II elastics are part of the treatment mechanics. Controlled mesial movement of the upper second molars can be achieved with a palatal bar between the upper second molars in combination with anchor bends a couple of millimeters mesial to the second molar tubes. Upper premolars have a natural tendency to move distally into the direction of the extraction sites. A low-force, intra-arch elastic attached to a hook in the canine bracket is used to stimulate this movement to transform a Class II premolar interdigitation into a Class I interdigitation. To accelerate the Class II correction, the use of Class II elastics can be considered. These elastics are attached on the same hook in the canine bracket to a hook on the lower molars. With this one-phase treatment, there is no need for skeletal anchorage or extra-oral traction. A possible bite-closing effect of extraction of maxillary first molars could be an indication in patients with a vertical growth pattern.

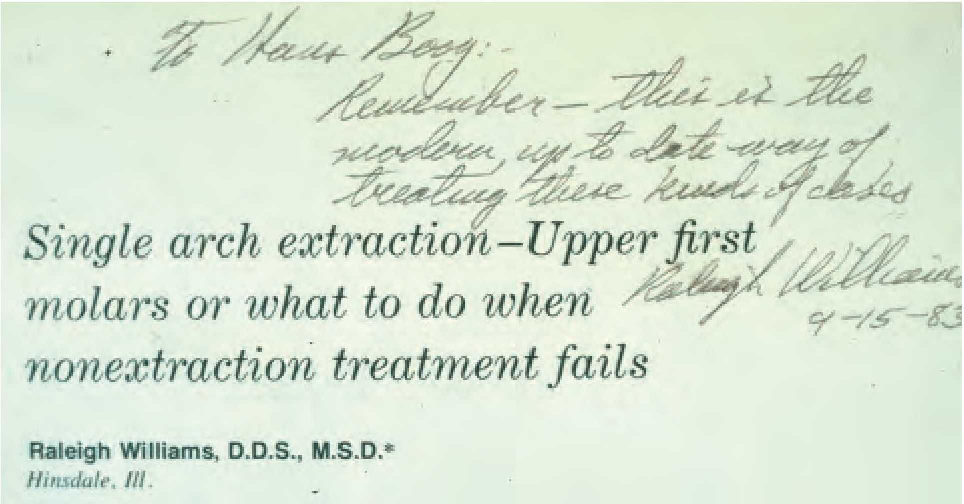

FIGURE 1.1 The author of this PhD was introduced to this method personally by Dr. Raleigh Williams: "Remember – this is the modern up-to-date way of treating these kinds of cases (9-15-83)."

Rationale for and aims of the present study

Class II division 1 malocclusion is the most frequently treated orthodontic anomaly. The orthodontist can choose from a wide range of methods based on jaw orthopedics and/or dento-alveolar compensation. Research has been performed on treatment outcomes with these methods, but well-designed RCTs are lacking, and the level of evidence is still rather low.

Class II treatment after extraction of the upper first molars can be very effective, but to date, no research has been done on this type of treatment for a large group of patients. The aim of this study was to structure the treatment method and study the quality and post-treatment changes of Class II treatment after upper first molar extractions.

Research questions

- In this PhD thesis, the following research questions will be addressed:
- How is a Class II division 1 treatment after upper first molar extractions structured, and what are the components of the appliance? (Chapter 2)
- How are overjet correction and space closure achieved after upper first molar extractions in patients with a Class II division 1 malocclusion? (Chapter 3)
- Do two treatment modalities for Class II division 1 (maxillary first molar extraction versus Herbst appliance) give different results for dento-skeletal outcome and facial profile? (Chapter 4)

- What are the post-treatment cephalometric effects of orthodontic treatment with extraction of maxillary first permanent molars in patients with Class II division 1 malocclusion? (Chapter 5)
- What are the post-treatment dento-alveolar results of orthodontic treatment with extraction of maxillary first molars in patients with Class II division 1 malocclusion measured with the PAR index? (Chapter 6)

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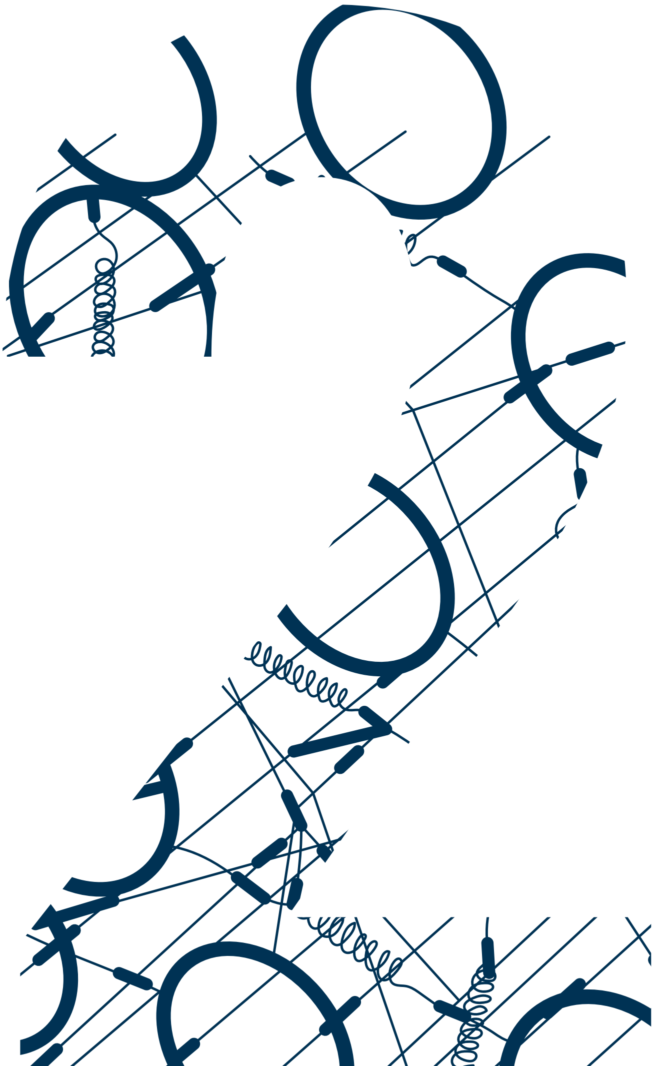


CHAPTER 2

A TREATMENT METHOD FOR CLASS II DIVISION 1 PATIENTS WITH EXTRACTION OF PERMANENT MAXILLARY FIRST MOLARS

Booij JW, Kuijpers-Jagtman AM, Katsaros C. *A treatment method for Class II division 1 patients with extraction of permanent maxillary first molars*.

World J Orthod. 2009;10(1):41-48

ABSTRACT

Throughout the years, various treatment modalities have been presented for the treatment of Class II division 1 malocclusions. The goal of this paper is to present a treatment approach that involves the extraction of the maxillary first molars followed by use of fixed appliances with low-friction brackets. This treatment approach has proven to be an efficient treatment modality for Class II division 1 malocclusions, especially with noncompliant patients.

INTRODUCTION

A great variety of treatment modalities has been presented for the treatment of Class II malocclusions. Many rely heavily on patient cooperation vis a vis headgear or intermaxillary elastics [1]. This explains why noncompliance treatment modalities have become increasingly popular, with absolute anchorage using orthodontic implants, onplants, miniscrews, or bone plates as the latest additions to the orthodontic repertory [2].

Eliminating the need for headgear or removable functional appliances was among the aims of the treatment approach described here, which involves extraction of the maxillary first molars without special precautions to preserve anchorage. Williams proposed this treatment in 1979 but noted it in an earlier paper [3,4]. We will describe this treatment approach in detail and discuss its contribution to the treatment modalities of Class II malocclusions.

METHOD

The treatment procedure can be divided into three phases: Class II correction, space closure and torque, and detailing/finishing. In deep bite cases, a pretreatment stage with a fixed appliance in the mandibular arch and a biteplate in the maxilla is necessary to reduce the pronounced curve of Spee. The method is illustrated by drawings (Figs. 2.1 to 2.3) and the presentation of a patient (Figs. 2.4 to 2.9).

Phase 1: Class II correction

Maxilla
The second molars are banded. The molar bands have 7- mm buccal tubes and palatal sheaths. The maxillary first molars are separated to facilitate extraction. After extraction and a healing period of three weeks, low-friction brackets, such as Begg lightwire brackets, are placed (Fig. 2.1a).

The maxillary premolars are not bonded in the first phase of treatment to prevent binding. The maxillary second molars are connected by a palatal bar to increase anchorage and correct eventual rotations and transversal malpositions. An individually made archwire constructed of 0.016-in premium plus pull straightened Australian wire (Wilcock, Whittlesea, Australia) is placed in the maxillary arch. If the maxillary anterior teeth cannot easily be attached to the archwire, this is completed after space is created by distal movement of the maxillary canines. An anchor bend approximately 5 mm mesial of the second molar tubes prevents mesial tipping of these teeth. The degree of these bends depends on the desired amount of bite opening. The maxillary canines are fixed with stainless steel high hat lock pins (TP, La Porte, Indiana,

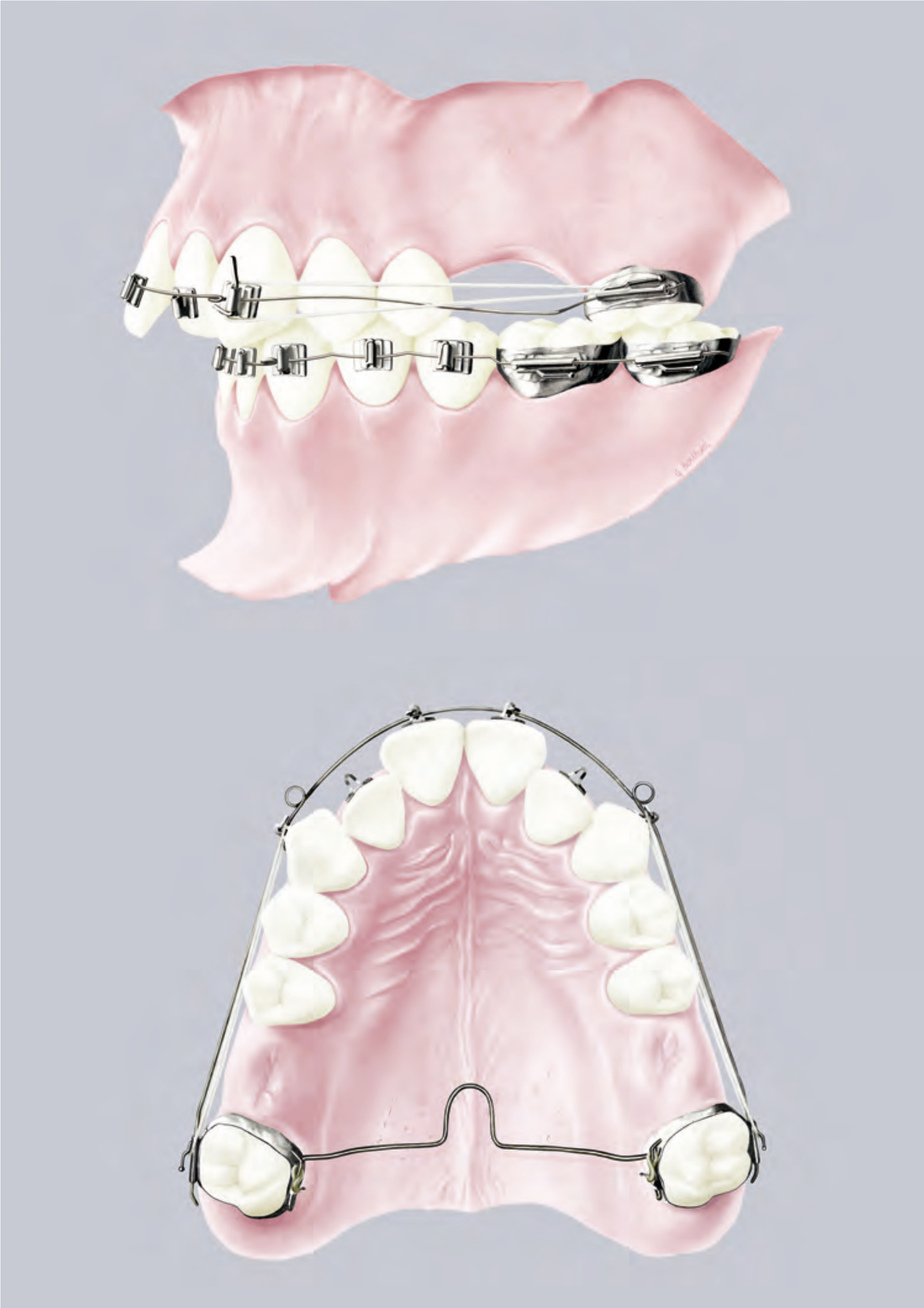


FIGURE 2.1A Beginning of Class II correction

USA) to the main arch. The occlusal part of these pins is partially bent mesially to serve as a hook for the horizontal elastics (5/16 in, 2.6 oz), which are attached to the buccal hooks on the maxillary second molar bands. The patient is instructed to replace the elastics only once per week. To prevent irritation of the gingiva in the premolar area, these elastics should run inside the anchor bends in the main arch. The system results in separate movement of the maxillary canines along the arch. Patients are seen at seven-week intervals. The maxillary second molars sometimes move forward too quickly. In these cases, the horizontal elastics must be replaced by Class II elastics (5/16 in, 2.6 oz). In asymmetric situations, the elastics should be adjusted accordingly. A Class I canine and premolar interdigitation is usually reached within six months. As soon as the intercuspation is corrected, the patient is instructed to wear the elastics only at night. Spaces can appear in the maxillary premolar area because of spontaneous distal movement (Fig. 2.1[b]).

Mandible

The mandibular arch carries full-fixed appliances, as well. At some point, the 0.016-in starting archwire is replaced by a 0.018-in premium plus archwire (Wilcock, Whittlesea, Australia), while the original arch form is maintained. An anchor bend mesial of the mandibular first molar tubes together with v-bends between both premolars and between premolars and canines results in the desired bite opening.

Phase 2: Space closure and torque

Maxilla

When the maxillary premolars are bonded, the 0.016-in maxillary archwire is modified with offset bends, anchor bends and vertical offsets between second molars and second premolars (Fig. 2.2[a]). Depending on the required bite opening, v-bends between both premolars and premolars and canines are added.

The alignment of the maxillary premolars takes approximately one month, after which the 0.016-in archwire is replaced by a 0.018-in premium plus archwire.

Individual adjustments are made as needed, for example, to correct the relation of maxillary central and lateral incisors in conjunction with the smile line. The form of the maxillary arch is adapted to the form of the original arch. An individual two-spur torque auxiliary of 0.014-in regular wire (Wilcock, Whittlesea, Australia) ending distally of the maxillary canine brackets is applied (Fig. 2.2[b]). Aside from the torque effect, this spring has the tendency to protrude the maxillary anterior teeth. This adverse effect is eliminated by horizontal traction in the lateral regions. If extensive torque is required and rest spaces are small, the palatal bar between the maxillary second molars is maintained. In the opposite situation, the bar is temporarily

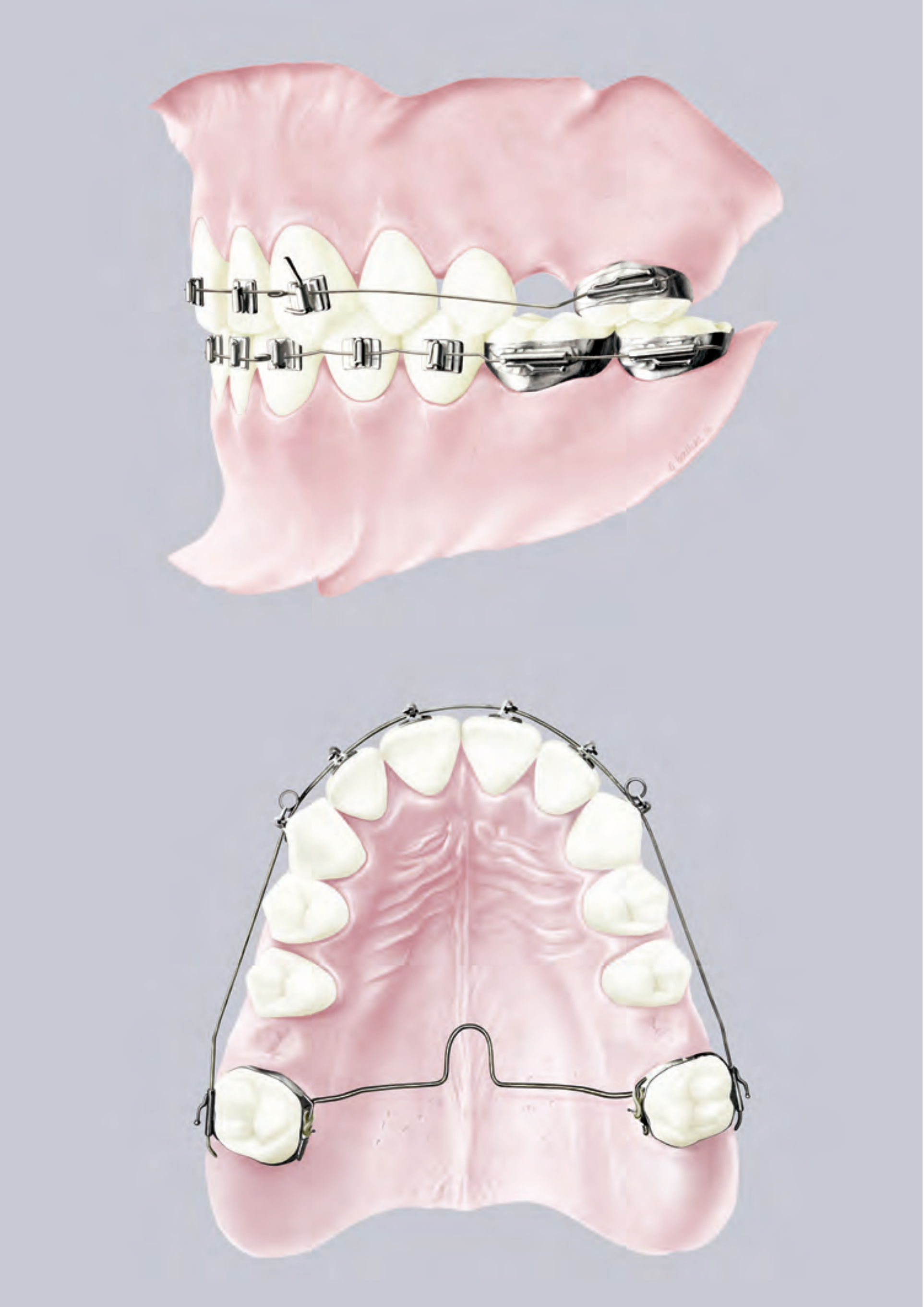


FIGURE 2.1B Completion of Class II correction**;** Class I canine and premolar interdigitation is realized

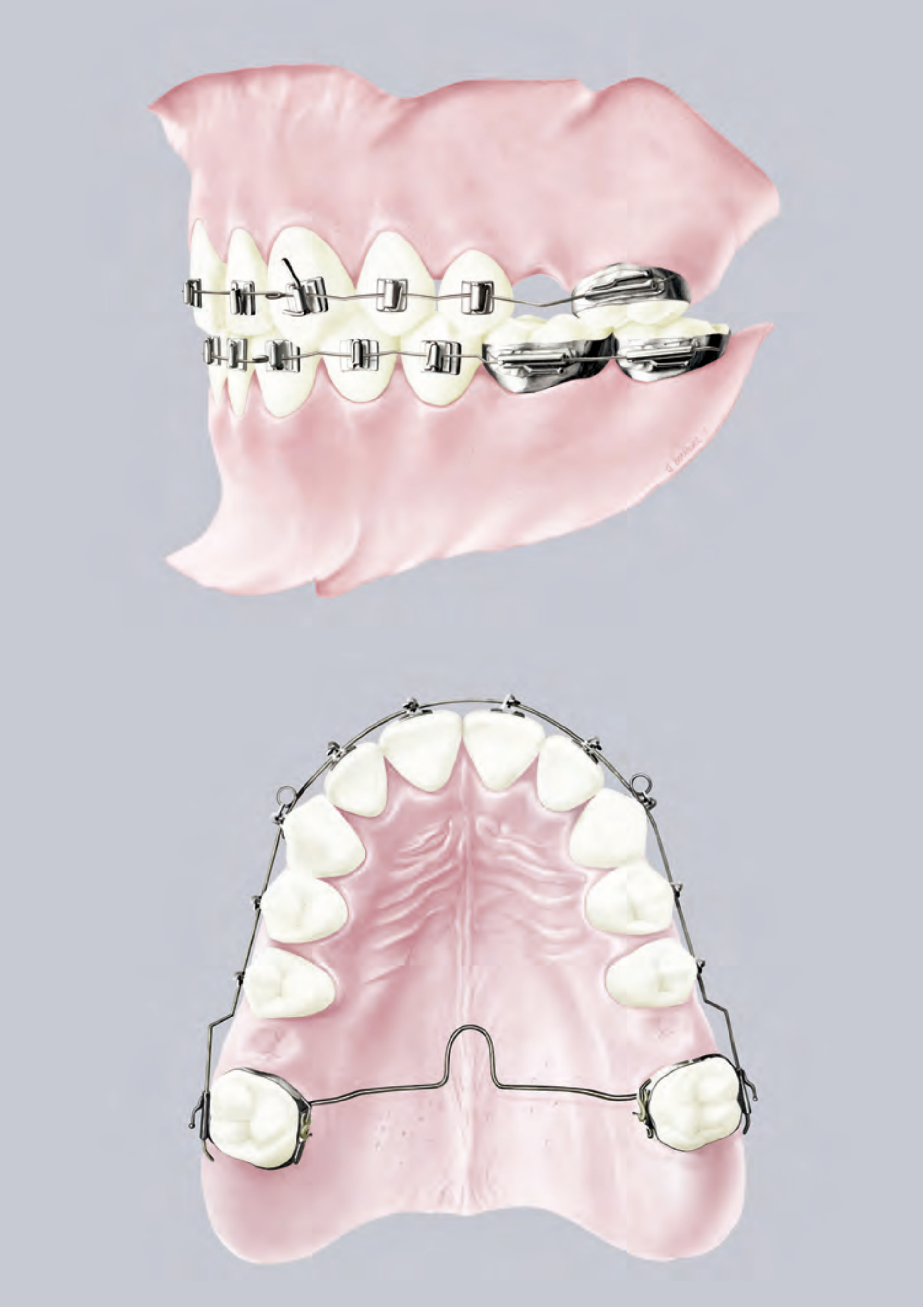


FIGURE 2.2A Beginning of space closure and torque; the maxillary premolars are bonded and the maxillary 0.016-in archwire is adjusted

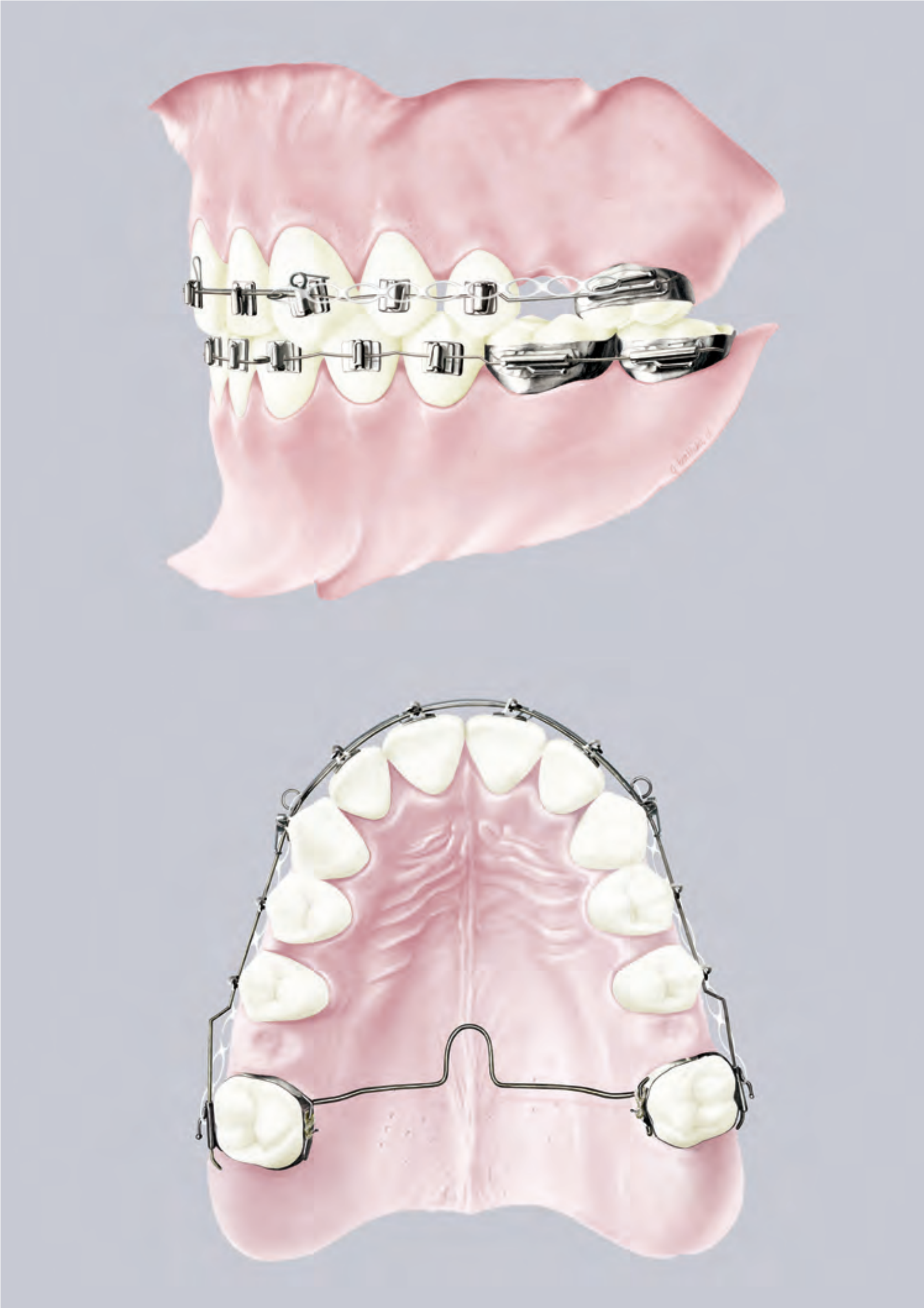


FIGURE 2.2B A 0.018-in maxillary archwire in combination with a 0.014-in torqueing auxiliary, uprighting and horizontal tractions; the palatal bar can be temporarily removed

removed. Uprighting springs (TP, La Porte, Indiana, USA) are placed in the vertical slots of the maxillary canine brackets. The amount of activity of these springs is individually adjusted as needed. The patients are seen at intervals of six to eight weeks. The closing of the lateral spaces and the torque action must be balanced. Orthodontists have to observe the progress and decide about individual adaptations in the use of horizontal tractions, uprighting springs and eventual wear of Class II elastics.

Mandible
In case of the eventual wear of Class II elastics, the mandibular archwire shape is expanded to compensate for lingual tipping of the mandibular molars. When indicated, individual uprighting springs are placed in the vertical slots.

Phase 3: Detailing and finishing

Maxilla and mandible
In the final phase of treatment, adjustments are made in the archwires for detailed finishing and the palatal bar is reinserted when indicated (Fig. 2.3[a]). Each tooth can be uprighted independently by placement of springs, taking into account the adverse effects of the uprighting springs that all point into the same direction and causing a mesial directed tendency. When the amount of torque is satisfactory, the torque auxiliary can easily be removed.

In most cases, retention is realized by means of fixed retainers. To prevent overeruption of the mandibular second molars, local retention wires are bonded buccally between the mandibular first and second molars. These sectionals are removed when the maxillary third molars are in occlusal contact with the mandibular second molars (Fig. 2.3[b]).

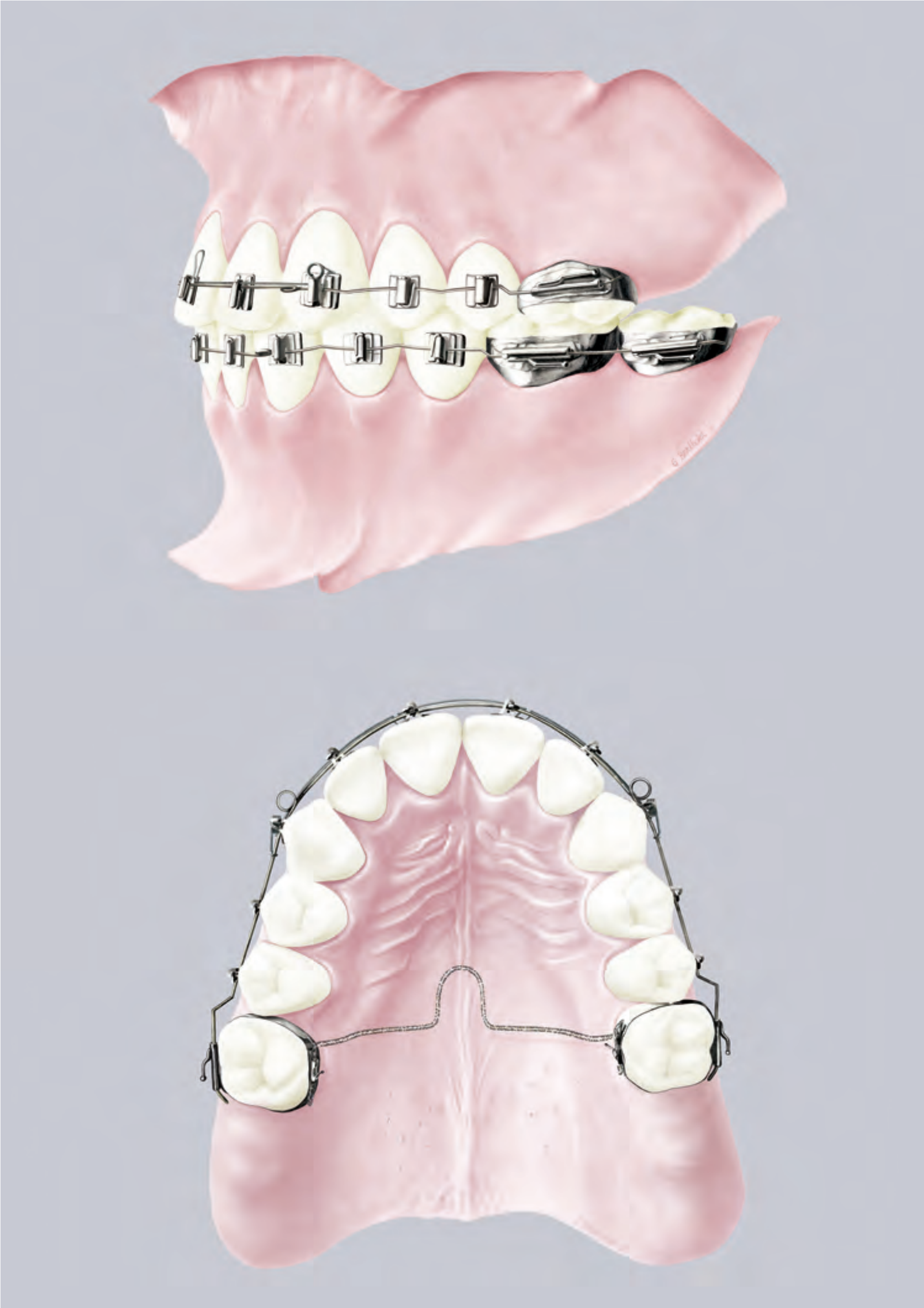


FIGURE 2.3A Space closure, torque, and uprighting are complete

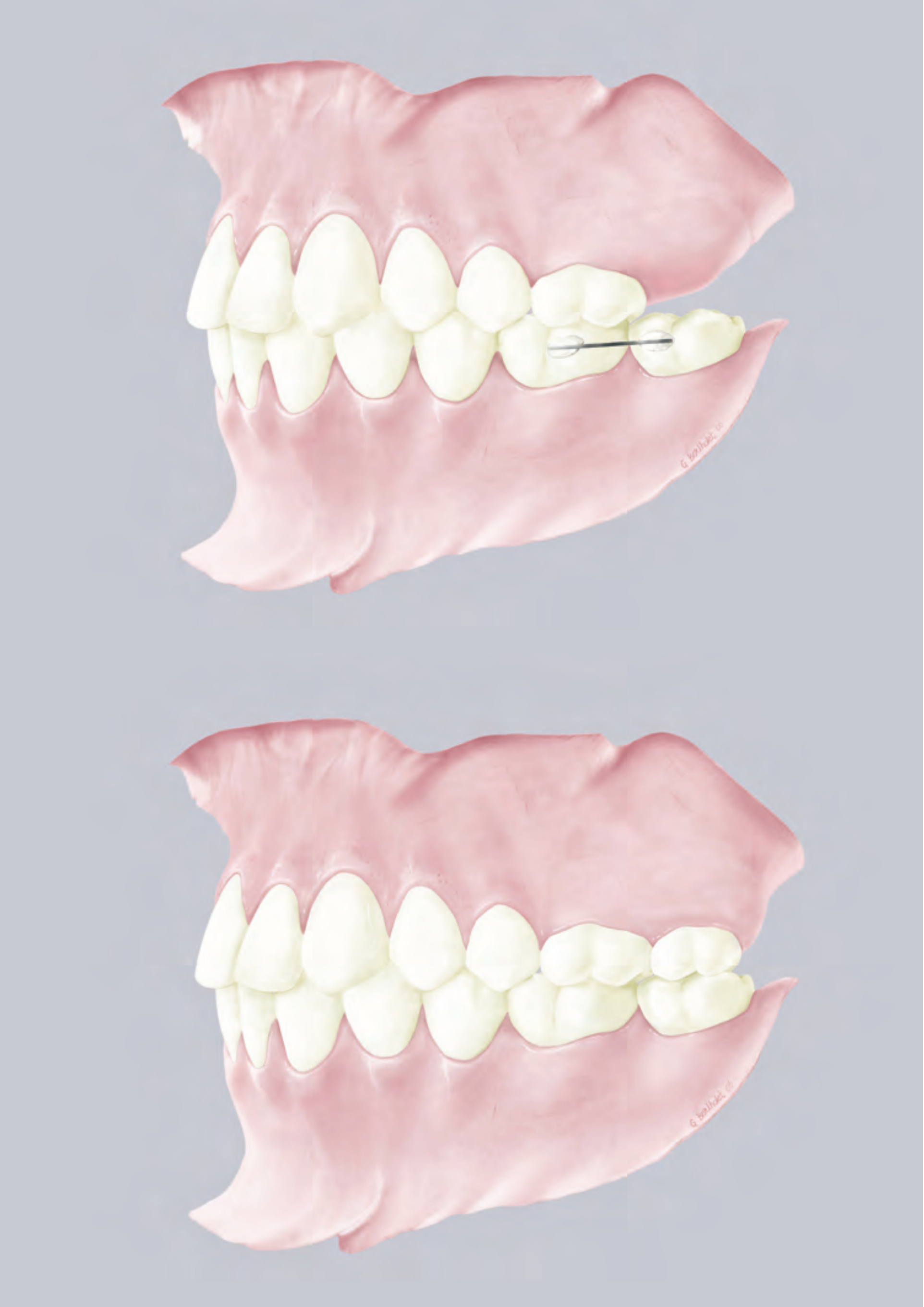
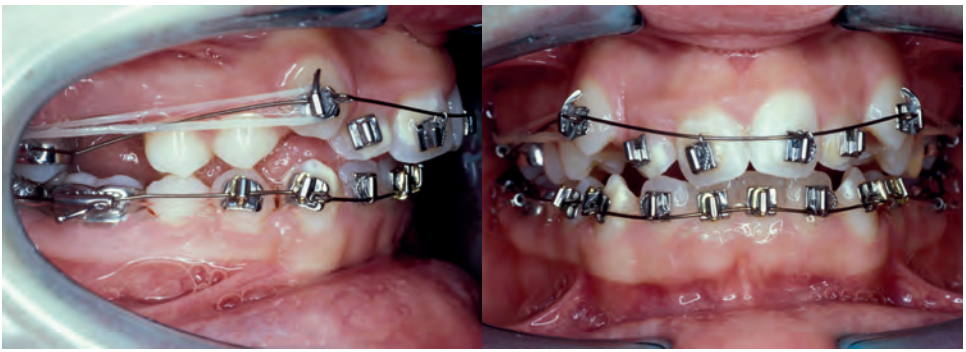
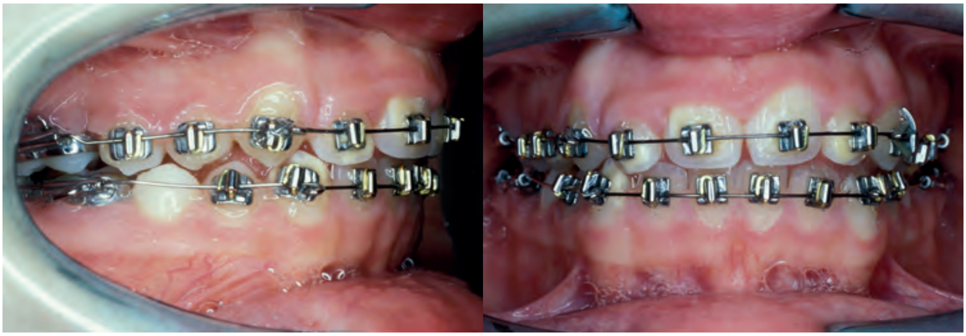


FIGURE 2.3B The bonded wire between the mandibular first and second molars is removed after settling in of the maxillary third molar

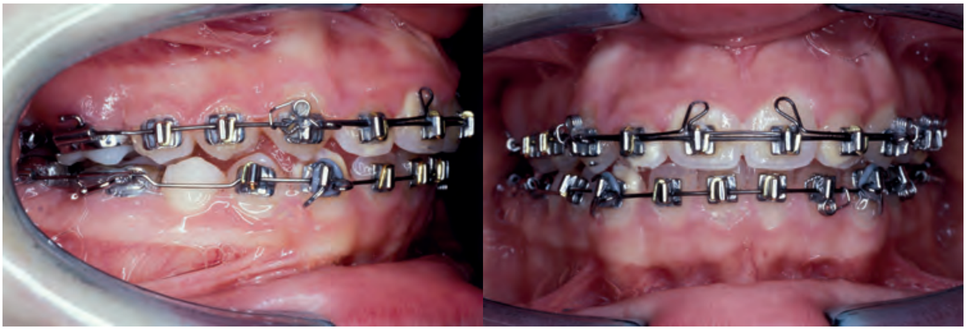
FIGURES 2.4 Beginning of treatment



FIGURES 2.5 Beginning of the Class II correction after extraction of the maxillary first molars



FIGURES 2.6 Beginning of space closure and torque; the maxillary premolars are bonded, and the maxillary 0.016-in archwire is adjusted



FIGURES 2.7 A 0.018-in maxillary archwire with a 0.014-in torqueing auxiliary

FIGURES 2.8 Completion of treatment

FIGURES 2.9 Five years posttreatment

DISCUSSION

This paper presented a method to treat Class II malocclusion with low friction brackets after extraction of the maxillary first molars. To extract healthy maxillary first molars is a difficult decision that may cause confusion and resistance within dental community. It also must be mentioned that maxillary first molar extractions are not always without complication. However, this method is used only when third molars are present and second and third molar anatomy is normal. It is expected that after mesial maxillary second molar movement the third molars have a better chance of erupting than compared with non-extraction treatment. So far, though, this is an unproven statement that needs to be investigated further. After orthodontic treatment and eruption of the third molars, the result is a dentition with what looks like a full complement of teeth. Moreover, several maxillary molar distal movement techniques, for example, the skeletal anchorage system (SAS) described by Sugawara et al. [5] can often be carried out only after extraction of the second or third molars. We can conclude, therefore, that the different treatment methods result in an equal number of molars. Patient cooperation is of great importance in orthodontics, and it can be a real challenge. If patient cooperation can be restricted to only toothbrushing and replacement of horizontal elastics, as in the proposed treatment modality, this could be a solution for a group of problem patients, although in some cases, Class II elastics are necessary anyway. It is obvious that this treatment is not a noncompliance therapy, but it could at least be termed a “less-compliance therapy”. The treatment as proposed results in a dentoalveolar correction of the Class II division 1 malocclusion. In the past, it had been assumed that headgear or functional appliances have a skeletal effect, as well. However, a recent meta-analysis of randomized clinical trials in which these types of treatment were compared showed that the skeletal effect of headgear and functional appliances is neglectable [6]. It might be a matter of concern that extraction of maxillary first molars can adversely influence the profile. However, a recent study that evaluated 100 consecutively treated cases with the treatment approach as described here has shown that extraction of maxillary first permanent molars has only a small effect on the soft tissue profile [7]. In that study, the maxillary incisor retraction was on average 2.7 mm relative to the A-pogonion line with maintenance of a good inclination of the incisors. A retrusion of 1.4 mm of the upper lip relative to soft tissue subnasale-soft pogonion was found, which means that the upper lip followed the movement of the maxillary incisors for about 50% after extraction of first molars. This is comparable to treatment outcome after extraction of first premolars [7, 8, 9]. Although the method described in this article looks rather simple, it requires precise supervision. Each individual reacts in a different way and it is the orthodontist who has to balance between elastic wear, effects of archwires, and auxiliaries in progress and also has to signal undesired reactions. If performed well, this method has shown to obtain a high-quality treatment result; Stalpers et al. described a 90% improvement of the peer-assessment rating (PAR) index [10]. Taking advantage of the natural tendency of mesial migration of the second molars and distal migration of premolars, the forces that are used to accomplish the desired tooth movements can be low. Tipping of maxillary incisors is usually not as severe as one would expect, probably due to the presence of both premolars. Anchorage control is obtained by a combination of palatal bar and anchor bends in the archwire mesial of the second molar tubes, even to a minor extent in open bite cases. The use of brackets with ample freedom of movement and low friction is a prerequisite. Overall, this method can be used in selected patients with expected poor compliance or after failure of non-extraction treatment, in patients with poor quality maxillary first permanent molars as well as in patients with divergent facial types. The presence of healthy second and third molars with good anatomy is of course required.

CONCLUSION

Extraction of maxillary first molars, followed by fixed appliance treatment with low-friction brackets with thin round wires and a palatal bar, is an effective and efficient treatment modality for Class II division 1 malocclusions, especially for less compliant patients.

ACKNOWLEDGEMENTS

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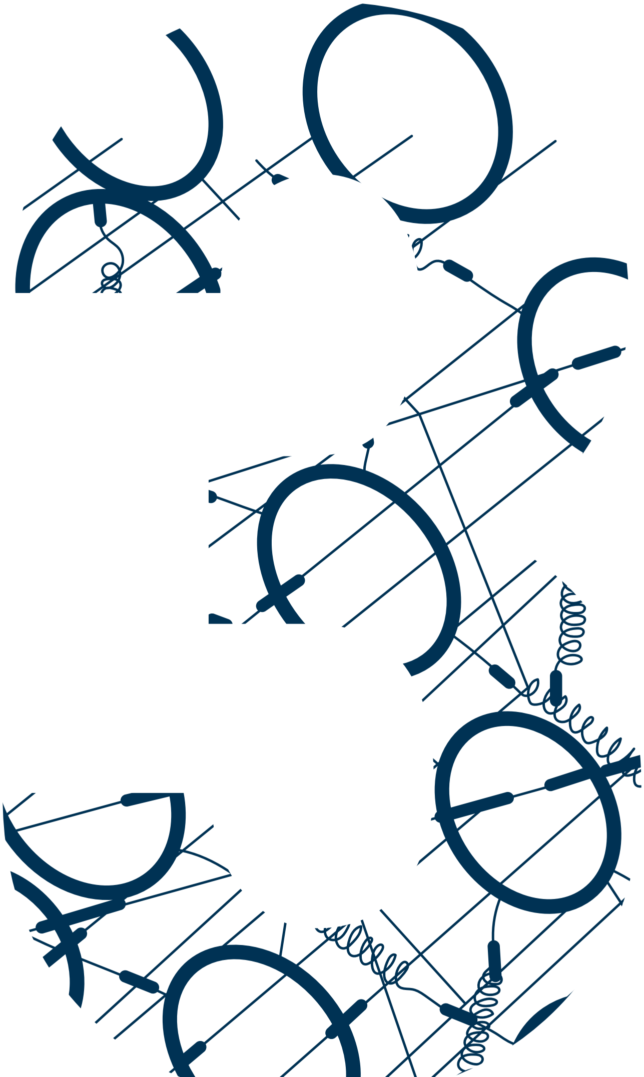

CHAPTER 3

OVERJET CORRECTION AND SPACE CLOSURE MECHANISMS FOR CLASS II TREATMENT BY EXTRACTING THE MAXILLARY FIRST MOLARS

Booij JW, Goeke J, Bronkhorst EM, Pancherz H, Ruf S, Katsaros C. *Overjet correction and space closure mechanisms for Class II treatment by extracting the maxillary first molars.*

J Orofac Orthop. 2011;72(3):196-203

ABSTRACT

Objective. To analyze the mechanism of overjet correction and space closure when treating Class II Division 1 patients by extracting the maxillary first molars.

Patients and methods. A total of 100 prospective, consecutively treated Class II Division 1 patients (45 female, 55 male; 10.5–17.2 years old). Standardized lateral cephalograms prior to and after treatment were evaluated via a modified sagittal occlusion analysis (SO analysis).

Results. The mean degree of overjet correction was 5.2 mm (95% CI = 4.8–5.6 mm) and was on average achieved by means of 1.7 mm skeletal and 3.5 mm dental changes. The relationship between the premolars improved by 4.8 mm toward a Class I relationship, facilitated by 1.7 mm skeletal and 3.1 mm dental changes. The 11.3 mm space closure in the maxillary first molar extraction area resulted from distalization of the second premolars (1.4 mm) and a mesialization of the second molars (9.9 mm).

Conclusions. Overjet correction was essentially achieved by a retrusion of the upper incisors, as well as by ventral growth of the lower jaw and protrusion of the lower incisors. Space closure was only partly achieved by distalization of the premolars.

INTRODUCTION

Class II Division 1 is one of the most common types of malocclusion for which various types of treatment have been described in the literature [1, 7]. According to the patient's age and severity of the malocclusion, functional jaw orthopedic treatment, camouflage therapy with premolar extraction and combined orthodontic and surgical therapy are available [7].

An alternative to camouflage therapy, by which the maxillary first permanent molars are extracted and low friction mechanisms are applied, has recently been described [2]. Good results have been achieved with this method. Stalpers et al. [6] report on an improvement in the PAR index of 90%, with just minor deterioration in the soft-tissue profile. However, the exact mechanism, that is, the relative contribution of the dental and skeletal changes which led to this positive outcome, remains unknown.

Therefore, the aim of this study was to analyze the overjet correction and space closure mechanisms in a large group of prospectively treated Class II Division 1 patients who underwent extraction of the maxillary first permanent molars.

SUBJECTS AND METHOD

Patients and treatment method

A total of 100 prospective, consecutively treated patients (45 girls, 55 boys) were surveyed. They were treated between 1998 and 2004 by the same orthodontist (J.W.B.). The inclusion criteria were the following: Caucasian race, Class II Division 1 malocclusion ≥1/2 premolar width, overjet ≥4 mm, no missing teeth or tooth agenesis (oligodontia or hypodontia), permanent dentition, maxillary third molars present, and treatment via a multi-bracket appliance and extraction of the maxillary first permanent molars. Before treatment, the vertical jaw base relationship was on average normal (35.0 ± 5.7 degree). The patients' mean age at the beginning of treatment was 13.2 years, ranging between 10.5 and 17.2 years. The mean duration of active treatment was 2.5 ± 0.6 years. The treatment was divided into three phases: (1) Class II correction, (2) space closure and torque and (3) fine adjustment plus finishing. The second upper molars were banded and connected by means of a transpalatal arch. Low-friction brackets, Begg light-wire brackets, were bonded in the upper (3–3) and lower jaw. An Australian wire (ca. 0.41 cm [0.16'']) with anchor bends (tip back) mesial to the maxillary second molars and lower first molars was inserted. Class I and/or Class II elastics were used for Class II correction. Prior to space closure, the maxillary premolars were included in the appliances and a 0.18" Australian wire was inserted. Torque arches and uprighting springs were also used. Further details about the clinical treatment steps have recently been described [2].

Cephalometric measurements

Standardized lateral cephalograms prior to (T1) and after (T2) the active treatment were evaluated. All X-ray images were analyzed by the same examiner (J.G.). Linear magnification (approximately 8% in the midsagittal plane) was not corrected. A minor modification in the sagittal occlusion analysis (SO analysis) according to Pancherz [5] was applied (Figure 3.1). By means of this analysis, skeletal and dental effects in the upper and lower jaw can be correlated with the sagittal occlusal changes observed (overjet, molar relationships). The SO analysis variables used in this study are described in Table 3.1. After positively testing the data for normal distribution, the changes between T1 and T2 were analyzed using the paired t test. SPSS® Version 16.0 (SPSS, Chicago, IL, USA) was used as statistical software.

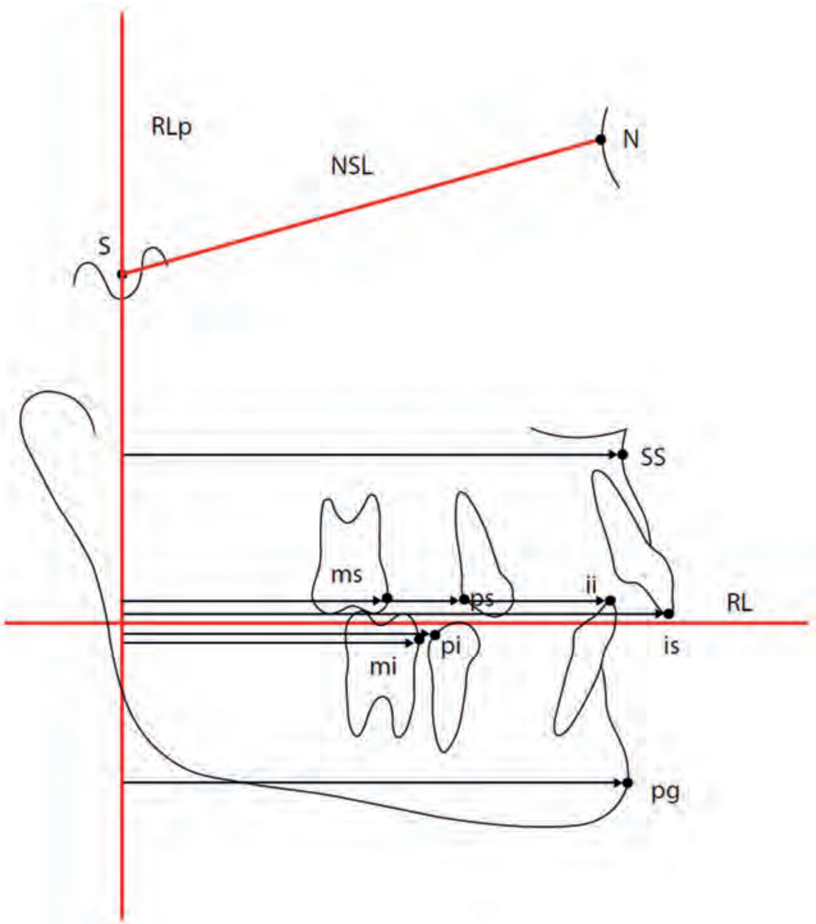

FIGURE 3.1 Reference points and lines of the modified SO analysis. The variables are defined in Table 1

TABLE 3.1 Variables used in the modified SO analysis

is/RLp – ii/RLp	Overjet
ms/RLp – ps/RLp	Maxillary extraction space
ss/RLp	Position of the maxillary base
pg/RLp	Position of the mandibular base
is/RLp	Position of the maxillary central incisor
ii/RLp	Position of the mandibular central incisor
ps/RLp	Position of the maxillary second premolar
pi/RLp	Position of the mandibular second premolar
ms/RLp	Position of the maxillary second molar
mi/RLp	Position of the mandibular first molar
is/RLp (d) – ss/RLp (d)	Change in the position of the maxillary incisor within the maxilla
ii/RLp (d) – pg/RLp (d)	Change in the position of the mandibular incisor within the mandible
ps/RLp (d) – ss/RLp (d)	Change in the position of the maxillary second premolar within the maxilla
pi/RLp (d) – pg/RLp (d)	Change in the position of the mandibular second premolar within the mandible
ms/RLp (d) – ss/RLp (d)	Change in the position of the maxillary second molar within the maxilla
mi/RLp (d) – pg/RLp (d)	Change in the position of the mandibular first molar within the mandible

Method error

To identify the method error in the cephalometric analysis, the measurements taken of the lateral cephalograms of 36 patients were repeated by the same examiner four weeks later. To detect the intra-observer error, the duplicate measurement error was determined as the standard deviation of the difference between the double measurements, divided by $\sqrt{2}$. Using paired t tests, the systematic differences between the two measurements were identified. Table 3.2 illustrates the results of the method error analysis. Since the extraction space in the upper jaw was always 0 at T1, this variable was excluded from the analysis. Even though the double measurements revealed good correlation, a systematic error was detected in two measurements (highlighted in Table 3.2). In both cases, the systematic difference was 0.5 mm. This error was considered to be a sufficiently minor error so as to not exclude both of these variables from further analysis.

TABLE 3.2 Method error for 36 duplicate measurements. Reliability was calculated as Pearson's correlation coefficients; the duplicate measurement error (DME) expresses the random error, while the paired t test was applied to test for systematic differences. The confidence interval (CI) is given.

Variables (mm)	Reliability	DME	Difference	95% CI for diff	p-value
Overjet is/RLp – ii/RLp	0.81	1.3	0.2	[–0.4…0.9]	0.451
Maxillary position ss/RLp	0.98	0.9	0.5	[0.0…0.9]	**0.036**
Mandibular position pg/RLp	0.96	1.5	–0.1	[–0.8…0.6]	0.791
Upper incisor is/RLp	0.79	1.0	–0.5	[–1.0…0]	**0.047**
Lower incisor ii/RLp	0.80	1.5	–0.2	[–0.9…0.6]	0.620
Upper second premolar ps/Rlp	0.97	1.0	0.1	[–0.4…0.6]	0.688
Lower second premolar pi/Rlp	0.97	1.1	0.1	[–0.4…0.6]	0.781
Upper second molar ms/RLp	0.97	1.1	0.2	[–0.3…0.7]	0.412
Lower first molar mi/RLp	0.97	1.1	0.1	[–0.4…0.6]	0.781
Upper incisor is/RLp (d) – ss/RLp (d)	0.98	1.0	0.0	[–0.5…0.4]	0.853
Lower incisor ii/RLp (d) – pg/RLp (d)	0.96	1.4	–0.3	[–1.0…0.4]	0.416
Upper second premolar ps/RLp (d) – ss/RLp (d)	0.83	1.1	–0.4	[–0.9…0.2]	0.165
Lower second premolar pi/RLp (d) – pg/RLp (d)	0.96	0.8	0.2	[–0.2…0.5]	0.368
Upper second molar ms/RLp (d) – ss/RLp (d)	0.78	1.2	–0.3	[–0.8…0.3]	0.391
Lower first molar mi/OLp (d) – pg/OLp (d)	0.96	0.7	0.2	[–0.2…0.5]	0.368

RESULTS

Overjet

The overjet was reduced by 5.2 mm. This was achieved by skeletal changes of 1.7 mm and dental changes of 3.5 mm (Figure 3.2, Table 3.3). The skeletal changes resulted from a 0.3 mm posterior movement of point ss and a 1.4 mm forward movement of point pg. The dental changes were achieved by a 2.4 mm retrusion of the upper incisors and a 1.1 mm protrusion of the lower incisors (Figure 3.2, Table 3.3).

Premolar relationship

The premolar relationship changed by 4.8 mm toward Class I. This was achieved by 1.7 mm skeletal and 3.1 mm dental changes (Figure 3.3, Table 3.3). The dental changes consisted of a 1.4 mm distalization of the maxillary premolars and a 1.7 mm mesialization of the mandibular premolars.

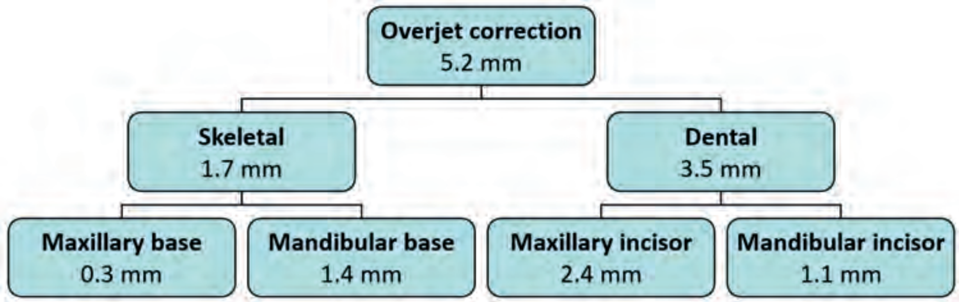

FIGURE 3.2 Overjet correction mechanism (mean values)

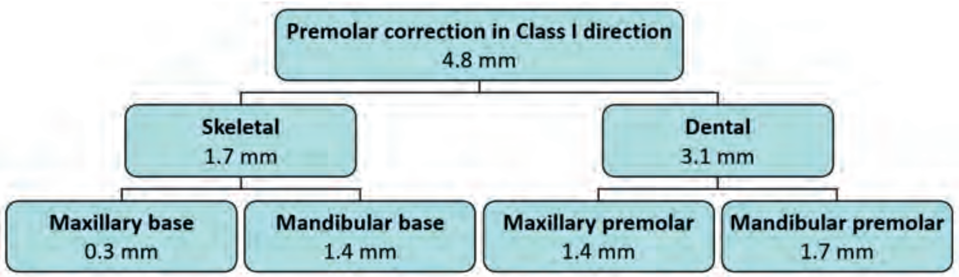

FIGURE 3.3 Premolar correction mechanism (mean values)

Space closure in the upper jaw

Space closure in the upper jaw of 11.3 mm was achieved by a 1.4 mm distalization of the second premolars and a 9.9 mm mesialization of the second molars (Figure 3.4, Table 3.3).

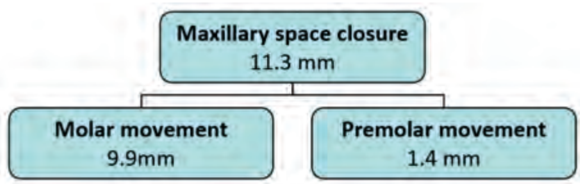

FIGURE 3.4 Extraction space closure mechanism in the upper jaw (mean values)

TABLE 3.3 Variables of the modified SO analysis before (T1) and after (T2) treatment as well as their changes during treatment(T2-T1). The results for the paired t-tests and the confidence intervals (CI) are given.

	T1		T2		T2-T1		
Variables (mm)	**Mean**	**sd**	**Mean**	**sd**	**Changes**	**p-value**	**95% CI**
Overjet is/RLp – ii/RLp	8.1	1.99	3.0	1.51	–5.2	p<0.001	[–5.6…–4.8]
Maxillary extraction space ms/RLp – ps/RLp	–11.3	1.76	0.0	0.00	11.3	p<0.001	[11.0…11.7]
Maxillary position ss/RLp	79.6	3.78	79.3	4.54	–0.3	p=0.221	[–0.8…0.2]
Mandibular position pg/RLp	77.7	4.81	79.2	6.16	1.4	p<0.001	[0.7… 2.1]
Upper incisor is/RLp	87.9	4.41	85.2	4.82	–2.7	p<0.001	[–3.3…–2.1]
Lower incisor ii/RLp	79.8	4.48	82.2	4.86	2.5	p<0.001	[1.9…3.1]
Upper second premolar ps/Rlp	55.1	3.57	53.4	4.22	–1.7	p<0.001	[–2.6…–1.2]
Lower second premolar pi/Rlp	53.9	3.99	57.0	4.58	3.1	p<0.001	[2.5…3.7]
Upper second molar ms/RLp	43.8	3.72	53.4	4.22	9.6	p<0.001	[9.0…10.2]
Lower first molar mi/RLp	53.9	3.99	56.9	4.62	3.0	p<0.001	[2.3…3.6]
Upper incisor is/RLp (d) – ss/RLp (d)	8.3	2.22	6.0	2.39	–2.4	p<0.001	[–2.9…–1.9]
Lower incisor ii/RLp (d) – pg/RLp (d)	2.0	3.31	3.1	3.75	1.1	p<0.001	[0.7…1.4]
Upper second premolar ps/RLp (d) – ss/RLp (d)	–24.5	2.14	–25.8	2.35	–1.4	p<0.001	[–1.8…–0.9]
Lower second premolar pi/RLp (d) – pg/RLp (d)	–23.9	3.01	–22.2	3.53	1.7	p<0.001	[1.3…2.1]
Upper second molar ms/RLp (d) – ss/RLp (d)	–35.8	2.36	–25.8	2.35	9.9	p<0.001	[9.5…10.4]
Lower first molar mi/OLp (d) – pg/OLp (d)	–23.8	3.00	–22.3	3.74	1.5	p<0.001	[1.1…2.0]

DISCUSSION

This is the first study to analyze overjet correction and space closure mechanisms in a large prospective group of Class II Division 1 patients undergoing extraction of the maxillary first permanent molars. All patients were treated by the same orthodontist with extensive experience in applying this method. However, the analysis was carried out by independent examiners in the academic field. All patients showed a Class I molar relationship (upper 7th to lower 6th) at the end of treatment. Since the treatment was carried out on young people and since an untreated control group was not available, it is not possible to differentiate between growth-related and therapeutic effects. We did not anticipate spontaneous improvements in the overjet, the Class II relationship and sagittal jaw base relationship since the patients already presented with a complete permanent dentition at the beginning of the treatment [1]. However, the patients' age range was relatively large (10.5–17.2 years) as they were not selected based on age or remaining growth potential. Nevertheless, this should not have any particular impact on the space closure mechanism.

A slightly modified SO analysis was used to analyze the overjet correction and extraction space closure mechanisms during the treatment of Class II malocclusion involving extraction of the maxillary first permanent molars and low-friction mechanics [5]. The reliability of the SO analysis was confirmed in an earlier analysis [8], in which three different cephalometric superimposition methods according to Björk [9, 10], Ricketts [11] and Pancherz,[5] were compared. The SO analysis turned out to be the most reliable method to compare orthodontic treatment effects between subject groups. The measurement-error analysis in our study showed good reliability on average. However, two variables (ss/ RLp, is/RLp) revealed a systematic difference between the two double measurements. As this error was so minor, it was assumed that it would not affect further analysis of the data.

Using the type of therapy applied, overjet correction was in particular achieved by retrusion of the upper incisors and to a lesser extent by protrusion of the lower incisors and ventral growth of the lower jaw. It was already shown that this retrusion of the upper incisors has only a minor impact on the upper lip's sagittal position [6]. The distalization of the upper premolars, ventral growth of the lower jaw and mesialization of the lower premolars contributed equally to the correction of the Class II relationship. As expected, the growth of the upper jaw had only an insignificant effect on the correction of the Class II malocclusion [1].

The most important and least expected result of this study was the high degree of anchorage loss and the resulting distinct mesialization (9.9 mm) of the maxillary second molars, which by far exceeded the distalization (1.4 mm) of the maxillary premolars. This clearly demonstrates that the transpalatal arches and anchor bends used for anchorage of the maxillary second molars were inadequate for stabilizing the molars' positions. Nevertheless, the transpalatinal arch prevented the second molars from rotating. Alternatively, orthodontists have several varieties of implants and miniscrew anchorage devices at their disposal, which appear indispensable if greater distalization of the upper premolars is desired. In terms of a clinically successful Class II correction, however, this seems unnecessary when applying the type of therapy presented here. Nevertheless, considering the relatively minor extent of premolar distalization, the question arises as to whether non- extraction therapy would have been possible. If a patient is cooperative, this is certainly possible. Even though it appears initially contradictory, the treatment we describe was carried out in uncooperative patients. We were able to clearly establish that the extraction had a positive influence on our patients' willingness to cooperate. Since they were confronted with large extraction spaces in the upper jaw, it is understandable to want them closed. This may well have been the reason why even those patients who were not initially willing to cooperate were motivated by the treatment progress, as the space closure was easy to see. As a consequence, none of the treatments had to be discontinued, and all 100 patients selected for the study completed treatment. In contrast, in their Class II multicenter study, O'Brien et al. [4] reported that 34% of a Twin Block group and 13% of a Herbst group dropped out during the functional jaw orthopedic phase.

A potential contraindication for the treatment we describe here is the lack of upper third molars, or their extremely ectopic position. In general, uprighting and spontaneous eruption of the third molars is possible after mesialization of the second molars, so that in most cases a second orthodontic therapy is not required [3]. However, extraction of both maxillary first molars is an essential aspect of the treatment method described in this article. While the decision to extract both first molars is easy, especially when they are badly damaged by caries decay or hypomineralization, the decision to remove healthy molars is a difficult one that must be explained in great detail to colleagues unfamiliar with this kind of treatment. However, the low dropout rate during this one-phase treatment, the absence of laboratory costs, the 90% improvement in the PAR index, minimal negative impact on the soft-tissue profile, and low demand for cooperation make extraction of the maxillary first molars an interesting alternative to the Class II Division I therapy [6].

CONCLUSION

Class II treatment including extraction of the maxillary first permanent molars and low friction mechanics entails:

- overjet correction is mainly achieved by an upper incisor retrusion and to a lesser extent by ventral growth of the lower jaw and protrusion of the lower incisors, and
- a relatively small portion of the extraction space is used to distalize the premolars. However, this did not affect the clinical success rate.

Conflict of interest

The corresponding author states that there are no conflicts of interest.

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4

CHAPTER 4

CLASS II TREATMENT BY EXTRACTION OF MAXILLARY FIRST MOLARS OR HERBST APPLIANCE: DENTOSKELETAL AND SOFT TISSUE EFFECTS IN COMPARISON

Booij JW, Goeke J, Bronkhorst EM, Pancherz H, Katsaros C, Ruf S. *Class II treatment by extraction of maxillary first molars or Herbst appliance: dentoskeletal and soft tissue effects in comparison.*

J Orofac Orthop. 2013;74(1):52-63

ABSTRACT

Aim. To compare dentoskeletal and soft tissue treatment effects of two alternative Class II division 1 treatment modalities (maxillary first permanent molar extraction versus Herbst appliance).

Methods. One-hundred-fifty-four Class II division 1 patients that had either been treated with extractions of the upper first molars and a lightwire multibracket (MB) appliance (n= 79; 38 girls, 41 boys) or non-extraction by means of a Herbst-MB appliance (n= 75; 35 girls, 40 boys). The groups were matched on age and sex. The average age at the start of treatment was 12.7 years for the extraction and 13.0 years for the Herbst group. Pretreatment (T1) and posttreatment (T2) lateral cephalograms were retrospectively analyzed using a standard cephalometric analysis and the sagittal occlusal analysis according to Pancherz.

Results. The SNA angle decrease was 1.10° (p= 0.001) more pronounced in the extraction group, the SNB angle increased 1.49° more in the Herbst group (p= 0.000). In the extraction group, a decrease in SNB angle (0.49°) was observed. The soft tissue profile convexity (N-Sn-Pog) decreased in both groups, which was 0.78° more (n. s.) pronounced in the Herbst group. The nasolabial angle increased significantly more (+ 2.33°, p= 0.025) in the extraction group. The mechanism of overjet correction in the extraction group was predominantly dental (65% dental and 35% skeletal changes), while in the Herbst group it was predominantly skeletal (58% skeletal and 42% dental changes) in origin.

Conclusion. Both treatment methods were successful and led to a correction of the Class II division 1 malocclusion. Whereas for upper first molar extraction treatment more dental and maxillary effects can be expected, in case of Herbst treatment skeletal and mandibular effects prevail.

INTRODUCTION

Class II division 1 is the most prevalent sub-classification of malocclusion, and many treatment methods have been described. A Class II therapy approach via extraction of the upper first permanent molars was first suggested by Williams [45] in 1979. This approach is of particular interest in patients presenting totally destroyed or already extracted upper first permanent molars. Stalpers et al. [42] reported a 90% improvement in the PAR index in a group of 100 Class II division 1 patients treated with upper first molar extraction, thus, demonstrating the efficacy of this approach. In the first molar extraction study by Stalpers et al. [42], the maxillary incisors were retracted an average 2.7 mm relative to the A-pogonion line, while maintaining a good incisor inclination. The upper lip followed incisor movement by about 50%, thus, resulting in retrusion of the upper lip by 1.4 mm relative to the subnasale–soft tissue pogonion line. This amount of soft tissue change resembles outcomes reported involving first premolar extraction approaches [19, 20, 31]. Booij et al. [11] described the mechanism of overjet correction and extraction space closure during first molar extraction treatment. Due to an unexpectedly large degree of upper second molar anchorage loss, relatively little of the extraction space was used to distalize the premolars (12.5%). Although overjet correction was still accomplished (mainly via upper incisor retraction), the second largest effect contributing to overjet correction was forward growth of the mandible. We have, thus, aimed to compare the dentoskeletal and soft tissue effects of first molar extraction treatment with the Herbst treatment in this study so as to provide the clinician with additional data for future differential treatment planning.

SUBJECTS AND METHODS

Patients and treatment methods

The present study is a retrospective longitudinal two-group outcome analysis. The Class II division 1 patient sample comprised two groups, the upper first molar extraction group and the Herbst group. Our inclusion criteria were as follows:

- Caucasian origin; complete records,
- overjet ≥ 4 mm,
- treatment includes extraction of maxillary first permanent molars or Herbst appliance,
- age at start of treatment between 10 and 15 years,
- no aplasia or additional extractions,
- no craniofacial anomalies, and
- teeth 18 and 28 present (extraction group only)

Extraction group

Patients were selected from a private practice in the Netherlands. All patients had undergone treatment by the same clinician (J.W.B.) entailing extraction of the upper first permanent molars and lightwire appliances. The study patients were selected from a consecutively treated group of patients whose records were complete. A detailed description of the treatment approach has already been published [12]. Our final sample consisted of 79 patients (38 girls, 41 boys) aged between 10.5 and 14.7 years at the start of treatment (mean age 12.7 years). Treatment duration ranged from 18–40 months (mean 28 months).

Herbst group

Patients were selected from the files at the Department of Orthodontics, Justus Liebig University, Giessen, Germany. Several clinicians carried out successful therapy using the Herbst appliance followed by a multibracket appliance according to a standardized protocol published earlier [27]. After matching for age and sex with the extraction group, our Herbst group consisted of 75 patients (35 girls, 40 boys). The age at the start of treatment ranged between 10.7 and 15.5 years (mean age13.0 years), and treatment lasted from 9–31 months (mean 20 months).

Cephalometric analysis

Standardized lateral cephalometric radiographs (taken as part of clinical routine) from before (T1) and after (T2) active treatment (= removal of all active orthodontic appliances) were evaluated. We did not correct for linear enlargement of approximately 8% in both groups. Standard cephalometric parameters (Figure 4.1) and the sagittal occlusal (SO) analysis ([28], Figure 4.2, Table 4.1) were used for the lateral cephalometric analysis. All tracings and measurements were carried out by an independent investigator (J.G). To minimize method error, all lateral cephalograms were traced twice at an interval of at least 2 weeks between tracings. The mean of both measurements was used in the final evaluation.

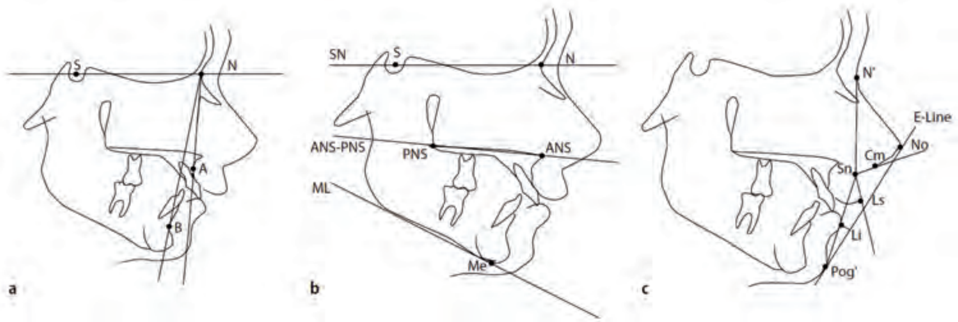

FIGURE 4.1 Cephalometric reference points and reference lines used in this study

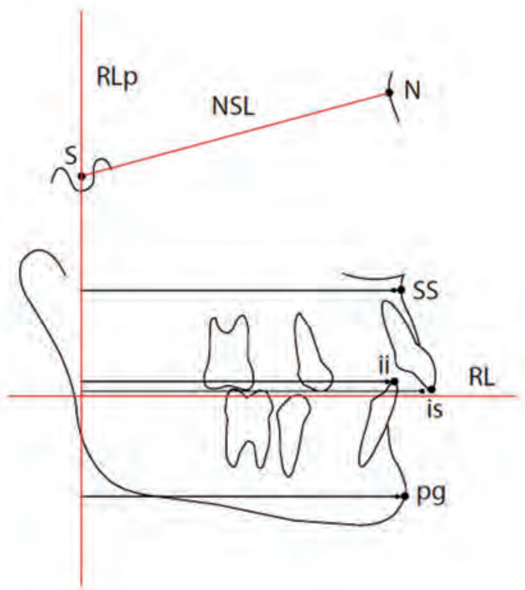

FIGURE 4.2 Sagittal occlusal (SO) analysis according to Pancherz [28]. Variables are defined in Table 4.1

TABLE 4.1 Sagittal occlusal analysis parameters. Reference points provided in Figure 4.2

is/RL–ii/RL	Overbite
is/RLp–ii/RLp	Overjet
ss/RLp	Maxillary base position
pg/RLp	Mandibular base position
is/RLp	Maxillary central incisor position
ii/RLp	Mandibular central incisor position
is/RLp (d)–ss/RLp (d)	Change in maxillary incisor position
ii/RLp (d)–pg/RLp (d)	Change in mandibular incisor position

Method error

Measurement error was assessed in 37 randomly chosen patients from each group. Duplicate measurements were analyzed separately for T1 and T2. Testing was done using the paired t-test. Random error was expressed as the duplicate measurements error (standard deviation of difference/√2). Reliability was calculated as the correlation between the duplicate measurements.

Statistical analysis

Normal data distribution was ascertained using the Levene test. All group differences (T1, T2, and T2–T1) were then analyzed using the unpaired t-test. The increments themselves were analyzed using the paired t-test. SPSS 16.0 was used for all analyses. The level of significance was set at 0.05. Thus, p values equal or ≤ 0.05 were considered significant.

RESULTS

General findings

Overjet, overbite and the occlusal relationship were normalized by treatment in both groups. The extraction spaces were closed and a Class I occlusal relationship between the upper second permanent molars and lower first permanent molars was attained in the extraction group.

We observed low reliability (Table 4.2) for the nasolabial angle, overjet, ii/RLp–pg/RLp at T1 and Li-ELine, Ls-ELine, nasolabial angle, is/RLp–ss/RLp at T2, and noted a statistically significant difference (Table 4.2) between the original and duplicate measurements (i.e., SN/ML and N-Sn-Pog at T1, and N-Sn-Pog, pg/RLp, ii/RLp and is/RLp–ss/RLp at T2). Concerning the duplicate measurement error: some values were higher, for example, those of the nasolabial angle and pg/RLp (Table 4.2). However, we considered all the errors to be small enough not to require the exclusion of those variables from further analysis.

The pretreatment cephalometric characteristics of both groups are illustrated in Table 4.3 and Table 4.4. Both groups exhibited similar dentoskeletal morphology at T1 (Table 4.5) except for the extraction group's significantly larger mandibular plane angle (SN/ML + 2.66°) and inter-jaw base angle (ANS-PNS/ML + 2.75°). Nevertheless, the differences in vertical jaw base relationship in both groups fell within the range of normodivergency. Furthermore, the extraction group presented a more protruded upper incisor position (is/RLp–ss/RLp=+ 1.03 mm), while the Herbst group had a larger mean overbite (+ 1.15 mm). The SNB angle (Table 4.6) after treatment was significantly (+ 1.56°, p= 0.005) larger in the Herbst group compared to the extraction group. The pretreatment differences in the mandibular plane and inter-jaw base angles were slightly greater due to the extraction group's posterior mandible rotation. That group also presented a significantly more convex soft tissue facial profile (+ 2.04°; p= 0.016) and a larger nasiolabial angle (+ 4.52°, p= 0.006) posttreatment.

TABLE 4.2 Method error for the variables used in comparing upper first molar extraction treatment and Herbst appliance treatment. Analysis of duplicate measurements of 37 subjects from each group before (T1) and after all active treatment (T2). Duplicate measurement error (DME), reliability (rel), p-value (p) for systematic differences (diff) between the two repeated observations, and 95% confidence interval (CI) are shown

	T1 (before treatment)					T2 (after treatment)				
Variable	**DME**	**Rel**	**p**	**Diff**	**95% CI**	**DME**	**Rel**	**p**	**Diff**	**95% CI**
SNA	1.14	0.92	0.055	0.53	[–0.01 to 1.07]	0.93	0.95	0.711	0.08	[–0.36 to 0.52]
SNB	0.50	0.98	0.109	0.19	[–0.04 to 0.42]	0.57	0.98	0.543	–0.08	[–0.35 to 0.19]
ANB	0.77	0.84	0.453	0.14	[–0.23 to 0.50]	0.75	0.84	0.195	–0.23	[–0.58 to 0.12]
SN/ANS-PNS	0.93	0.90	0.577	–0.12	[–0.56 to 0.32]	0.69	0.95	0.214	0.20	[–0.12 to 0.53]
SN/ML	1.00	0.97	0.019	–0.57	[–1.04 to –0.1]	2.14	0.90	0.453	0.38	[–0.63 to 1.39]
ANS-PNS/ML	1.56	0.91	0.103	–0.61	[–1.34 to 0.13]	1.62	0.92	0.094	–0.65	[–1.41 to 0.12]
N-Sn-Pog	0.75	0.93	0.013	0.46	[0.10 to 0.81]	0.96	0.87	0.020	0.54	[0.09 to 0.99]
LiELine	0.43	0.97	0.593	–0.05	[–0.26 to 0.15]	1.33	0.68	0.322	0.31	[–0.32 to 0.94]
LsELine	0.63	0.93	0.465	0.11	[–0.19 to 0.41]	1.53	0.61	0.368	0.32	[–0.40 to 1.05]
Nasolabial angle	5.42	0.66	0.196	–1.66	[–4.22 to 0.89]	4.74	0.79	0.932	0.09	[–2.14 to 2.33]
Overbite	0.59	0.95	0.436	–0.11	[–0.39 to 0.17]	0.28	0.90	0.071	0.12	[–0.01 to 0.25]
Overjet	1.64	0.66	0.779	–0.11	[–0.88 to 0.67]	0.44	0.82	0.708	–0.04	[–0.24 to 0.17]
ss/RLp	1.13	0.94	0.878	0.04	[–0.49 to 0.57]	1.08	0.95	0.067	–0.47	[–0.98 to 0.03]
pg/RLp	1.43	0.94	0.050	–0.68	[–1.35 to 0.00]	2.45	0.86	0.021	–1.38	[–2.53 to –0.22]
is/RLp	0.93	0.97	0.113	–0.35	[–0.79 to 0.09]	1.70	0.90	0.026	–0.92	[–1.72 to –0.11]
ii/RLp	1.81	0.90	0.567	–0.24	[–1.10 to 0.61]	1.55	0.92	0.020	–0.88	[–1.61 to –0.15]
is/RLp–ss/RLp	0.86	0.90	0.058	–0.39	[–0.80 to 0.01]	1.44	0.58	0.192	–0.44	[–1.12 to 0.23]
ii/RLp–pg/RLp	1.93	0.70	0.343	0.43	[–0.48 to 1.34]	1.29	0.86	0.104	0.50	[–0.11 to 1.11]

TABLE 4.3 Cephalometric characteristics and treatment changes in 79 upper first molar extraction patients. The mean and standard deviations (SD) are shown for the observations points before (T1) and after (T2) treatment, as well as for the treatment period (T2–T1). The p-value (p) and 95% confidence interval (CI) are presented

	T1		T2		T2–T1			
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p**	**95% CI**
SNA	81.25	3.53	79.44	4.16	–1.81	2.22	0.000	[–2.31 to –1.31]
SNB	74.86	3.71	74.37	3.69	–0.49	1.74	0.014	[–0.88 to –0.1]
ANB	6.43	2.34	4.97	2.32	–1.46	1.55	0.000	[–1.80 to –1.11]
SN/ANS-PNS	8.94	3.05	9.02	3.65	0.08	1.83	0.690	[–0.33 to 0.49]
SN/ML	35.49	5.50	35.72	6.45	0.23	2.68	0.453	[–0.37 to 0.83]
ANS-PNS/ML	26.58	4.70	27.31	5.26	0.73	2.81	0.024	[0.10 to 1.36]
N-Sn-Pog	155.58	5.11	156.63	5.44	1.05	2.97	0.002	[0.39 to 1.72]
LiELine	0.59	2.58	–1.11	2.85	–1.70	2.43	0.000	[–2.24 to –1.15]
LsELine	–0.26	2.98	–2.97	3.14	–2.72	2.48	0.000	[–3.27 to –2.16]
Nasolabial angle	116.18	9.53	119.21	11.01	3.03	6.54	0.000	[1.57 to 4.50]
Overbite	3.22	2.53	1.79	0.97	–1.43	2.33	0.000	[–1.95 to –0.91]
Overjet	8.23	1.91	2.98	1.63	–5.26	2.12	0.000	[–5.73 to –4.78]
ss/RLp	79.46	3.91	79.11	4.73	–0.34	2.69	0.261	[–0.95 to 0.26]
pg/RLp	77.39	4.86	78.89	6.25	1.51	3.88	0.001	[0.64 to 2.37]
is/RLp	87.68	4.68	85.11	4.96	–2.57	3.23	0.000	[–3.29 to –1.84]
ii/RLp	79.45	4.64	82.14	5.10	2.69	3.12	0.000	[1.99 to 3.39]
is/RLp–ss/RLp	8.23	2.33	6.00	2.53	–2.23	2.42	0.000	[–2.77 to –1.68]
ii/RLp–pg/RLp	2.06	3.24	3.25	3.84	1.18	1.99	0.000	[0.74 to 1.63]

TABLE 4.4 Cephalometric characteristics and treatment changes in 75 Herbst patients. The mean and standard deviations (SD) are provided for the time points before (T1) and after (T2) treatment, as well as for the treatment period (T2–T1). The p-value (p) and 95% confidence interval (CI) are presented

Descriptives Herbst group								
	T1		T2		T2–T1			
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p**	**95% CI**
SNA	81.08	3.34	80.37	3.30	–0.71	1.85	0.001	[–1.13 to –0.28]
SNB	74.93	2.86	75.93	3.11	0.99	1.97	0.000	[0.54 to 1.45]
ANB	6.31	1.97	4.49	2.07	–1.82	1.71	0.000	[–2.21 to –1.43]
SN/ANS-PNS	9.41	3.20	9.48	3.49	0.07	2.34	0.806	[–0.47 to 0.61]
SN/ML	32.83	5.51	32.67	5.82	–0.16	2.46	0.575	[–0.73 to 0.41]
ANS-PNS/ML	23.83	5.18	23.14	5.26	–0.69	2.55	0.021	[–1.28 to –0.11]
N-Sn-Pog	156.85	5.41	158.67	4.92	1.83	3.77	0.000	[0.96 to 2.69]
LiELine	0.29	3.02	–0.82	2.36	–1.11	2.35	0.000	[–1.65 to –0.57]
LsELine	–0.47	2.76	–2.91	2.26	–2.45	1.96	0.000	[–2.90 to –2.00]
Nasolabial angle	113.99	8.88	114.69	8.83	0.70	6.22	0.333	[–0.73 to 2.13]
Overbite	4.37	2.08	1.91	0.85	–2.46	2.12	0.000	[–2.95 to –1.97]
Overjet	7.72	2.65	3.21	1.68	–4.51	2.79	0.000	[–5.15 to –3.87]
ss/RLp	79.40	4.26	79.67	4.67	0.27	2.72	0.399	[–0.36 to 0.89]
pg/RLp	77.54	4.80	80.43	6.24	2.89	3.95	0.000	[1.98 to 3.79]
is/RLp	86.60	5.13	85.99	5.56	–0.61	2.78	0.060	[–1.25 to 0.03]
ii/RLp	78.88	4.80	82.77	5.40	3.89	3.04	0.000	[3.19 to 4.59]
is/RLp–ss/RLp	7.20	2.54	6.32	2.44	–0.88	2.86	0.009	[–1.54 to –0.22]
ii/RLp–pg/RLp	1.34	2.64	2.35	3.85	1.01	3.11	0.007	[0.29 to 1.72]

TABLE 4.5 Cephalometric differences before treatment (T1) between 79 upper first molar extraction patients and 75 Herbst patients. The mean difference (mean diff), standard error of differences (SE diff), 95% confidence interval (CI) and p-value (p) are illustrated

	Mean diff	**SE diff**	**95% CI**	**p**
SNA	0.17	0.55	[−0.92 to 1.27]	0.755
SNB	−0.07	0.54	[−1.13 to 0.99]	0.893
ANB	0.12	0.35	[−0.57 to 0.81]	0.724
SN/ANS-PNS	−0.48	0.50	[−1.47 to 0.52]	0.346
SN/ML	2.66	0.89	[0.91 to 4.41]	0.003
ANS-PNS/ML	2.75	0.80	[1.17 to 4.32]	0.001
N-Sn-Pog	−1.26	0.85	[−2.94 to 0.41]	0.138
Li-ELine	0.30	0.45	[−0.59 to 1.19]	0.505
Ls-ELine	0.21	0.46	[−0.71 to 1.12]	0.656
Nasolabial angle	2.18	1.49	[−0.75 to 5.12]	0.144
Overbite	−1.15	0.37	[−1.89 to −0.42]	0.002
Overjet	0.51	0.37	[−0.23 to 1.25]	0.172
ss/RLp	0.06	0.66	[−1.24 to 1.36]	0.933
pg/RLp	−0.15	0.78	[−1.69 to 1.38]	0.844
is/RLp	1.08	0.79	[−0.48 to 2.65]	0.173
ii/RLp	0.57	0.76	[−0.93 to 2.07]	0.455
is/RLp−ss/RLp	1.03	0.39	[0.25 to 1.80]	0.010
ii/RLp−pg/RLp	0.72	0.47	[−0.21 to 1.66]	0.130

TABLE 4.6 Cephalometric differences after treatment(T2) between 79 upper first molar extraction patients and 75 Herbst patients. The mean difference (meandiff), standard error of differences (SEdiff), 95% confidence interval (CI) and p-value (p) are shown

	Mean diff	**SE diff**	**95% CI**	**p**
SNA	−0.93	0.60	[−2.12 to 0.26]	0.125
SNB	−1.56	0.55	[−2.65 to −0.47]	0.005
ANB	0.49	0.35	[−0.21 to 1.19]	0.171
SN/ANS-PNS	−0.46	0.58	[−1.60 to 0.68]	0.425
SN/ML	3.05	0.99	[1.09 to 5.01]	0.003
ANS-PNS/ML	4.17	0.85	[2.50 to 5.84]	0.000
N-Sn-Pog	−2.04	0.84	[−3.70 to −0.39]	0.016
LiELine	−0.29	0.42	[−1.13 to 0.55]	0.496
LsELine	−0.06	0.44	[−0.94 to 0.81]	0.890
Nasolabial angle	4.52	1.61	[1.33 to 7.07]	0.006
Overbite	−0.12	0.15	[−0.41 to 0.17]	0.407
Overjet	−0.24	0.27	[−0.76 to 0.29]	0.374
ss/RLp	−0.55	0.76	[−2.05 to 0.94]	0.466
pg/RLp	−1.53	1.01	[−3.52 to 0.46]	0.130
is/RLp	−0.87	0.85	[−2.55 to 0.81]	0.306
ii/RLp	−0.63	0.85	[−2.31 to 1.04]	0.455
is/RLp−ss/RLp	−0.32	0.40	[−1.11 to 0.47]	0.429
ii/RLp−pg/RLp	0.90	0.62	[−0.32 to 2.12]	0.149

TABLE 4.7 Difference in treatment changes (T2–T1) between 79 upper first molar extraction patients and 75 Herbst patients. The mean difference (mean diff), standard error of differences (SEdiff), 95% confidence interval (CI) and p value (p) are given

	Mean diff	SE diff	95% CI	p
SNA	−1.10	0.33	[−1.76 to −0.45]	0.001
SNB	−1.49	0.30	[−2.08 to −0.90]	0.000
ANB	0.36	0.26	[−0.16 to 0.88]	0.168
SN/ANS-PNS	0.02	0.34	[−0.65 to 0.68]	0.963
SN/ML	0.39	0.42	[−0.43 to 1.21]	0.352
ANS-PNS/ML	1.42	0.43	[0.57 to 2.28]	0.001
N-Sn-Pog	−0.78	0.55	[−1.85 to 0.30]	0.157
LiELine	−0.59	0.39	[−1.35 to 0.17]	0.128
LsELine	−0.27	0.36	[−0.98 to 0.44]	0.458
Nasolabial angle	2.33	1.03	[0.30 to 4.37]	0.025
Overbite	1.03	0.36	[0.32 to 1.74]	0.005
Overjet	−0.75	0.40	[−1.54 to 0.04]	0.062
ss/RLp	−0.61	0.44	[−1.47 to 0.25]	0.164
pg/RLp	−1.38	0.63	[−2.63 to −0.13]	0.030
is/RLp	−1.96	0.49	[−2.92 to −0.99]	0.000
ii/RLp	−1.20	0.50	[−2.19 to −0.22]	0.017
is/RLp–ss/RLp	−1.35	0.43	[−2.19 to −0.50]	0.002
ii/RLp–pg/RLp	0.18	0.42	[−0.65 to 1.00]	0.673

The two group's treatment changes and corresponding group comparisons are provided in Table 4.3, Table 4.4 and Table 4.7. The sagittal jaw base relationship improved during treatment. The SNA and ANB angles decreased in both groups towards the standard value. At 1.1°, the extraction group's SNA decrease was more pronounced (p= 0.001), while the SNB angle increased 1.49° more in the Herbst group (p= 0.000). Contrary to the Herbst group's changes, the extraction group's SNB angle decreased (0.49°, p= 0.014). The changes in the vertical jaw base relationship (ANS-PNS/ ML angle) were also the opposite, as we observed an increase in the extraction group (0.73°) and a decrease in the Herbst group (0.69°). This group difference was statistically significant (p=0.001). The soft tissue profile convexity (N-Sn-Pog) decreased in both groups—more so in the Herbst group (by 0.78°), while the lip position (Li-ELine, Ls-Eline) became more retrusive in both groups. None of these group differences was statistically significant. In contrast, the nasolabial angle increased significantly more (+ 2.3°, p= 0.025) in the extraction group. Having presented a larger pre-treatment overbite, the Herbst group showed a significantly greater overbite reduction (+ 1.03 mm; p= 0.005).

Sagittal occlusion (SO) analysis

The amount of overjet correction was slightly larger in the extraction group (Figure 4.3, Table 4.7). The mechanism of overjet correction was predominantly dental in the extraction group (65% dental and 35% skeletal changes), and predominantly skeletal in the Herbst group (58% skeletal and 42% dental changes). These differences were mainly due to significantly greater mandibular advancement (+ 1.38 mm, p= 0.030) in the Herbst group and the extraction group's significantly larger degree of upper incisor retrusion (+ 1.35 mm, p= 0.002). The changes in maxillary base and lower incisor position, however, revealed no statistically significant group differences. Nevertheless, we detected slightly more maxillary skeletal effects (0.61 mm; n.s.) contributing to overjet correction in the extraction group than in the Herbst cohort.

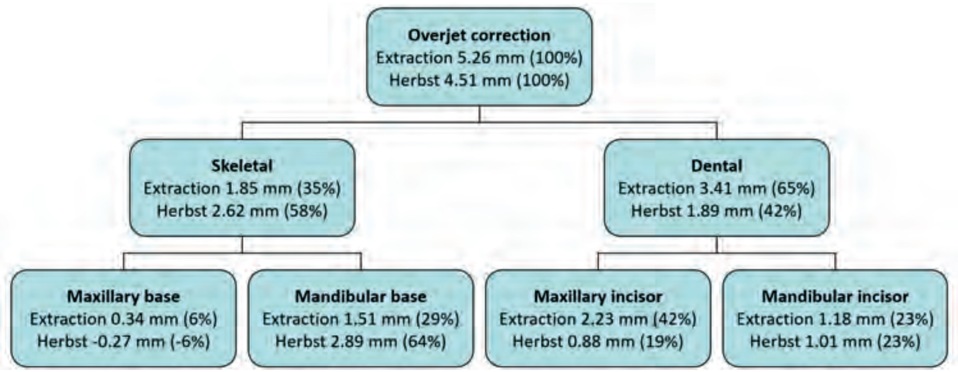

FIGURE 4.3 The mechanism of overjet correction (mean values) in the 79 upper first molar extraction patients and 75 Herbst patients

DISCUSSION

We draw the reader's attention to the fact that all comparisons with the literature are restricted to studies with adolescent patients in the following discussion. The present study investigated two groups of patients matched for age and sex. They presented quite similar pretreatment dentoskeletal morphology displaying typical characteristics of a Class II division 1 malocclusion, such as an increased ANB angle (extraction group 6.43°; Herbst group 6.31°) and an increased overjet (extraction group 8.23 mm; Herbst group 7.72 mm). The most important group differences were the significantly increased mandibular plane (+ 2.66°) and inter-jaw base (+ 2.75°) angles in the extraction group, probably due to differences in the local populations at the two treatment settings (The Netherlands and Germany). Nevertheless, both groups presented normodivergent facial growth patterns on average. Thus, no fundamentally different reaction to treatment was likely.

The extraction group's mean total treatment duration was on average 28 months and, thus, 8 months longer than that in the Herbst group. This difference is in line with the literature both in terms of the absolute treatment length for extraction protocols as well as the longer duration compared to non-extraction approaches [14, 39, 41, 43]. The duration of Herbst-MB treatment (mean 20 months) is also in line with that reported in the literature [26, 27]. Analysis of the treatment effects in the extraction and Herbst groups showed that both methods were successful in correcting the Class II division 1 malocclusion.

The treatment effects contributing to overjet correction, however, differed between the groups. The mechanism of overjet correction in the extraction group was predominantly dental (65% dental and 35% skeletal changes) but predominantly skeletal in the Herbst group (58% skeletal and 42% dental changes). We observed more maxillary dental (greater upper incisor retraction) and maxillary skeletal (larger SNA decrease) effects in conjunction with upper first molar extraction therapy. In contrast, the overall amount of skeletal changes in the Herbst group was larger and due to larger mandibular effects (larger SNB increase, more anterior position of pogonion). The group difference in the SNB angle change we noted was highly significant. In contrast, Bravo et al. [13] detected no group differences between four premolar extractions versus non extraction MB treatment. The smaller mandibular effect in the extraction group was compensated by larger distal movement of the upper premolars into the extraction space in comparison to non-extraction Herbst subjects [18]. Generally speaking, the different reaction patterns observed in our two groups reflect the different treatment approaches aiming to influence the maxilla (in the extraction group) and the mandible (in the Herbst group).

Effects on the SNA angle similar to those observed in our extraction group have been reported in conjunction with upper second molar and premolar extraction therapies [4, 5, 13, 16]. Significant group differences between premolar extraction cases and non-extraction cases have also been reported [5, 6]. Nevertheless, it remains unclear whether our and those previously reported larger SNA angle reductions are due to a restriction of maxillary growth, or whether they are simply the result of increased remodeling of the A-point due to the greater degree of upper incisor retraction in our cohort and previous extraction groups [2, 10]. Our Herbst group showed a significant increase in the SNB angle and mandibular prognathism after therapy. This increase in the SNB angle resulting from Herbst treatment is in line with previous studies [9, 15, 24, 29]. It was due to a larger increase in mandibular prognathism (Pg/RLp + 1.38 mm) in the Herbst group, which is caused by the stimulation of posterior condylar and glenoid fossa growth by the Herbst appliance [32, 34, 35, 36, 37]. Our Herbst cohort's slight anterior mandibular plane rotation also contributed to this SNB reduction. No initial effects by the Herbst appliance on the mandibular plane angle were detected in a long-term follow-up of Herbst patients [38], but after its removal, a continuous decrease in the angle was measured. The SNB angle worsened slightly—but nevertheless significantly—in the extraction group (0.49°). SNB angle changes in extraction studies have been consistently very small (–0.2° to + 0.2°) [4, 7, 13, 16]. In our extraction cohort, this was at least partly due to posterior rotation of the mandibular plane. The latter may be attributed to the more intense use of intermaxillary elastics, which, due to extrusion of the lower molars, result in the mandible's posterior rotation [25, 33]. In a recent study by Nelson et al. [24] examining Begg patients without extraction and Herbst patients, the authors also observed an increase in the mandibular plane angle in their extraction group and a reduction in that angle in their Herbst group. In contrast, Bishara et al. [8] and Al-Nimri [1] reported neither anterior rotation nor any other change in rotation in premolar extraction treatments.

We observed a significant decrease in soft tissue facial profile convexity in both groups (extraction group 1.05°; Herbst group 1.83°). These findings are in line with published reports describing similar degrees of soft tissue facial profile convexity reductions in other extraction or Herbst cohorts [6, 8, 9, 17, 23, 30]. The convexity reduction was 0.78 degrees larger in the Herbst sample. This group difference is the result of the Herbst group's more favorable mandibular changes mentioned earlier. In contrast, other studies comparing extraction and non-extraction approaches found no significant differences [3, 16, 44]. Nevertheless, we also demonstrate in this study that little or no change in the facial profile occurred in 51% of the extraction and 45% of the Herbst cases [18]. Katsaros et al. [19] arrived at the same result, highlighting the difficulty of reliably predicting soft tissue profiles in extraction therapy because they are subject to such interindividual variation.

The nasolabial angle increased by 3.0° in our extraction group and by 0.7° in the Herbst group. This significant group difference is due to greater retrusion of the upper incisors. Bravo et al. [13] describe a 3.7° enlargement of the subnasal angle after premolar extraction, while Lo et al. [21] found no significant differences in the nasolabial angle after extraction therapy in comparison to non extraction treatment. Treatment with the Herbst appliance resulted in retrusion of the upper incisors as well, which is why we also noted an increase in the nasolabial angle in the Herbst group. The data in the literature on changes in the nasolabial angle after functional appliance treatment are contradictory. Schäfer et al. [40] observed a decrease of 0.1° in the nasolabial angle after Herbst treatment and an increase of 4.8° after treatment with the Twin Block. Looi et al. [22] also detected an increase of 5.6° in this angle after activator treatment.

CONCLUSION

Both treatment methods were successful and led to a correction of Class II division 1 malocclusion. Whereas more dental and maxillary effects can be expected in conjunction with upper first molar extraction treatment, the skeletal and mandibular effects will prevail with Herbst therapy.

Conflict of interest

On behalf of all authors, the corresponding author states that there are no conflicts of interest.

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CHAPTER 5

CLASS II DIVISION 1 MALOCCLUSION TREATMENT WITH EXTRACTION OF MAXILLARY FIRST PERMANENT MOLARS: CEPHALOMETRIC EVALUATION OF TREATMENT AND POSTTREATMENT CHANGES

Booij JW, Kuijpers-Jagtman AM, Bronkhorst EM, Rangel FA, Livas C, Ren Y, Katsaros C, Ongkosuwito EM. *Class II Division 1 malocclusion treatment with extraction of maxillary first permanent molars: cephalometric evaluation of treatment and posttreatment changes.*

Submitted

ABSTRACT

Objective: To investigate cephalometric outcome and posttreatment changes following orthodontic treatment including extraction of upper first molars in patients with Class II Division 1 malocclusion.

Methods: Retrospective longitudinal study involving 83 patients treated with fixed appliances and extraction of 16 and 26. Mean age at entry was 13.2 ± 1.5 years. Lateral cephalograms were available pretreatment (T1), posttreatment (T2), and at 2.6 years posttreatment (T3). The sample was divided into hypodivergent (n=18), normodivergent (n=17), and hyperdivergent (n=48) facial type. Mean increments, standard deviations, and 95% confidence intervals were calculated for T2-T1 and T3-T2. Increments were tested using paired-samples t tests, and variables between groups by applying ANOVA followed by Tukey's post-hoc test. Linear regression was used to examine the effect of facial type, age, and sex.

Results: Significant changes emerged during treatment for most cephalometric variables, except for skeletal vertical measures. Posttreatment, the growth pattern showed a tendency to return to the original. Facial type had only a minor influence on cephalometric increments during and after treatment.

Conclusions: Posttreatment skeletal, soft tissue, and dentoalveolar changes are limited. Facial type had only a very minor influence during and after treatment. Care must be taken to control lower incisor inclination during treatment.

INTRODUCTION

Class II Division 1 malocclusion is a common indication for orthodontic treatment. The orthodontist faces many dilemmas when making choices between early or late treatment, one- or two-phase treatment, extraction or non-extraction therapy, dentoalveolar compensation or mainly jaw orthopedics, and orthognathic surgery or not. Treatment options also are based on patient age at referral, malocclusion severity, maxillofacial growth pattern, patient expectations, and the current state of art in orthodontics. Most patients prefer a fast non-extraction treatment with minimal discomfort and esthetically pleasing appliances with minimal adherence required [1,2].

For dentoalveolar correction of Class II division 1 malocclusion two different treatment approaches could be considered: maxillary molar/premolar distalization or extractions in the upper arch. Extraction therapy, however, may affect the soft tissue facial profile, and further development of nose and chin in a growing patient must be considered as well. A systematic review on soft tissue changes in patients with Class II malocclusion treated with extractions showed an increased nasolabial angle from 2.4 to 5.4 degrees in a 2-premolar extraction protocol and from 1 to 6.84 degrees in a 4-premolar extraction protocol [3]. A recent systematic review [4] and meta-analysis on soft tissue changes following extraction versus non-extraction treatment found comparable results. Nevertheless, these authors concluded that the present state of the art in orthodontics fails to precisely forecast the profile response to different orthodontic treatments because existing studies are too heterogeneous [4].

Expected low cooperation, failed non-extraction treatment, large restorations, or endodontic treatment, a bite-closing effect in patients with a hyperdivergent facial type, and facilitating normal eruption of the third molar could be reasons to consider extraction of first maxillary molars instead of premolars for dentoalveolar Class II malocclusion treatment [5-7]. In a large group of Class II Division 1 patients treated with this method, good treatment outcome was reported, and effects on the facial soft tissue profile were limited [8]. However, little is known about posttreatment changes of treatments based on dentoalveolar compensation. Bondemark et al. [9] published a systematic literature review on stability until at least 5 years postretention, but evidence was limited for predictions about stability at the individual level. More recently, Maniewicz Wins et al. [10] published a systematic review on sagittal stability after extraction or non-extraction treatment, with functional or fixed appliances, in Class II malocclusions with a minimum follow-up period of 2 years. Neither systematic review reported long-term results of orthodontic treatment including maxillary first permanent molar extractions.

Reports on orthodontic treatment including upper first molar extractions are rare. To our knowledge, no other studies have addressed posttreatment skeletal, soft tissue, and dentoalveolar changes of Class II treatment with maxillary first molar extraction. Therefore, the aim of this explorative study was to evaluate cephalometric changes in a large group of consecutively treated patients with maxillary first molar extraction after a mean follow-up period of 2.6 years.

SUBJECTS AND METHODS

Subjects

The cohort consisted of consecutively treated patients (36 girls, 47 boys) treated by one orthodontist (J.W.B.). The intake period was from December 1997 to August 2002. The following inclusion criteria were used: Caucasian, Class II division 1, molar relationship between ½ to 1 premolar width Class II, sagittal overjet of ≥4 mm, extraction of maxillary first permanent molars, no extracted teeth except maxillary first molars, no agenesis, maxillary third molars present, and 1-stage full fixed appliance treatment. Patients with cleft lip and palate or with craniofacial deformities were excluded.

This retrospective study involved a longitudinal, one-group outcome analysis in a private practice, with outcome evaluation by an independent academic hospital. This research was conducted in accordance with the Helsinki Declaration with regard to research in human participants. All patients gave written permission to have their anonymized patient records used in the study and signed informed consent.

Treatment method

Treatment with fixed appliances started 2 weeks after the extraction of the maxillary first molars. In case of a deep bite, the extractions were delayed, and treatment was started with an upper bite plate and fixed appliances in the lower arch. Second maxillary molars were fully erupted before the extractions were carried out. All patients were treated with fixed appliances and no additional anchorage control appliances according to the principles of the light-wire technique. The method has been described in detail earlier [6]. To summarize, the treatment method can be divided into three phases: Class II correction, torque and space closure, and finishing and detailing. At the beginning of treatment, in the Class II correction phase, Class I elastics (Light 5/16,T.P., Westville, IN, USA) were hooked from a high hat lock pin in the upper canine bracket to an attachment on the upper second molar band. The patient was told to replace these elastics every week. Class II elastics (Medium 5/16,T.P., Westville, IN, USA) were likewise attached from the high hat lock pin in the upper canine bracket to a ball end hook on the tube bonded to the lower first molar. The Class II elastics were replaced every day, and as soon as a solid Class I premolar occlusion was reached, the wearing time was reduced. After debonding, fixed canine-to-canine retainers were bonded to all lower and upper anterior teeth (0.195-inch Wildcat, GAC, Central Islip, NY, US). In cases of absence of occlusion of the mandibular second molars, a buccal retention wire (0.195-inch Wildcat, GAC, Central Islip, NY, US) was bonded between the first and second molars to prevent further eruption. After complete eruption of the maxillary third molars, these buccal retention wires were removed.

Cephalometric outcome

Cephalograms of all patients were made at the following stages: T1 (pretreatment), T2 (posttreatment), and T3 (follow-up). To study the effect of treatment for different facial types, the participants were allocated into three groups based on pretreatment cephalometric values: hypodivergent (ANS-Me/N-Me ≤ 56%; n = 18), normodivergent (56% <ANS-Me/N-Me <58%; n = 17), and hyperdivergent (ANS-Me/N-Me ≥58%; n = 48) [11]. The cephalometric measurements were done by one experienced observer who was not involved in the orthodontic treatment of the patients. The cephalometric analysis was performed in Viewbox 3 (dHAL software, Athens, Greece). Life size correction was done for all tracings. The soft tissue, skeletal, and dental cephalometric landmarks and reference lines are illustrated in Figure 1. To allow determination of intra-observer reliability, the same observer repeated measurements in 35 patients after one month.

Statistical analysis

Statistical analysis was performed with SPSS version 22 for Windows (IBM, Armonk, NY, USA). The reliability coefficients between two measurements were calculated as Pearson's correlation coefficients. Paired-samples t-tests were applied to identify systematic differences between the first and second measurements. The duplicate measurement error was calculated as the standard deviation (SD) of the difference between two observations divided by √2. Additionally, Bland–Altman plots were made for each variable.

Means, SDs, and 95% confidence intervals (CIs) were calculated for all cephalometric variables at T1, T2, and T3. Mean increments, SDs, and 95% CIs also were calculated for T2-T1, and T3-T2. The increments were tested using paired-samples *t* tests. The cephalometric variables were compared between groups (hypodivergent, normodivergent, and hyperdivergent) by applying ANOVA followed by Tukey's post-hoc test. Linear regression was used to examine the effect of facial type (reference is normodivergent facial type), age, and sex (independent variables) on the dependent cephalometric variable. The amount of variance explained by the independent variables was estimated by the R^2 values. The level of significance was set at $P \leq 0.05$.

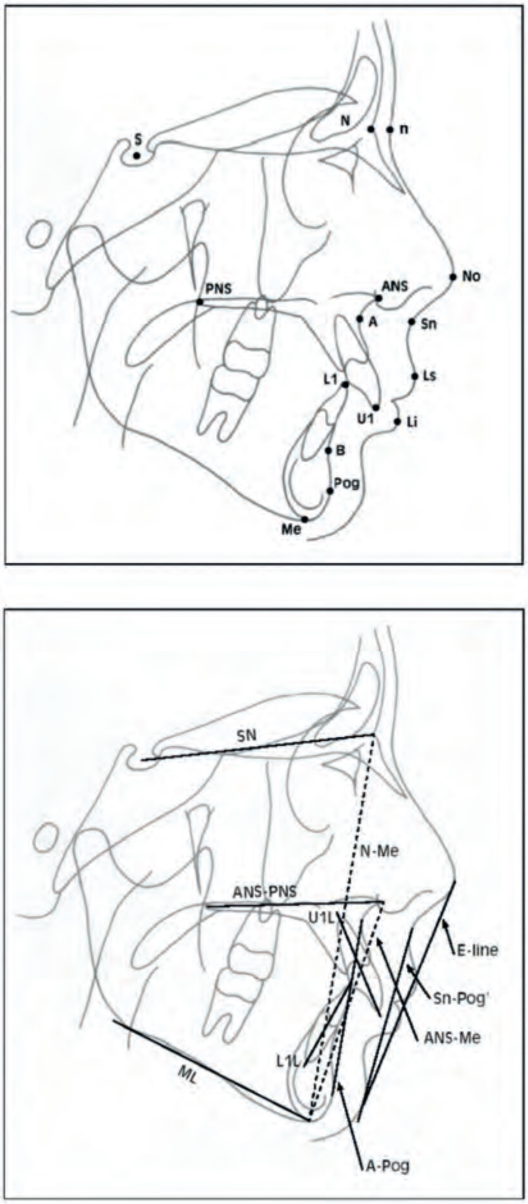

FIGURE 1 Reference lines and cephalometric points used in this study: **A** = A-point; **ANS** = Anterior nasal spine; **B** = B – point; **L1** = Lower incisor edge tip; **Li** = Lower lip; **Ls** = Upper lip: **Me** = Menton; **N** = Nasion; **n** = Soft tissue nasion; **No** = Pronasale; **PNS** = Posterior nasal spine; **Pog** = Pogonion; **S** = Sella; **Sn** = Subnasale; **U1** = Upper incisor edge tip (figure adapted from Stalpers et al. [8])

RESULTS

Participants

The distribution of the sample is shown in Table 1. The average age at T1 was 13.2 ± 1.5 years, and the average age at T2 was 15.6 ± 1.6 years, with a mean treatment duration of 2.46 year (SD 0.56). The mean age at T3 was 18.2 ± 1.9 years, and the mean posttreatment period was 2.63 year (SD 1.12). A hyperdivergent facial type was found in 48 (57.8%) of the patients.

TABLE 1 Sample distribution. The facial type at the start of treatment is indicated. Mean age and SD (years and months)

Treatment stage and facial type		N	male	female	Mean age (SD)	Min	Max
T1	Start of treatment	83	47	36	13.2 (1.5)	10.5	17.1
	hypodivergent	18	14	4			
	normodivergent	17	9	8			
	hyperdivergent	48	24	24			
T2	End of treatment	83	47	36	15.6 (1.6)	12.4	19.3
T3	Two years posttreatment	83	47	36	18.2 (1.9)	14.4	23.9

Error of the method

In Table 2, the intra-observer reliability and measurement error for the cephalometric variables are given. For the following seven cephalometric variables, a statistically significant difference between the two measurements was found: SNB(°), SN/ANS-PNS (°), ANS-PNS/ML (°), L1L/ML (°), L1 to A-Pog (mm), Ls-U1 (mm), and Li-L1 (mm). However, in all cases, these differences, although clearly present from a statistical point of view, were too small to have a relevant influence in this study. All duplicate measurement errors were small compared to the SDs of the variables and not clinically meaningful (Table 3). Bland–Altman plots for all outcomes are shown in Supplementary Figure 1.

Cephalometric analysis/descriptive data

Descriptive statistics for the cephalometric variables at T1, T2, and T3 are summarized in Table 3. At T1, the patient group had typical Class II Division 1 characteristics, such as an enlarged ANB angle (mean 5.5° ± 1.8°) and protruded position of the maxillary incisor in relation to the A-Pog line. During treatment, SNA decreased (Table 3) from 79.48° (SD, 3.66) to 77.25° (SD, 3.71) but increased again after treatment to 80.07° (SD, 3.79). Angle ANB also decreased between T1-T2 from 5.48° (SD, 1.77) to 3.6° (SD, 2.19) but increased again to 4.22° (SD, 2.2) from T2-T3. During treatment, the lower incisors were protruded from

97.77˚ (SD, 6.28) to 103.2˚ (SD, 6.44), and posttreatment (T3), the lower incisor inclination remained the same at 103.87˚ (SD, 6.99). At T1, the nasolabial angle was 115.1˚ (SD, 9.12), which increased to 117.05˚ (SD, 9.78) at T2 and remained unchanged at T3 (117.09˚; SD, 8.71).

TABLE 2 Intra-observer reliability and measurement error for the cephalometric values. Reliability expressed by Pearson's correlation coefficient. Results of paired t-test for the mean diff (P-values).

Variable	Reliability	DME	Mean diff	95% CI for diff.	P value
SNA (⁰)	0.981	0.42	-0.07	-0.27... 0.14	0.502
SNB (⁰)	0.994	0.25	-0.15	-0.27...-0.03	**0.018**
ANB (⁰)	0.971	0.38	0.07	-0.11... 0.26	0.421
SN/ANS-PNS (⁰)	0.979	0.46	0.36	0.14... 0.59	**0.002**
SN/ML (⁰)	0.998	0.30	-0.14	-0.28... 0.01	0.065
ANS-PNS/ML (⁰)	0.992	0.51	-0.49	-0.74...-0.24	**<0.001**
ANS-Me by N-Me (ratio)	0.961	0.53	-0.01	-0.26... 0.25	0.968
U1L/ANS-PNS (⁰)	0.989	0.64	0.16	-0.15... 0.47	0.295
U1 to A-Pog (mm)	0.892	0.72	0.03	-0.33... 0.38	0.883
L1L/ML (⁰)	0.975	1.17	0.75	0.18... 1.32	**0.012**
L1 to A-Pog (mm)	0.979	0.26	0.27	0.14... 0.39	**<0.001**
Nasolabial angle (⁰)	0.849	3.60	0.70	-1.05... 2.45	0.423
Ls to E-line (mm)	0.941	0.56	-0.19	-0.46... 0.08	0.164
Li to E-line (mm)	0.953	0.45	-0.15	-0.37... 0.06	0.159
n-No (mm)	0.972	0.75	-0.14	-0.50... 0.23	0.451
Ls-U1 (mm)	0.912	0.67	0.40	0.08... 0.73	**0.017**
Li-L1 (mm)	0.840	0.64	-0.67	-0.98...-0.36	<0.001

Abbreviations: DME, duplicate measurement error (in mm or degree); Mean diff, mean difference between first and second measurement (in mm or degree); and 95% CI for diff, 95% Confidence Interval

Outcome analysis

Table 4 shows the mean increments and 95% CIs for T2-T1, T3-T2, and the *P* values for the paired-samples t tests. All skeletal sagittal dimensions decreased significantly during treatment but increased again significantly between T2 and T3. The ratio of ANS-Me by N-Me was the only vertical dimension that changed significantly during treatment, but in the posttreatment period (T3-T2), all vertical dimensions showed significant changes. The inclination of the upper incisor to palatal plane (U1L/ANS-PNS) decreased significantly during treatment (-2.10˚; 95% CI -3.51 to -0.68; *P* = 0.004) but remained stable after treatment (T2-T3). The lower incisors (L1L/ML) were proclined (5.43°; 95% CI 4.29–6.56; $P < 0.001$) and remained stable afterwards. All soft tissue variables showed significant changes during treatment, and remained stable in the posttreatment period except for the distance of the upper lip to the E-line (Ls to E-line) which slightly further decreased (T3-T2) (-0.67mm; 95% CI, -0.99 to -0.36; $P < 0.001$). The same was true for the length of the nose (n-No).

TABLE 3 Descriptive statistics for cephalometric variables (mean and SD) at the start of treatment (T1), posttreatment (T2) and 2 years posttreatment (T3)

Variable	T1	T2	T3
Skeletal sagittal			
SNA (⁰)	79.48 (3.66)	77.25 (3.71)	80.07 (3.79)
SNB (⁰)	74.00 (3.51)	73.65 (3.54)	75.86 (3.74)
ANB (⁰)	5.48 (1.77)	3.60 (2.19)	4.22 (2.20)
Skeletal vertical			
SN/ANS-PNS (⁰)	7.58 (3.21)	7.63 (3.18)	5.65 (3.18)
SN/ML (⁰)	35.35 (5.48)	35.68 (6.04)	34.15 (6.59)
ANS-PNS/ML (⁰)	27.77 (5.22)	28.05 (5.64)	28.61 (6.23)
ANS-Me by N-Me (ratio)	57.98 (2.39)	58.33 (2.38)	59.47 (2.15)
Dentoalveolar			
U1L/ANS-PNS (⁰)	110.23 (5.63)	108.13 (5.52)	108.04 (6.16)
U1 to A-Pog (mm)	9.00 (2.42)	6.36 (1.89)	5.88 (1.96)
L1L to ML (⁰)	97.77 (6.28)	103.20 (6.44)	103.87 (6.99)
L1 to A-Pog (mm)	1.61 (2.02)	3.94 (1.86)	2.90 (2.04)
Soft tissue			
Nasolabial angle (⁰)	115.10 (9.12)	117.05 (9.78)	117.09 (8.71)
Ls to E-line (mm)	-0.73 (2.57)	-3.30 (2.25)	-3.97 (2.52)
Li to E-line (mm)	0.08 (2.44)	-1.58 (2.37)	-1.67 (2.76)
n-No (mm)	48.82 (3.79)	51.8 (3.96)	52.77 (4.15)
Ls-U1 (mm)	11.08 (2.18)	13.52 (1.98)	13.66 (2.00)
Li-L1 (mm)	14.61 (1.53)	13.05 (1.42)	13.22 (1.55)

We used ANOVA to analyze differences in increments for the three facial types and two periods. The results showed significant differences between facial types for five variables between T1 and T2 (Table 5). No significant differences (not shown in table) between facial types were found in increments for any of the variables during the posttreatment period (T3-T2). Tukey's range test showed no significant difference in the increments between the hyperdivergent and normodivergent facial types. For four variables out of 17, increments differed significantly between normo- versus hypodivergent biotypes and/or between hypo- versus hyperdivergent facial types.

Linear regression analysis (Supplementary Table I) showed a few significant age and sex effects, mainly on the soft tissue cephalometric variables during treatment (T1 to T2), but the explained variance was very low, except for n-No (R^2 = 0.419). After treatment (T2 to T3), there also were only a few significant age and sex effects. The highest explained variance was found for the angle ANS-PNS/ML (R^2 = 0.211). Facial type had only a very minor influence on cephalometric increments during and after treatment.

TABLE 4 Mean increments and 95% Confidence Intervals (95% CI) for the different time periods. P values for the paired samples *t* tests.

	T2-T1			**T3-T2**		
	Mean diff	**95% CI**	**P value**	**Mean diff**	**95% CI**	**P value**
Skeletal sagittal						
SNA (⁰)	-2.23	-2.66...-1.80	<0.001	2.82	2.19...3.45	<0.001
SNB (⁰)	-0.35	-0.64...-0.07	0.016	2.21	1.75...2.67	<0.001
ANB (⁰)	-1.88	-2.22...-1.54	<0.001	0.61	0.18...1.04	0.006
Skeletal vertical						
SN/ANS-PNS (⁰)	0.04	-0.28...0.37	0.797	-1.98	-2.46...-1.49	<0.001
SN/ML (⁰)	0.33	-0.04...0.70	0.08	-1.53	-2.06...-0.99	<0.001
ANS-PNS/ML (⁰)	0.28	-0.09...0.66	0.137	0.56	0.06... 1.06	0.029
ANS-Me by N-Me (ratio)	0.35	0.07…0.63	0.015	1.14	0.81… 1.48	<0.001
Dentoalveolar						
U1L/ANS-PNS (⁰)	-2.10	-3.51...-0.68	0.004	-0.09	-0.96... 0.77	0.828
U1 to A-Pog (mm)	-2.64	-3.05...-2.22	<0.001	-0.48	-0.74...-0.22	<0.001
L1L/ML (⁰)	5.43	4.29... 6.56	<0.001	0.67	-0.11... 1.45	0.092
L1 to A-Pog (mm)	2.33	1.97... 2.68	<0.001	-1.03	-1.30...-0.77	<0.001
Soft tissue						
Nasolabial angle (⁰)	1.95	0.49... 3.41	0.009	0.04	-1.56... 1.64	0.961
Ls to E-line (mm)	-2.57	-2.93...-2.20	<0.001	-0.67	-0.99...-0.36	<0.001
Li to E-line (mm)	-1.67	-2.02...-1.31	<0.001	-0.09	-0.36... 0.18	0.519
n-No (mm)	2.98	2.50... 3.46	<0.001	0.97	0.51... 1.42	<0.001
Ls-U1 (mm)	2.44	2.11... 2.78	<0.001	0.13	-0.23... 0.50	0.469
Li-L1 (mm)	-1.56	-1.90...-1.22	<0.001	0.18	-0.11... 0.46	0.223

TABLE 5 ANOVA followed by Tukey's post-hoc test for the differences in the increments of the cephalometric variables for the three facial types. Only variables that showed significant differences for the three facial types are given.

					95% CI for Mean			Tukey		
cephalometric variable	**facial type**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**	**ANOVA p-value**	**normo vs hypo**	**normo vs hyper**	**hypo vs hyper**
T2-T1										
ANB (^{0})	Hypo	18	-2.64	1.24	-3.26	-2.03	0.034	x		
	Normo	17	-1.35	1.27	-2.00	-0.70				
	Hyper	48	-1.78	1.64	-2.26	-1.30				
SN/ANS-PNS (^{0})	Hypo	18	-0.86	1.43	-1.57	-0.15	0.005			x
	Normo	17	-0.10	1.15	-0.69	0.49				
	Hyper	48	0.43	1.48	0.00	0.86				
ANS-Me by N-Me (ratio)	Hypo	18	0.91	1.19	0.31	1.50	0.027			
	Normo	17	0.64	0.91	0.17	1.11				
	Hyper	48	0.04	1.36	-0.36	0.43				
U1L/ANS-PNS (^{0})	Hypo	18	2.30	6.34	-0.85	5.45	0.004	x		x
	Normo	17	-3.24	6.87	-6.77	0.29				
	Hyper	48	-3.34	5.77	-5.02	-1.67				
U1 to A-pog (mm)	Hypo	18	-1.41	2.01	-2.41	-0.41	0.004			x
	Normo	17	-2.56	1.94	-3.56	-1.57				
	Hyper	48	-3.12	1.69	-3.61	-2.63				

X indicates between which facial types Tukey's post-hoc test found a significant difference
Abbreviations facial type: hypo, hypodivergent, normo, normodivergent, hyper, hyperdivergent)

DISCUSSION

Posttreatment changes

To our knowledge, this study is the first on cephalometric outcomes including posttreatment changes of orthodontic treatment with extraction of maxillary first permanent molars in patients with Class II Division 1 malocclusion. We found significant changes during treatment for most cephalometric variables except for the skeletal vertical ones. In the posttreatment period, the growth pattern showed a tendency to return to the original pattern, but the dentoalveolar and soft tissue changes were small.

Sagittal and vertical skeletal changes

Most skeletal changes were highly significant, probably because of normal growth as the mean age at the end of treatment (T2) was 15.6 years. Both the SNA angle and SNB angle decreased during treatment (T1-T2) but increased after treatment (T2-T3), which is a change toward the original growth pattern. The palatal plane-mandibular plane angle (ANS-PNS/ML) remained the same during treatment, indicating that the therapy did not influence the vertical jaw relation. In an earlier study of Class II Division 1 treatment, we compared this treatment and two-phase treatment consisting of Herbst appliance followed by fixed appliances [12]. At the end of active treatment, we found larger dental effects for the extraction group, whereas in the case of Herbst treatment, skeletal effects prevailed. Interestingly, a meta-analysis including 12 Herbst appliance studies with data on the ANB-angle and a posttreatment follow-up period of at least one year found a mean ANB reduction during treatment of 1.5 degrees while the mean change after treatment was 0.2 degrees [13]. So the net treatment reduction with the Herbst appliance of −1.3 degrees at follow-up is the same as found in the present study.

Dentoalveolar changes

The upper incisor inclination (U1L/ANS-PNS) decreased by 2.10 degrees during treatment (95% CI -3.51 to -0.68; $P = 0.004$) and was stable in the posttreatment period. The lower incisor inclination (L1L/ML) increased significantly during treatment, by 5.43 degrees (95% CI 4.29–6.56; $P < 0.001$) and remained stable in the posttreatment period, probably because of the fixed retainers. This rather large proclination likely resulted from leveling of the curve of Spee and the use of Class II elastics, although in most cases, this use was limited.

Proclined lower incisors are assumed to be a risk factor for gingival recessions. This topic has attracted a lot of attention the last 10 years. In a systematic review of orthodontic therapy and gingival recession, the authors found weak evidence that orthodontically proclined lower incisors form a risk for gingival recession [14]. However, in a more recent 5-year follow-up study comparing proclined and non-proclined lower incisors, no association was found between proclination of mandibular incisors and the prevalence of gingival recessions [15]. Two recent studies in which orthodontically treated patients 10 to 15 years posttreatment were compared with an untreated control group found comparable labial/buccal and lingual/palatal recessions between groups [16, 17]. In the absence of evidence, great care must be taken to control the position of the lower incisors during treatment, for example, by reducing the use of Class II elastics or by interproximal stripping of teeth in the lower dental arch, and extractions in the lower arch likely also must be considered more often. However, extractions in both jaws will be expected to have a greater effect on the soft tissue changes [4].

Extraction of the maxillary first molars may also affect the inclination of the second and third molars. The findings of Livas et al. [18] show that extraction of the upper first molars results in an improvement of the inclination of the second and third molars. In a recent study on dental outcome we found that in 83.3% of the patients both third molars had erupted at the end of the posttreatment follow-up of 2.5 year [19]. In 8 out of 96 patients one of the molars had erupted at that point of time, and in another 8 patients they still had to erupt, but when checked on the X-rays only one third molar seemed to have a doubtful prognosis, supporting the assumption that normal eruption of the M3s after extraction of the first molars is to be expected.

Soft tissue changes

The patients in this study showed an increase in the nasolabial angle and a flattening of the profile with reduction of the overjet. As is known, orthodontic treatment may influence a patient's profile, especially with extractions and extensive retraction of the upper incisors [20]. However, the pattern of soft tissue response after tooth extractions and incisor retraction is rather unpredictable [21]. To interpret the soft tissue profile changes over the treatment- and posttreatment periods, physiological growth changes first must be taken into consideration. The nasolabial angle does not change significantly with normal growth [25-27]. The Burlington Growth Study showed that nasal projection, chin projection, and upper and lower lip thickness increased with growth between the ages of 6 and 18 years [24]. The midsagittal facial tissue thickness of children and adolescents showed significant sex differences at all ages [25]. Bishara et al. [26] and Nanda et al. [27] reported that the upper and lower lips become significantly more retruded to the E-line during growth. Sex differences were reported: in women, the lower lip was positioned 2.0 mm posterior to the E-line, which was slightly more retruded in men [28]. Bishara et al. [26] found for the lower lip position an average of 1.7 mm posterior to the E-line for adolescent girls and boys at age 15, which compares to our findings.

A systematic review on soft tissue changes in Class II malocclusion patients treated with extractions concluded that the debate on extraction effects on soft tissue changes is still far from over [3]. Factors such as soft tissue thickness, sex differences, pretreatment labial tension, type of malocclusion, crowding, and face height influence how extractions affect soft tissues [29-35]. In one systematic review that included seven articles on upper premolar extractions, the authors reported a mean increase in the nasolabial angle from 2.4 degrees to 11.6 degrees during treatment. Furthermore, the distance from upper and lower lips to the E-line (Ricketts Aesthetic line) changed during treatment, between -0.75 mm and -5.03 mm for Ls to E-line and between -1.00 mm and -4.19 mm for Li to E-line [3].

In our sample, we found an increase in the nasolabial angle of 1.99 degrees over the total observation period, which favors making extractions more distally in the dental arch. Individual variation (SD) was large, however. Ls to E-line changed in our group by -2.57 mm (95% CI -2.93 to -2.20; $P < 0.001$) during treatment, comparable with the findings of Janson et al. [3]. This change in Ls to E-line continued after treatment because of growth of the nose and chin [36]. The Li to E-line changed by -1.67 mm (95% CI -2.93 to -2.20; $P < 0.001$) during treatment, again comparable with the findings of a systematic review by Janson et al. [3], and this effect remained unchanged in the posttreatment period. A recent systematic review [4] on soft tissue changes following extraction vs. non-extraction orthodontic fixed appliance treatment reported a considerably heterogeneous soft tissue posttreatment response after Class II extraction therapy, which precluded a consistent prediction of the soft tissue response.

No real differences can be highlighted, comparing outcomes for soft tissue changes in Class II treatment with upper first molar extractions and other extraction modalities, as reported in the systematic reviews [3,4]. Our study further showed that facial type had hardly any effect on treatment outcome or stability after treatment, which means that for all facial types, Class II treatment with the extraction of the maxillary first permanent molars can be considered. A study on the dental outcome of this patient group using the Peer Assessment Rating showed that the PAR was reduced from 28.26 (SD 7.10) at the start of the treatment to 1.22 (SD 2.36), and this rose slightly to 2.86 (SD 3.57) during the follow-up period (T2-T3) [19].

When the orthodontist has decided to extract in the upper arch to treat a Class II malocclusion, the treatment method described in this paper could be considered, in particular when the status of the first maxillary molars is worse than for the first or second premolars. The result will be an "eight premolar smile," comparable with non-extraction treatment. The presence of the upper third molars is a prerequisite. Although extraction of first molars is a heavier burden for the patient and dentist than extraction of premolars, the advantage is the good prognosis of the upper third molars, which prevents future surgical removal [7].

LIMITATIONS

This retrospective study was a longitudinal, one-group outcome analysis, and the design has its limitations. Selection bias cannot be ruled out. In our sample, hyperdivergent patients were overrepresented, which may not be representative for the Dutch population. Furthermore, compared to a multicenter, multi-operator trial, a single-center, one-operator study design is less favorable for generalizability. However, because this is the first study of posttreatment changes of Class II Division 1 treatment after upper first permanent molar extractions, we believe that the design was a good beginning to gaining more knowledge about the possibilities and limitations of this treatment method.

The outcome was assessed from the orthodontist's perspective. The importance of cephalometrics as a valid outcome measure is now being questioned. Nevertheless, we performed standard cephalometrics because lateral cephalograms were routinely available in this orthodontic practice, while 3D tools such as stereophotogrammetry were unavailable. At the time of these procedures and follow-up, patient-reported outcome and experience measures were not yet widely used, and data that represent the patient's perspective thus were not collected. In addition, the opinion of the referring general dentists regarding the extraction of the first permanent molars could have been of interest.

CONCLUSION

The results of this study of Class II Division 1 fixed appliance treatment with extraction of the maxillary first permanent molars suggest that posttreatment skeletal, soft tissue, and dentoalveolar changes are limited. Facial type had only a very minor influence on cephalometric changes during and after treatment. Care must be taken to control lower incisor inclination during treatment.

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DISCLOSURE OF INTEREST

The authors report no conflict of interest.

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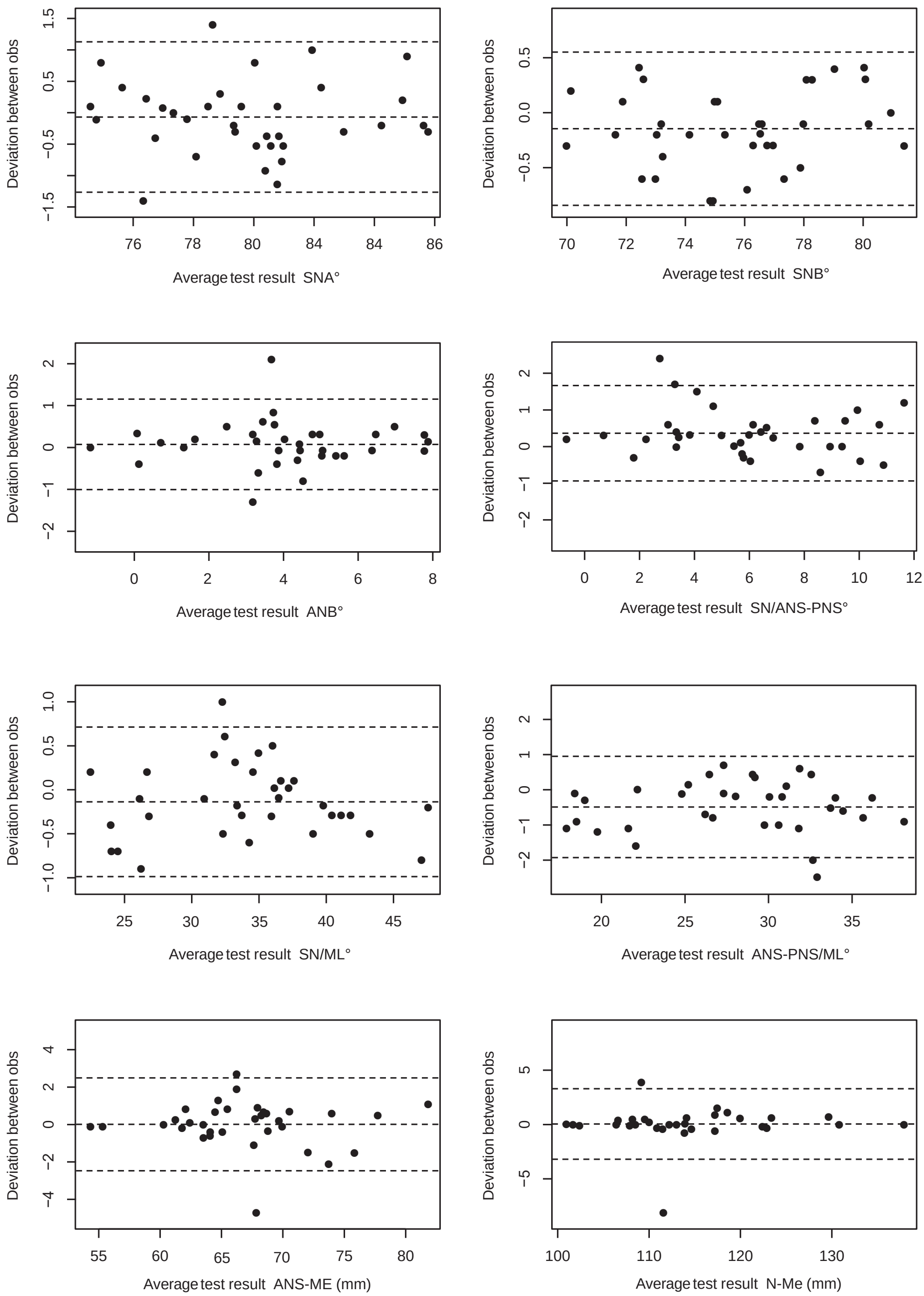
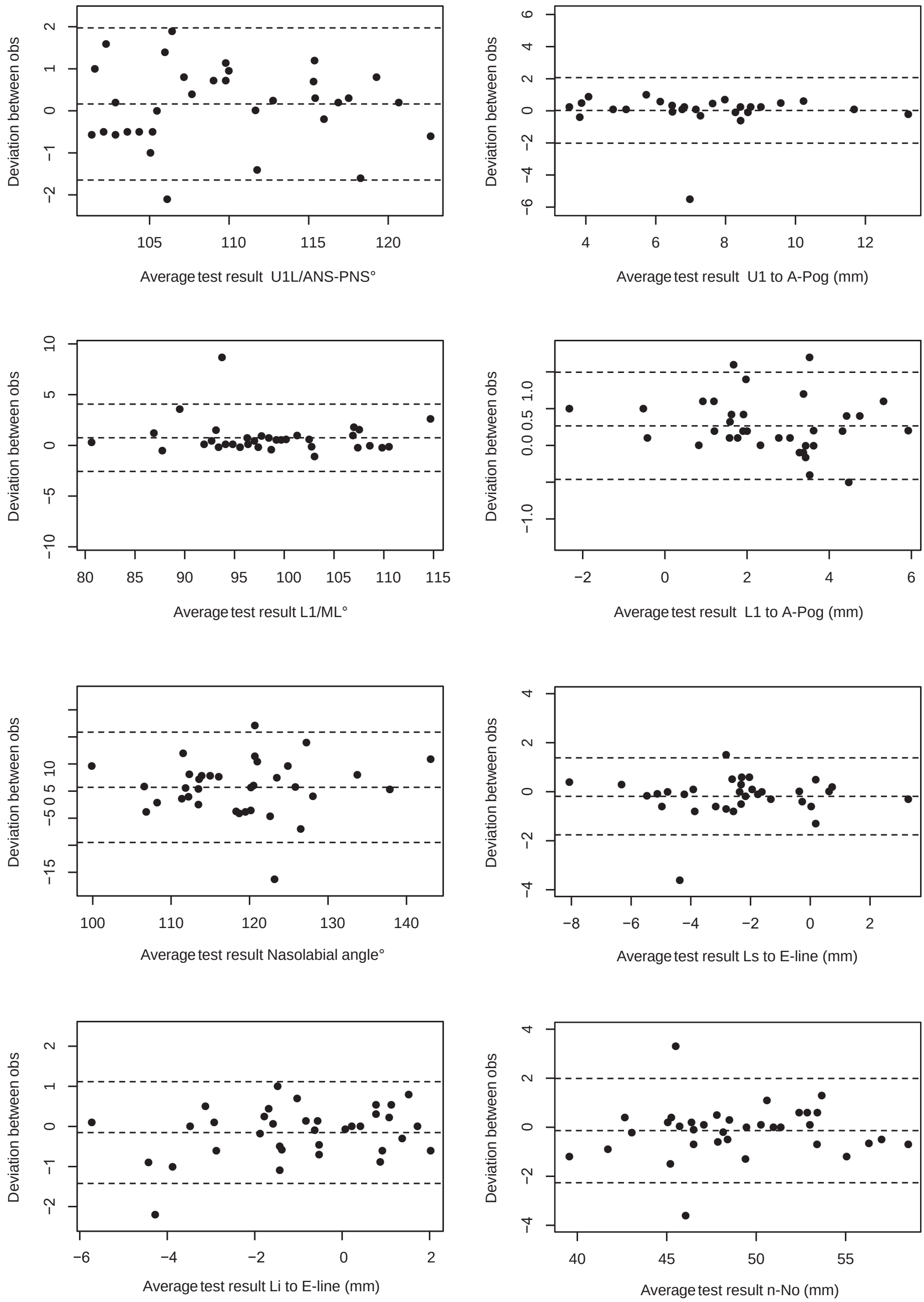
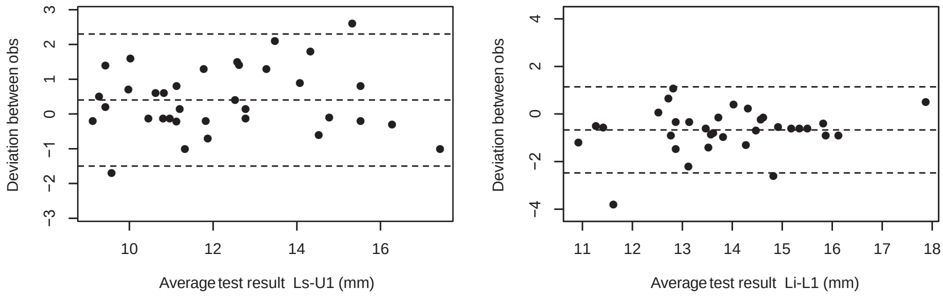


SUPPLEMENTARY FIGURE 1 Bland-Altman plots for the cephalometric variables



SUPPLEMENTARY FIGURE 1 Bland-Altman plots for the cephalometric variables



SUPPLEMENTARY FIGURE 1 Bland-Altman plots for the cephalometric variables

SUPPLEMENTARY TABLE I. Linear regression analysis to analyze the effects of sex, age, hypodivergent facial type, and hyperdivergent facial type (reference is normodivergent) on cephalometric outcome variables.

		Analysis T1 to T2 (during treatment)					**Analysis T2 to T3 (after treatment)**				
		Intercept	**Gender (M=0; F=1)**	**Age**	**Hypo**	**Hyper**	**Intercept**	**Gender (M=0; F=1)**	**Age**	**Hypo**	**Hyper**
skeletal		**Outcome (degrees): SNA (R2=0.032)**					**Outcome (degrees): SNA (R2=0.13)**				
sagittal	*Effect*	-3.66	0.47	0.13	-0.52	-0.55	7.35	0.89	-0.43	2.12	0.37
	95%CI	[-8.11...0.8]	[-0.46...1.4]	[-0.19...0.44]	[-1.88...0.84]	[-1.68...0.59]	[1.19...13.52]	[-0.4...2.17]	[-0.86...0.01]	[0.23...4.01]	[-1.19...1.94]
	P	0.106	0.316	0.431	0.449	0.34	0.02	0.172	0.056	0.028	0.635
		Outcome (degrees): SNB (R2=0.07)					**Outcome (degrees): SNB (R2=0.085)**				
	Effect	-0.28	-0.14	0	0.64	-0.17	5.24	0.13	-0.29	1.34	0.73
	95%CI	[-3.16...2.61]	[-0.74...0.46]	[-0.21...0.2]	[-0.24...1.53]	[-0.9...0.56]	[0.66...9.81]	[-0.82...1.09]	[-0.61...0.04]	[-0.06...2.74]	[-0.43...1.89]
	P	0.85	0.637	0.967	0.151	0.648	0.026	0.787	0.081	0.061	0.216
		Outcome (degrees): ANB (R2=0.123)					**Outcome (degrees): ANB (R2=0.084)**				
	Effect	-3.4	0.61	0.13	-1.15	-0.39	2.14	0.75	-0.14	0.77	-0.36
	95%CI	[-6.7...-0.1]	[-0.08...1.3]	[-0.1...0.37]	[-2.16...-0.14]	[-1.23...0.45]	[-2.15...6.43]	[-0.14...1.65]	[-0.44...0.17]	[-0.55...2.08]	[-1.45...0.73]
	P	0.044	0.081	0.265	*0.026*	0.355	0.323	0.097	0.368	0.248	0.516
skeletal		**Outcome (degrees): SN/ANS-PNS (R2=0.153)**					**Outcome (degrees): SN/ANS-PNS (R2=0.079)**				
vertical	*Effect*	1.49	0.29	-0.13	-0.68	0.46	-0.91	-1.26	-0.02	-0.29	-0.3
	95%CI	[-1.64...4.63]	[-0.36...0.95]	[-0.35...0.09]	[-1.64...0.28]	[-0.33...1.26]	[-5.81...3.99]	[-2.28...-0.23]	[-0.37...0.33]	[-1.79...1.21]	[-1.54...0.94]
	P	0.345	0.372	0.25	0.162	0.25	0.713	0.017	0.901	0.7	0.633
		Outcome (degrees): SN/ML (R2=0.029)					**Outcome (degrees): SN/ML (R2=0.105)**				
	Effect	2.33	-0.1	-0.12	-0.73	-0.37	-6.02	0.74	0.38	-1.41	-0.97
	95%CI	[-1.47...6.13]	[-0.89...0.69]	[-0.39...0.15]	[-1.89...0.44]	[-1.33...0.6]	[-11.31...-0.73]	[-0.36...1.84]	[0.01...0.76]	[-3.03...0.21]	[-2.31...0.37]
	P	0.226	0.799	0.374	0.217	0.449	0.026	0.185	0.045	0.087	0.154
		Outcome (degrees): ANS-PNS/ML (R2=0.079)					**Outcome (degrees): ANS-PNS/ML (R2=0.211)**				
	Effect	0.94	-0.41	0	-0.05	-0.85	-5.34	1.85	0.43	-0.87	-0.57
	95%CI	[-2.84...4.72]	[-1.2...0.38]	[-0.27...0.27]	[-1.21...1.11]	[-1.81...0.11]	[-10.01...-0.67]	[0.88...2.82]	[0.1...0.76]	[-2.3...0.56]	[-1.75...0.62]

SUPPLEMENTARY TABLE I. Continued.

		Analysis T1 to T2 (during treatment)					Analysis T2 to T3 (after treatment)				
		Intercept	Gender (M=0; F=1)	Age	Hypo	Hyper	Intercept	Gender (M=0; F=1)	Age	Hypo	Hyper
	P	0.623	0.307	0.989	0.932	0.083	0.026	<0.001	0.012	0.227	0.345
		Outcome (ratio): ANS-Me by N-Me (R2=0.096)					**Outcome (ratio): ANS-Me by N-Me (R2=0.104)**				
	Effect	-0.52	-0.03	0.09	0.25	-0.56	3.21	0.29	-0.18	0.98	-0.11
	95%CI	[-3.32...2.28]	[-0.62...0.55]	[-0.11...0.29]	[-0.61...1.11]	[-1.28...0.15]	[-0.12...6.53]	[-0.4...0.99]	[-0.41...0.06]	[-0.04...2]	[-0.95...0.74]
	P	0.713	0.916	0.381	0.56	0.118	0.058	0.402	0.136	0.059	0.801
Dento-alveolar		**Outcome (degrees): U1L/ANS-PNS (R2=0.137)**					**Outcome (degrees): U1L/ANS-PNS (R2=0.087)**				
	Effect	-3.42	-1.15	0.05	5.25	-0.04	3.23	-1.89	-0.27	0.46	1.74
	95%CI	[-17.19...10.36]	[-4.02...1.72]	[-0.92...1.03]	[1.03...9.47]	[-3.54...3.46]	[-5.41...11.87]	[-3.69...-0.09]	[-0.89...0.34]	[-2.18...3.11]	[-0.45...3.93]
	P	0.623	0.427	0.913	0.015	0.981	0.459	0.04	0.375	0.729	0.118
		Outcome (mm): U1 to A-Pog (R2=0.13)					**Outcome (mm): UI to A-Pog (R2=0.055)**				
	Effect	-2.19	-0.18	-0.02	1.11	-0.56	-1.54	-0.01	0.08	-0.53	0.14
	95%CI	[-6.27...1.9]	[-1.03...0.67]	[-0.31...0.27]	[-0.14...2.36]	[-1.6...0.48]	[-4.18...1.09]	[-0.56...0.54]	[-0.1...0.27]	[-1.34...0.27]	[-0.53...0.8]
	P	0.29	0.672	0.881	0.081	0.285	0.247	0.961	0.373	0.191	0.688
		Outcome (degrees): L1L to ML (R2=0.05)					**Outcome (degrees): L1L to ML (R2=0.013)**				
	Effect	15.47	-1.35	-0.67	-0.01	-1.19	0.01	0.21	0.03	-0.52	0.42
	95%CI	[3.87...27.07]	[-3.77...1.07]	[-1.49...0.15]	[-3.56...3.54]	[-4.13...1.76]	[-8.13...8.16]	[-1.48...1.91]	[-0.54...0.61]	[-3.01...1.97]	[-1.64...2.49]
	P	0.01	0.271	0.11	0.994	0.425	0.997	0.802	0.91	0.679	0.684
		Outcome (mm): L1 to A-Pog (R2=0.127)					**Outcome (mm): L1 to A-Pog (R2=0.034)**				
	Effect	6.62	-0.62	-0.31	0.7	-0.09	-2.01	0	0.07	-0.34	0.2
	95%CI	[3.11...10.13]	[-1.35...0.11]	[-0.56...-0.07]	[-0.38...1.77]	[-0.98...0.8]	[-4.77...0.75]	[-0.57...0.58]	[-0.12...0.27]	[-1.19...0.5]	[-0.5...0.9]
	P	<0.001	0.097	0.014	0.2	0.847	0.152	0.994	0.474	0.42	0.569
soft tissue		**Outcome (degrees): Nasolabial angle (R2=0.066)**					**Outcome (degrees): Nasolabial angle (R2=0.02)**				
	Effect	12.83	-3.2	-0.68	-2	-0.14	-5.68	-0.29	0.42	1.68	-0.05
	95%CI	[-1.94...27.6]	[-6.28...-0.12]	[-1.73...0.36]	[-6.52...2.52]	[-3.89...3.61]	[-22.3...10.93]	[-3.75...3.18]	[-0.76...1.59]	[-3.41...6.76]	[-4.27...4.17]

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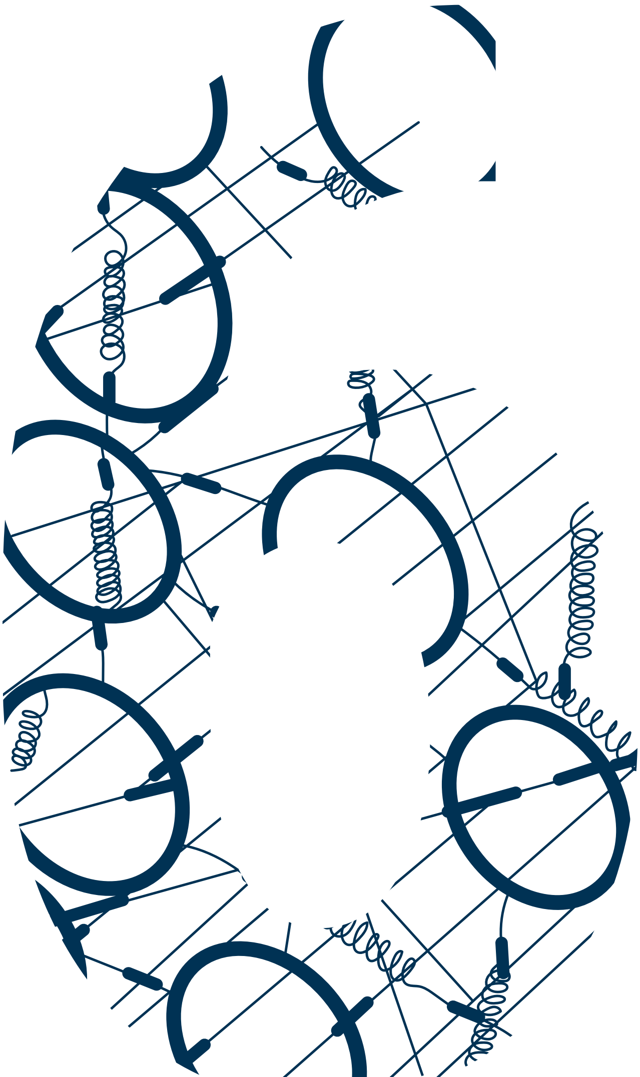
SUPPLEMENTARY TABLE I. Continued.

	Analysis T1 to T2 (during treatment)					Analysis T2 to T3 (after treatment)				
	Intercept	**Gender (M=0; F=1)**	**Age**	**Hypo**	**Hyper**	**Intercept**	**Gender (M=0; F=1)**	**Age**	**Hypo**	**Hyper**
P	0.088	0.042	0.198	0.381	0.942	0.498	0.87	0.48	0.514	0.981
	Outcome (mm): Ls to E-line (R2=0.104)					**Outcome (mm): Ls to E-line (R2=0.068)**				
Effect	-6.44	0.65	0.3	-0.43	-0.53	-3.04	0.74	0.14	0.24	0.18
95%CI	[-10.07...-2.81]	[-0.1...1.41]	[0.05...0.56]	[-1.55...0.68]	[-1.45...0.39]	[-6.21...0.13]	[0.08...1.4]	[-0.08...0.37]	[-0.73...1.21]	[-0.63...0.98]
P	<0.001	0.089	0.021	0.439	0.254	0.06	0.029	0.205	0.624	0.658
	Outcome (mm): Li to E-line (R2=0.02)					**Outcome (mm): Li to E-line (R2=0.048)**				
Effect	-2.73	0.32	0.07	0.32	-0.14	-2.27	0.33	0.13	0.6	0.41
95%CI	[-6.44...0.98]	[-0.45...1.09]	[-0.19...0.33]	[-0.82...1.45]	[-1.08...0.8]	[-5.07...0.53]	[-0.26...0.91]	[-0.07...0.32]	[-0.26...1.45]	[-0.3...1.12]
P	0.147	0.412	0.59	0.581	0.77	0.111	0.269	0.205	0.169	0.254
	Outcome (mm): n-No (R2=0.419)					**Outcome (mm): n-No (R2=0.121)**				
Effect	13.45	-2.58	-0.71	-0.31	0.18	6.67	-1.2	-0.37	-0.81	-0.15
95%CI	[9.59...17.3]	[-3.38...-1.78]	[-0.99...-0.44]	[-1.49...0.87]	[-0.8...1.16]	[2.19...11.14]	[-2.13...-0.27]	[-0.69...-0.06]	[-2.18...0.56]	[-1.29...0.98]
P	<0.001	<0.001	<0.001	0.602	0.721	0.004	0.012	0.021	0.243	0.787
	Outcome (mm): Ls-U1 (R2=0.023)					Outcome (mm): Ls-U1 (R2=0.099)				
Effect	1.68	-0.07	0.06	-0.35	0.22	2.16	0.5	-0.2	0.24	0.59
95%CI	[-1.78...5.13]	[-0.8...0.65]	[-0.19...0.3]	[-1.41...0.71]	[-0.65...1.1]	[-1.48...5.79]	[-0.26...1.26]	[-0.46...0.06]	[-0.87...1.35]	[-0.33...1.52]
P	0.337	0.837	0.646	0.513	0.613	0.241	0.195	0.125	0.669	0.204
	Outcome (mm): Li-L1 (R2=0.042)					Outcome (mm): Li-L1 (R2=0.031)				
Effect	-2.84	-0.44	0.11	0.21	0.05	1.37	0.06	-0.11	0.31	0.34
95%CI	[-6.33...0.65]	[-1.17...0.29]	[-0.14...0.35]	[-0.86...1.28]	[-0.83...0.94]	[-1.57...4.31]	[-0.55...0.67]	[-0.32...0.1]	[-0.59...1.21]	[-0.41...1.08]
P	0.11	0.236	0.398	0.698	0.905	0.357	0.846	0.285	0.494	0.373



CHAPTER 6

CLASS II DIVISION 1 MALOCCLUSION TREATMENT WITH EXTRACTION OF MAXILLARY FIRST MOLARS: EVALUATION OF TREATMENT AND POSTTREATMENT CHANGES BY THE PAR INDEX

Booij JW, Kuijpers-Jagtman AM, Bronkhorst EM, Livas C, Ren Y, Kuijpers MAR, Katsaros C. *Class II Division 1 malocclusion treatment with extraction of maxillary first molars: Evaluation of treatment and posttreatment changes by the PAR Index.*

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ABSTRACT

Objective: To investigate occlusal result and post-treatment changes after orthodontic extraction of maxillary first permanent molars in patients with a Class II division 1 malocclusion.

Setting and Sample: Retrospective longitudinal study in a private practice, with outcome evaluation by an independent academic hospital. Ninety-six patients (53 males, 43 females) consecutively treated by one orthodontist with maxillary first permanent molar extraction were studied, divided into three facial types, based on pre-treatment cephalometric values: hypodivergent (n = 18), normodivergent (n = 21), and hyperdivergent (n = 57).

Methods: Occlusal outcome was scored on dental casts at T1 (pre-treatment), T2 (post-treatment), and T3 (mean follow-up 2.5 ± 0.9 yr) using the weighted Peer Assessment Rating (PAR) Index. The paired sample *t*-test and one-way ANOVA followed by Tukey's post hoc test were used for statistical analysis.

Results: PAR was reduced by 95.7% and 89.9% at T2 and T3, respectively, compared with the start of treatment. The largest posttreatment changes were found for overjet and buccal occlusion. Linear regression analysis did not reveal a clear effect (R-Square 0.074) of age, sex, PAR score at T1, incremental PAR score T2–T1, overjet and overbite at T1, and facial type on the changes after treatment (incremental PAR score T3–T2).

Conclusions. The occlusal outcome achieved after Class II division 1 treatment with maxillary first permanent molar extractions was maintained to a large extent over a mean post-treatment follow-up of 2.5 years. Limited changes after treatment were found, for which no risk factors could be discerned.

INTRODUCTION

A great variety of treatment options exists for the treatment of Class II malocclusions, including facial orthopaedic, functional, non-extraction, and extraction procedures. Treatment options depend on the type and severity of the malocclusion, age and facial growth status of the patient, educational background of the orthodontist, and treatment preferences of the patient [1]. In young patients, growth modification with functional appliances or extra-oral traction is often the treatment of choice, although nowadays the concept of long-term growth modification of the mandible and maxilla is questioned [2,3]. Recent alternatives for Class II correction by upper-molar distalising mechanics are provided by appliances fixed with temporary anchorage devices (TAD's), an implant in the frontal part of the palate, or bone anchors attached to the zygomatic arches [4]. When crowding in the upper and lower arch is present, orthodontists may choose a dental correction by extraction of four premolars. When there is a good lower arch in the presence of an overjet, extractions may be limited to upper first or second premolars only. There are also other options, such as extraction of the maxillary second or first molars. Williams [5] was in 1979 one of the first to publish a treatment concept involving extraction of maxillary first molars using a light wire technique. In 2009 the method was described in detail by Booij et al [6]. Several studies have reported the short-term results of this procedure [7- 9]. Using the PAR index to measure occlusal outcome in 100 consecutive patients at the end of active treatment, 73% were in the "greatly improved" and 27% in the "improved" group [7]. There were no patients in the "worse or no different" group. The cephalometric analysis revealed that this type of treatment had only a minimal bite-closing effect, while no significant differences for change in mandibular plane angle were found between different facial types. The patients showed a flattening of the profile and an increase in the nasolabial angle, comparable to the soft-tissue outcomes of other extraction modalities, as reported in systematic reviews [10, 11]. To our knowledge, no previous studies have reported on stability of Class II division 1 malocclusion treatment with maxillary first permanent molar extractions. As post-treatment changes occur mostly in the first 2 years [12-14], the aim of this study was to evaluate occlusal results of Class II division 1 treatment with extraction of maxillary first permanent molars after a mean follow-up period of 2.5 years, in a large group of consecutively treated patients.

SUBJECTS AND METHODS

Subjects

This was a retrospective longitudinal, 1-group outcome study in a private practice, with outcome evaluation by an independent academic hospital. The research was conducted in accordance with the Helsinki Declaration with regard to research on human subjects. All parents and patients agreed to have their patient records used in the study and gave signed informed consent. Ethical approval was not needed, as this was an observational study using anonymised, routinely collected health data. The sample consisted of 99 consecutively treated patients (45 girls, 54 boys) treated by 1 orthodontist (J.W.B.). The following inclusion criteria were used: Caucasian, Class II division 1, sagittal overjet of ≥4 mm, extraction of maxillary first permanent molars, no missing teeth or agenesis, maxillary third molars present, and 1-stage full fixed appliance treatment. Cleft lip and palate patients and patients with craniofacial deformities were excluded. The intake period was from December 1997 to August 2002.

Dental casts of all patients were made at T1 (pre-treatment), T2 (post-treatment), and T3 (follow-up). The standard recall schedule was 2 years after treatment and the minimum follow-up was set at 24 months with a deviation of -20%. To study the effect of treatment for different facial types, the sample was divided into three groups, based on pre-treatment cephalometric values: horizontal (ANS-Me/N-Me ≤ 56%; n = 18), normal (56% <ANS-Me/N-Me <58%; n = 21), and vertical (ANS-Me/N-Me ≥58%; n = 60) [7, 15].

Treatment method

Treatment with fixed appliances started 2 weeks after the extraction of the maxillary first permanent molars. In case of a deep bite, the extractions were delayed, with initial placement of an upper bite plate and a fixed appliance in the lower arch. Second maxillary molars were fully erupted before the extractions were carried out. All patients were treated with fixed appliances according to the principles of the light-wire technique. In short, at the start of treatment in the Class II correction phase, horizontal elastics (Light 5/16,T.P., Westville, USA) were attached from a high hat lock pin in the upper canine bracket to a ball end hook on the upper second molar band. The patient was instructed to replace these elastics once a week. Class II elastics (Medium 5/16,T.P., Westville, USA) were used and had to be replaced every day. Wearing time was reduced as soon as a solid Class I premolar occlusion was reached. After appliance removal, fixed retainers were bonded to all upper and lower anterior teeth (0.195-inch Wildcat, GAC, Central Islip, NY, US). In cases of non-occlusion of the mandibular second molars a buccal retention wire (0.195-inch Wildcat, GAC, Central Islip, NY, US) was bonded between the first and second molar to keep these teeth in position. These buccal retention wires were removed after complete eruption of the maxillary third molars.

Occlusal outcome

For assessment of the results, the dental casts were randomly placed on a table and identified by only a non-traceable number. The scoring was performed by one observer (CL) calibrated in the use of the Peer Assessment Rating (PAR) Index, who was not involved in the treatment. Occlusal outcome was scored on the dental casts at T1 (pre-treatment), T2 (post-treatment), and T3 (2 or more years post-treatment) using the PAR Index [16]. The PAR Index consists of the sum of seven subcomponent scores: upper anterior segment, lower anterior segment, left and right buccal occlusion, overjet, overbite, and centreline. Weighted PAR scores (British weightings) were used, which means that the individual scores for overjet were multiplied by 6, overbite by 2, and centreline by 4. A weighted PAR score of 0 means good alignment and higher scores indicate the level of irregularity. The degree of success of the orthodontic treatment is reflected by the percentage reduction in the total weighted PAR score. The PAR subcomponent “anterior cross bite” was excluded because this sample consisted of Class II division 1 patients and only one patient scored on this item. It concerned an end-to-end position of two lateral incisors (patient number 65). Nomograms were used to visualize the degree of improvement following treatment and to visualize the degree of final improvement between the starting condition and 2 years post-treatment. In these nomograms [17] the degree of change of the weighted PAR score is divided into three categories: worse or no different (cases with less than 30% reduction), improved (patients with ≥30% reduction), and greatly improved (generally a reduction of 22 weighted PAR points or more). The weighted PAR scores were used to evaluate treatment outcome, treatment efficiency, operator experience, and the change after treatment. Treatment efficiency was defined as the treatment efficiency index (TEI) according to Janson et al [18] as the PAR reduction between T1 and T2 divided by treatment duration (in months). Furthermore, the weighted PAR scores of the three vertical facial types were compared. To determine the error of the method, the same observer re-assessed 21 series of models (at T1, T2, and T3) 2 weeks after the first assessment. The eruption status of the third molars at T3 was evaluated on the dental casts and the radiographs (orthopantomogram and/or lateral cephalogram).

Statistics

The statistical analysis was performed using SPSS version 22 for Windows (IBM, North Castle, USA). For the overall PAR-score the reliability coefficients between the two measurements were calculated as Pearson’s correlation coefficients. Paired sample t-tests were applied to identify systematic differences between the first and second measurement. The duplicate measurement error (DME) was calculated as the SD of the difference between two observations divided by $\sqrt{2}$. The intra-observer reliability for the PAR subcomponents was calculated using weighted kappa statistics. A kappa less than 0 reflects “poor”, 0 to 0.20 “slight”, 0.21 to 0.4 “fair”, 0.41 to 0.60 “moderate”, 0.61 to 0.8 “substantial”, and above 0.81 “almost perfect” agreement [19].

Outcomes are presented as a variable with a mean and ± SD. The paired sample *t*-test was applied to analyse the changes in the PAR score between T1 and T2, T2 and T3, and T1 and T3. One-way ANOVA followed by Tukey's post hoc test was applied to test for differences in the TEI between the three facial types. Linear regression analysis was applied to analyse the effects of the independent variables age, sex, PAR score at T1, incremental PAR score T2–T1, overjet and overbite at T1, and facial type at T1 on the incremental PAR score T3–T2 (the dependent variable). A *P* value of <0.05 was considered to indicate statistical significance.

RESULTS

Subjects

All 99 patients finished their treatment, no treatments were discontinued or finished early. Two patients (2.02%) were lost to follow-up at T3, and one patient had a follow-up period of less than the target follow-up and was excluded, leaving a final sample size of 96 (53 boys and 43 girls). A hypodivergent facial type was seen in 18 patients (14 boys, 4 girls), 21 patients were normodivergent (10 boys, 11 girls), and 57 were hyperdivergent (29 boys, 28 girls). The average treatment duration 2.5 years (SD 0.6; range 1.4–4.5). The mean age at the start of treatment was 13.2 years (SD 1.5; range 10.5–17.2), the mean age at T2 was 15.7 years (SD 1.6; range 12.4–19.8), and the mean age at T3 was 18.2 years (SD 1.8; range 14.4–23.9). The average post-treatment period was 2.5 years (SD 0.9; range 1.7–5.8).

Error of the method

For the overall PAR-score the Pearson's correlation coefficient was 0.998. The duplicate measurement error (DME) was 0.638 PAR points. The mean difference between the first and the second measurement was 0.159 PAR-points (95% CI, -0.068...0.386) which was not statistically significant ($P = 0.167$). The kappa values for the weighted subcomponents ranged from 0.833 to 1.000, reflecting almost perfect agreement.

Outcome

The results for the PAR index at T1, T2, and T3 are presented in Table 1 and Figure 1. The mean weighted PAR score at the start of treatment (T1) was 28.26 (SD 7.10). At the end of treatment (T2) the PAR was 1.22 (SD 2.36), and this rose slightly to 2.86 (SD 3.57) during the follow-up period (T2-T3). The largest changes after treatment were found for overjet and buccal occlusion. PAR was reduced by 95.7% at the end of treatment, and was still reduced by 89.9% at the end of the follow-up period as compared with the start of treatment. The overjet, overbite, and centreline – the three PAR subcomponents that have a weighting – represented almost the same percentage of the total PAR score at T1, T2, and T3, being 67%, 69%, and

68%, respectively. This is demonstrated by the blue surfaces of the three subcomponents in the ring map (Figure 2). In addition to this, the contribution of the other subcomponents changed from T1 to T3. For example, at the end of the follow-up period the left and right buccal occlusion represented 24% of the total PAR score while this was 10% at T1. Figure 3a shows the nomogram with the weighted PAR score at T1 compared with the score at T2. No patients were in the “not improved” section, 26 patients (27.1%) were in the “improved” section, and 70 patients (72.9%) were in the “greatly improved” section. Figure 3b shows the nomogram with the weighted PAR score at T1 compared with the score at T3. No patients were in the “not improved” section, 37 patients (38.6%) were in the “improved” section, and 59 patients (61.4%) were in the “greatly improved” section. Table 2 shows the changes in the PAR index and the changes of the subcomponents during treatment (T2–T1), after treatment (T3–T2), and for the entire time period (T3–T1). At the end of treatment a significant decrease of –27.04 (95% CI: -28.51…-25.57) PAR points was found ($P < 0.001$). The scores for all subcomponents also decreased significantly during treatment. After treatment (T3–T2) there was a slight but significant increase in the PAR index of 1.65 PAR points (95% CI: 0.99…2.30; $P < 0.001$). The scores for all subcomponents increased significantly, except for the lower anterior segment. Linear regression analysis for the effect of the independent variables age, sex, PAR score at T1, incremental PAR score T2–T1, overjet and overbite at T1, and facial type on the changes after treatment (incremental PAR score T3–T2) revealed only a minor effect of the change of the total PAR score during treatment on the changes after treatment (B = -0.291, 95% CI -5.581…-0.001, $P = 0.049$; R Square 0.074).

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TABLE 1 Mean weighted PAR scores. Means and SD for the total PAR score and the subcomponents before treatment (T1), after treatment (T2), and after a mean follow-up of 2.5 years after treatment (T3).

			PAR subcomponents						
Time	N	PAR Total (weighted)	Upper anterior segment	Lower anterior segment	Right buccal occlusion	Left buccal occlusion	Overjet	Overbite	Centreline
T1	96	28.26 (7.10)	5.02 (2.94)	1.51 (1.64)	1.24 (1.11)	1.59 (2.61)	15.00 (5.37)	2.38 (1.52)	1.63 (2.43)
T2	96	1.22 (2.36)	0.04 (0.20)	0.08 (0.35)	0.10 (0.34)	0.16 (0.42)	0.50 (1.67)	0.13 (0.57)	0.21 (0.89)
T3	96	2.86 (3.57)	0.11 (0.38)	0.11 (0.38)	0.30 (0.73)	0.40 (0.79)	1.06 (2.46)	0.33 (0.99)	0.54 (1.38)

TABLE 2 Changes of the weighted PAR scores (means and SD) and the subcomponents during treatment (T2-T1), after treatment (T3-T2), and for the entire time period (T3-T1). Results of paired samples *t*-test.

		Paired Differences			
			95% Confidence Interval of the Difference		
time period (N)	**Weighted PAR total and subcomponents**	**Mean**	**Lower**	**Upper**	**Sign. (2-tailed)**
T2-T1 (N=96)	PAR total	-27.04	-28.51	-25.57	<0.001
	upper anterior segment	-4.98	-5.58	-4.38	<0.001
	lower anterior segment	-1.43	-1.76	-1.09	<0.001
	right buccal occlusion	-1.14	-1.36	-0.91	<0.001
	left buccal occlusion	-1.44	-1.97	-0.90	<0.001
	overjet	-14.5	-15.61	-13.39	<0.001
	Overbite	-2.25	-2.57	-1.93	<0.001
	centreline	-1.42	-1.93	-0.90	<0.001
T3-T2 (N=96)	PAR total	1.65	0.99	2.30	<0.001
	upper anterior segment	0.07	0.01	0.14	0.034
	lower anterior segment	0.03	0.00	0.07	0.083
	right buccal occlusion	0.20	0.08	0.31	0.001
	left buccal occlusion	0.24	0.11	0.37	<0.001
	overjet	0.56	0.00	1.12	0.049
	overbite	0.21	0.02	0.40	0.032
	centreline	0.33	0.05	0.61	0.02
T3-T1 (N=96)	PAR total	-25.40	-26.90	-23.89	<0.001
	upper anterior segment	-4.91	-5.51	-4.30	<0.001
	lower anterior segment	-1.40	-1.74	-1.05	<0.001
	right buccal occlusion	-0.94	-1.17	-0.70	<0.001
	left buccal occlusion	-1.20	-1.73	-0.66	<0.001
	overjet	-13.94	-15.09	-12.79	<0.001
	Overbite (N=95)	-2.04	-2.39	-1.69	<0.001
	centreline	-1.08	-1.64	-0.53	<0.001

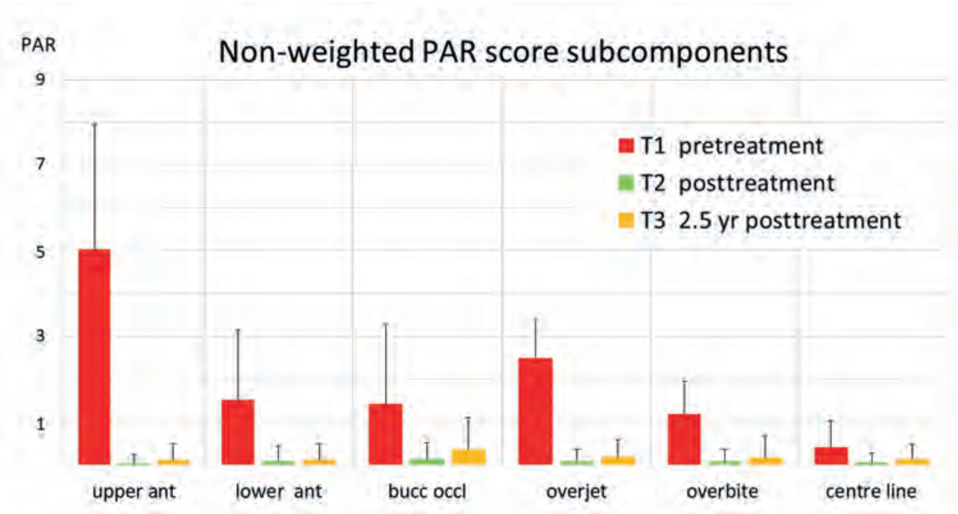

FIGURE 1 Non-weighted PAR scores (mean and SD) for the subcomponents of the PAR before treatment, after treatment, and after a mean follow-up of 2.5 years after treatment.

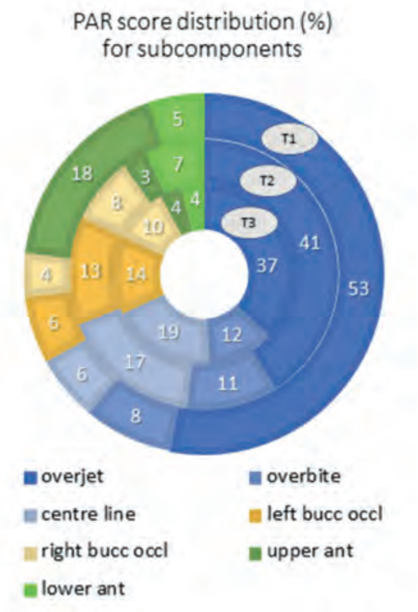

FIGURE 2 Ring map of the distribution of the PAR subcomponents before treatment, after treatment, and after a mean follow-up of 2.5 years after treatment.

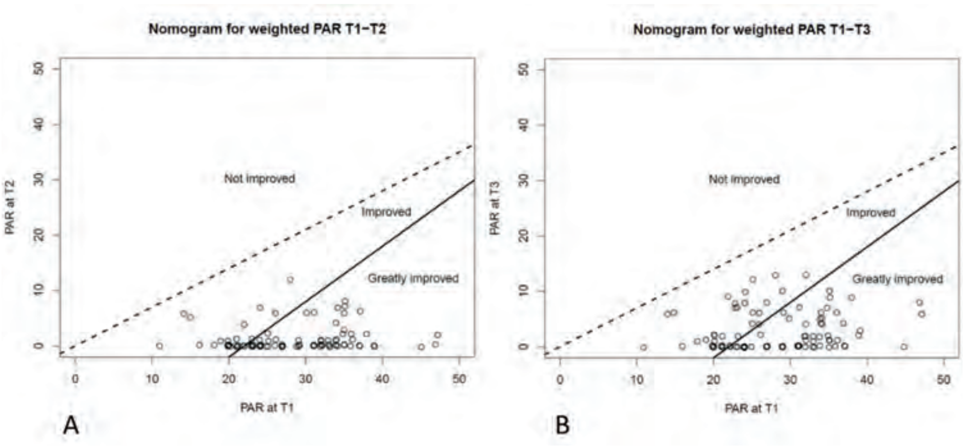

FIGURE 3 Nomograms showing the categorization of improvement of the weighted PAR scores at T1 plotted against T2 (a), and T1 plotted against T3 (b).

Operator experience

To determine the operator experience, the first 20 treated patients were compared with the last 20 treated patients with regard to the weighted PAR score at T2. For the first 20 patients, the weighted PAR score at T1 was 28.4 (SD 7.1), and for the last 20 patients it was 26.6 (SD 7.1). The changes in the PAR scores for the first and last 20 patients between T1 and T2 were -26.95 (SD 6.70) and -25.95 (SD 7.62), respectively, and not significantly different from each other (independent samples *t*-test $P = 0.662$). Operator experience had also no effect on the change in the PAR score between T2 and T3, which amounted to 1.6 (SD 3.82) PAR points for the first 20 patients and 1.2 (SD 1.88) for the last 20 patients ($P = 0.677$). In both groups, 8 of 20 patients (40%) showed a change in the PAR score after treatment. The Treatment Efficiency Index (TEI) for the total group was 3.35 (SD 0.85). We also compared TEI for the first and last 20 treated patients between T1 and T2. The first group had a TEI of 2.88 (SD 0.65) and the more recently treated group had a TEI of 3.87 (SD 0.70). This difference was highly significant ($P < 0.001$), indicating a greater PAR reduction per treatment month in the more recently treated group.

Maxillary third molars

In 52 patients (54.2%) a buccal retention wire was placed at the first and second lower molar in cases of non-occlusion of the mandibular second molars at T2 (n=4 on one side, n=48 at two sides). At T3 in 11 patients (11.5%) these wires were still present (n=4 on one side, n=7 at two sides). In 80 patients (83.3%), both maxillary third molars were present at T3. In 8 patients one of the molars was erupted at that point of time. The 24 as yet unerupted maxillary third molars were checked on the X-rays and 23 of them had a good prognosis for eruption. The prognosis of 1 molar was doubtful.

DISCUSSION

We investigated occlusal outcome of Class II division 1 treatment after extraction of the upper first permanent molars in a group of 97 patients. This retrospective longitudinal study addresses an interesting topic for clinical orthodontists as it reports the results of a large consecutively treated cohort of relatively rare material. At the end of treatment the mean PAR score showed an improvement of 95.7%. The PAR score changed 5.8% after treatment, resulting in an improvement of the PAR score of 89.9% after a mean follow-up period of 2.5 years. A PAR score improvement of 80% at the end of active treatment is accepted as a "good result", while a good standard of orthodontic treatment is achieved when the reduction of the PAR score is greater than 70% [20]. Studies reporting post-treatment outcomes using the PAR index in which the patient group was restricted to Class II patients are limited. In a study on 50 Class II division 1 malocclusions, Otuyemi and Jones [21] found a post-treatment PAR score improvement of 82.5%, which decreased after one year to 69.9%, and 10 years post-treatment 48.6% of the improvement persisted. Late lower-anterior crowding was the major factor for this deterioration. In our sample, upper- and lower-bonded 3-3 retainers were part of the treatment protocol, explaining the minimal change in the anterior segments in our patient group. Except for Class III malocclusions, nearly all studies on long-term treatment outcomes have not been restricted to specific malocclusion types [22-25]. All those studies had varying lengths of follow-up and all reported a decrease of the PAR score after treatment, varying from 12.9% to 33%. Al Yami et al [12] studying a large group of patients, reported a post-treatment PAR score improvement of 67.1%, which decreased 2 years after the end of retention to 54%. This reduction continued at a slower pace, and 10 years post-treatment the PAR improvement was 45.2%. Al Yami et al [12] concluded that 50% of the post-treatment change occurs in the first 2 years after treatment. The present study's outcome of 5.8% post-treatment change, after a mean follow-up of 2.5 years, is very acceptable. The subcomponents that changed the most after treatment were overjet and left and right buccal occlusion, as may be expected because this was a sample of Class II division 1 malocclusion. The rating for the buccal occlusion is very sensitive and, in our sample, the occlusal relationships between the upper and lower first molar at T1, and upper second molar and lower first molar at T2 and T3, were assessed. The anatomy of the upper second molar is slightly different from that of the upper first molar, and this influences the PAR score for the buccal occlusion subcomponent in a negative way. In only a few studies that used the PAR index to assess treatment outcome has the course of the individual unweighted subcomponents been reported. Miao and Liu [24] found a large relapse for alignment, overjet, and overbite. Al Yami et al [12] concluded, after a 10-year follow-up study, that all subcomponents changed gradually over time but remained stable from 5 years post-retention on, except the lower anterior component in cases without a fixed retainer. In an 8-year follow-up study [25] a 3-fold increase in the irregularity of the lower anterior teeth was found in participants without a lower cuspid-to-cuspid retainer. All patients in our study had fixed retention in the upper and lower arch from canine to canine, bonded to all teeth. This explains the minimal change we found in the post-treatment period for the upper and lower anterior subcomponents. The recent study of Schütz-Fransson et al [26] showed that maintaining fixed retainers from canine to canine, for 2 to 3 years only, cannot prevent changes of mandibular incisor alignment later on, and therefore lifelong retainers are needed if the patient wants to keep the lower front teeth straight. In our study, the post-treatment changes of the other subcomponents were small as well. This may be explained by the fact it concerns a one-phase treatment aimed at tooth movement rather than growth modification. The regression analysis showed that change after treatment (with the incremental PAR score T3–T2 as the dependent variable) could only be explained for 7.4% from the independent variables we tested: age, sex, PAR score at T1, incremental PAR score T2–T1, overjet and overbite at T1, and facial type, which means we could not find clear risk factors for change in the PAR score after treatment. Some studies gave similar outcomes, [22,23] while others showed that patients with more severe PAR index scores at the start of treatment tended to be less stable, [27] and that females had more changes than males 10 and 15 years post-treatment [28]. A systematic review on long-term stability after orthodontic treatment [29] was not able to draw evidence-based conclusions regarding stability in Class II patients due to the low quality of the available studies. However, the number of published orthodontic randomised controlled trials is gradually increasing [30]. It is to be hoped that this improvement in study design will provide more insight into factors related to treatment stability, resulting in better predictability of the long-term stability of any individual orthodontic treatment. Concerning operator experience, there was no difference in treatment outcome for the first 20 patients and the last 20 patients of our study group. All patients were treated by one experienced orthodontist (J.W.B) who apparently did not change his standard of case finishing over the years. We could not verify this with other studies, as such a finding has not been reported before now. On the other hand, the Treatment Efficiency Index (TEI) gave a highly significant difference between the first 20 and the last 20 patients, indicating a greater PAR reduction per treatment month in the more recently treated group (TEI = 2.88 versus TEI = 3.87), in turn indicating that the orthodontist became more efficient with experience. The total group had a mean TEI of 3.35 (SD 0.85). Janson et al [18] found a TEI of 3.78 (SD 1.27) for 69 Class II patients treated by a 2-maxillary-premolar-extraction protocol. In a similar study of 26 patients, Pinzan-Vercelino et al [31] reported a TEI of 4.02 (SD 1.37). Comparable findings for upper-first-molar extractions are not available. This is the first study on post-treatment changes of Class II division 1 treatment including extraction of maxillary first permanent molars in which a large patient group was involved. The favourable results reported here will support the orthodontist in the clinical decision whether to extract these molars or not. Large restorations, hypomineralisation, or endodontic treatment of these teeth will make it easier to decide for extraction. In children older than 11 years, the maxillary first permanent molar is the most caries-prone tooth [32]. Furthermore, in Dutch children an increase in the prevalence of molar-incisor hypomineralisation was found between 1999 and 2003, [33, 34] when 12.7% of the children had at least two affected molars. It should also be noted that endodontically treated first permanent molars have more complications than other endodontically treated single-rooted teeth [35]. To optimize the quality of the dentition, extraction of poorly conditioned maxillary first permanent molars is a good option for Class II malocclusion treatment, if the second and third molars are of good quality. The third molars have also been shown to have a better prognosis for normal eruption when the first molars are extracted [8] which was also confirmed in the present study as only one third molar showed a bad prognosis and 83.3% of the third molars had already erupted at the follow-up observation.

LIMITATIONS

This study was a longitudinal cohort study for which the data were collected in a private practice. All treatments were carried out by the same orthodontist. As compared to a multicentre, multi-operator trial, the single-centre, one-operator study design is less favourable for the generalisability of the results. As compared to the randomised controlled trial, the retrospective study design has well-known drawbacks. Not all clinical orthodontic research questions can be studied, however, in randomised controlled trials. For example, ethical concerns – extraction version non-extraction therapy – may limit the application of the most rigorous design. As this was a one-group longitudinal study we are not able to determine the contribution of physiological changes to the treatment and post-treatment changes we found. An earlier study, however, showed that the PAR score in non-treated individuals between 12 and 22 years of age remained the same, irrespective of the Angle classification, although clinically relevant changes were found in individual cases [36].

We are aware of the limitations of the PAR index. Dental variables, like proclined lower incisors and retroclined upper incisors, are not represented in the rating. Furthermore, the PAR index uses a weighting system for several subcomponents of the index. Overjet, for example, has a weighting of 6 in the British weighting system, which adds considerably to a high pre-treatment PAR score in a sample of Class II division 1 cases with a large overjet, as in our study. For that reason it is easier to realise remarkable changes in the PAR score when the initial PAR score is high [37]. A recent study in a Chinese population suggested that different Angle classifications may need different weightings [38]. This supports the discussion, for more than two decades, of the British weightings overemphasizing overjet and insufficiently weighting overbite [39]. Some have suggested extending the PAR index with a score for sufficient torque, good axial control of lower incisors, and the irregularity index [27, 40]. Overall quality of the treatment manifested as the presence of root resorption, gingival recessions, white spots, dysfunctions, facial aesthetics, and patient satisfaction and quality of life were not measured in this study.

CONCLUSION

The occlusal outcome achieved after Class II division 1 treatment with maxillary first permanent molar extractions was maintained to a large extent over a mean post-treatment follow-up of 2.5 years. Sex, age, facial type, overbite and overjet, and the PAR score at the start of treatment had no effect on the changes after treatment.

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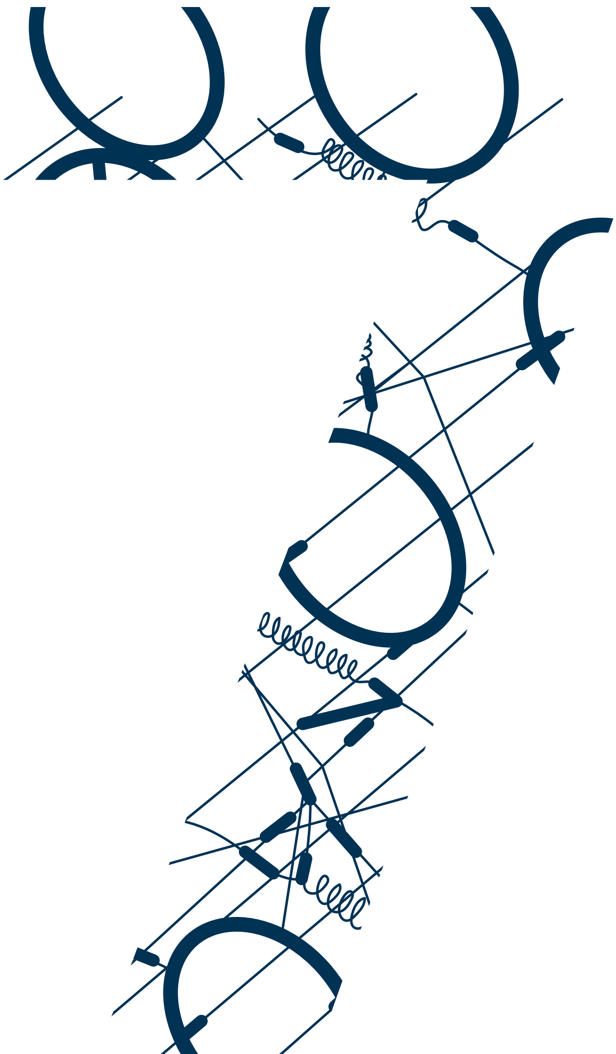

CHAPTER 7

GENERAL DISCUSSION AND FUTURE PERSPECTIVES

INTRODUCTION

This PhD thesis deals with a study of orthodontic treatment of patients with Class II division 1 malocclusion with a low-friction fixed appliance after upper first molar extractions[1]. The patients were followed until 2 years after treatment.

We showed that the overjet correction during treatment was mainly achieved by retruding the upper incisors, as well as by forward growth of the mandible and protrusion of the lower incisors. Space closure was mainly achieved by mesialization of the second molars and only partly by distalization of the premolars [2].

Dentoskeletal and soft tissue treatment effects were also compared between our extraction group and a group of patients treated with the Herbst appliance. This comparison of treatment options was chosen because of the different treatment approaches to influencing the maxilla (in the extraction group) or the mandible (in the Herbst group). Both treatment methods were successful and led to correction of the Class II division 1 malocclusion. The mechanism of overjet correction in the extraction group was predominantly dental (65% dental and 35% skeletal changes) but predominantly skeletal in the Herbst group (58% skeletal and 42% dental changes) [3].

The Peer Assessment Rating (PAR) index was used to measure treatment outcome at the dental level [4]. The average reduction of the PAR score amounted 95.5% at the end of treatment, and all cases could be categorized as "improved" and "greatly improved." The changes after treatment were minimal and independent of type of facial growth.

Finally, we performed a cephalometric study of the skeletal, dental, and soft tissue changes during and after treatment and to examine the influence of facial type on treatment and post-treatment results. Differences were detected among hypodivergent, normodivergent, and hyperdivergent growers for only a few parameters. In the post-treatment period, the three different growth types showed no differences.

In this final chapter, we discuss the strengths and limitations of this study, along with the results, clinical implications, and future perspectives.

STRENGTHS AND LIMITATIONS OF THE STUDY

Study design

This study was longitudinal, with data collected in a private practice and data analysis supervision and support sought from an academic department. The design is a hybrid retrospective and prospective cohort design (fig. 7.1). The study started when orthodontic treatment of a number of cases was already in progress. After discussions between the researcher and the academic center, the design of the study was decided upon and new cases added until the required sample size was reached. Compared to a randomized controlled trial (RCT), the current study design has well-known drawbacks, and selection bias in particular cannot be ruled out. Unfortunately, not all clinical orthodontic research questions can be studied in RCTs. For example, ethical concerns, such as regarding extraction version non-extraction therapy, may limit application of the most rigorous design.

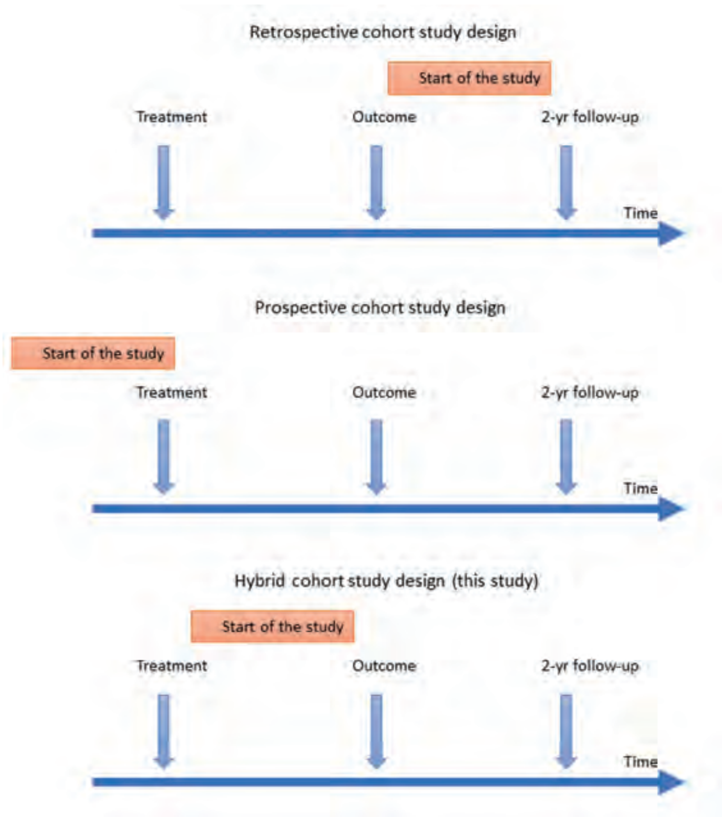

FIGURE 7.1 Schematic representation of cohort study designs (modified from Polychronopolou, 2013) [5].

Nevertheless, these types of observational studies will remain important in orthodontics because they require less time and are less costly than RCTs.

The inclusion criteria for this cohort study involved clear pretreatment characteristics: adolescents with mild to severe Class II malocclusions. All treated cases were included in the report. It was impossible to blind the patient or the operator to this treatment, but independent experienced orthodontists carried out the data collection for PAR scores and cephalometry, and they were not involved in the treatment of the patients. Bias was carefully considered in the interpretation of the study results.

Compared to a multicenter, multi-operator trial, a single-center, single-operator study design is less favorable for generalizability of the results. However, because this study is the first to evaluate treatment and post-treatment changes of Class II division 1 treatment after upper first molar extractions, in our opinion, the design represents a good starting point for gaining more knowledge about the possibilities and limitations of this treatment method.

Sample

The original sample consisted of 99 patients (45 girls, 54 boys). The following inclusion criteria were used: Caucasian, adolescent, Class II division 1 malocclusion, sagittal overjet of ≥4 mm, no missing teeth or agenesis, erupted upper second molars, maxillary third molars present, and a treatment plan that included extraction of maxillary first permanent molars and one-stage full fixed appliance treatment. Patients were treated by the only orthodontist (JW Booij) in a small provincial town, and because of a waiting list, not all patients could be seen in time to start an eventual treatment with appliances for jaw growth modification. For this reason, treatment initiation depended on the timing of the referral by the general dentist and place on the waiting list.

The design of this hybrid cohort study may have introduced selection bias. For example, the proportion of boys (54%) in our study was rather high for an orthodontic research group. It is possible that more boys than girls were selected unintentionally because of an unconscious assumption that boys are less adherent than girls so that a 'low-compliance treatment' would be a fit for them. O'Brien et al. [6] and Skidmore et al. [7] found a better treatment outcome for girls, which they ascribed to differences in cooperation between girls and boys. In contrast, other authors have found comparable orthodontic outcomes between boys and girls [8, 9]. These latter were two multi-center longitudinal observational studies, one involving different types of orthodontic appliances and the other removable retainers only. A recent systematic review found conflicting results for a sex effect on adherence with removable orthodontic appliances and adjuncts [10]. Girls were more adherent in three studies [11, 12, 13], but results from other studies contrasted with those findings [14, 15, 16].

The relatively high number of high angle cases in the Class II division 1 group (48 of 83; 57.8%) could also indicate selection bias, and this group may not be representative for Dutch patients with a Class II division 1. This possibility is supported by the reported prevalence of orthodontic disorders in this patient population, with 8% of a large sample of 11-year-old Dutch children having an open bite [17]. However, the definition these authors used was based on clinical examination of the vertical overbite, whereas we used cephalometric criteria to define the facial growth pattern.

At the end of treatment (T2), all patients were still in the study and could be documented at 4 weeks after fixed appliance removal. At T3, at least 2 years post treatment, 97 patients were available for a recall visit in the office, and impressions were made. Although it took a great deal of effort to motivate the patients and parents to come to the office for documentation, the final result was a remarkably high response rate. The models made at T1, T2, and T3 were used to score the dental changes with the PAR index. A total of 83 patients (36 girls, 47 boys) gave permission for taking cephalograms, which were used to study cephalometric changes across T1-T2, T2-T3, and T1-T3. The remaining patients in the study did not differ from those who were lost to follow-up for the cephalometric study, as revealed by the treatment outcome measured by the PAR index at T2 and T3. For detecting statistical significance for clinically relevant changes, a sample size of 30–40 is usually enough [18]. Therefore, we can reliably assume that the group of 83 patients was still representative of the study sample and sufficiently large to allow for detection of meaningful changes over time.

Outcome measures

The main outcome measures for treatment success in this study were dental and occlusal changes as measured by the PAR index and skeletal, dento-alveolar, and soft tissue changes, as assessed by cephalometric measurements.

The American Board of Orthodontics Discrepancy Index and the PAR are comparable systems for assessment of treatment outcome. The PAR score is more frequently used in orthodontic research, enabling comparisons with published data, which is the reason for our preference for this index. The PAR index has five components: upper and lower anterior segments, left and right buccal occlusion, overjet, overbite, and centerline [4].

We are aware of the limitations of the PAR. The index was developed to quantify the extent to which dentition deviates from an ideal occlusion and ideally shaped dental arches. Dental variables, such as proclined lower incisors and retroclined upper incisors, are not represented in the rating. To overcome these shortcomings, the PAR should be combined with a cephalometric analysis, as shown from the results of our study and others [19]. Furthermore, the PAR index uses a weighting system for some subcomponents of the index. Overjet, for example, has a weighting of 6 in the British weighting system, which adds considerably to a high pretreatment PAR score in a sample of Class II division 1 cases with a large overjet like in our study. For that reason, it is easier to realize remarkable changes in the PAR score when the initial PAR score is high [20]. A recent study in a Chinese population suggested that different Angle classifications may need different weightings [21]. For example, the authors found in Chinese Angle Class II cases weightings for overjet, overbite, and centerline of 5.5, 2.5, and 3, respectively, representing a higher predictive value than for British weightings of 6, 2, and 4, respectively. This difference supports the discussion that has been ongoing for more than two decades about the possibility that the British weightings overemphasize overjet and insufficiently weight overbite [22].

Most studies using the PAR index do not report the details of its subcomponents in the outcome analysis. In our opinion, reporting results for the subcomponents provides more insight into the areas that are more prone to relapse. For example, in the post-treatment period, we found the greatest change for overjet and buccal occlusion. In addition, the score for lateral occlusion is very sensitive: even a minor deviation from full interdigitation is already scored as non-optimal occlusion. In Class II samples, as in our study, this result will arise more often than in samples of mixed malocclusions.

The importance of cephalometrics as a valid outcome measure is being questioned. Moyers and Bookstein already pointed out in 1979 [23] and Bookstein repeated in 2016 [24] that conventional cephalometrics 1) "may have little basis in either biology or biometrics"; 2) "fails to capture the curving of form and its changes, excludes proper measures of size for bent structures, and misrepresents growth, portraying it as vector displacement rather than a generalized distortion"; and 3) "misinforms by fabrication of misleading geometric quantities." The translation of knowledge from cephalometrics to the benefit of the individual patient remains uncertain.

Nevertheless, we performed standard cephalometrics because lateral cephalograms were routinely available in this orthodontic practice and no 3D tools such as CBCT or stereophotogrammetry were present. We also conducted the standard cephalometric analysis because without a control group, we had no opportunity for shape analysis using geometric morphometrics. For future research in this field, stereophotogrammetry especially has potential as a non-radiological imaging modality with a fast acquisition time (less than 2 ms). The recently developed small handheld 3D cameras for stereophotogrammetry enable the clinician to capture the patient's face from three angles with one camera at the chairside and may prove useful in the clinic because of lower costs and higher user-friendliness [25].

The recent trend in clinical studies is to include outcome measures that have real meaning for the patient. O'Brien pointed out in 2013 that the results of many orthodontic studies are important for the orthodontist but not for the patient [26]. The patient, for example, is unlikely to be interested in our finding that the ANB angle changed 2 degrees. Patient interest likely would have been higher had we studied patient-oriented outcomes such as patient perception of the treatment, effect on facial esthetics and quality of life, cost effectiveness, patient-reported outcome measures (PROMs), and patient-reported experience measures (PREMs). Unfortunately, data on patient and parent perspectives are not available for this sample. Other groups have research in progress to define appropriate research outcomes that will be useful for both patients and clinicians and make future research in orthodontics more meaningful. In preparation for developing a list of possible important outcomes, Tsichlaki et al. [27] performed a scoping literature review on reported outcomes of orthodontic trials. They found that outcomes were centered mainly around the assessment of morphologic changes, with patient-centered outcomes remaining underrepresented. Furthermore, there was wide heterogeneity for the measured outcomes, a lack of uniformity that makes comparisons among studies in systematic reviews and meta-analyses very difficult. One solution might be the development of a core set of appropriate outcomes that matter to both patients and clinicians for use in future clinical research in an attempt to establish better outcomes homogeneity [28].

DISCUSSION OF THE STUDY RESULTS

Overjet correction and closure of extraction spaces

Overjet correction was essentially achieved by a retrusion of the upper incisors, as well as by ventral growth of the lower jaw and protrusion of the lower incisors. Contrary to our expectations, space closure was only partly achieved by distalization of the premolars [2]. Large individual differences were seen in the ease of extraction space closure after upper first molar extractions. In most cases, a full Class II premolar relation could be transformed into a Class I relation within 6 months, with a different amount of mesial movement of the upper second molars that resulted in smaller or larger residual extraction spaces. In the first treatment phase, the upper premolar moved over the distance of a full cusp size against the lower premolar, which was not displaced. In addition, we had to deal with the natural mesial drift of the upper second molars. The results for overjet correction and extraction space closure showed that a 11.3-mm space closure in the maxillary first-molar extraction area resulted from distalization of the second premolars (1.4 mm) and a mesialization of the second molars (9.9 mm) [2]. Because this finding was rather unexpected, we redid the analysis, which gave the same outcome as before. Apparently, despite anchor bends mesial to the upper molar tubes and a palatal bar on the second molars, we lost anchorage. Furthermore, the second molars had been rotated with the palatal bar, which can cause difficulties in determining the mesial surfaces of the second molars on a lateral head film.

In our study, the maxillary sinus did not present an obstacle to moving the second molars and premolars toward each other, and no complications could be detected. Other experimental and clinical studies have shown that orthodontic movement of molars and premolars across the floor of the maxillary sinus can cause moderate apical root resorption and variable degrees of tipping [29, 30]. In our patient group, we could not detect excessive root resorption on the post-treatment orthopantomograms, and in all cases, the extraction diastemas could be closed completely. In another study on Class II treatment after upper first molar extractions using a selection from our sample, Livas et al. reported a possible influence of the lower sinus area on the second molar and premolar inclination and suggested consideration of appropriate mechanics to control root uprighting [31]. The facial type also influences the relation between the sinus floor and the apices of the maxillary second molars. Costea et al. [32] found that patients with a hypodivergent facial growth type had significantly fewer second molar roots into the maxillary sinus than patients with a normodivergent or hyperdivergent facial type. Because the maxillary sinus tends to enlarge with increasing age and our research group consisted of adolescents, more sinus-related complications may arise with an upper first molar extraction protocol in adults [33]. However, in our patient group, we did not find this type of sinus-related problem.

Comparison of skeletal and soft tissue outcomes with those of Herbst treatment

When we compared this extraction treatment modality to non-extraction Herbst treatment, the overjet correction in the extraction group was 35% because of skeletal changes and 65% because of dental changes. In the Herbst group, these percentages were 58% and 42%, respectively [3]. The two methods showed similar outcomes, with large individual differences, for the soft tissue profile. Profile convexity (N-S-Pog), which decreased in both groups, did not differ significantly between the groups. On the other hand, the nasolabial angle increased significantly more (+ 2.33°; P=0.025) in the extraction group.

The groups were matched for age and sex, but the initial PAR index was not measured in the Herbst group. It might be possible that the initial PAR score of the upper first molar extraction group was higher than in the Herbst group because extractions were indicated. In many ways, an RCT would have given higher quality information. Furthermore, it is to be expected that for these two Class II treatment modalities, outcome measures regarding the experiences of patients and parents will differ. In this respect, the availability of PREMs and PROMs could have been of great interest.

Skeletal, dento-alveolar, and soft tissue changes

The outcome measures concerning the cephalometric analysis we assessed in this study can be divided into sagittal and vertical skeletal changes, dento-alveolar changes, and soft tissue changes.

Most **skeletal changes** were highly significant, likely because of growth, given that the mean age at T2 (the end of treatment) was 15.6 years. The SNA angle decreased during treatment (T1-T2) by 2.23 degrees. SNA increased after treatment (T2-T3) by 2.82 degrees, which is a change in the direction of the initial growth pattern. SNB angle decreased slightly during treatment, by -0.35 degrees. SNB increased after treatment by 2.21 degrees, which must be attributed to normal growth. The palatal plane mandibular plane angle (ANS-PNS/ML) remained the same during treatment. This stability is an indication that the therapy did not influence the vertical jaw relation. In addition, in the post-treatment period, we found no differences in skeletal changes among the three growth types. We can conclude that in Class II division 1 cases with an unfavorable vertical growth pattern, there is no contraindication for the treatment modality with upper first molar extractions.

Observing the **dento-alveolar changes**, the upper incisor inclination (U1L/ANS-PNS) decreased by 2.10 degrees during treatment and remained the same in the post-treatment period. The use of light wires and low friction brackets for the overjet correction can cause considerable retroclination of the upper incisors, which was successfully counteracted with a torque spring auxiliary. However, during treatment, the lower incisor inclination (L1L/ML) increased significantly, by 5.4 degrees, which remained unchanged post treatment. This rather large proclination is probably the result of leveling of the curve of Spee and the use of Class II elastics. These profound dentoalveolar changes are not reflected in the PAR score, and that also applies for the effects on the periodontal tissues.

In a systematic review, Bollen et al. [34] could not find reliable evidence for positive effects of orthodontics on periodontal health and even found that small detrimental effects to the periodontium are more likely. Proclined lower incisors after treatment are assumed to be a risk factor for gingival recessions, caused by the movement of the incisors out of the osseous envelope of the alveolar process. In a systematic review on the effect of changes in incisor inclination by orthodontic treatment, Joss-Vassali et al. [35] found only weak evidence for a causal link between incisor inclination and the appearance of gingival recessions. In a 5-year follow-up study comparing proclined and non-proclined lower incisors, Renkema et al. [36] found no association between proclination of mandibular incisors and the prevalence of gingival recessions. Gebistorf et al. [37] performed a study of the long-term development of gingival recession and compared an orthodontically treated group with untreated patients with malocclusion. At 10 to 15 years post treatment, the prevalence of labial/buccal recession was similar between groups. It can be concluded that the cause of gingival recessions is multifactorial, and more randomized controlled studies with clinical examination of the gingival condition and oral hygiene before, during, and after orthodontic treatment are necessary to learn more about unfavorable orthodontic movement of teeth and the occurrence of gingival complications.

To reduce a possible risk of the emergence of gingival recessions after treatment, it is advisable to prevent proclination of the lower incisors. With the treatment of Class II malocclusion with fixed appliances, this can be achieved by reducing the use of Class II elastics, more interproximal stripping of the teeth in the lower dental arch, and probably more often also extractions in the lower arch. Further, a reversed torque auxiliary or rebonding the lower incisors with brackets with another torqueing prescription can be considered. Clinicians must recall that these measures also can move the roots outside the osseous envelop of the alveolar process and create another risk factor for gingival recessions in the long term. Some proclination of the lower incisors as a side effect of orthodontic treatment must probably be accepted. Individual anatomy of the mandibular symphysis varies widely, and research with new techniques, such as CBCT, could yield important information about the ideal placement of the lower incisors in an individual patient.

Looking at the **soft tissue changes**, the patients in this study showed an increased nasolabial angle and flattening of the profile through reduction of the sagittal overjet. The increase in the nasolabial angle was 1.99 degrees (95% confidence interval [CI] 0.18–3.80; P=0.031) over the total observation period, but with a large individual variation. The distance from the upper lip (Ls) to the E-line changed in our group, by -2.57 mm (95% CI -2.93 to -2.20; P<0.001) during treatment. Furthermore, the distance from the lower lip (Li) to the E-line changed by -1.67 mm (95% CI -2.93 to -2.20; P<0.001) during treatment. In a systematic review on soft tissue changes in Class II malocclusion patients treated with extractions, Janson et al. [38] concluded that the debate on extraction effects on soft tissue changes is still far from over. Factors such as soft tissue thickness, sex differences, pre-treatment labial tension, type of malocclusion, crowding, and face height will influence how extractions affect the soft tissues. In their review, these authors included seven articles on upper premolar extractions. Traditional anchorage yielded a mean increase in the nasolabial angle of 2.4 degrees to 5.40 degrees during treatment, whereas in cases with anchorage support by mini-implants, this increase extended to 11.55 degrees. It is conceivable that optimized anchorage does not always benefit the patient's profile. The mean changes during treatment in the distance from the upper- and lower lip to the E-line were comparable with the outcome in our study.

In a recent systematic review and meta-analysis entitled "Soft tissue changes following extraction vs. non-extraction orthodontic fixed appliance treatment," Konstantonis et al.

[39] concluded: "although tooth extractions seem to affect patient profile, existing studies are too heterogeneous and no consistent predictions of profile response can be made.". These authors found in the included studies with upper premolar extractions that the nasolabial angle increased significantly compared with non-extraction treatments (mean difference=2.4°; 95% CI 0.88–3.87; P=0.002). The distance from the upper lip (Ls) to the E-line changed by -0.43 mm (95% CI -1.54 to 0.68; P=0.45), and the distance from lower lip (Li) changed by -1.30 mm (95% CI -2.90 to 0.29; P=0.11). With the information from these systematic reviews, we can conclude that treatment effects in our study after upper first permanent molar extraction, such as changes in the nasolabial angle and distance from the upper and lower lips to the E-line, are comparable with those in upper premolar extraction cases. In our study, the change in the upper lip (Ls) to E-line continued in the period after treatment, shifting by -0.67 mm (95% CI -0.99 to -0.36; P<0.001), which can be attributed to growth of the nose and chin [40]. The distance of the lower lip (Li) to the E-line remained unchanged in the post-treatment period.

Dental and occlusal changes

The PAR outcome measures we assessed in this study showed a percentage reduction of the weighted PAR score of 95.7% during treatment, which decreased to 89.9% at 2 years post treatment. The reduction in the PAR score was independent of the PAR score at T1. No statistically significant correlation was found between the amount of PAR reduction and treatment duration. Regression analysis did not reveal any predictive factors for change after treatment (relapse). Also, no effect was found of facial type on the change in the weighted PAR score in the post-treatment period. Concerning operator experience, no difference in treatment outcome was found between the first and last 20 patients. On the other hand, the Treatment Efficiency Index showed a highly significant difference between the early and late operator experience groups. This difference indicated a positive learning curve for the orthodontist who performed the procedures in this study, resulting in a greater PAR point reduction per month with increasing experience.

It is proposed that a good standard of orthodontic treatment is achieved when the reduction in the PAR score is greater than 70% [41]. Several studies have concluded that the orthodontist is the most important factor in establishing a good treatment result. Reukers et al. [42] found significant differences between clinicians in an RCT comparing treatments with standard edgewise brackets and fully programmed straight-wire brackets but not between appliances. In another RCT, two orthodontists treated patients with customized and non-customized brackets [43]. The quality of the treatment result and treatment duration were influenced by the orthodontist and the severity of the original malocclusion rather than by the bracket system. In an RCT comparing treatment outcomes using a 0.18" versus 0.22" slot size, Yassir et al. [44, 45] also reported no differences between the systems and concluded that the effect of the orthodontist was greater than the influence of the bracket slot size. O'Brien reported at "Kevin O'Brien's Orthodontic Blog" about this study with the comment, "there is nothing magic about brackets and wires" [46]. In orthodontic treatment in the present study, light wire brackets and Australian wires were used, which seems to be of minor importance given the present evidence.

We chose to evaluate our group of patients again 2 years after treatment because earlier studies have shown that changes after treatment mostly occur in the first 2 years after treatment completion [47-49]. Most studies on long-term treatment outcomes have not been restricted to a specific malocclusion. In a 5-year follow-up study, Birkeland et al. [50] found in the post-treatment period an increase of 12.9% in the PAR score. In their 6.5-year follow-up study, Woods et al. [51] found a 15.2% increase in PAR score. A comparable study showed an 8-year post-treatment "relapse rate" of 13.0% [52]. De Freitas et al. [53] noted in a 5-years post-treatment study an 11.9% increase in PAR score. Steinnes et al. [54] reported a decrease of 14.0% in PAR score at 8.5 years post treatment. Compared with these studies and taking into account that 50% of the post-treatment change occurs in the first 2 years after treatment, the outcome of a 5.8% change after 2 or more years in our study is quite acceptable.

As stated above, in our study group, post-treatment changes were limited. One explanation could be that a jaw orthopedic correction was not part of this treatment protocol, so that subsequently there was no relapse in the jaw relationship into the direction of a Class II. Because we did not target a jaw orthopedic correction, functional appliances were not used during the retention phase. For all patients, the retention was limited to C-C retainers in the upper and lower jaws, fixed to all six anterior teeth. It is interesting to report that in none of these adolescents did we use a Hawley type of retainer to prevent re-opening of the extraction diastemas. The mesial drift of the maxillary second molars supported by the third molars and the established Class I sagittal premolar interdigitation could be an explanation. Anyway, it reduces the costs and the necessity for too many supplementary retention control visits.

CLINICAL IMPLICATIONS

Treatment of Class II division 1 malocclusion including upper first permanent molar extractions is an unconventional treatment modality that is not part of mainstream treatment options that most orthodontists would consider. Providing an evidence base for this treatment approach was a long process, which started with the treatment of just a single case. The low discontinuation rate, predictability of the treatment outcome, and long-term stability have stimulated higher uptake of this Class II treatment modality more routinely and the start of a clinical study in cooperation with the orthodontic department of a university clinic. Whether it is justified to remove healthy upper first molars or healthy upper premolars while heavily restored first molars are present remains a difficult question to answer. Overall, this one-phase Class II therapy with upper first permanent molar extractions could become a treatment option to consider, for example in cases with a well-aligned lower dental arch, while extractions in the maxilla are indicated and one or two of the upper first molars have a less favorable prognosis, such as molars with large restorations, endodontic treatment, and hypomineralized enamel. This treatment also could be suitable for adolescents with an expected moderate level of cooperation and in cases where non-extraction treatment has failed. The upper third molars should be present and consequently the post-treatment observation period in the orthodontic office can be terminated only after the third molars are in occlusion. The upper third molars have a good prognosis, and for that reason, future surgical removal is not likely [55].

Extractions are more associated with anxiety and can cause higher uncooperative behavior in comparison with other dental appointments [56] and from the *patient's and parent's* perspective, extraction of upper first molars is a more drastic approach than extraction of upper first or second premolars. It is obvious that the patient and the parents must play an important role in the extraction decision. Avoiding extra-oral traction and/or placement of skeletal anchorage could work in favor of extractions. The possibility of the removal of an upper first molar with a large restoration will also influence the decision-making process of the child and the parents.

Extraction of upper first molars is certainly not the *general dentist's* typical first choice because root fractures and antrum perforations are more common in molar extractions than in premolar extractions. The evidence-based, good prognosis of the corrected Class II division 1 malocclusion and the good prognosis of the upper third molars may motivate the dentist or oral surgeon to carry out the extractions. To facilitate control of the mesial drift of the second molars, the timing of the extractions must be determined after a dialogue between the dentist and the orthodontist because the latter must be able to band the second molars to allow for initiation of fixed appliance treatment.

After publication of "A treatment method for Class II division 1 patients with extraction of permanent maxillary molars" in 2009 [1], some fine-tuning of the technique was done. We limited the use of Class II elastics to prevent excessive lower incisor protrusion. In some cases, when a well-aligned lower dental arch is present, the appliance can even be limited to the upper jaw with no intermaxillary elastics use at all.

The final result of this treatment approach is an extraction therapy with an "eight premolar smile" while the upper third molars, as "forgotten molars," have a good prognosis.

FUTURE PERSPECTIVES AND FINAL REMARKS

The decision-making process about whether to extract is complicated, and evidence is lacking to support one option over another. For the treatment of a Class II division 1 malocclusion, choices are extraction of first premolars, second premolars, first molars, or second molars. However, evidence remains insufficient for an effect of different extractions on treatment outcome, soft tissues, smile esthetics, long-term stability, development of an obstructive sleep apnea syndrome and patient-related outcome variables. Theoretically, RCTs could provide answers for these questions about the effects of different extractions, but performing such trials is ethically untenable and therefore likely impossible. Perhaps a reasonable alternative would be well-designed prospective cohort studies.

The controversy over the effects on the facial soft tissue of extracting different tooth types remains unresolved. One reason is that soft tissue change is a dynamic three-dimensional phenomenon that is difficult to assess two-dimensionally. Newer non-invasive imaging modalities such as MRI and 3D and 4D stereophotogrammetry are promising research tools for detecting these treatment effects on soft tissues.

Furthermore, a growing number of publications address the emergence of gingival recessions as a possible side-effect of orthodontic treatment. In the present era with a tendency to non-extraction treatment, long-term studies on this topic are of utmost importance to gain more insight into the effect on the periodontium and to prevent eventual detrimental outcomes. One possible solution could be for orthodontists to consider extractions more frequently when making an orthodontic treatment plan.

The patients involved in this study were treated in an orthodontic office, and the research outcome was the result of cooperation with an academic orthodontic department. This concept of independent teamwork in practice-based research could offer great potential for increasing knowledge in orthodontics and developing evidence-based treatment protocols [57]. Academic orthodontic departments should take the initiative to create networks with existing study clubs and locally organized groups of orthodontists, first to start pilot studies that can later be expanded when funding is acquired. Such efforts would stimulate the orthodontic profession to participate in collaborative studies, which in the end will offer great benefit for our patients.

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8

CHAPTER 8

SUMMARY

Chapter 1 introduces the topic of this PhD thesis. Class II division 1 malocclusion is the most frequent orthodontic anomaly treated. The orthodontist can choose between a wide range of treatment methods based on jaw orthopedics and/or dento-alveolar compensation. Recent alternatives offered in the literature are the use of miniscrew implants and sub-mucosal bone anchored miniplates. Research has been performed into the treatment outcome of these methods but with the lack of well-designed RCT's, the level of evidence is still rather low.

Class II treatment after extraction of the upper first permanent molars can be very effective. This approach involves extraction of upper first molars to facilitate the rearrangement of the dentition and the occlusion incorporating the natural tendency for mesial drift of the upper second molars and distal drift of the upper premolars. Until now research on this type of treatment in a large group of patients was rare. The aim of this study was to refine the treatment method and to study the quality and long-term stability of Class II treatment after upper first molar extractions.

Chapter 2 provides a detailed description of the treatment method for Class II division 1 malocclusions including extraction of maxillary first permanent molars that is investigated in this study. Through the years a great variety of treatment modalities has been presented for the treatment of Class II malocclusions. Many of them rely heavily on patient cooperation in wearing extra-oral appliances or intermaxillary elastics. This explains why non-compliance treatment modalities became more and more popular over the last decades with absolute anchorage using orthodontic implants, onplants, miniscrews or bone plates as the latest addition to the orthodontic repertory. Eliminating the need to use extra-oral traction or removable functional appliances was one of the aims of the treatment approach described here, which involves extraction of the upper first molars without special precautions to preserve anchorage. The treatment procedure can be divided into three phases: Class II correction phase, torque and space closure phase and the detailing/finishing stage. In deep bite cases a pretreatment stage is necessary with fixed appliance in the mandibular arch and a biteplate in the maxilla, to reduce the pronounced curve of Spee. In this chapter the treatment method is illustrated with figures and by a case presentation.

Chapter 3 presents the results of a study into the mechanism of overjet correction and space closure when treating Class II Division 1 patients by extracting the maxillary first permanent molars. A total of 100 consecutively treated Class II Division 1 patients (45 females, 55 males; 10.5– 17.2 years old) was enrolled. Standardized lateral cephalograms prior to and after treatment were evaluated using a modified sagittal occlusion analysis (SO analysis). The mean degree of overjet correction was 5.2 mm (95% CI = 4.8–5.6 mm) and was on average achieved by means of 1.7 mm skeletal and 3.5 mm dental changes. These dental changes were accomplished by 2.4 mm retraction of the upper incisors and 1.1 protrusion of the lower incisors. The relationship between the premolars improved by 4.8 mm toward a Class I relationship, facilitated by 1.7 mm skeletal and 3.1 mm dental changes. The 11.3 mm space closure in the maxillary first molar extraction area resulted from distalization of the second premolars (1.4 mm) and mesialization of the second molars (9.9 mm). We concluded that overjet correction was essentially achieved by retrusion of the upper incisors, as well as by ventral growth of the lower jaw and protrusion of the lower incisors. Space closure was only partly achieved by distalization of the premolars.

In **chapter 4** the results are given of a study that compared Class II division 1 treatment as described in chapter 2 of this thesis and a two-phase treatment consisting of Herbst appliance followed by fixed appliances. Dento-skeletal and soft tissue treatment effects of these two Class II division 1 treatment modalities were compared with 79 children in the extraction group and 75 children in the Herbst group. These groups, with an average age of 12.7 years at the start of treatment for the extraction group and 13.0 years for the Herbst group, had been matched for age and sex. Pre-treatment (T1) and post-treatment (T2) lateral cephalograms were retrospectively analysed using a standard cephalometric analysis and the SO-analysis according to Pancherz. The SNA decrease was 1.10° (p=0.001) more pronounced in the extraction group than in the Herbst-group, while the SNB angle increased 1.49° more in the Herbst group (p=0.000). In the extraction group a significant decrease in the SNB angle of 0.49° was seen. The soft tissue profile convexity (N-Sn-Pog) decreased in both groups. Concerning the soft tissues the nasolabial angle increased significantly more (+2.33°, p=0.025) in the extraction group. The overjet correction in the extraction group was predominantly dental (65% dental and 35% skeletal changes), while in the Herbst group it was predominantly skeletal (42% dental and 58% skeletal changes). It could be concluded that both treatment methods were successful in correcting the Class II division I malocclusion.

In **chapter 5** the long-term cephalometric outcome was evaluated and divided into sagittal and vertical skeletal changes, dentoalveolar changes and soft tissue changes. The sample consisted of 83 consecutively treated patients (36 girls, 47 boys) treated by one orthodontist (J.W.B.). Again, based on the mandibular plane angle the material was divided in a hypo-, normo- and a hyperdivergent group. Most post treatment skeletal changes were highly significant. This is probably due to growth as the mean age at T2, the end of treatment, was 15.6 years. The SNA angle decreased during treatment (T1-T2) with 2.23 degrees and increased after treatment (T2-T3) with 2.82 degrees which is a change into the direction of the initial growth pattern. Angle SNB decreased slightly during treatment with -0.35 degrees and increased after treatment with 2.21 degrees which must be explained by normal growth. The palatal plane-mandibular plane angle (ANS-PNS/ML) remained the same during treatment. This indicated that the therapy did not influence the vertical jaw relation. Only for a few variables growth influenced the treatment outcome. Besides that, in the post treatment period no differences in skeletal changes were found between the three different growth types.

Observing the dentoalveolar changes, the upper incisor inclination (U1L/ANS-PNS) decreased with 2.10 degrees during treatment and remained the same in the post treatment period. The use of light wires and low friction brackets for the overjet correction can cause considerable retroclination of the upper incisors which was successfully counteracted with a torqueing spring auxiliary. However, during treatment, the lower incisor inclination (L1L/ML) increased significantly with 5.4 degrees, which remained unchanged post treatment. This rather large proclination is probably the result of leveling of the curve of Spee and the use of Class II elastics.

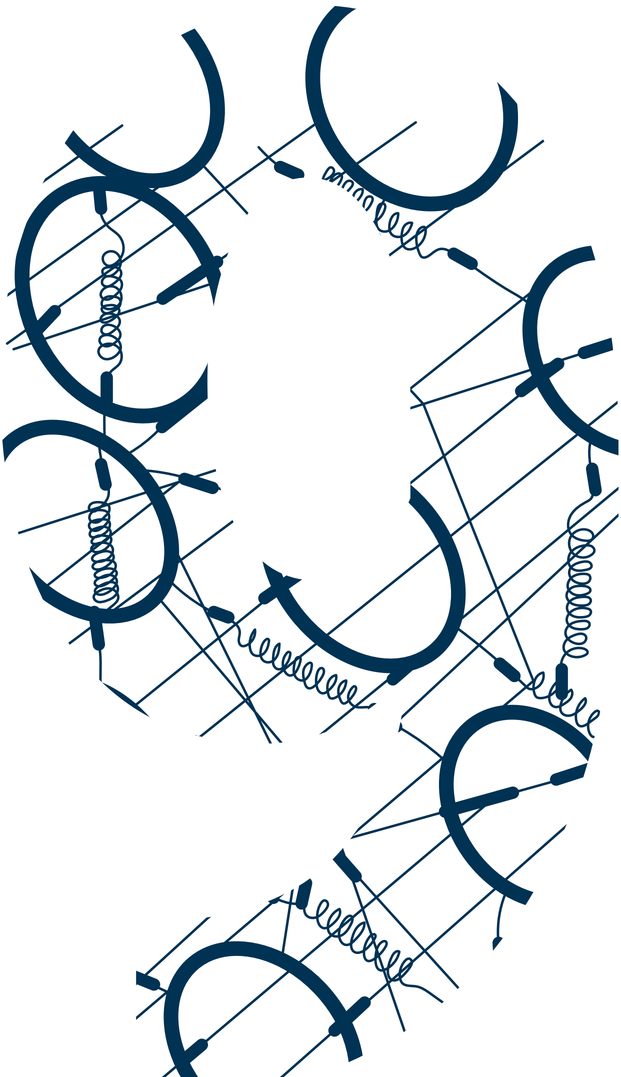
Concerning the soft tissue changes, the patients in this study showed an increase of the nasolabial angle and some flattening of the profile. The increase of the nasolabial angle was 1.99 degrees (95% CI 0.18… 3.80, P=0.031) over the total observation period, but there was a large individual variation.

Linear regression was used to examine the effect of facial type, age, and gender. Facial type had only a very minor influence on the cephalometric changes during and after treatment.

Overall, post treatment cephalometric changes were limited. In the total observation period the extractions in this Class II division 1 treatment modality had only minor effects on the facial profile.

Chapter 6 describes the long-term outcome of this treatment measured with the PAR-index. The sample consisted of 96 consecutively treated patients (43 girls, 53 boys) treated by one orthodontist. Based on the mandibular plane angle the sample was divided into a hypo-, normo- and a hyperdivergent group. Retention was carried out with upper- and lower fixed retainers. The PAR outcome measures we assessed in this study showed a percental reduction of the weighted PAR score with 95.7% during treatment which decreased to 89.9% two years post treatment. The reduction of the PAR score was independent of the PAR score at T1. No statistically significant correlation was found between the amount of PAR reduction and treatment duration. Regression analysis did not reveal any risk factors for change after treatment (relapse). Also, no effect was found of the facial biotype on the change of the weighted PAR score in the post treatment period. Concerning the operator experience, no difference in treatment outcome was found between the first twenty patients and the last twenty patients. On the other hand, the Treatment Efficiency Index (TEI) showed a highly significant difference between the early and late operator experience group. This indicated a positive learning curve for the orthodontist involved, resulting in shorter treatment duration with the same results. This method resulted in a good treatment outcome and the stability two years after appliance removal was good.

In **chapter 7** the method of Class II division 1 treatment with upper first permanent molar extraction is discussed, and the results of this research are put into a broader perspective. Clinical implications for the orthodontist, the general dentist and patients and parents are discussed. The good long-term prognosis of the corrected Class II division 1 malocclusion after upper first permanent molar extractions could aid in the decision-making process for an orthodontic treatment. Especially when upper first molars are not in good condition this treatment method should be considered. Nevertheless, the controversy on the effect of extraction of different tooth types on the facial soft tissue remains still unsolved. Newer non-invasive imaging modalities like 3D and 4D stereophotogrammetry, and MRI are promising research tools to detect treatment effects on the soft tissues. Together with independent teamwork in practice-based research this could have a great potential to increase our knowledge in orthodontics and to develop evidence-based treatment protocols.



CHAPTER 9

SAMENVATTING

De Klasse II malocclusie, met als belangrijkste kenmerk het naar voren staan van de boventanden, is de gebitsafwijking die het frequentst voorkomt en ook het meest voor een orthodontische behandeling in aanmerking komt. Voor de correctie van Klasse II gebitsafwijkingen zijn de afgelopen honderd jaar veel verschillende behandelmethoden ontwikkeld. Sommige zijn gebaseerd op het beïnvloeden van de groei van de boven- en/of onderkaak en andere richten zich puur op het door het kaakbot verplaatsen van de gebitselementen. “Verankering” is bij de behandeling vaak een sleutelwoord; verankeringsverlies kan de orthodontische behandeling compliceren. Een tweede sleutelwoord is “medewerking”. Patiënten en hun ouders willen mooie behandelresultaten resulterend in een fraai gebit met minimale inspanning van henzelf. Het spreekt voor zich dat er veel onderzoek gedaan is naar de behandeling van de Klasse II malocclusie, maar door het gebrek aan goed ontworpen gerandomiseerde klinische trials (RCT's) is het niveau van bewijs nog steeds vrij laag.

Hoofdstuk 1 is een inleiding op het onderwerp van dit proefschrift dat gaat over een behandelmethode van Klasse II/1 afwijkingen met daarbij het verwijderen van de blijvende eerste molaren in de bovenkaak. Deze therapie, die alleen gericht is op het verplaatsen van tanden en kiezen en niet op het beïnvloeden van groei van de kaken, kan zeer effectief zijn. Er wordt onder andere gebruik gemaakt van de natuurlijke neiging tot *mesial drift* van de tweede molaren en *distal drift* van de premolaren in de bovenkaak. Hierdoor ontstaat ruimte in de boventandboog om de bovensnijtanden en hoektanden naar achteren te verplaatsen. Het verlies aan verankering vindt op een gecontroleerde manier plaats en de vereiste medewerking van de patiënt is niet al te groot. Tot nu toe is het effect van deze behandeling bij een grote patiëntengroep niet onderzocht. Het doel van dit promotieonderzoek was om deze behandelingsmethode nauwkeurig te beschrijven en te verfijnen en de kwaliteit en stabiliteit van de resultaten op lange termijn te bestuderen. Tevens werd gekeken naar de wijze waarop behandeleffecten tot stand kwamen en werden de resultaten van de onderzoeksgroep vergeleken met die van een soortgelijke patiëntenpopulatie die op een andere manier behandeld werd.

Hoofdstuk 2 geeft een gedetailleerde beschrijving van de behandelmethode van de Klasse II/1 afwijking na extractie van de eerste blijvende molaren in de bovenkaak, het onderwerp van dit proefschrift. In de loop der jaren is een breed scala aan behandelmethoden voor dit type gebitsafwijking ontwikkeld, waarvan het succes erg afhankelijk is van de medewerking van de patiënt zoals bij extra-orale tractie, functionele apparatuur en intermaxillaire elastieken het geval is. Dit verklaart de in de afgelopen decennia gegroeide populariteit van therapieën, die minder afhankelijk zijn van de motivatie van de patiënt. Volledige verankering wordt in die gevallen verkregen door gebruik te maken van implantaten, botschroefjes en botankers. Bij de behandelmethode met extractie van de eerste blijvende molaren in de bovenkaak is de orthodontist ook minder afhankelijk van de medewerking van de patiënt en hoeven er geen maatregelen genomen worden om de verankering veilig te stellen. De behandelprocedure kan in drie fases verdeeld worden: de Klasse II correctiefase gevolgd door een combinatie van torque van het bovenfront en het sluiten van de laterale restdiastemen en tot slot een detaillering en afrondingsfase. Is er sprake van een diepe beet, dan is er een voortraject nodig met plaatsing van een opbeetplaat in de bovenkaak en vaste apparatuur in de onderkaak om allereerst de curve van Spee te reduceren. In dit hoofdstuk wordt de behandelmethode met tekeningen geïllustreerd en wordt een voorbeeld van de behandeling gegeven.

Hoofdstuk 3 geeft de resultaten weer van een onderzoek naar de manier waarop de reductie van de sagittale overbeet tot stand komt bij de behandeling van de Klasse II/1 afwijking, na extractie van de eerste blijvende molaren in de bovenkaak. Ook werd de manier van sluiting van de extractiediastemen onderzocht. Het onderzoek omvatte een groep van in het totaal 100 achtereenvolgende behandelingen (45 meisjes, 55 jongens; 10.5-17.2 jaar). Gestandaardiseerde laterale röntgenschedelprofielfoto's van voor en na behandeling werden geëvalueerd met gebruikmaking van een gemodificeerde sagittale occlusie analyse (SO analysis). De gemiddelde mate van sagittale overbeetcorrectie was 5.2 mm (95% CI 4.8-5.6 mm). Dit werd bereikt door gemiddeld 1.7 mm skelettale en 3.5 mm dentale verandering. Deze dentale verandering bestond uit 2.4 mm retractie van de bovenincisieven en 1.1 mm protrusie van het onderfront. De premolaarrelatie verbeterde met 4.8 mm in de richting van een Klasse I relatie als gevolg van 1.7 mm skelettale en 3.1 mm dentale veranderingen. De sluiting van de diastemen van 11.3 mm na extractie van de eerste blijvende molaren kwam tot stand door distaal verplaatsing van de tweede premolaren (1.4 mm) en mesiaal verplaatsing van de tweede molaren in de bovenkaak. We concludeerden dat de correctie van de sagittale overbeet hoofzakelijk tot stand kwam door retractie van het bovenfront en ventrale groei van de mandibula en daarnaast protrusie van het onderfront. Het sluiten van de grote extractiediastemen kon slechts gedeeltelijk verklaard worden door de distaalwaartse beweging van de premolaren.

In **Hoofdstuk 4** worden de resultaten van de in hoofdstuk 2 van dit proefschrift beschreven methode van Klasse II/1 behandeling vergeleken met een behandeling uitgevoerd met Herbst-apparatuur gevolgd door volledig vaste apparatuur. Dentale, skelettale en weke delen effecten van deze twee behandelmethoden werden vergeleken met 79 kinderen in de extractiegroep (gemiddelde leeftijd: 12.7 jaar) en 75 kinderen in de Herbst groep (gemiddelde leeftijd: 13.0 jaar). Deze twee groepen waren "gematched" op leeftijd en geslacht. De individuele verschillen waren groot. Laterale schedelfoto's van voor de behandeling (T1) en na de behandeling (T2) werden retrospectief geanalyseerd door gebruik te maken van een gestandaardiseerde cephalometrische analyse en de SO-analyse volgens Pancherz. De SNA-hoek nam 1.10°(p=0.001) meer af in de extractiegroep in vergelijking met de Herbst groep, terwijl de toename van de SNB-hoek in de Herbst groep 1.49°(p=0.000) groter was dan in de extractiegroep. Daarnaast werd in de extractiegroep een significante afname van 0.49°van de ANB-hoek gevonden. Beide groepen toonden een afname van de convexiteit van het weke delen profiel (N-Sn-Pog). Verder bleek uit de weke delen analyse dat de toename van de nasolabiale hoek in de extractiegroep groter was (+2.33˚, p=0.025). De correctie van de sagittale overbeet was in de extractiegroep hoofdzakelijk dentaal (65% dentaal, 35% skelettaal) terwijl in de Herbst groep de skelettale componenten een grotere rol speelden (42% dentaal, 58% skelettaal). Geconcludeerd werd dat beide behandelmethodes succesvol waren in de correctie van de Klasse II/1 malocclusie en dat de zichtbare verschillen tussen beide groepen klein waren.

In **Hoofdstuk 5** werden de cefalometrische veranderingen geëvalueerd, onderverdeeld in sagittale en verticale skelettale veranderingen, dento-alveolaire veranderingen en veranderingen van het weke delen profiel. De onderzoeksgroep bestond uit 83 achtereenvolgende behandelingen (36 meisjes, 47 jongens) die door dezelfde orthodontist uitgevoerd waren. Gebaseerd op de *mandibular-plane-angle* werd de onderzoeksgroep onderverdeeld in een hypo-, normo- en een hyperdivergente groep. De meeste skelettale veranderingen in de twee jaar na afloop van de behandeling waren significant. Dit is hoogstwaarschijnlijk te verklaren door de groei omdat op T2 de gemiddelde leeftijd 15.6 jaar was, het moment waarop de orthodontische apparatuur verwijderd werd. De SNA-hoek nam tijdens de behandeling (T1-T2) af met 2.23 graden en werd na behandeling (T2-T3) weer 2.82 graden groter, een verandering in de richting van het oorspronkelijke groeipatroon. De SNB-hoek nam tijdens de behandeling 0.35 graden af, terwijl deze in de periode na de behandeling, vermoedelijk als gevolg van normale groei, met 2.21 graden toenam. De *palatal plane-mandibular plane* hoek (ANS-PNS/ML) bleef ongewijzigd tijdens de behandeling. Dit duidt erop dat de therapie niet van invloed is op de verticale kaakrelatie. Voor slechts een paar variabelen had het groeitype invloed op de behandeluitkomsten terwijl in de periode daarna geen verschillen in de skelettale veranderingen voor de drie groeitypes gevonden werden.

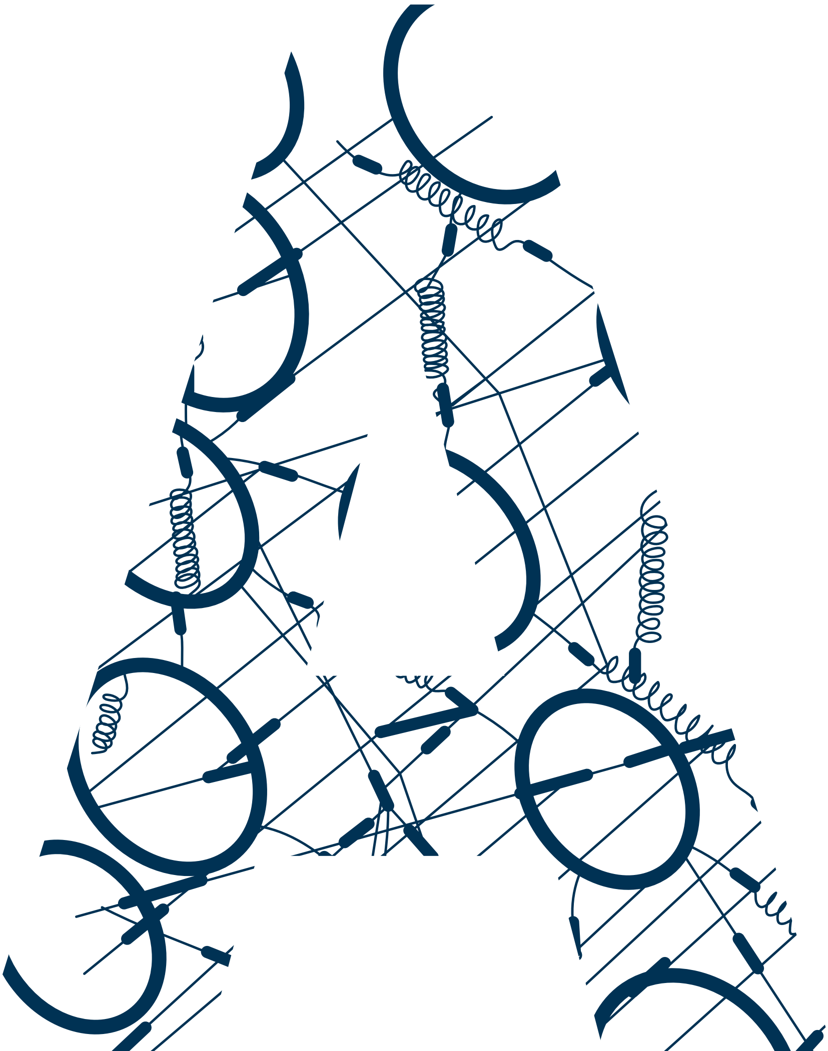
Wat betreft de dento-alveolaire veranderingen, was er tijdens de behandeling een afname in de asrichting van de bovenincisief (U1L/ANS-PNS) met 2.10 graden, die in de periode na afloop van de behandeling ongewijzigd bleef. De combinatie van dunne ronde draden en frictie-arme brackets zou bij het reduceren van een sagittale overbeet in een ongewenste steilstand van het bovenfront kunnen resulteren maar bij deze behandelingen werd dat voorkomen door het gebruik van een torque hulpboog. Daarentegen was er wel een significante ongunstige verandering in asrichting van de onderincisief (L1L/ML) met 5.4 graden proclincatie, die in de periode na afloop van de behandeling hetzelfde bleef. Dit was vermoedelijk een neveneffect van het afvlakken van de curve van Spee en het gebruik van Klasse II elastieken.

Wat de weke delen betreft, lieten de patiënten in deze studie een toename zien van de nasolabiale hoek en een afvlakking van het profiel. Over de totale periode (T1-T3) nam de nasolabiale hoek toe met 1.99 graden (95% CI 0.18… 3.80, P=0.031) maar, er waren grote individuele verschillen.

Alles bij elkaar genomen waren de cefalometrische veranderingen na de behandeling zeer beperkt. Lineaire regressieanalyse liet zien dat het gelaatstype slechts een zeer geringe invloed had op de cefalometrische veranderingen tijdens en na de behandeling. De invloed op het profiel was beperkt.

In **Hoofdstuk 6** komen de dentale veranderingen aan de orde, gemeten met de PAR-index. De onderzoeksgroep omvatte 96 achtereenvolgende behandelingen (43 meisjes, 53 jongens) die door dezelfde orthodontist waren uitgevoerd. Op basis van de grootte van de *mandibular-plane-angle* werden de patiënten onderverdeeld in een hypo-, normo- en een hyperdivergente groep. Als retentie na de orthodontische behandeling werden draden achter het boven- en onderfront geplaatst. De PAR-score gaf een reductie van 95.7% gedurende de behandeling te zien. Twee jaar later was deze teruggelopen tot 89.9%. De reductie van de PAR-score was onafhankelijk van de PAR score op T1, de start van de behandeling. Er werd geen statistisch significante correlatie gevonden tussen mate van reductie van de PAR score en de duur van de behandeling. Uit de regressieanalyse kwamen geen factoren naar voren die van invloed waren op veranderingen in de periode na de behandeling. Ook gelaatsvorm had geen effect op de mate van verandering van de PAR-score in de periode na afloop van de behandeling. Om een beeld te krijgen van de mogelijke invloed van een toegenomen ervaring van de behandelaar op het eindresultaat werden de uitkomsten van de eerste en laatste twintig patiënten met elkaar vergeleken. Hieruit kwamen geen verschillen. Daarentegen, werd er bij de vergelijking van de vroege- en late groep, wel een hoog significant verschil gevonden voor de *Treatment Efficiency Index* (TEI). Dit kon geïnterpreteerd worden als een positieve leercurve voor de betrokken orthodontist die resulteerde in een afname van de behandelduur bij gelijkblijvende kwaliteit. De behandelmethode gaf goede resultaten en in de twee jaar na afloop van de behandeling bleven veranderingen beperkt.

In **Hoofdstuk 7,** wordt de behandelmethode bediscussieerd en worden de resultaten van dit onderzoek in een breder perspectief geplaatst. De klinische betekenis ervan voor de orthodontist, de tandarts en de patiënten en hun ouders wordt beschreven. Deze behandelmethode, met goede lange termijn prognose, kan een optie zijn voor de behandeling van Klasse II/1 malocclusies. Vooral wanneer de eerste blijvende molaren in de bovenkaak niet in goede conditie zijn, moet deze behandelingsmethode overwogen worden. Ondanks het vele onderzoek dat is verricht, blijft de controverse over het effect van de diverse extracties op de weke delen van het gezicht nog steeds onopgelost. Nieuwe niet-invasieve beeldvormende technieken zoals 3D en 4D stereofotogrammetrie en MRI zijn veelbelovende onderzoeksinstrumenten om behandelingseffecten op de weke delen te analyseren. Het vormen van praktijknetwerken voor grootschalig klinisch onderzoek in samenwerking met academische centra heeft een potentieel veel waarde om de kennis in de orthodontie te vergroten en nieuwe evidence-based behandelingsprotocollen te ontwikkelen.



APPENDICES

- **ACKNOWLEDGEMENTS**
- **CURRICULUM VITAE**
- **LIST OF PUBLICATIONS**
- **PHD PORTFOLIO**
- **RESEARCH DATA MANAGEMENT**

DANKWOORD/ACKNOWLEDGEMENTS

Don't tell this story in the USA, they will kill you! (John Bennett, 2005)

Het is een geruststellende gedachte dat er nu toch enige wetenschappelijke onderbouwing van deze Klasse II behandelmethode is.

Veel mensen hebben hieraan bijgedragen en eenieder wil ik daarvoor uit de grond van mijn hart bedanken en een aantal wil ik daarbij graag persoonlijk noemen.

Hooggeachte professor Kuijpers-Jagtman, beste Anne Marie jij bent mijn eerste promotor en het belangrijkste wat ik van jou geleerd heb is, dat onderzoek doen best leuk kan zijn. Ik bewonder je engelengeduld, je veelzijdigheid, je niet aflatende energie en je enthousiasme. Je was een echte docent voor mij, ik had het niet beter kunnen treffen. Je oprechte belangstelling voor mijn materiaal gaf mij vertrouwen in de voltooiing van dit promotieonderzoek en ik beschouw het als een zeer grote eer dat jij mij hebt willen begeleiden. Eén keer heb ik je aanbod getest dat ik je tot middernacht mocht bellen. Het klopte! In de toekomst zal er iets meer tijd zijn om over lekker eten, mooie wijnen, reizen en onze families te praten. Mijn dank is groot.

Hooggeachte professor Katsaros, beste Christos jij bent mijn tweede promotor en lange tijd geleden, toen je nog aan het Radboudumc verbonden was, stond jij aan de wieg van dit promotietraject. Je was in mijn praktijk om een indruk op te doen van Klasse II behandelingen na extractie van de eerste blijvende boven molaren en jij suggereerde als eerste om hier een proefschrift over te schrijven. Je wetenschappelijke manier van denken heeft mij geïnspireerd tot beter nadenken over iets dat op het eerste gezicht vanzelfsprekend lijkt. Je bent een orthodontische vraagbaak die zijn weerga niet kent met altijd weer door humor doorspekte antwoorden. Ik waardeer dat zeer. Misschien dat die website over molaarextracties er nog eens komt maar "*life is difficult*".

De artikelen uit dit proefschrift hadden niet tot stand kunnen komen zonder de uitmuntende statistische begeleiding van Dr. Ewald Bronkhorst. Ewald je bent fenomenaal: meestal kwam je per kerende post met oplossingen voor problemen die we tegenkwamen. Geen moeite was je te veel om extra analyses uit te voeren. O ja, het boek over statistiek dat je me uitgeleend hebt, krijg je nog terug! Ewald, jouw "betrouwbaarheid(sinterval)" is groots waarvoor veel dank.

Alle medewerkers van de voormalige afdeling Orthodontie en Craniofaciale Biologie die dichterbij of verder weg bij dit onderzoek betrokken waren, speciaal Dr. Edwin Ongkosuwito en Dr. Mette Kuijpers, wil ik danken voor de ondersteuning en de gastvrijheid.

Esteemed professors Pancherz and Ruf, dear Hans and Sabine, it was a great honor to me to be approached by the Orthodontic Department of the University of Giessen to carry out joint research. This cooperation resulted in the "Doctorarbeiten" of Juliane Goeke and Caroline Knieling and two articles of this PhD thesis. I realize very well that both of you have done a tremendous amount of work. For example Hans, after my expressed doubts, did all the measurements again! Anchorage loss does not always have to be bad, but it's good to be in control of it. Fortunately, there are still enough questions left to do more research into the mystery of the effect of orthodontics on the soft tissues. "Giessen, vielen Dank!"

Hooggeachte professor Meijer, beste Gert, ik realiseer mij dat het veel werk is om voorzitter van een manuscriptcommissie te zijn. Onze *roots* liggen op het Tandheelkundig Instituut in Utrecht en het feit dat ik vermoedelijk de laatste promovendus met een Utrechts tandartsdiploma ben, zal je beslissing om mee te werken, mede bepaald hebben. Mijn dank hiervoor.

Hooggeachte professor de Pauw, beste Guy, als lid van de manuscriptcommissie ben ik ook jou dank verschuldigd. Jouw leermeester werd in Groningen opgeleid en dat was indertijd de bakermat van de Begg techniek in Europa. Met jouw achtergrond was dit manuscript terecht aan jou toevertrouwd.

Hooggeachte collega Jongsma, beste Bert, jij vond het een grote eer dat je voor de manuscriptcommissie gevraagd werd. Vaktechnisch hebben wij een gemeenschappelijke basis en daar zijn we trots op. Bedankt dat jij je in dit proefschrift hebt willen verdiepen.

Drs. Mattijs Stalpers en Dr. Chris Livas voerden metingen uit als onafhankelijke ter zake kundige observatoren. Bedankt voor jullie tijd en bereidwilligheid.

Dr. Frits Rangel, jouw steun is voor mij van onschatbare waarde geweest. Jij slaagde er in om enorme bestanden aan elkaar te koppelen waardoor dit onderzoek voortgezet kon worden.

Hooggeachte professor Ren, beste Yijin, jij neemt een speciaal plekje in mijn hart in. Dank voor je supervisie van verder onderzoek met en publicaties over dit klinische materiaal én dank voor de introductie van onze Studieclub in jouw geboorteland waardoor ik "mijn verhaal" ook in Shanghai en Wuhan kon vertellen.

Beste patiënten, wat ben ik bevoorrecht dat ik jullie bijna dagelijks over de vloer krijg. Jullie zijn jongelui in een spannende leeftijdsfase en dan kun je niet al te veel gezeur van een orthodontist verdragen. Voor de behandelingen van dit onderzoek waren geen blokbeugels en buitenbeugels nodig, dat scheelde iets. Bedankt voor het dragen van de elastieken en het meewerken aan dit onderzoek. Wel goed blijven poetsen!

Leonie, Ingeborg, Julia, Kübra en niet te vergeten Anita, wil ik bedanken voor de extra inzet om tussen de bedrijven door, soms ten koste van de koffiepauze, alle benodigde foto's en gebitsafdrukken te maken. Eindelijk zien jullie wat hiermee tot stand kon worden gebracht. Ik ben niets zonder jullie!

Ook veel dank voor alle samenwerkende tandartsen en kaakchirurgen. Orthodontie na extractie van eerste boven molaren is niet de weg van de minste weerstand. Jullie mochten het "vuile werk" opknappen en jullie hebben in ieder geval naar de patiëntjes en hun ouders het vertrouwen uitgestraald dat het uiteindelijk allemaal wel recht zou komen. Telefoontjes met de vraag *"staan er wel de correcte elementen op het extractiebriefje"* krijg ik zelden meer. Bedankt voor jullie support! Zo kan ik het lang volhouden en plezier beleven aan een mooi specialisme.

De medische illustraties zijn gemaakt door Guusje Bertholet. Bij toeval ontmoetten we elkaar bij een diner waar ik voor het goede doel kookte. Het heeft zo moeten zijn. Ik wil je nog een keer bedanken voor het geduld dat je met me hebt gehad. Tekeningen zeggen meer dan duizenden woorden, vooral als het zulke goede zijn.

Natuurlijk wil ik ook alle lieve vriendinnen en vrienden bedanken voor hun begrip en om de "wanneer-vraag" maar niet meer te stellen. Dat gaf de broodnodige rust.

I also would like to thank the members of the Angle Society of Europe for their critical appraisal and constructive remarks on this unusual approach of Class II malocclusion treatment.

Voor mij is er maar één studieclub en dat is de Studieclub DMO! Dank voor de proefpromoties, daar heb ik veel van geleerd.

Een boek moet een smoel hebben dat de nieuwsgierigheid prikkelt. Vera Galis bedankt voor de inspiratie hiervoor en James Jardin, dank voor de uitwerking hiervan en bovenal voor de constructieve samenwerking.

Dolf Hoeksema, een betere leermeester in de klinische orthodontie had ik mij niet kunnen wensen. Ik heb er groot respect voor hoe jij ons door orthodontische uitdagingen loodste. Dat heeft vertrouwen gegeven waar ik in de praktijk nog dagelijks de vruchten van pluk.

Met mijn paranimfen, Hans Hordijk en Anton Dijk heb ik in mijn leven al heel wat lief en leed gedeeld. Dat jullie mij nu ook terzijde willen staan bij de verdediging van mijn proefschrift geeft mij extra het gevoel hier niet alleen te staan. Ik ben er trots op dat jullie mijn vrienden zijn.

Tot slot:

Zomervakantie. Thuis. Koffie op het terras. De zon, een libel, ruisend riet en zo waar een ijsvogeltje! "Wil je nog een tweede kopje? Ja graag, maar wel in m'n studeerkamer. Sorry, ik moet door….." Marina Rose, heel erg bedankt voor je liefde en de ruimte die jij me gedurende al die jaren gaf. Samen relativeren bij tegenslag, je gaf me onvoorwaardelijke ondersteuning. Zo vroeg je zelden "hoe lang nog?" en door jou kon ik zo veel mogelijk plezier in het hele project houden. Laurine, Lex en Coen, onze meest dierbaren, ook jullie kon ik niet altijd alle tijd geven. Dat gaat nu veranderen en daar verheug ik me op, natuurlijk samen met Laura, Eveline, Christiaan en Maurits.

CURRICULUM VITAE

The author of this PhD thesis was born March 19, 1954, in Groningen, the Netherlands. After graduating from the 'Heymans lyceum' in 1971, he started studying dentistry at the University of Utrecht and was active in the dental students association 'John Tomes'. He graduated in 1977 and became a dental officer in the Royal Dutch Navy for a period of almost two years. From 1979 to 1983 he took the postgraduate course at the Department of Orthodontics of the University of Utrecht. In that period this department was under the leadership of Dolf Hoeksema, who taught him the enthusiasm and love for orthodontics. Before starting his orthodontic practice in the province town of Gorinchem, just south of Utrecht, he made an orthodontic study tour in the USA. There he met, among others, Raleigh Williams, who introduced the treatment method for Class II malocclusions after upper first permanent molar extractions, which is the subject of the articles in this dissertation. Inspired by the good long-term treatment results of this method, the enthusiasm arose to do research into it. With the indispensable and inspiring support of Anne Marie Kuijpers-Jagtman and Christos Katsaros, the framework for this dissertation was designed. The realization took quite some time, partly because the long term results were also investigated.

From 1985 to 2000 he has been the Honorary Secretary of "de Nederlandse Vereniging voor Orthodontische Studie" and in 1997 he was the President of the European Begg Society and organized an international congress in Maastricht. Since 2002 to present he is the Honorary Secretary of the Booy Foundation.

He married Marina Rose den Uijl and they got three children: Coen, Lex and Laurine. Since its foundation, he has been chairman of the IKTFC cooking club and in 1997 he won the title of best amateur chef in the Netherlands.

LIST OF PUBLICATIONS

Publications included in this PhD thesis.

- **Booij JW**, Kuijpers-Jagtman AM, Katsaros C. A treatment method for Class II Division 1 patients with extraction of permanent maxillary first molars. World J Orthod. 2009;10(1):41-8.
- **Booij JW**, Goeke J, Bronkhorst EM, Pancherz H, Ruf S, Katsaros C. Overjet correction and space closure mechanisms for Class II treatment by extracting the maxillary first molars. J Orofac Orthop. 2011;72(3):196-203.
- **Booij JW**, Goeke J, Bronkhorst EM, Katsaros C, Ruf S. Class II treatment by extraction of maxillary first molars or Herbst appliance: dentoskeletal and soft tissue effects in comparison. J Orofac Orthop. 2013;74(1):52-63.
- **Booij JW**, Kuijpers-Jagtman AM, Bronkhorst EM, Livas C, Ren Y, Kuijpers MAR, Katsaros C. Class II Division 1 malocclusion treatment with extraction of maxillary first molars: Evaluation of treatment and post-treatment changes by the PAR Index. Orthod Craniofac Res. 2020 Jul 29.doi: 10.1111/ocr.12412. Epub ahead of print.
- **Booij JW**, Kuijpers-Jagtman AM, Bronkhorst EM, Rangel FA, Ren Y, Katsaros C, Ongkosuwito EM. Long-term cephalometric outcome of orthodontic treatment with extraction of maxillary first permanent molars in patients with Class II Division 1 malocclusion. Submitted, 2020

Other publications

- **Booij JW**, Markens IS. Occurrence of oxytalan fibers in the temporomandibular joint of the rat. Am J Orthod. 1983;84(2):166-70.
- Stalpers MJ, **Booij JW**, Bronkhorst EM, Kuijpers-Jagtman AM, Katsaros C. Extraction of maxillary first permanent molars in patients with Class II Division 1 malocclusion. Am J Orthod Dentofacial Orthop. 2007;132(3):316-23.
- Mock L, **Booij JW**. Correction of an Angle Class II / Subdivision with unilateral maxillary molar extraction. Inf Orthod Kieferorthop 2010;42:63–67.
- Livas C, Halazonetis DJ, **Booij JW**, Katsaros C. Extraction of maxillary first molars improves second and third molar inclinations in Class II Division 1 malocclusion. Am J Orthod Dentofacial Orthop. 2011;140(3):377-82.
- Livas C, Halazonetis DJ, **Booij JW**, Pandis N, Tu YK, Katsaros C. Maxillary sinus floor extension and posterior tooth inclination in adolescent patients with Class II Division 1 malocclusion treated with maxillary first molar extractions. Am J Orthod Dentofacial Orthop. 2013;143(4):479-85.

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- **Booij JW**. A treatment method for Class II division1 patients with extraction of permanent maxillary molars. In: *Orthodontic Pearls.* Ed. Mizrahi E. London: CRC Press, 2015. Pg 165-172
- Livas C, Pandis N, **Booij JW**, Halazonetis DJ, Katsaros C, Ren Y. Influence of unilateral maxillary first molar extraction treatment on second and third molar inclination in Class II subdivision patients. Angle Orthod. 2016 ;86(1):94-100.
- Livas C, Pandis N, **Booij JW**, Halazonetis DJ, Katsaros C, Ren Y. Influence of unilateral maxillary first molar extraction treatment on second and third molar inclination in Class II subdivision patients. Angle Orthod. 2016;86(1):94-100.
- Livas C, Halazonetis DJ, **Booij JW**, Katsaros C, Ren Y. Does fixed retention prevent overeruption of unopposed mandibular second molars in maxillary first molar extraction cases? Prog Orthod. 2016;17:6.
- **Booij JW**, Livas C. Unilateral maxillary first molar extraction in Class II subdivision: An unconventional treatment alternative. Case Rep Dent. 2016;2016:2168367.

PHD PORTFOLIO

Name PhD candidate:	J.W. Booij
PhD period:	2010-2020
Promotor(s):	Prof. dr. A.M. Kuijpers-Jagtman
	Prof.dr. C. Katsaros (University of Bern)
Department:	Dentistry
Graduate School:	Radboud Institute for Health Sciences

One ECTS stands for around 28 working hours (including preparation, self-study, examinations etc.).

1. PhD training: research skills

	Year	Workload (ECTS)
Four-year postgraduate programme in orthodontics, Orthodontic Department, Tandheelkundig Instituut University of Utrecht: • Biostatistics and research methodology • Craniofacial growth • Cephalometric radiography • Growth and treatment analysis • Biomaterials and biomechanics • Long-term effect of orthodontic treatment	1979-1983	60
Critical Appraisal online course	2019	0.8
Digital Orthodontics - New technologies; Angle Society of Europe, Going, Austria	2019	0.5
Scientific Integrity; Studieclub DMO (Dento Maxillaire Orthopedie), Arnhem, the Netherlands	2018	0.2
Scientific Methodology; Angle Society of Europe, Going, Austria	2016	0.3
Oral Health related Quality of Life research; Studieclub DMO (Dento Maxillaire Orthopedie), Nijmegen, the Netherlands	2015	0.1
PubMed Workshop; Angle Society of Europe, Going, Austria	2012	0.2
Literature search strategies; Studieclub DMO (Dento Maxillaire Orthopedie), Nijmegen, the Netherlands	2007	0.3

2. Presentations

	Year	Workload (ECTS)
Evidence-based tooth extraction for orthodontics-4, 5, 6 or 7? *Oral presentation. By invitation.* Australasian Begg Society of Orthodontists; Darwin, Australia	2019	1.5
Patientenfälle aus der Praxis *Oral presentations. By invitation.* KFO – Seminar; Bad Zwischenahn, Germany	2018-1986	16
A treatment method for Class II division 1 patients with extraction of permanent maxillary molars. *Oral presentation. By invitation.* SIDO (Società Italiana di Ortodonzia); Florence, Italy	2016	1.0
A treatment method for Class II division 1 patients with extraction of permanent maxillary molars. *Oral presentation. By invitation.* Shanghai 9th People's Hospital; Shanghai, China	2016	0.5
Treatment of Class II subdivision 1 malocclusion. *Oral presentation. By invitation* European Begg Society; Leiden, the Netherlands	2015	0.5
A treatment method for Class II division 1 patients with extraction of permanent maxillary molars. *Oral presentation. By invitation.* Symposion Praktische Kieferorthopädie; Berlin, Germany	2014	0.5
Begg memorial lecture. *Oral presentation. By invitation* European Begg Society; Bad Oeynhausen, Germany	2014	1.0
Special tooth displacements. *Oral presentation. By invitation.* Fédération Française d'Orthodontie; Paris, France	2009	1.0
Proclined lower incisors, what can we do? *Oral presentation.* Angle Society of Europe; Going, Austria	2011	1.0
Upper first molar extraction treatment in Class II division 1 malocclusion and the vertical dimension. *Oral presentation* Angle Society of Europe; Going, Austria	2009	1.0
Long-term evaluation of Class II subdivision type 2 treatment with unilateral maxillary first molar extraction. *Oral presentation* Angle Society of Europe; Going, Austria	2015	1.0
Treatment of patients with Class II division 1 malocclusion with extraction of first maxillary molars- long term results. *Oral presentation* Angle Society of Europe; Going, Austria	2018	1.0

3. (Inter)national conferences attended (since 2010)

	Year	Workload (ECTS)
Angle Society of Europe; Going, Austria	2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019	10.0
Dutch Association of Orthodontists (NVvO)	2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019	2.7
Australasian Begg Society of Orthodontists 52nd Meeting Darwin, Australia	2019	0.8
Interdisciplinary Orthodontics; Booy Foundation Amsterdam, the Netherlands	2019	0.5
Second Congress on tooth transplantation. Rotterdam, the Netherlands	2018	0.5
Academia Italiana di Ortodonzia. International meeting. Venice, Italy	2018	0.5
European Begg Society. Congress. Amsterdam, the Netherlands	2017	0.5
Patient-important outcomes in Orthodontics. Società Italiana di Ortodonzia. Florence, Italy	2016	0.5
First Congress on Tooth Transplantation. Sopot, Poland	2015	0.5
European Begg Society. Congress. Leiden, the Netherlands	2015	0.5
European Begg Society. Congress. Ghent, Belgium	2013	0.5
Annual Congress of the European Orthodontic Society Santiago di Compostela, Spain	2012	0.7
European Begg Society. Congress. Bad Oeynhausen, Germany	2011	0.5

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4. Seminars and Workshops (since 2010)

	Year	Workload (ECTS)
Kieferorthopädie Seminar, Bad Zwischenahn, Germany	2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018	5.4
Opfriscursus stralingshygiëne voor tandartsen en orthodontisten (N5AM) Utrecht, the Netherlands	2018	0.2
Orthodontic Treatment Mechanics now and in the future. John Bennett. Booy Foundation Amsterdam, the Netherlands	2018	0.3
Mini Implants: a practical hands-on course. Richard Cousley. Leiden, the Netherlands	2015	0.2
Tageskurs Clear Aligner. Bad Zwischenahn, Germany	2015	0.2
Skelettale orthodontische verankering. Booy Foundation Amsterdam, the Netherlands	2014	0.4
Innovative concepts of modern anchorage. Bjőrn Ludwig Traben-Trarbach, Germany	2013	0.6
Miniplate anchorage for midface protraction in Class III patients and molar distalization in Class II cases. Hugo de Clerck Ghent, Belgium	2013	0.2

5. Teaching activities

	Year	Workload (ECTS)
Anatomy classes for 1st year dental students, Department of Anatomy, University of Utrecht, the Netherlands	1972-1973	1.0
Clinical teaching, Pediatric dentistry, Tandheelkundig Instituut, University of Utrecht, the Netherlands	1976	2.0
Seminar Begg technique, postgraduate orthodontic program, ACTA, Amsterdam, the Netherlands	2017, 2014	0.8
A treatment method for Class II division 1 patients with extraction of permanent maxillary first molars. Postgraduates and faculty Wuhan University, School of Stomatology; Wuhan, China	2016	0.5
Seminar Begg technique, postgraduate orthodontic program, University Medical Center, Groningen, the Netherlands	2015	0.4
Seminar Begg technique, postgraduate orthodontic program, Radboud University Medical Center, Nijmegen, the Netherlands	2008, 2010, 2012	1.2
The Begg technique, postgraduate orthodontic program, University of Bristol Dental Hospital, Great Britain	2010	0.5

6. Other activities

	Year	Workload (ECTS)
Honorary Secretary Nederlandse Vereniging voor Orthodontische Studie	1985-2000	2.5
Council member European Begg Society	1988-1999	0.8
President European Begg Society	1996-1997	2.0
Program chairman European Begg Society San Sebastian, Spain; Thun, Switzerland	1993, 2007	2.0
Program chairman Angle Society of Europe	2012	1.0
Member of the organizing committee European Orthodontic Society Congress Amsterdam, the Netherlands	2005	1.0
Honorary Secretary Booy Foundation	2002-present	2.5

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RESEARCH DATA MANAGEMENT

This research was conducted in accordance with the Helsinki Declaration with regard to research in human participants. All patients agreed to have their patient records used in the study and signed informed consent. The signed informed consent forms are stored in the secure patient archive of the orthodontist practice J.W. Booij in Gorinchem.

Digitized cephalograms

The anonymized digitized cephalograms are saved at the Research Network disc of the Department of Dentistry, Radboudumc, Nijmegen. Access to this data is restricted and permitted only through the research coordinator of Orthodontics and Craniofacial Biology, Radboudumc Nijmegen, dr. Edwin Ongkosuwito. He can be contacted at Edwin.ongkosuwito@radboudumc.nl.

The digitized radiographs are stored in jpg-format which runs on any cephalometric software. In this study Viewbox Cephalometric Software was used (www.dhal.com).

Plaster models

All dental models used in this study are stored in special model boxes in the secure model storage archive room of orthodontist practice J.W. Booij in Gorinchem.

Statistical data

Data used in the statistical analyses are saved at the Research Network disc of the Department of Dentistry, Radboudumc, Nijmegen. The biostatistician, Dr. Ewald M. Bronkhorst, was involved in this research and has access to the data. He can be reached at ewald.bronkhorst@radboudumc.nl.

Datafiles are in excel format and statistical files in .sav format (SPSS).

The datasets analyzed during these studies are available from the corresponding author of the published papers on reasonable request.

The data are documented in English according to the FAIR principles.