Permanent retention from a long-term perspective

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Colofon

Permanent retention from a long-term perspective
Thesis Radboud University Nijmegen Medical Centre
The Netherlands
ISBN: 978-90-9027866-7

Printed in the Netherlands by Ipskamp Drukkers

Artwork: Yvonne Visser
Layout: Arne M.D. Padmos & Jens A.D. Padmos
Figures: Arne M.D. Padmos & Jens A.D. Padmos
Primary Typeface: Constantia
Headings: Trebuchet MS
Proofreaders: A. Faye Klein Meulekamp,
Jens A.D. Padmos, Alianne A.P. Renkema

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Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus
prof. mr.S.C.J.J. Kortmann
volgens besluit van het college van decanen
in het openbaar te verdedigen op
vrijdag 13 december 2013 om 10.30 uur precies

door

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geboren op 2 februari 1953
te Oost- en West-Souburg

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Dedicated to Daniel, Arne and Jens

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Chapter 1

General introduction

1.1 General

Ideally, clinical interventions should produce favourable and stable results. Patients ought to show health benefits after therapy and their quality of life should improve. It is desirable that these effects last for a prolonged time. Unfortunately, obtaining stability after orthodontic treatment can be challenging, and many patients demonstrate, to some degree, return of certain pre-treatment characteristics following active orthodontic treatment if the teeth are not retained. This phenomenon is traditionally termed *relapse*.

1.2 Relapse and post-treatment changes

Studies on long-term effects of orthodontic therapy showed that, despite good results at the end of active treatment, 40-90% of the patients may have major dental irregularities post-treatment, with large individual and unpredictable variations.[1-6] Particularly the anterior region of the mandibular dental arch is rather unstable,[7-9] and more than one-quarter of all patients may exhibit a marked incisor recrowding.[10,11]

Many factors have been hypothesized to be involved in relapse such as (1) craniofacial growth, (2) forces acting on the dentition from the orofacial musculature, periodontal tissues, and occlusal contacts, and (3) the nature and modality with which the correction was achieved and retained.[12]

A number of studies indicate that the individuals' craniofacial growth potential can be related to post-treatment changes.[7,13-15] For example, McReynolds and Little[11] suggested that vertical growth could play an important role in determining the amount of post-treatment relapse. Also, Driscoll-Gilliland *et al*[16] showed that subjects who had greater growth in the vertical dimension of the mandible demonstrated larger increases in irregularity.

It was also implied that the resting pressures of the soft tissues determine the final tooth position and the ultimate stability of any treatment.[17] Intentional alteration of the tooth position or dental arch form can thus affect the balance of various forces acting on the teeth, and it can increase the likelihood of instability of the final outcome. Therefore, maintenance of the original dental arch form during orthodontic treatment is advisable.[3]

The influence of different treatment modalities on the long-term stability has been the subject of intensive research. In some clinical situations—such as early mixed dentition treatment with early self-alignment without fixed appliance therapy,[18] non-extraction therapy with generalized spaces,[19] and lower incisor extraction cases[20]—acceptable long-term results were found. However, most studies found little or no correlation between treatment method and post-treatment changes.[21-28]

In summary, the research to date suggests that there is no single factor causing relapse of the dental arch alignment following orthodontic treatment. Instead, relapse is considered to be a multifactorial phenomenon that occurs to some extent in practically every patient.[29,30] It should be emphasized, however, that relapse is a temporal event that occurs primarily directly after treatment.[31] Later changes cannot be distinguished from normal ageing processes that occur invariably following orthodontic treatment.[4,5]

1.3 Ageing effects

Longitudinal studies on individuals who had not been treated orthodontically showed that the dental arches did not remain static throughout life.[32,33] During normal development a moderate increase in arch length and width is seen until the permanent cuspid erupts.[34,35] Thereafter a gradual and progressive loss in arch length is noted from the mixed dentition into early adulthood,[33] which continues even as late as the sixth decade of life.[36] This appears to be a normal result of ageing, although a considerable individual variation in arch form occurs.[32] The net effect of the decrease in arch length is an increase in incisor crowding with age.[2] These changes are, according to Little,[3,37] variable, difficult to predict, and very similar in nature to orthodontic relapse. Unfortunately, there is no method to distinguish between post-treatment changes due to growth and ageing, and changes directly related to relapse.[5,38,39] Blake and Garvy[40] are therefore of the opinion that the term "post-treatment change" is more appropriate, because it includes alterations due to both relapse and growth/ageing.

1.4 Prevention of post-treatment changes

Several methods to prevent or reduce post-treatment changes have been proposed. (1) Because orthodontic tooth movement requires remodelling of the bone, periodontal tissues, and gingiva, maintaining the teeth exactly in their corrected positions for an extended period of time might allow these structures to complete remodelling and adaptation to the new situation.[41] (2) Also, supracrestal fiberotomy[42] was suggested to increase post-treatment stability. The rationale for this method was based on the observation that full adaptation of supracrestal fibers to the altered position of the tooth might last for an extended period of time. As a result, stretched supracrestal fibers produce a force responsible for relapse. Fiberotomy, releasing the tooth from forces generated by supracrestal fibers, could reduce this source of relapse. (3) Maximum interdigitation following orthodontic treatment was also implied to minimize relapse.[43,44] All these methods, although effective in certain cases, cannot entirely eliminate post-treatment changes. At present, it is impossible to predict neither nature nor direction of these alterations. This means that there is an undetermined life-long potential for dental arch changes in each patient. However, even though these late changes may well have little or no correlation with prior orthodontic treatment, the patient will often equate it to unsuccessful orthodontic treatment[30] and request retreatment.

1.5 Orthodontic retention

Orthodontic retention is used to counteract the post-treatment changes. The proposed basis for retention, i.e. holding the teeth in their new positions, is to: (1) allow for periodontal and gingival tissue reorganization, (2) permit neuromuscular adaptation to the corrected tooth position, (3) minimize changes due to continued growth after orthodontic treatment, and (4) maintain unstable tooth positions, if such positioning is required for reasons of compromise or aesthetics.[45] Thus, orthodontic retainers aim to resist the tendency of teeth (1) to return to their initial positions, or (2) to move to a position dictated by ageing. Preferably, retainers should be passive devices that allow the teeth to settle or guide the teeth into their final positions during function[46]—they can be classified into removable and fixed retainers.[12]

1.6 Removable retainers

Removable retainers can serve effectively for retention against intra- and inter-arch instability. Two main types are used: (1) the Hawley-based retainer[47] and (2) vacuum formed retainers (VFR's). The Hawley retainer, originally constructed as an active removable appliance to open the bite and retract incisors,[48] is one of the most frequently used removable retaining devices.[49] Basic elements are an acrylic plate, a labial bow and retentive clasps. The type and position of the clasps may vary.[48] In case first premolars have been extracted the standard Hawley labial bow extends across the extraction spaces, tending to wedge them open. A common modification of the Hawley retainer used in extraction treatment is a bow soldered to the buccal section of Adams clasps on the first molars.[50] The Begg wrap-around retainer[51] is another modification of the Hawley retainer, with a continuous labial bow that inserts into the acrylic distally to the terminal molars. Potential occlusal interferences are avoided and the wire does not keep crowns of cuspids and premolars apart, which makes it a perfect retainer in extraction cases.[48] The Van der Linden retainer[52] is a Hawley-type retainer with a modified labial bow to offer complete control over the maxillary anterior teeth, with firm fixation provided by clasps on the canines, and C-clasps engaging the mesial undercut of the terminal molars to enhance retention. Disadvantages of the Hawley-based removable acrylic retainers include (1) discomfort, (2) poor aesthetics from the labial bow, (3) orthodontic extrusive movements of incisors are not retained,[52] and (4) dependence on patients' compliance.[53,54]

Vacuum formed retainers (VFR's), first described in 1971 by Ponitz,[55] are made of clear thermoplastic material heated and formed on a patient's plaster model in a vacuum machine.[56] The initial VFR's were prone to cracking and distortion due to the inferior quality of plastic used for their fabrication. With the introduction of durable, thin, clear polymers for intraoral use, VFR's became a reasonable alternative to conventional retention devices.[56] The advantages of VFR's over Hawley retainers and similar removable acrylic retainers are its aesthetic superiority and ease of fabrication. In addition, VFR's are inexpensive and quickly produced, have minimal bulk and high strength, and do not interfere with speech.[48]

All types of removable retainers have the benefit that they can be removed at will and in accordance with the recommendations of the orthodontist, i.e., while eating, for efficient oral- and appliance-hygiene, and on social occasions, when the presence of the appliance would make the patient feel self-conscious.[48] Unfortunately, it is a common clinical experience that patient compliance with removable retainers is unpredictable,[57] which may lead to relapse and frustration for both clinicians and patients.[30]

1.7 Fixed retainers

Fixed orthodontic retainers are normally used in situations where intra-arch instability is anticipated and prolonged retention is planned to minimize relapse and late lower incisor crowding.[50]

Fixed retention has a long history dating back to the beginning of the 20th century. Fixed *banded* retainers were described in detail by Angle.[58] A banded cuspid-to-cuspid retainer was advocated in 1935 as the best retaining device.[59] Interestingly, it is still in use.[56] Thomas[60] reported possible hazards of the banded cuspid-to-cuspid retainers and emphasized to check the retainer frequently, especially when left in place for extensive periods of time. While the *banded* cuspid-to-cuspid retainer proved to be very effective in stabilizing the cuspids and incisors, most patients objected to it for aesthetic reasons. Moreover, a disadvantage of this type of retainer is the influence on oral hygiene, which might lead to decalcification and decay on the banded teeth.[61]

The introduction of the acid-etch technique[62] opened new possibilities because it became possible to fix a retainer that was invisible from anterior. In 1973, Knierim[63] reported the use of a *bonded* retainer—he described a lower cuspid-to-cuspid retainer, made of 0.028-inch round stainless steel wire, which was adjusted on a plaster model. In a second report on *bonded* lower canine-to-canine retainers, Wolfson and Servoss[64] described a 0.036-inch stainless steel round wire with welded mesh pads, bonded to both mandibular canines.

The first follow-up study on effectiveness of fixed retainers was published in 1977 by Zachrisson.[65] After an observation period of 1-2.5 years, he found a low failure rate—detached retainers—and excellent patients' acceptance with a bonded retainer made of round 0.032-inch and 0.036-inch Blue Elgiloy® wire, with terminal retention loops. Some years later, in 1982, Årtun and Zachrisson[66] proposed the use of a thick multi-stranded wire without retention loops, bonded only to the canines. They listed an increased mechanical retention for the composite as a potential advantage of this wire.

Also in 1982, Zachrisson[67] proposed the use of a thin 0.015-inch flexible spiral wire bonded to all anterior teeth instead of only bonded to the canines. Thanks to this, physiological tooth mobility would be possible, even when several adjacent teeth were bonded.[68] Since that time, numerous variations in the design of bonded retainers—different wire types with various diameters, different shapes, the use of mesh pads, different composites and bonding procedures—have been used.[69] According to Zachrisson,[70] a combination of a thin flexible wire bonded with wear-resistant composite is the most useful mode of retention for a variety of orthodontic situations.

Bonded retainers are considered reliable,[71] appear to be well accepted by patients,[53,72] are invisible from anterior, and are relatively independent of long-term patient cooperation.[70,73] A debatable disadvantage of bonded retainers is their restriction of physiological tooth mobility, with the consequence of inactivity atrophy.[74,75] Schwarze *et al*[74] found a significant reduction in tooth mobility for various retainers and recommended the use of highly flexible wire material, preferably with a diameter of 0.015-inch. Watted *et al*[75] investigated the influence of two different types of retainer on tooth mobility. The first type was made of rounded rectangular wire and bonded only to the canines, and the second was made of 0.0175 flexible spiral wire bonded to all 6 anterior teeth. They found that tooth mobility decreased with the number of teeth to which the retainer was bonded. Nonetheless, the mobility remained within the physiological range.

An obvious disadvantage of bonded retainers is that, unlike removable counterparts, they hinder oral hygiene—particularly flossing is challenging—and favour the accumulation of plaque and calculus[65,68,73,77-83] especially around the retainer in the lower dental arch.[78] Several studies investigated long-term effects of fixed retainers on periodontal tissues.[68,84] A general conclusion was that retention with bonded lingual retainers is not detrimental for the dentition and periodontal tissues, provided good oral hygiene is maintained.[68,84] However, evidence from other investigations suggests a possible role of bonded retainers in periodontal breakdown.[79] Given the fact that subjects *with* bonded retainers are more predisposed to plaque and calculus accumulation, and are more prone to gingival inflammation compared to subjects *without* bonded retainers,[82,83] bonded retainers have been associated with an increased incidence of gingival recessions.[82] In spite of this controversy, fixed retainers remain the gold standard for orthodontic retention.

Occasionally, bonded retainers may fail. Failures can occur at the wire-composite interface, at the adhesive-enamel interface, or as a stress fracture of the wire, and may lead to unwanted tooth movement.[76] Studies on retainer defects have revealed that the failure rates range between 6 and 53 percent.[65,71,77,78,85-89] Because of the large variation in observation periods, wires, bonding materials and bonding techniques, it is difficult to draw general conclusions. Overall, it was found that bond failures and fractures were less frequent in the mandibular arch than in the maxillary arch.[71,78,87,88,90] A low incidence of failures was also found with the use of a 5-stranded flexible wire.[78] Additionally, operator's experience may be related to retainer failure rate.[70,71,73,91] Zachrisson recommended the use of adequate composite resin over the wire, smooth contouring of the adhesive, careful adaptation of the wire to the lingual/palatal surfaces of the teeth, and avoidance of occlusal interference from opposing teeth as measures to decrease plaque retention and failure rate.[70,91]

1.8 Effectiveness of bonded retainers

Although there is a large number of studies reporting the failure rate of bonded retainers,[65,71,77,78,85-89] relatively few investigated the effectiveness of lower bonded retainers in maintaining the post-treatment alignment of teeth (Table 1) or the detrimental effects of long-term fixed retention (Table 2).

As presented in the tables, relatively small samples were investigated in the vast majority of publications. Also, the follow-up periods are rather short. As a result, it is difficult to reach definite conclusions about the post-treatment stability and the gingival health of the anterior teeth with a bonded lingual retainer as a retention device. Moreover, there is insufficient evidence to confidently state that one type of bonded retainer is better than another type.[30]

Table 1. *Summary of published papers reporting on the effectiveness of bonded retainers in maintaining the result following orthodontic treatment; N = number of retainers*

Authors	Retainer design	N	Observation time in months	Changes
Dahl & Zachrisson 1991[78]	3-strand FSW 0.0195/0.0215" 5-strand FSW 0.0215"	29 17	67 (18) 38 (5)	Small changes with and without failures[a]
Årtun *et al* 1997[86]	Plain wire 0.032" Spiral wire 0.032" 3-strand FSW 0.0205" Removable spring retainer	11 13 11 14	36 (0)	Significant Significant None[b] Significant
Andrén *et al* 1998[87]	3-strand FSW 0.0175" 5-strand FSW 0.015" 5-strand FSW 0.0175" 5-strand FSW 0.0195"	33 32 20 15	60-174 (140)	23% underwent minor changes[d]
Störmann & Ehmer 2002[89]	6-strand coaxial 0.0195" 6-strand coaxial 0.0215" Plain wire prefabricated[c]	30 36 32	2.0 (0)	None[a] 20%[d] 80% (*P*<.*0001*)
Atack *et al* 2007[92]	Multistrand FSW[c] Hawley retainer	29 29	At least 12[e]	Both groups significant small changes

[a] *Method of measurement not recorded*

[b] *Failures not included*

[c] *Wire dimension/properties not given*

[d] *Data/calculations not given*

[e] *Mean and/or standard deviations not given*

Table 2. *Summary of published papers reporting on detrimental effects of bonded retainers; N = number of retainers*

Authors	Retainer design	N	Observation time in months	Observed/ not observed
Zachrisson 1977[65]	Plain wire 0.032" Plain wire 0.036"	23 20	12-30 (15.7)	Calculus[a,b] No demineralisation No carious lesions
Lee 1981[77]	Plain wire 0.028" Ribbon wire 0.015"x0.036"	33 13	At least 6[c]	Plaque[a] Calculus Rotation incisors No demineralization
Årtun 1984[68]	Plain wire (PW) 0.032" Spiral wire (SW) 0.032" Reference group no wire 3-strand FSW 0.0195" Removable retainer	31 18 25 14 20	16 (7) 64 (27) 31 (8) 27 (13) 14 (7)	Plaque Calculus More plaque along PW than along SW No carious lesions No deep pockets
Årtun *et al* 1987[85]	Plain wire 0.032" Spiral wire 0.032" 3-strand FSW 0.0205" Removable spring retainer	11 11 11 11	4 (0)	Gingivitis decreased No differences between the groups
Axelsson & Zachrisson 1992[90]	5-strand FSW 0.0215-inch Two-unit Three- or four-unit	 47 14	 28[c] 30[c]	Plaque Gingivitis Pockets Some demineralisation No carious lesions No white spots
Årtun *et al* 1997[86]	Plain wire 0.032" Spiral wire 0.032" 3-strand FSW 0.0205" Removable spring retainer	11 13 11 14	36 (0)	Gingivitis decreased Minor plaque Moderate calculus No white spots
Heier *et al* 1997[79]	3-strand FSW 0.0175" Removable retainer	22 14	1, 3, 6 (0)	Slightly more plaque and calculus in the bonded retainer group
Störmann & Ehmer 2002[89]	6-strand coaxial 0.0195" 6-strand coaxial 0.0215" Plain wire prefabricated[c]	30 36 32	24 (0)	Accumulation plaque for all retainer types[b]
Pandis *et al* 2007[81]	3-strand FSW 0.0195" 3-strand FSW 0.0195" (= control group)	32 32	108-132[c] 3-6[c]	More calculus, pockets, and increased marginal recession in the long-termed group
Levin *et al* 2008[82]	Orthodontic treatment with bonded retainer Orthodontic treatment without bonded retainer	32 32	55 (26)	Bonded retainers were associated with an increased plaque, gingivitis and recession

[a]*Method of measurement not recorded*

[b]*Data/calculations not given*

[c]*Mean and/or standard deviations not given*

1.9 Objectives of this thesis

The overall objective of this study was to evaluate the effectiveness of lower bonded retainers in maintaining the alignment of teeth and to elucidate the role of orthodontic treatment—followed by permanent retention with lower bonded retainers—in the development of labial gingival recessions. The specific aims were:

1. To survey retention procedures in the Netherlands.
2. To assess the effectiveness of two frequently applied fixed retainers; the one bonded only to the mandibular canines and the other bonded to all mandibular anterior teeth.
3. To evaluate the development of labial gingival recessions in a cohort of orthodontic patients in whom bonded retainers were used as a retention device.
4. To determine the association between the change of inclination of lower incisors during treatment and the development of labial gingival recessions.
5. To investigate the development of labial gingival recessions in patients treated with fixed orthodontic appliances and retained with bonded retainers compared to untreated controls.

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Chapter 2

A survey on orthodontic retention procedures in the Netherlands

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Eur J Orthod 2009;31:432-437

Summary

The objective of this study was to survey retention procedures used in orthodontic practices in the Netherlands.

A questionnaire was sent to all 279 orthodontists working in the Netherlands. The questionnaire consisted of six parts, mainly containing multiple-choice questions. Information as to background data on the individual orthodontist, retention in general, frequency of different types of removable or bonded retainers that were used, retention protocol, and type and size of the wire used for bonded retainers was assessed. All statistical analyses were performed using Statistical Package for Social Sciences version 12.0.1. Tests for the relationship between two items were based on the chi-square test.

The overall response rate was 91%. Most orthodontists placed a bonded retainer in the upper and lower arch, except when the upper arch was expanded during treatment or when extractions were performed in the upper arch, in which case they placed a removable retainer. Opinions varied with regard to how many hours the removable retainer should be worn and the duration of the retention phase. Contra-indications for bonded retainers were given by 96% of the orthodontists, with poor oral hygiene being the most commonly mentioned. As far as bonded retainers were concerned, 84% of the orthodontists preferred permanent retention. Fifty-nine per cent of the orthodontists believed that a practice guideline for retention after orthodontic treatment needs to be developed, which was confirmed by the varied responses in this survey.

2.1 Introduction

To minimize or even prevent relapse, almost every patient who has had orthodontic treatment is given some type of retainer. Two surveys on the type of retainer used by orthodontists have been published.[1,2] The survey of Keim *et al*[1] among specialist practitioners in the United States of America (USA) showed that, although decreasing, the Hawley retainer remained the most commonly used retainer, while "invisible" retainers had continued to gain popularity. In addition, the use of bonded retainers had increased with nearly one-third of the clinicians using them routinely in the mandibular arch. Compared with two prior surveys, conducted in 1990 and 1996, respectively, the respondents prescribed more permanent retention, 27% in 2002 compared with 15% in 1990 and 23% in 1996.[1] However, the response rate in that survey was only 9%, so no conclusions could be drawn. The second survey[2] was carried out in Australia and New Zealand. The response rate was 59%. The results showed that upper clear retainers and lower canine-to-canine bonded retainers were most commonly used. Half of the surveyed orthodontists used a specific retention period, with a median of 2 years. Orthodontists applied permanent retention in either a very high or a very low percentage of their cases. The conclusion of that study was that retention procedures were variable and depended largely on personal preferences. Wong and Freer[2] concluded that there does not seem to be any consistent pattern in the application of retention methodologies.

The purpose of the present investigation was to survey retention procedures used in orthodontic practice in the Netherlands.

2.2 Materials and Method

Full lists of names and addresses of orthodontists were obtained from the Dutch Association of Orthodontists and the Dutch Dental Association. The questionnaire was sent to 279 orthodontists in October 2005. One month later a reminder was sent to 106 orthodontists who had not returned the questionnaire. In January 2006, the non-responding orthodontists were contacted by telephone. If requested, another copy of the questionnaire was sent. If the orthodontist was not willing to return the questionnaire, the reason for not responding was recorded.

2.2.1 Questionnaire

The questionnaire consisted of six parts, mainly containing multiple-choice questions, which had been piloted on four orthodontists and subsequently modified. Background information on the individual orthodontist was assessed in part A. It contained questions concerning the type of practice in which the orthodontist was working. If the orthodontist was working as a locum only, or was retired, the questionnaire was excluded from the analysis. Part B consisted of questions on retention in general, for example "What is the reason for choosing a specific kind of retainer?" and "Do you provide the patient with information regarding the retainer?". Parts C and D consisted of questions on the frequency of different types of removable or bonded retainers that were used and the retention protocol. Part D contained questions about the type and size of the wire used for bonded retainers. Part E consisted of tables in which the orthodontist could tick which type of retainer was used in which specific situation. In the last part, the orthodontists could express their opinions as to the need for a clinical practice guideline (CPG) for retention after active orthodontic treatment.

2.2.2 Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS), version 12.0.1 (SPSS Inc, Chicago, Illinois, USA). Background information on the individual orthodontist was described in frequencies and the other results in percentages. All tests for the relationship between two items in the questionnaire were based on the chi-square test. For two-by-two cross-tables, Fisher's exact test was used. If necessary, for larger cross-tables, Monte Carlo simulation[3] was used to improve the estimate of the *P* value. For this simulation, default SPSS parameters were applied (i.e. 99% confidence interval for *P*, 10000 replications).

2.3 Results

2.3.1 General

Questionnaires were completed by 254 (91%) of the 279 orthodontists. Of the 254 orthodontists, 230 worked in an (associated) practice and 30 at a university; 12 worked as locums and 9 were retired (partly or fully). Combinations were also possible. Working in an (associated) practice and at a university was the most common combination (20 orthodontists). Orthodontists who were only working as a locum (n = 7) and fully retired orthodontists (n = 6) were excluded from further analysis. Of the remaining 241 orthodontists, 25% had been trained abroad; 18 in Germany, 16 in the USA or Canada, 11 in Belgium, 8 in Denmark, 5 in the United Kingdom, and 5 in other countries.

2.3.2 Choice of type of retainer

Sixty-four per cent of the orthodontists used retention for almost every patient, independent of the situation prior to active orthodontic treatment.

The choice for a certain retainer was determined not only by the situation prior to treatment but also by other factors such as the occlusion post-treatment, the end result, and oral hygiene (Table 1). The intended treatment also influenced the choice of a specific retainer. Table 2 shows the percentages of orthodontists who, given a specific situation, generally used a bonded retainer, a removable retainer, or a combination of both. Most orthodontists placed a bonded retainer in the upper and lower arch, except when the upper arch was expanded during treatment or when extractions were performed in the upper arch, in which case they placed a removable retainer. For the placement of bonded retainers, contra-indications were given by 96% of the orthodontists (Table 3). Eighty-five per cent reported poor oral hygiene, which might cause periodontal problems, caries, and the need for restorations, as a contraindication for the placement of bonded retainers. Contact with the retainer or the bonding material during occlusion or articulation was reported by 39% of the orthodontists as a contraindication for placing a bonded retainer in the upper arch.

Table 1. *Percentage of orthodontists indicating that a certain factor influences their choice for a specific type of retainer*

Factor	%
Pre-treatment situation	74
Interdigitation after treatment	69
Poor oral hygiene	69
End result	65
Periodontal tissues	56
Motivation	48
Age	41
Myofunctional aspects	38
Anatomy of teeth	28
Third molars	7
Wish of patient/parents	3
Others	10

Of the practicing orthodontists in the Netherlands, 95% used one or more types of removable retainers. Bonded retainers were used by 97%. The orthodontists who only use bonded retainers (5%) did not want to be dependent on the co-operation of the patient. They considered that with the use of a removable retainer, relapse takes place during or after the retention period. These views differed significantly from those orthodontists who used both removable and fixed retainers ($P < 0.001$). The orthodontists who only used removable retainers (3%) had the opinion that bonded retainers often break and come loose. They also stated that these retainers caused plaque accumulation, caries, and/or calculus. These views differed significantly from those of orthodontists who used both types of retainers ($P < 0.001$).

Table 2. *Percentage of orthodontists who used fixed, removable, or both types of retainers in specific situations. The most often used retainers in a certain situation are give in bold*

	Type of retainer					
	Upper arch			Lower arch		
Type of treatment/situation	Bonded	Removable	Bonded and removable	Bonded	Removable	Bonded and removable
Extractions	24	**43**	33	**79**	11	10
Closing a diastema in the anterior region	**64**	13	23	**90**	5	5
Crowding in the anterior region	**62**	23	15	**94**	4	3
Expansion of the respective arch	13	**61**	26	**73**	20	7
Impacted anterior teeth	**60**	25	15	**92**	7	1
Intrusion of the anterior teeth	**50**	35	15	**90**	6	4
Extrusion of the anterior teeth	**65**	23	12	**91**	6	3
Severe rotations of the anterior teeth	**79**	8	13	**94**	3	3
Root resorption of the anterior teeth	**69**	18	13	**90**	8	2
Anterior open bite	**68**	18	14	**88**	9	3
Remaining overjet	**37**	36	27	**79**	12	9
Re-treatment in the upper and lower arch	**73**	13	14	**90**	4	6
Adult patient	**49**	30	21	**86**	12	2
Only fixed appliances in the upper arch	**55**	20	25	**88**	3	9

Table 4 shows that a Hawley-type retainer in the upper arch was the most often used removable retainer; the orthodontists indicated that they applied this type of retainer in 41% of their patients. Noticeable is the large standard deviation (SD). The table shows that a clear retainer was also often used (16%).

In the lower jaw, the most frequently used fixed retainer was the canine-to-canine retainer, bonded to all anterior teeth (70%). The most used types of fixed retainer in the upper arch were the canine-to-canine retainer and the lateral-to-lateral incisor retainer, both bonded to all anterior teeth (Table 4). These canine-to-canine retainers were used either frequently or almost never.

Table 3. *Percentage of orthodontists who stated contra-indications for the placement of bonded retainers*

Contra-indications	*% Orthodontists*
Poor oral hygiene, periodontal problems, caries	85
Occlusion (deep bite)	39
Incomplete treatment result (i.e. diastema)	14
Motivation	12
Anatomy	4
Type of treatment	3
Expected relapse	1
Side-effect torque	<1
Others	3

2.3.3 Retention period

The situation before active treatment predetermined the duration of retention for 40% of the orthodontists. Opinions about the hours the removable retainers should be worn and the duration of the retention phase varied. During the first period of retention (duration average 5.7 months, SD, 7), the patient should wear the removable retainer for an average of 18 hours a day (SD, 7.5), 7 days a week (SD, 0.07). The total duration of the retention period for removable retainers differed considerably: 6% of the orthodontists ended the retention period within 6 months, while 80% continued for more than 1 year. When bonded retainers were used, 84% of the orthodontists used permanent retention. The other 16% removed the retainers at a specific time, which was determined by several factors such as the eruption of the third molars, growth of the patient, or individual determination of the time period.

Table 4. *Average percentages of patients who are given a specific type of removable or bonded retainer*

	***Upper** arch (% patients)*	***Lower** arch (% patients)*
Removable retainers		
Hawley-type retainer	41 ± 35.9	5 ± 16.4
Clear retainer	16 ± 26.1	7 ± 17.5
Spring retainer	<1 ± 2.2	1 ± 8.1
Headgear	<1 ± 4.0	
Positioner	3 ± 12.7	
Functional appliance	2 ± 6.3	
Bonded retainers		
Bonded to the canines only	<1 ± 2.6	16 ± 32.7
Bonded to all anterior teeth	34 ± 37.8	70 ± 38.0
Bonded to central incisors	2 ± 10.1	<1 ± 6.5
Bonded to all incisor teeth	25 ± 33.7	2 ± 11.5
Bonded to all teeth from the first premolar to the first premolar	1 ± 6.6	2 ± 9.1

2.3.4 Check-ups

After placement of a removable retainer, 87% of the orthodontists checked their patients two to four times during the first year of retention, visits for repairs not included (Table 5); 1% did not see their patients subsequently. After the first year, the removable retainers were checked again by 72% of the orthodontists. Table 5 also shows that the patients with bonded retainers had fewer check-ups compared with those with removable retainers ($P < 0.001$). Orthodontists who undertook fewer removable retainer check-ups during the first year also tended to carry out fewer fixed retainer check-ups, and *vice versa*; orthodontists who undertook more removable retainer check-ups carried out more fixed retainer check-ups as well ($P < 0.001$). There was a difference in the number of check-ups between orthodontists trained in different countries ($P = 0.02$).

Table 5. *Number of check-ups during the first year after placement of a removable or bonded retainer*

No. of check-ups during first year	Removable (% orthodontists)	Bonded (% orthodontists)
0	1	3
1	5	20
2	22	32
3	38	28
4	27	15
>4	7	2

2.3.5 Information and instructions

After placement of a removable or bonded retainer, all orthodontists gave written information concerning the retainer to their patients. Two per cent of the orthodontists never gave any oral instruction to the patient after placement of a bonded retainer. The other orthodontists provided the patient with a variety of instructions (Table 6). Instructions on the use of toothpicks were given more often by orthodontists who listed poor oral hygiene, caries, and periodontal problems as a contraindication ($P = 0.003$). When placing the retainer, the majority of the orthodontists gave extra oral hygiene instructions (91%) and instructions as to what to do in case of failure of the retainer (97%). The latter instructions involved telling the patients that they should make an appointment with the orthodontist (92%) or dentist (35%) as soon as possible if the retainer caused a problem. In general, there was communication with the dentist about checking and repairing bonded retainers (78%). Half of the orthodontists requested the dentist to check the bonded retainer during every periodic check-up, and in case of failure of the retainer—detached or broken—to refer the patient to the orthodontist. Nearly a quarter of the orthodontists did not communicate with the dentist about this subject.

Table 6. *Percentage of orthodontists who provide the patients with instructions after the placement of a bonded retainer*

Instructions	*Orthodontists*
With regard to breakage/loosening	97
Extra oral hygiene	91
With regard to nutrition	59
Toothpicks	47
Floss	38
Interdental brushes	22
Electric toothbrush	20
Others	2

2.3.6 The need for a practice guideline

Fifty-nine per cent of the orthodontists agreed that a practice guideline on retention procedures after orthodontic treatment should be developed. Thirty per cent considered a protocol necessary, 7% did not, and 4% remained neutral. A larger number of the orthodontists educated in the Netherlands have the opinion that it would be useful to develop a protocol compared with orthodontists who had their orthodontic training abroad ($P = 0.002$).

2.4 Discussion

2.4.1 General

A very high percentage of the orthodontists working in the Netherlands participated in this survey; 25% of these orthodontists had their orthodontic training abroad. The group of non-responding and excluded orthodontists was so small that it could not bias the outcome of the respondent group. Compared with the two previous surveys conducted in the USA and Australia/New Zealand,[1,2] the response rate to this survey was excellent.

2.4.2 Choice of type of retainer

In both previous surveys in the USA and Australia/New Zealand, removable retainers were mostly used in the upper arch, whereas in the present study most orthodontists placed fixed retainers in the upper arch. However, some orthodontists used removable retainers most of the time. Individual orthodontists used removable retainers either very often or rarely. For this reason Table 4 shows large SDs. Most respondents preferred the use of bonded retainers in the lower arch. A minority of the orthodontists (3%) never use bonded retainers and stated that bonded retainers often break and come loose. However, the failure rates vary widely in the literature. Bearn[4] reported overall failure rates for bonded retainers in the upper and lower arch from 10.3% to 47.0%. Rogers and Andrews[5] reported a failure rate in the mandible at less than 0.1% during 3 years of study. It was stated that the low failure rate could be ascribed to their bonding protocol and the fact that the retainer was bonded only to the mandibular canines. The findings of Störmann and Ehmer[6] corroborate this; retainers in the mandible bonded to the canines only displayed an 18% detachment rate, a value significantly lower than the 29% to 53% determined for retainers bonded to all mandibular anterior teeth. It is difficult to compare these failure rates since the studies were performed with different wire materials, bonding procedures, and follow-up periods.

Very few prospective studies have evaluated the effectiveness of retention. A Cochrane review revealed only two randomized clinical trials and three pseudo-randomized clinical trials that evaluated the effectiveness of different retention strategies used to stabilize tooth position after orthodontic treatment.[7] No reliable evidence could be taken from the data on which to base clinical practice of retention.

2.4.3 Contra-indications

Three per cent of the orthodontists only used removable retainers because they assume that bonded retainers cause plaque accumulation, calculus, and caries; this is not supported by evidence available from the literature. The presence of a bonded retainer can cause plaque accumulation, but it has no influence on gingiva inflammation.[8] Gorelick *et al*[9] did not find white spots on the lingual surfaces of mandibular canines and incisors after prolonged use of a canine-to-canine bonded retainer. Pandis *et al*[10] found higher calculus accumulation, greater marginal recessions, and increased probing depth, but no difference with respect to the plaque and gingival indices and bone level in a group of patients with mandibular retention for a long period of time compared with an equal number of patients retained for a period between 3 and 6 months. Of course, poor oral hygiene may lead to caries and periodontal problems but not necessarily to a higher degree in the region of a bonded retainer than elsewhere in the oral cavity. Nonetheless, poor oral hygiene, which can cause periodontal problems, caries, and the need for restorations, was reported as a contraindication for placing a bonded retainer by 85% of the orthodontists in the present study.

2.4.4 Duration of retention

It has been shown that it takes on average a minimum of 232 days for fibers around the teeth to remodel to the new tooth position.[11] Other authors found a half-life of collagen fibers around rat teeth varying from 1 to 12 days in the periodontal ligament and 2 to 152 days for dento-gingival fibres.[12-15] In addition, even if the teeth are held in position during this period, studies have shown that, in the long term, some relapse will take place.[16,17] A retention period with removable retainers of more than 1 year was employed by 80% of the orthodontists in the Netherlands. Wong and Freer[2] found that a regular retention period of more than 2 years was preferred, but they did not distinguish between removable and fixed retainers. The respondents in the present investigation used a longer period of retention with bonded retainers. Eighty-four per cent of the orthodontists had a preference for permanent retention. This is a very high percentage compared with the survey by Keim *et al*[1]—27% of their respondents used permanent retention. However, the response rate in the latter study was only 9%. It is possible that bonded retainers might be unnecessary in a number of patients. The problem is that it is not known in which patients a limited period of retention can be used. The extended duration of the retention period with fixed retainers substantially increases the number of patients under supervision. The long-term consequences of permanent retention with bonded retainers have not been well documented.[18]

2.4.5 Check-ups

The number of check-ups during the first year after placement of a removable or fixed retainer varied from none to more than four.

It seems that the orthodontists who do not check the retainer at all during the first year (1-3%) give the responsibility for the retention phase completely to the patient and the dentist. Since these orthodontists communicated with the patient's dentist about checking and repairing fixed retainers, it might be the case that they hand over the supervision of the retention phase to the dentist directly after placement of the retainers.

Most of the orthodontists (87%) carried out two to four check-ups during the first year of the retention phase, which seems to be appropriate. With more than four check-ups, the question arises whether this is really necessary. It certainly is cost and time consuming.

2.4.6 Information and instructions

Prolonged or even permanent retention with a bonded retainer leads to the need for regular check-ups, for example once a year. An unnoticed bond failure can result in an irregularity in the anterior region. Unexpected complications with bonded lower retainers as described by Katsaros *et al*[19] are another reason to perform regular check-ups. For the orthodontist, it is impossible to supervise every patient with bonded retainers for years and years. It is inevitable that the patient and the patient's general practitioner are both responsible for regular check-ups. When delegating this responsibility to the patient and the dentist, it is necessary to inform them about the problems that might occur and that the retainer therefore needs regular check-ups. Nearly a quarter of the orthodontists in the present study did not communicate with dentists about this subject. This shows that more communication with the dentists in this area is needed.

2.4.7 Guideline development

Over the past 20 years, quality of care and CPGs have gained increased interest in many areas of health care.[20] The development of evidence-based CPGs appears to be one of the most promising and effective tools for improving the quality of care.[21] An assessment of the view of Dutch general practitioners on CPGs showed that about half of Dutch general dental practitioners were in favour of the development and implementation of CPGs.[22] In the present study, almost 90% of the orthodontists agreed or considered that a practice guideline for retention procedures after orthodontic treatment should be developed. This high percentage can be explained by the fact that retention and relapse are problems explicitly perceived in daily practice. Guidelines for these daily practice problems will probably be more easily accepted than CPGs on topics that are not deemed as relevant by practitioners.[21] However, there is less knowledge of the attitudes, expectations, and views of orthodontists with regard to the development and use of CPGs. Confidence in the quality of the guidelines and the credibility of the developers are essential aspects for their acceptance.[22]

Orthodontists who were trained abroad stated that they would not find a retention guideline as advantageous as those who were educated in the Netherlands. This was an unexpected result as CPGs in countries such as the United Kingdom, USA, Canada, and Finland have been used for many decades, while in the Netherlands CPGs have only been developed on a very limited scale.

2.5 Conclusions

This survey provides an insight into the retention procedures used in orthodontic practices in the Netherlands. These procedures are mainly experience-based as evidence-based information is not yet available.

The varied responses in this survey indicate the need to develop an evidence-based practice guideline for retention procedures after orthodontic treatment.

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Chapter 3

Effectiveness of lingual retainers bonded to the canines in preventing mandibular incisor relapse

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Am J Orthod Dentofacial Orthop 2008;134:179.e1-179.e8

Summary

Introduction

A retainer bonded to the lingual surfaces of the mandibular canines (3-3 retainer) is a widely used type of retention. Our aim in this study was to assess the effectiveness of the 3-3 mandibular lingual stainless steel retainer to prevent relapse of the orthodontic treatment in the mandibular anterior region.

Methods

The sample consisted of the dental casts of 235 consecutively treated patients (96 male, 139 female) from the archives of the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands, who received a 3-3 mandibular lingual stainless steel retainer at the end of active orthodontic treatment. The casts were studied before treatment (Ts), immediately after treatment (To), and 2 years (T2), and 5 years (T5) post-treatment.

Results

The mean irregularity index decreased significantly from 7.2 mm (SD, 4.0) at Ts to 0.3 mm (SD, 0.5) at To; it increased significantly during the post-treatment period to 0.7 mm (SD, 0.8) at T2 and 0.9 mm (SD, 0.9) at T5. The irregularity index was stable during the 5-year post-treatment period (To-T5) in 141 patients (60%) and increased by 1.0 mm (SD, 0.8) in 94 patients (40%). The intercanine distance increased 1.3 mm between Ts and To and remained stable during the post-treatment period.

Conclusions

The 3-3 mandibular lingual stainless steel retainer (bonded to the canines only) is effective in preventing relapse in the mandibular anterior region in most patients, but a relatively high percentage will experience a small to moderate increase in mandibular incisor irregularity.

3.1 Introduction

Several studies on longitudinal post-treatment stability of the orthodontic treatment result have demonstrated relapse in the alignment of the mandibular anterior teeth.[1-8] This relapse occurs even after prolonged retention combined with light interproximal stripping.[9] As a consequence, various types of removable or fixed mandibular retainers are used either for an extended period of time or permanently.

One widely used type of fixed mandibular retainer is bonded only to the lingual surfaces of the canines (3-3 retainer). Although the technical procedures and the advantages and disadvantages of these retainers have been discussed in the literature,[10] only limited information is available concerning their effectiveness. A Cochrane review showed only 2 prospective randomized clinical trials and 3 pseudo-randomized clinical trials that evaluated the effectiveness of different retention strategies to stabilize tooth positions after orthodontic treatment.[11] Only 1 study assessed—among other issues—stability of incisor alignment after a 3-year period of retention with bonded retainers.[12] Two of the 4 test groups in this study received retainers bonded to the canines only (n = 24) and experienced occasional minor increases in incisor irregularity. In patients whose retainers failed, greater increase in incisor irregularity could be measured.

A prospective study that was excluded from the Cochrane review compared a small group of patients (n = 32) who received mandibular retainers bonded only to the canines with 2 groups of patients who received retainers attached to all anterior teeth.[13] After an observation period of 2 years, the relapse rate in the patients with mandibular retainers bonded only to the canines was 80%, much higher than in the other 2 groups. However, the average increase in irregularity was rather small (median, 0.4 mm), and the intercanine distance remained stable. A stable intercanine distance was also reported by Lang *et al*,[14] who retrospectively studied post-treatment stability in 132 patients for 6 years on average (SD, 1.2) after active orthodontic treatment. The 121 patients who received a bonded mandibular 3-3 retainer attached only to the canines experienced small post-treatment increases of the irregularity index (0.3 mm on average). This increase could not be attributed to lack of control by the lingual retainer, since many patients discontinued their retention before the follow-up. Only 85 of the 132 patients still used a mandibular retainer at the follow-up control (it is not clear from the data whether a few had a removable retainer); this group had even smaller post-treatment increases of the irregularity index (0.2 mm on average).

From the above-mentioned studies, it is difficult to reach any definite conclusions about the post-treatment stability of the mandibular anterior teeth with a bonded lingual retainer as a retention device, since they are based on small patient groups or short observation periods. In the absence of evidence, we aimed to assess the effectiveness of the mandibular lingual stainless steel retainer (bonded only to the canines) in a large group of patients over a long period of time.

3.2 Material and Methods

Our material consisted of dental casts from the archives of the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands. We selected 235 patients according to the following criteria: (1) treated with full fixed appliances, (2) with a lingual retainer bonded only to the mandibular canines with the same wire dimensions (0.0215 x 0.027-inch stainless steel rounded rectangular wire) (Figure 1), (3) no retreatment, (4) both mandibular permanent canines present before treatment, (5) no spacing in the mandibular anterior region before and after treatment, and (6) dental casts

Figure 1. Lingual retainer (0.0215 x 0.027-inch stainless steel rounded rectangular wire) bonded to the mandibular canines only

available before treatment (Ts), after treatment (To), at least 2 years after treatment (T2), and at least 5 years after treatment (T5) available. No inter-proximal enamel reduction or circumferential supracrestal fiberotomy was systematically performed.

The measurements for both the irregularity index and the intercanine distance were made with an electronic caliper (digital 6, Mauser, Winterthur, Switzerland) with an accuracy of 0.01 mm. The beaks of the electronic caliper were sharpened to a fine edge to permit access and to make accurate measurements. The intercanine distance was measured from the middle of the cusp of the mandibular left canine to the middle of the cusp of the mandibular right canine. In case of abrasion of a cusp, an estimation of the middle of the surface was made.

The irregularity index (Figure 2) was used to describe the contact point displacement of the mandibular anterior teeth. The irregularity index is the sum (in millimeters) of the 5 distances between the anatomic contact areas from the mesial aspect of the left canine through the mesial aspect of the right canine.[15] When anatomic contact points of adjacent teeth are touching, the measurement is zero. With increased irregularity, greater displacement leads to an increased index score. Before measurement, the anatomic contact areas of the mandibular incisors and the mesial anatomic contact areas of the canines were marked on the dental casts. The linear distance between the markings was then measured, and the 5 values were added. Because the beaks of the caliper were sharpened, it was possible to measure very small distances, often resulting in irregularity index values just marginally larger than 0 mm.

Figure 2. The irregularity index: the sum of the distances between the anatomic contact points from the mesial aspect of the left canine through the mesial aspect of the right canine

The irregularity index was not rounded, but it was decided to consider all patients with scores smaller than 0.25 mm to have a perfect alignment. All measurements were performed at Ts, T0, T2, and T5.

Gender, age, treatment duration, and failures were obtained from the patient files. Angle classification was determined on the right side of the plaster models. Sagittal contact of the incisors after treatment was determined from the plaster models in occlusion. Regarding extractions, patients were divided into 4 categories: (1) non-extraction, (2) extraction of 1 premolar in every quadrant, (3) no extraction in the mandibular arch and extraction of 1 premolar or first molar in both maxillary quadrants, and (4) a rest group (extraction of the second molars, unilateral extractions, or asymmetric extractions). In patients with an increase of the irregularity index from T0 to T5, the direction of the displacement of the teeth was assessed. When the displacement was in the direction of the initial situation, it was judged to be relapse. Retainer failures were obtained from the patient files. If the retainer was completely detached, the number of failures was counted as 2.

One observer (AMR) performed all measurements. To determine the measurement error and assess the intra-observer and inter-observer agreement of both the intercanine distance and the irregularity index, a random sample of the 76 dental casts of 19 patients was, after calibration, evaluated by the main observer (AMR) and by a second observer (SAA). The 2 observers measured the 76 dental casts twice, with 3 months between the first and second measurements. The Angle classification, sagittal contact of the incisors, failures, and relapse were assessed twice by 1 observer (AMR).

Statistical analysis

Descriptive statistics with means and standard deviations were used to report the findings at Ts, T0, T2, and T5. Box plots were made for visual representations of distributions of the values measured.

For our analysis, the following factors that could have influenced the post-treatment changes in intercanine distances were taken into account: age at the start of treatment, treatment duration, extractions, post-treatment sagittal contact of the incisors, post-treatment intercanine distance (at T0), and number of failures. From T0 to T2, and from T0 to T5, 2 backward linear regression models were built to analyze the relationship between these potential explanatory variables and the changes in intercanine distance. The threshold for a variable to stay in the model during the backward elimination process was set at $P = 0.10$.

For the factors potentially influencing changes in the irregularity index, a similar procedure was applied, with 1 important difference. The distribution of the irregularity index did not allow for the use of a linear regression model. Therefore, the increment of the irregularity index was dichotomized (0 for values smaller than 0.25 mm, 1 for larger values), and logistic linear regression models were used. The following factors were considered: age at the start of treatment, treatment duration, extractions, post-treatment sagittal contact of the incisors, changes in intercanine distance, pre-treatment and post-treatment irregularity index values, and number of failures.

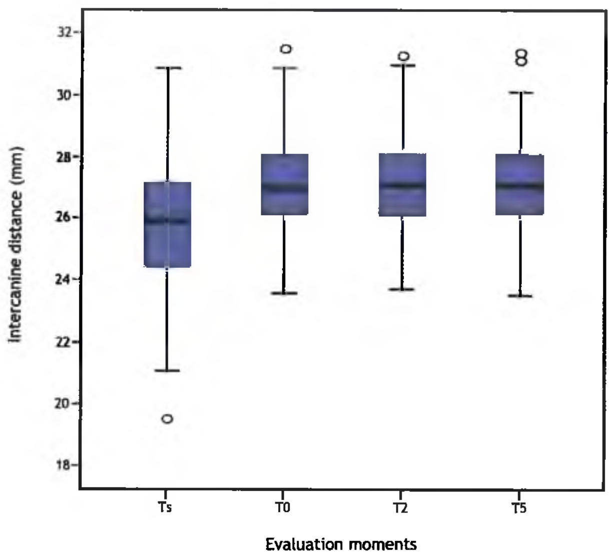
3.3. Results

With regard to the intercanine distance, the duplicate measurement errors were 0.18 mm for observer 1 (AMR) and 0.24 mm for observer 2 (SAA). The reliability coefficients were 0.991 for observer 1 and 0.985 for observer 2 (SAA). The mean inter-observer difference was 0.01. This difference was not statistically significant (P = 0.723; 95% CI: -0.059 ... 0.090 mm).

For the irregularity index, the duplicate measurement errors were 0.12 and 0.20 mm, respectively. The reliability coefficients were 0.998 and 0.997. The mean difference between the 2 observers was 0.07 mm. This difference was statistically significant (P = 0.032; 95% CI: 0.006 ... 0.133 mm). For Angle classification, failure, and relapse, the level of reliability was high (K = 1); it was also high (K = 0.89) for sagittal contact.

In the total sample, 96 patients (41%) were male, and 139 (59%) were female. The distribution of the Angle classifications at Ts was 40 Class I, 191 Class II, and 4 Class III patients. The mean ages were 12.8 years (SD, 2.7) at the beginning of the orthodontic treatment and 15.6 years (SD, 2.7) at the end of treatment. The mean treatment duration was 2.8 years (SD, 1.0). The distribution of the extraction categories was 63 subjects (26.8%) with extraction of 4 premolars, 39 (16.6%) without extraction in the mandibular arch and extraction of 1 premolar or first molar in both maxillary quadrants, 9 (3.8%) with extraction of the second molars, unilateral extractions, or asymmetric extractions, and 124 non-extraction subjects (52.8%).

The intercanine distances at Ts, To, T2, and T5 are shown in Figure 3. As a result of orthodontic treatment, the mean intercanine distance increased by 1.3 mm, from 25.8 mm at Ts to 27.1 mm at To. The mean values of the intercanine distances remained stable post-treatment: 27.3 mm at T2 and 27.2 mm at T5.

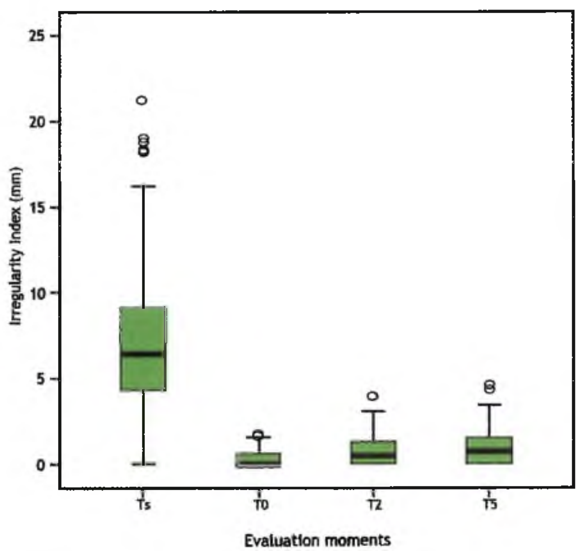


	Ts	T0	T2	T5
mean	25.8	27.1	27.3	27.2
SD	2.1	1.5	1.5	1.5
min	19.5	23.6	23.7	23.6
max	30.9	31.5	31.3	31.4

Figure 3. *Distribution and descriptive statistics of intercanine distances at Ts, T0, T2, and T5; N=235*

The irregularity index values at all stages are shown in Figure 4. The mean irregularity index for the whole sample was 7.2 mm (SD, 4.0) at Ts; it dropped to 0.3 mm (SD, 0.5) at To and increased to 0.7 mm (SD, 0.8) at T2. From T2 to T5, the mean irregularity index increased to 0.9 mm (SD, 0.9).

At T0, 154 patients had an irregularity index value of 0, and 81 had values of 0.25 to 1.80 mm (Figure 5). Since at T0 not all patients had an irregularity index value of 0, the sample was split into (1) a successfully treated group with an irregularity index of 0 - 0.25 mm (*n* = 154), and (2) a less successfully treated group with an irregularity index of 0.25 – 1.80 mm (*n* = 81). If we follow the development in the first group, we can see that, because of the increase of the irregularity index value, the numbers of patients with a score of 0 mm were reduced to 104 at T2 and to 97 at T5. In other words, 67.5% of these patients remained stable from T0 to T2, and 63.0% remained stable from T0 to T5. In the second group, the numbers of patients with no change in the irregularity index were 51 at T2 and 44 at T5. In this group, 63.0% of the patients were stable from T0 to T2, and 54.3% were stable from T0 to T5 (Figure 5).



	Ts	T0	T2	T5
mean	7.2	0.3	0.7	0.9
SD	4.0	0.5	0.8	0.9
min	0.0	0.0	0.0	0.0
max	21.3	1.8	3.9	4.6

Figure 4. *Distribution and descriptive statistics of irregularity index at Ts, T0, T2, and T5; N=235*

For the whole sample, we can state that, in 66.0% of the subjects (n = 155), the irregularity index was stable at T2, and in 60.0% (n = 141) it was stable at T5 (Figure 5).

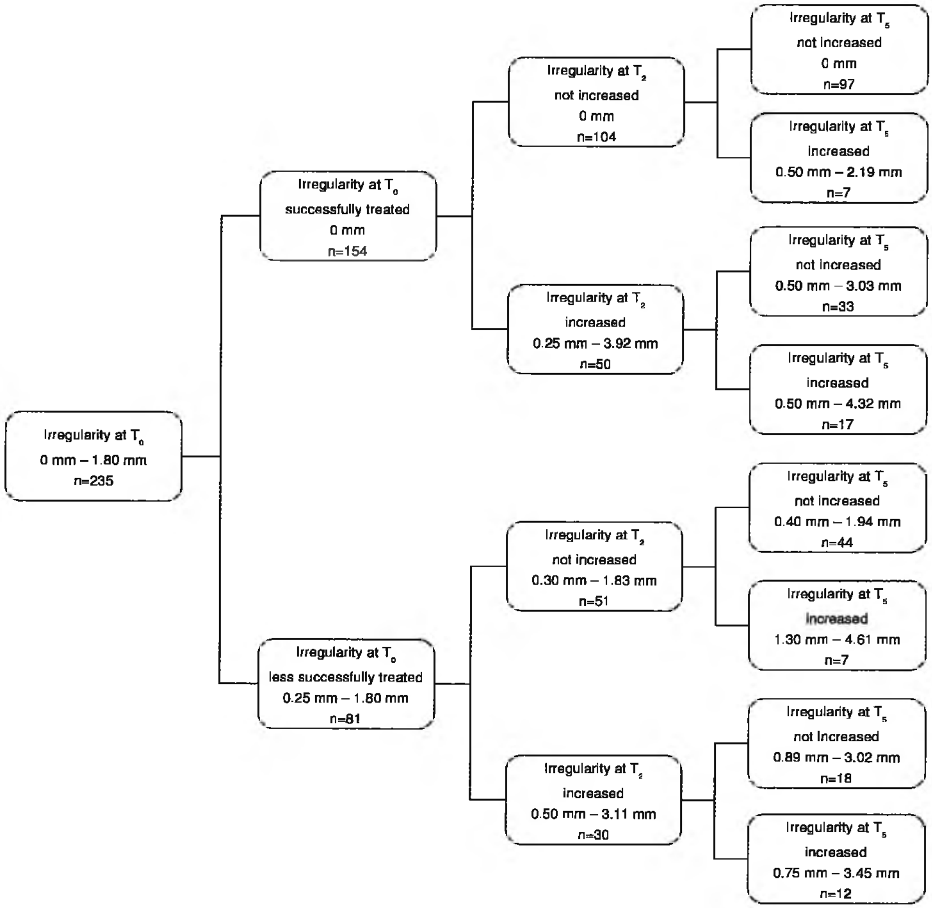


Figure 5. Tree plot of development of the irregularity index from T0, T2, and T5. First (left) node indicates treatment success; other nodes indicate stability of irregularity index

An alternative way to judge the development of irregularity is not to look at the irregularity index at the different stages but to look at its increments between To and T2, and between To and T5 (Figure 6). An increment of ≤ 1.00 mm was measured in 201 subjects from To to T2, and in 186 subjects from To to T5. Assuming that an increment of ≤ 1.00 mm is clinically irrelevant, we can characterize the alignment of the mandibular front teeth as stable in 85.5% of the patients at T2 and in 79.1% at T5. The largest increment was 3.92 mm from To to T2 and 4.32 mm from To to T5.

In the group of patients whose irregularity index increased from To to T5 (n = 94), in 49 patients (52.1%) this irregularity was not in the direction of the initial condition; in 45 patients (47.9%), the irregularity was in the direction of the initial irregularity. In the latter group, relapse occurred, for a relapse rate of 19.1% for the total sample.

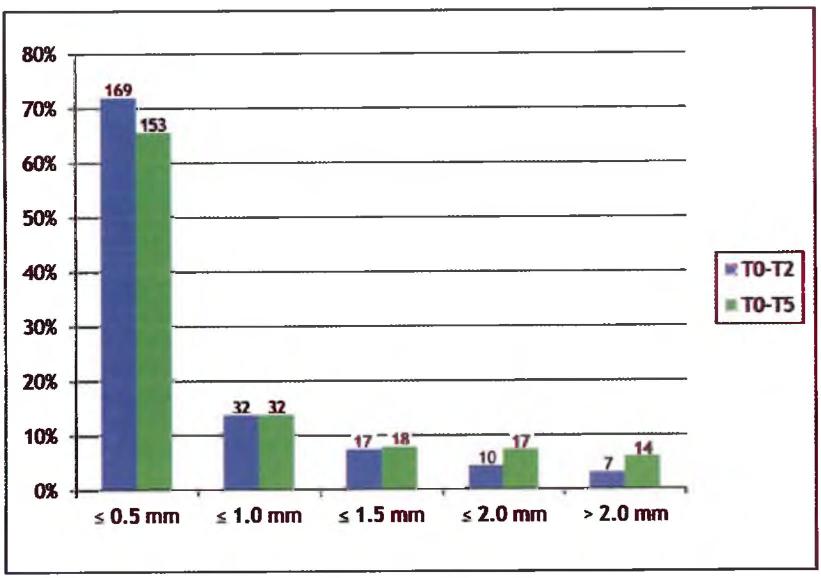


Figure 6. Percentages and numbers of patients with increments of the irregularity index of ≤ 0.50, ≤ 1.00, ≤ 1.50, ≤ 2.00, and > 2.00 mm from To to T2 and from To to T5 ; N = 235

The distribution of failures in the three time periods is shown in Table 1. At T5, 187 patients (79.6%) had never had a bond failure of their retainer, whereas 48 patients (20.4%) had at least 1 bond failure of their retainer. The failure rates (i.e., failures per year) were 12.1% from T0 to T2 and 6.4% from T0 to T5. These rates were calculated by comparing the number of failures (57 and 75) with the number of patients (235) divided by the time period in years (2 and 5).

Table 1. *Distribution of failures in the periods T0-T2, T2-T5, and T0-T5*

	T0-T2		T2-T5		T0-T5	
Times with registered failures	Patients (N)	Failures (N)	Patients (N)	Failures (N)	Patients (N)	Failures (N)
1	27	27	14	14	29	29
2	10	20	2	4	13	26
3	2	6	0	0	4	12
4	1	4	0	0	2	8
Total	40	57	16	18	48	75

Two backward linear regression models were built with changes in the intercanine distance as the dependent variables and potential explanatory variables as the independent variables: the first for changes at T2, and the second for changes at T5. In the first model, no explanatory variable remained. For the model covering the 5-year interval, only the number of retainer failures remained. The effect of a failure was estimated to be a decrease of the intercanine distance by 0.033 mm for each failure in the 5-year interval (95% CI: -0.069 ... 0.03), with a *P* value of 0.075.

For changes in the irregularity index, again 2 backward logistic models were built. The first had an increment of the irregularity index from T0 to T2 as the dependent variable. The second model analyzed the period from T0 to T5 . For the 2-year interval, only the number of retainer failures in the first 2 years remained in the model. The effect of this variable, expressed by odds ratio, was 1.76 (95% CI: 1.13 ... 2.76) with a *P* value of 0.013. For the 5-year interval, again the number of retainer failures in this period was the only variable remaining in the model. The odds ratio was 1.80 (95% CI: 1.21 ... 2.66), with a *P* value of 0.004.

3.4 Discussion

The material in this retrospective study was obtained from patients treated at the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands. Various staff members and postgraduate students perform several routine orthodontic procedures. Patients are recalled at 3 months, 6 months, 1 year, 2 years, 5 years, and 10 years post-treatment. However, there might be bias because of dropouts due to loss of dental casts or no-show patients. These are, of course, problems of retrospective studies that can only be solved with a prospective study design. However, it is mandatory to have a retrospective evaluation as a starting point for a prospective study.

The method error analysis for the categorical variables indicated very good reproducibility with kappa values of 0.89 or higher. For the irregularity index, the duplicate measurement error was near 0.2 mm for both observers.

The mean inter-observer difference was 0.01 mm, and the reliability coefficients for both observers were 0.985 and 0.991. Combining this with the range of irregularity index values measured, the errors were small. This implies that the measurement quality of the irregularity index warrants use of the variable. For the intercanine distance, all measurement errors were even smaller, and the reliability coefficients were next to perfect (0.998 and 0.997). A statistically significant difference between the observers was found, but the value of the difference (95% CI: 0.006 ... 0.133 mm) was too small for clinical significance. Therefore, the intercanine distance was also measured precisely enough in this study.

The mean increase of the intercanine distance with orthodontic therapy was 1.3 mm; this is comparable with the results of Kaplan[16] and Gardner and Chaconas.[17] Other researchers found more[9] or less[18] increase of intercanine distance after orthodontic treatment. After retention, the mandibular intercanine distance decreases.[2,9,17,18] The amount of decrease is regardless of the quantity of change by treatment, and it seems to occur in spite of maintenance of the initial arch width during treatment, arch expansion, or arch constriction.[2] In our study, with a bonded lingual retainer, the mean values of the intercanine distance were stable 2 and 5 years after treatment. The differences between the values of the intercanine distance at T_0, T_2, and T_5 are within the measurement error.

This demonstrates that the lingual retainer bonded only to the mandibular canines is effective in maintaining the intercanine distance, as was found in earlier studies.[13,14] In patients with failures of the bonded retainer, we found a small decrease in the intercanine distance. This agrees with the development of the intercanine distance in patients whose retention was discontinued.[2]

At T2, the irregularity index was stable in 66% of the patients; at T5, it was stable in 60% of the patients. Little[15] used a subjectively ranked scale with the following criteria: 0 mm, perfect alignment; 1-3 mm, minimal irregularity; 4-6 mm, moderate irregularity; 7-9 mm, severe irregularity; and 10 mm, very severe irregularity. This implies that an increment of ≤ 1.00 mm is clinically irrelevant. With this assumption in mind, the alignment of the mandibular front teeth in our sample can be characterized as stable at T2 in 88.5% of the patients and at T5 in 79.1% of the patients. In 6.0% of the patients (n = 14), the increment of the irregularity index from T0 to T5 was more than 2.00 mm, and the largest increment during that period was 4.32 mm, which is unacceptable. The increase of the irregularity from T0 to T5 was irrespective of pre-treatment irregularity, age at the start of treatment, treatment duration, extractions, post-treatment sagittal contact between incisors, changes in the intercanine distance, and post-treatment irregularity (at T0). The only responsible factor that could be determined was the number of failures. The obvious reason for the increased irregularity among patients with retainer failures might be the changes that occurred during the time lapse between the actual and reported failures.

Årtun *et al*[12] found in their prospective study minor changes in alignment in patients with retainers bonded only to the canines; in patients with failures of the retainer, the changes were larger. These findings are comparable with our results. It was suggested that less change in alignment might be expected when retention with the bonded 3-3 retainer is combined with interproximal enamel reduction and circumferential supracrestal fiberotomy, but this was not systematically performed in our sample.[19] There is some evidence that circumferential supracrestal fiberotomy leads to an increase in stability in both the maxillary and mandibular anterior segments,[20] but this evidence was judged by the Cochrane systematic review as weak and unreliable because of flaws in the study design.[11]

In only 47.9% of the patients, the development of irregularity was in the direction of the initial irregularity. This finding agrees with the study of Little et al,[2] who found that as many as half of the rotations or displacements returned in a pattern different from the original condition. This fact confirms that we cannot automatically claim relapse for post-retention displacement of the anatomic contact points of the mandibular anterior teeth.

In this study, 20.4% of our patients experienced retainer failures. The failure rates (failures per year) were 12.1% from T_0 to T_2 and 6.4% from T_0 to T_5. Our failure rate might be higher because we cannot rule out that, in some subjects, the patient's dentist rebonded the retainer. Reported failures of 3-3 bonded retainers vary widely from 0.1%[21] to 30.8%[12] of the patients. Because of the wide variety of observation periods and materials, it is difficult to compare these findings with ours.

Failures can be inherent, as a result of poor chair-side technique, or acquired, from wear or direct trauma to the retainer. The difference in failure rates can also be attributed to various bonding techniques and bonding materials. The patients in our study received their retainers between 1985 and 1993. Bonding materials have improved over the years, increasing the durability and effectiveness of bonded appliances and decreasing the numbers of failures. Because failures of the 3-3 mandibular retainer led to an increase of the irregularity index values after treatment, this is one reason to aim for a failure rate as low as possible and adhere to a meticulous bonding technique for the long-term success of bonded retainers.

3.5 Conclusions

Regarding the maintenance of the achieved alignment of the mandibular anterior region, we can conclude that the 3-3 mandibular lingual stainless steel retainer (bonded only to the canines) is effective in stabilizing the orthodontic treatment results in most patients. However, in a relatively high percentage of patients, a small to moderate increase in mandibular irregularity might occur. Because the stability of the alignment was negatively influenced by failures of the bonded retainer, the incidence of failures should be minimized as much as possible by paying attention to bonding procedures. It is also important to ask the patient to report a failure immediately in order to perform a repair as soon as possible.

The results of this study should enable clinicians to inform their patients about the limitations of retention of the mandibular front region with a lingual retainer bonded only to the canines and give them realistic expectations.

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Chapter 4

Long-term effectiveness of canine-to-canine bonded flexible spiral wire lingual retainers

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Am J Orthod Dentofacial Orthop 2011;139:614-621

Summary

Introduction

The flexible spiral wire (FSW) canine-to-canine lingual retainer bonded to all 6 anterior teeth is a frequently used type of mandibular fixed retainer. This study aimed to assess the long-term effectiveness of FSW canine-to-canine lingual retainers in maintaining the alignment of the mandibular anterior teeth after orthodontic treatment.

Methods

The sample consisted of dental casts of 221 consecutively treated patients (75 male, 146 female) from the archives of the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands, who received an FSW canine-to-canine lingual retainer bonded to all 6 anterior teeth after active orthodontic treatment. The casts were studied before treatment (Ts), immediately after treatment (T0), 2 years (T2), and 5 years (T5) post-treatment.

Results

The mean irregularity index decreased significantly from 5.35 mm (SD, 3.47) at Ts to 0.08 mm (SD, 0.23) at T0. At T5, the alignment of the mandibular anterior teeth was stable in 200 patients (90.5%); in 21 patients (9.5%), a mean increase of 0.81 mm (SD, 0.47) was observed. The increase of irregularity was strongly related to the bond failures of the retainer. In 6 patients (2.7%), unexpected post-treatment complications—torque differences of the incisors or increased buccal canine inclination—were observed.

Conclusions

The FSW canine-to-canine lingual retainer is very effective in maintaining the alignment of the mandibular anterior region after active orthodontic treatment. However, regular checkups are necessary to determine bond failures, post-treatment changes, and complications as early as possible.

4.1 Introduction

Many studies have demonstrated a high relapse rate of the alignment of the mandibular anterior teeth after orthodontic treatment and retention.[1-9] From the various types of removable or fixed mandibular retainers used to prevent relapse in the mandibular arch, the flexible spiral wire (FSW) canine-to-canine retainer bonded to the lingual surfaces of all 6 mandibular teeth is commonly used.[10] Although these retainers are widely used, only a limited number of studies deal with their long-term effectiveness. Littlewood *et al*[11] found in their Cochrane review only 1 prospective randomized clinical trial that assessed the stability of incisor alignment after 3 years of retention.[12] One of the 4 test groups in this study received retainers bonded to all 6 anterior teeth ($n = 11$) and experienced no increase in incisor irregularity (in the 8 patients with no detachment of the retainer). Similar results were reported in a prospective study that was excluded from the Cochrane review.[13] This study compared a small group of patients ($n = 34$) who received mandibular retainers bonded only to the canines with 2 groups of patients ($n = 31$ and 38) who received 2 other types of retainer attached to all anterior teeth. After an observation period of 2 years, no relapse was observed in patients with a 0.0195-in FSW canine-to-canine retainer, whereas the relapse rate in patients with a 0.0215-in FSW canine-to-canine retainer was 20%. However, in both FSW groups, the changes in the irregularity index were not significant.

In a recent retrospective study, a 0.65 mm mean increase in the irregularity index was shown 1 year after treatment in a small group of patients ($n = 29$) retained with FSW retainers.[14] This increase was not significantly different when compared with a group of 29 patients who received a removable retainer.

The shortcomings of the available literature (small patient groups or short observation periods) considerably restrict the evidence about the stability of orthodontic alignment of the mandibular anterior teeth retained with the FSW canine-to-canine lingual retainer. Therefore, we aimed to assess the long-term effectiveness of mandibular FSW canine-to-canine retainers bonded to all 6 teeth in a large consecutive group of patients.

4.2 Material and Methods

Our material consisted of dental casts from the archives of the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands. We selected 221 patients who were treated with full fixed appliances and received a mandibular lingual FSW retainer (0.0195-inch, 3-strand, heat-treated twisted wire, Wildcat, GAC International, Bohemia, NY), bonded to all 6 mandibular anterior teeth at the end of active orthodontic treatment (Figure 1). Dental casts and intraoral photographs were available before treatment (Ts), after treatment (T0), at least 2 years after treatment (T2), and at least 5 years after treatment (T5). Patients with spacing or missing teeth in the mandibular anterior region before or after treatment and retreated patients with any orthodontic appliance were excluded. No interproximal enamel reduction or circumferential supracrestal fiberotomy was systematically performed.

The measurements for both the intercanine distance and the irregularity index were made with an electronic caliper (digital 6, Mauser, Winterthur, Switzerland) with an accuracy of 0.01 mm. The beaks of the electronic caliper were sharpened to a fine edge to permit access and make accurate measurements. The intercanine distance was measured from the middle of the cusp of the mandibular left canine to the middle of the cusp of the mandibular right canine. In case of abrasion of a cusp, an estimation of the middle of the surface was made.

Figure 1. FSW canine-to-canine retainer, 0.0195-inch, 3-strand, heat-treated twisted wire, bonded to all 6 mandibular anterior teeth

The irregularity index (Figure 2) was used to describe the contact point displacement of the mandibular anterior teeth. The irregularity index is the sum (in millimeters) of the 5 distances between the anatomic contact points from the mesial aspect of the left canine through the mesial aspect of the right canine.[15] When anatomic contact points of adjacent teeth are touching, the measurement is zero. With increased irregularity, greater displacement led to an increased index score. Before measurement, the anatomic contact areas of the mandibular incisors and the mesial anatomic contact areas of the canines were marked on the dental casts. The linear distance between the markings was then measured, and the 5 values were added. Because the beaks of the caliper were sharpened, it was possible to measure small distances. The measurements were made at Ts, T0, T2, and T5. At T0, T2, and T5, the measurements were rounded to 0.25 mm, 0.50 mm, 0.75 mm and so on. Patients with scores less than 0.25 mm were considered as having a perfect irregularity index.

Gender, age, treatment duration, and failures were obtained from the patient files. Angle classification was determined on the right side of the plaster models. Sagittal contact of the incisors after treatment was determined from the plaster models in occlusion. Regarding extractions, the patients were divided into 4 categories: (1) non-extraction, (2) extraction of 1 premolar in every quadrant, (3) no extraction in the mandibular arch and extraction of 1 premolar or first molar in both maxillary quadrants, and (4) a rest group (extraction of the second molars, unilateral extractions, and asymmetric extractions).

Figure 2. The irregularity index: the sum of the distances between the anatomic contact points from the mesial aspect of the left canine through the mesial aspect of the right canine

In patients with an increase of the irregularity index from T0 to T5, the direction of the displacement of the teeth was assessed. When the displacement was in the direction of the initial situation, it was judged to be relapse. Retainer failures were obtained from the patient files. If the retainer was completely detached, the number of failures was counted as 6.

The dental casts and the intraoral photographs were meticulously inspected for post-treatment changes in the positions of the 6 mandibular teeth (torque difference between 2 adjacent mandibular incisors, or increased buccal inclination and movement of a mandibular canine) as described by Katsaros *et al.*[16]

One observer (AMR) performed all measurements. To determine the measurement error and assess the intra-observer and inter-observer agreement of both the intercanine distance and the irregularity index, a random sample of 80 dental casts of 20 patients was, after calibration, evaluated by the main observer (AMR) and a second observer (AR). The 2 observers measured the 80 casts twice, with 4 months between the first and second measurements. Angle classification, sagittal contact of the incisors, failures, and relapse were assessed twice by 1 observer (AMR).

Statistical analysis

Descriptive statistics with means and standard deviations were used to report the findings at Ts, T0, T2, and T5. Box plots were made for visual representations of the distributions of intercanine distances. Cross tabs and chi-square tests were used to analyze the relationships between bond failures and the increments of the irregularity index.

For all nominal variables, the reliability of the measurement was expressed by using the kappa statistic. For the continuous variables (intercanine distances at all time points and irregularity index at Ts), the reliability coefficient (calculated by Pearson's correlation coefficient) and the duplicate measurement error were determined. For these variables, the mean differences between the measured and re-measured variables were analyzed with the paired *t*-test.

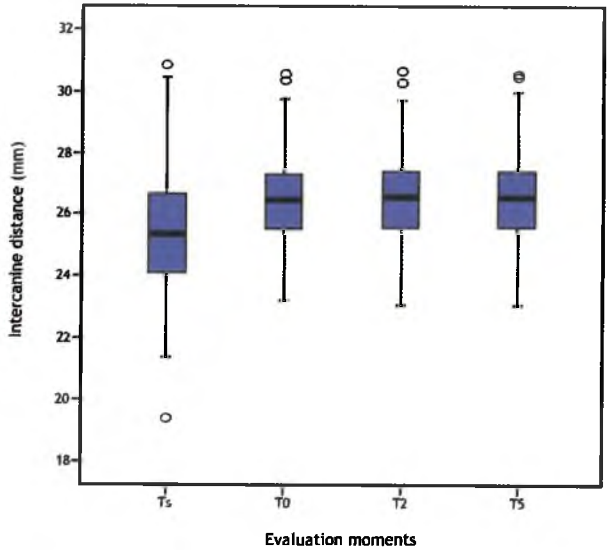
At time T0 and later nearly all subjects had an irregularity index of 0. Therefore, for those time points, the measurement error was expressed by using the kappa statistic, for a dichotomized (0 or > 0.0) irregularity index.

4.3 Results

The analysis of intra-observer and inter-observer performance for the continuous variables showed high reliability coefficients (0.977 or higher). The duplicate measurement errors for the intercanine distances ranged between 0.15 and 0.25 mm. For the irregularity index, the duplicate measurement errors were 0.34 mm (intra-observer) and 0.47 mm (inter-observer). In 2 cases for inter-observer performance, a significant difference between observers was found: 0.18 mm for intercanine distance at T0 and 0.14 mm for intercanine distance at T5. For all nominal variables, no measurement error was found; i.e., all kappa values, for both intra-observer and inter-observer, were equal to 1.

In the total sample, 75 patients (33.9%) were male, and 146 (66.1%) were female. The distribution of the Angle classifications at Ts was 25 Class I, 191 Class II, and 5 Class III patients. The mean ages were 13.4 years (SD, 4.2) at the beginning of orthodontic treatment and 16.3 years (SD, 4.2) at the end of treatment. The mean treatment duration was 2.9 years (SD, 0.9). The distribution of the extraction categories was 151 non-extraction subjects (68.3%), 35 (15.9%) with extraction of 1 premolar in every quadrant, 21 (9.5%) without extraction in the mandibular arch and extraction of 1 premolar or first molar in both maxillary quadrants, and 14 (6.3%) in the rest group.

The intercanine distances at Ts, T0, T2, and T5 are shown in Figure 3. As a result of orthodontic treatment, the mean intercanine distance increased by 1.1 mm—from 25.4 mm at Ts to 26.5 mm at T0. The mean values of the intercanine distance remained stable at T2 and T5 (26.5 mm).



	Ts	T0	T2	T5
mean	25.4	26.5	26.5	26.5
SD	1.9	1.4	1.4	1.4
min	19.4	13.2	23.1	23.1
max	31.0	30.6	30.8	30.6

Figure 3. *Distribution and descriptive statistics of intercanine distances at Ts, T0, T2, and T5; N=221*

The irregularity index values at all stages are shown in Table 1. At the left, the irregularity index values for the whole sample are presented; at the right, the values of subjects with an increase in irregularity from T0 to T5 are presented. The mean irregularity index was 5.35 mm (SD, 3.47) at Ts; it dropped to 0.08 mm (SD, 0.23) at T0 and increased to 0.13 mm (SD, 0.34) at T2. From T2 to T5, the mean irregularity index increased to 0.15 mm (SD, 0.36). Chi-square tests were used to test for differences in the distribution of patients with or without an irregularity index greater than 0 at the 3 time points. This showed that, only for the interval T0 to T5, the increase in the number of patients with an irregularity index greater than 0 was significant ($P = 0.023$ for T0-T5, $P = 0.162$ for T0-T2, and $P = 0.452$ for T2-T5).

Table 1. *Irregularity index values at Ts, To, T2, and T5*

Values for all subjects							Values for subjects with increased irregularity index from To to T5					
Time	n	Mean	Min	Max	SD	n with index>0	Time	n	Mean	Min	Max	SD
Ts	221	5.35	0.50	16.78	3.47	221	Ts	21	5.61	1.23	11.28	2.93
To	221	0.08	0.00	1.25	0.23	24	To	21	0.07	0.00	0.50	0.18
T2	221	0.13	0.00	2.50	0.34	35	T2	21	0.61	0.00	2.50	0.68
T5	221	0.15	0.00	2.50	0.36	42	T5	21	0.88	0.50	2.50	0.55

At To, 197 patients (89.1%) had an irregularity index value of 0, and 24 (10.9%) had values of 0.50 to 1.25 mm. At T2, the alignment of the mandibular front teeth was stable in 207 patients (93.7%); in 14 patients (6.3%) an increase of the irregularity index was measured. At T5, the situation was stable in 200 patients (90.5%) and in 21 patients (9.5%), a mean increase of 0.81 mm (SD, 0.47) was observed. The frequencies of the increments of the irregularity index from To to T2, T2 to T5, and To to T5 are given in Table 2.

In the group of patients whose irregularity index increased from To to T5 (n = 21), in 5 patients (23.8%), this irregularity was not in the direction of the initial condition; in 16 patients (76.2%), the irregularity was in the direction of the initial irregularity.

Table 2. *Increments of the irregularity index in the periods To-T2, T2-T5, and To-T5*

Increment in mm	Frequency from To-T2	Frequency from T2-T5	Frequency from To-T5
0.00	207	213	200
0.50	9	5	12
0.75	1	0	1
1.00	2	2	5
1.25	0	1	1
2.00	2	0	2
Total with an increment > 0.00 mm	14	8	21

The numbers and distributions of bond failures for the three time periods are shown in Table 3. At T5, 151 patients (68.3%) had never had a bond failure of their retainer, whereas 70 patients (31.7%) had at least 1 bond failure of their retainer.

In Table 4, the distribution of failures per tooth is shown. The number of bond failures of the incisors was, compared with the number of bond failures of the canines, significantly lower ($P < 0.001$). The difference between the number of bond failures of the central and lateral incisors was not significant ($P = 0.28$).

The bond failure rates were 31.7% from T0 to T2, and 17.4% from T0 to T5. These rates were calculated by comparing the number of failures (140 and 192) with the number of patients (221) divided by the time period in years (2 and 5).

In the 5-year post-treatment period, 1 retainer was broken between the mandibular right lateral incisor and canine. The intercanine distance and the irregularity index in this patient were stable.

Table 3. *Number and distribution of failures in periods T0-T2, T2-T5, and T0-T5*

		Patients with bond failures from T0-T2 (N)	Patients with bond failures from T2-T5 (N)	Patients with bond failures from T0-T5 (N)	Total number of bond failures from T0-T5 (N)
Patients with any number of bond failures		53	30	70	-
Number of patients with 1 to 14 bond failures	1 failure	22	13	32	32
	2 failures	13	11	12	24
	3 failures	11	3	9	27
	4 failures	0	2	4	16
	5 failures	2	0	6	30
	6 failures	1	0	3	18
	8 failures	1	0	0	0
	10 failures	1	0	2	20
	11 failures	1	0	1	11
	14 failures	1	0	1	14
Total number of failures		**140**	**52**	**192**	**192**

Table 4. *Distribution of failures per tooth in the periods T0-T2, T2-T5, and T0-T5*			
Mandibular tooth	**Failures T0-T2**	**Failures T2-T5**	**Failures T0-T5**
Left canine	5	1	6
Left lateral incisor	29	10	39
Left central incisor	32	11	43
Right central incisor	33	18	51
Right lateral incisor	29	8	37
Right canine	12	4	16
Total number of failures	**140**	**52**	**192**

The development of the mean irregularity index in patients with an increase of the irregularity index value from T0 to T2, from T2 to T5, and from T0 to T5 is presented in Table 1.

The increase of irregularity was found to be strongly related to the bond failures of the retainer. In those with bond failures, 49 patients (70%) showed no increase of the irregularity index value, whereas 21 patients (30%) had a mean increase of 0.81 mm (SD, 0.47). In Figure 4, the group of patients *both* with failures *and* an increase of the irregularity index is shown. Failures were not related to age or gender.

In 6 patients (2.7%), post-treatment changes in the position of the mandibular teeth were observed; 3 patients had a torque difference between the 2 mandibular central incisors (Figure 5), 2 patients had an increased buccal inclination of the mandibular left canine (Figure 6), and 1 patient had a torque difference between the 2 mandibular central incisors *and* increased buccal inclination of the mandibular left canine.

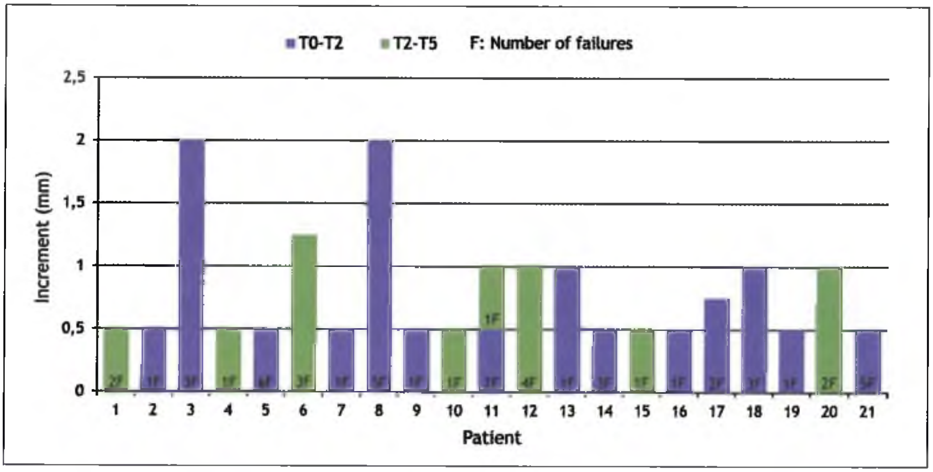


Figure 4. Increments of irregularity in the group of patients (n = 21) whose irregularity index increased during the post-treatment period. The bars indicate the increments between T0 and T2 and between T2 and T5; in the bars, the number of failures is indicated

4.4 Discussion

The material in this retrospective study was obtained from patients treated at the Department of Orthodontics and Craniofacial Biology, Radboud University Nijmegen Medical Center, the Netherlands. According to the standard post-treatment protocol, patients are recalled at 3 months, 6 months, 1 year, 2 years, 5 years, and 10 years post-treatment. Since this was a retrospective study, there might be bias because of dropouts caused by loss of dental casts, no-show patients, or retreatment within the 5-year post-treatment period. These biases can be prevented only with a prospective study design. However, it is mandatory to have a retrospective evaluation as a starting point before undertaking a prospective study.

All categorical variables showed a perfect kappa value. For all continuous variables, both very high intra-observer and inter-observer reliabilities were found (0.977 or better). The duplicate measurement errors were about 0.2 mm for intercanine distances and 0.4 mm for the irregularity index at T5. All these values can be interpreted as signs that the measurement quality warrants use of the variables. Only 2 measurements showed an unfavourable characteristic: the intercanine distances at T0 and T5. Here significant differences were found between the first and second measurements (P = 0.001, mean difference of 0.179 mm; P = 0.019, mean difference of 0.135 mm, respectively). We cannot explain this finding. However the sizes of the differences were deemed to be small enough as compared with the variability in these variables (SD, 1.4 mm for both). Therefore they can be considered as useful variables.

Figure 5. Torque difference between 2 mandibular central incisors

Figure 6. Increased buccal inclination of the mandibular left canine

It is well known that, during the post-retention period, the intercanine distance decreases.[2,9,17-19] The amount of decrease is regardless of the amount of change by treatment, and it seems to occur in spite of the maintenance of the initial arch width during treatment, arch expansion, or arch constriction.[2] In our study, the mean values of the intercanine distance were stable 2 and 5 years after treatment. The differences between the values of the intercanine distance at T0, T2, and T5 were within the measurement error. This demonstrates that the mandibular lingual FSW canine-to-canine retainer is effective in maintaining the intercanine distance. Thus, in this respect, the effectiveness of the FSW mandibular retainer is similar to that of the thick retainer bonded only to the mandibular canines.[20,21] In patients with failures of the bonded retainer, we found a small decrease in the intercanine distance. This agrees with the development of the intercanine distance in patients whose retention was discontinued.[9]

At T2, the irregularity index was stable in 93.7% of the patients; at T5, it was stable in 90.5%. According to Little's ranked scale,[15] we can say that at T0 the alignment of the mandibular front teeth was very good (irregularity index < 1.00 mm) in 97.7% of the patients; at T2 and T5 the percentages were 95.0% and 93.7%, respectively. Only a few patients experienced a post-treatment increase in the irregularity index more than 1 mm; in 3.6% of the patients (n = 8), the increment of the irregularity index from T0 to T5 was 1.00 mm or more; in less than 1% of the patients (n = 2), the increment of the irregularity index from T0 to T5 was 2.00 mm. The only factor that might account for the increase of the irregularity from T0 to T5 was bond failure. An interesting finding was that, in only 30% of the patients with bond failures, the irregularity increased. The obvious reason for the increased irregularity among the patients with retainer failures might be the changes during the time lapse between the actual and reported failures. In this respect, it is important to ask the patient to report a failure immediately in order to perform a repair as soon as possible. However, the problem with this type of retainer is that the patient is often unaware of a bond failure. This is different with the thick retainer bonded only to the mandibular canines—the patient immediately recognizes detachment of the wire.

If we compare our findings with those of a group of 235 patients with a mandibular lingual retainer bonded only to the canines, the increments of the irregularity index from T0 to T5 in our study were much lower; this means that the mandibular lingual FSW retainer—bonded to all 6 anterior teeth—is more effective in maintaining the alignment in this region than the thick mandibular lingual retainer bonded only to the canines.[20] This agrees with the comparative study of Störmann and Ehmer.[13]

In 76.2% of the patients, the development of irregularity was in the direction of the initial irregularity. This finding does not agree with the studies of Little *et al*[2] and Renkema *et al*,[20] who found perhaps as many as half the rotations or displacements returned in a pattern different from the original condition. An explanation for this difference cannot be given. However, this percentage still confirms that we cannot automatically claim relapse when post-treatment displacement of the anatomic contact points of the mandibular anterior teeth is observed. The term "post-treatment change" describes post-retention tooth displacement better than "post-treatment relapse".

In this study, 32.2% of our patients experienced retainer failures. In only 1 patient, the retainer was broken. The bond failure rate—i.e., bond failures per year—was higher during the first 2 years after treatment—32.0% from T0 to T2 and 17.6% from T0 to T5. Our failure rate might be higher because we could not rule out that, in some subjects, the patient's dentist rebonded the retainer. Our failure rate was higher than that reported by Dahl and Zachrisson[22] but similar to the failure rate reported by Lie Sam Foek *et al*[23] Because of the variety of observation periods and materials, it is difficult to compare those findings with ours. If we compare our findings with those of a group of 235 patients with a mandibular lingual retainer bonded only to the canines and the same follow-up stages, the failures rates are high, possibly because 6 teeth instead of 2 were bonded.[20] It might be better to assess and compare the number of failures and rebonding appointments. We found, as did Årtun *et al*[13] and Lie Sam Foek *et al*,[23] many more failures during the first period after treatment. It might be that the increased mobility of the teeth in the initial post-treatment period favours detachments.[23]

Failures can be inherent, as a result of poor chair-side technique, or acquired, from wear or direct trauma to the retainer. The differences in failure rates can also be attributed to various bonding techniques and bonding materials. The patients in our study received their retainers between 1995 and 2000. Bonding materials have improved over the years, increasing the durability and effectiveness of bonded appliances and decreasing the numbers of failures. Because failures of the canine-to-canine retainer can lead to an increase of the irregularity index values after treatment, it is conceivable that strict adherence to a meticulous bonding technique is an absolute condition for long-term success of bonded retainers.

In 6 subjects (2.7%), unexpected complications in the position of the mandibular anterior teeth were observed—torque difference between the 2 mandibular central incisors or buccal inclination and movement of the mandibular left canine—as discussed by Katsaros *et al.*[16] It can be argued that, because of the exclusion of retreated patients, the actual number of patients with such complications is higher than found in our study. Torque differences between 2 mandibular anterior teeth can influence the irregularity index. This was not found in our study, but it did alter the ultimate treatment result. Although these changes cannot be characterized as relapse, they can mean that retreatment is necessary.[16] Three patients were assessed as needing retreatment. The fact that these undesirable post-treatment changes might need retreatment stresses the importance of early detection. Patients and general dentists should be informed about the possibility of these complications and how to detect them. It is very important to recommend patients and general dentists to report post-treatment changes immediately, to prevent the necessity of retreatment.

4.5 Conclusions

1. The mandibular FSW canine-to-canine lingual retainer is effective in maintaining the alignment in the mandibular anterior region after active orthodontic treatment in a very high percentage of patients.
2. Attention should be paid to the bonding procedure to aim for a failure rate as low as possible, since failure of the mandibular FSW canine-to-canine lingual retainer is associated with increased post-treatment irregularity in the mandibular anterior region.
3. In a few patients, unexpected complications—torque difference between 2 adjacent mandibular incisors or increased buccal inclination and movement of a mandibular canine—can occur.
4. Regular checkups of patients with a mandibular FSW canine-to-canine lingual retainer as a retention device are necessary to detect bond failures, post-treatment changes, or complications as early as possible.

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Chapter 5

Development of labial gingival recessions in a cohort of orthodontically treated patients

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Am J Orthod Dentofacial Orthop 2013;143:206-212

Summary

Introduction

Our aim was to assess the prevalence of gingival recessions in patients before, immediately after, and 2 and 5 years after orthodontic treatment.

Methods

Labial gingival recessions in all teeth were scored (*Yes* or *No*) by two raters on initial, end-of-treatment, and post-treatment (2 and 5 years) plaster models of 302 orthodontic patients (38.7% male; 61.3% female) selected from a post-treatment archive. Their mean ages were 13.6 years (SD, 3.6; range: 9.5 - 32.7 years) at the initial assessment, 16.2 years (SD, 3.5; range: 11.7 - 35.1 years) at the end of treatment, 18.6 years (SD, 3.6; range: 13.7 - 37.2 years) at 2 years post-treatment, and 21.6 years (SD, 3.5; range: 16.6 - 40.2 years) at 5 years post-treatment. A recession was noted (scored *Yes*) if the labial cemento-enamel junction was exposed. All patients had a fixed retainer bonded either to the mandibular canines only (type I) or bonded to all 6 mandibular front teeth (type II).

Results

There was a continuous increase in gingival recessions after treatment from 7% at the end of treatment to 20% at 2 years post-treatment, and to 38% at 5 years post-treatment. Patients less than 16 years of age at the end of treatment were less likely to develop recessions than patients more than 16 years of age at the end of treatment ($P = 0.013$). The prevalence of recessions was not associated with gender ($P = 0.462$) or extraction treatment ($P = 0.32$). The type of fixed retainer did not influence the development of recessions in the mandibular front region ($P = 0.231$).

Conclusions

The prevalence of gingival recessions steadily increases after orthodontic treatment. The recessions are more prevalent in older than in younger patients. No variable, except for age at the end of treatment, seems to be associated with the development of gingival recessions.

5.1 Introduction

A *gingival recession* (Figure 1a and 1b) is defined as the displacement of the marginal tissue apical to the cemento-enamel junction.[1] Although its etiology is unclear, periodontal disease and mechanical trauma are considered as the primary factors in the pathogenesis of gingival recessions. Orthodontic treatment might promote the development of recessions.[2] A possible mechanism is that orthodontic tooth movement can result in root positions close to or outside the alveolar cortical plates—this can lead to bone dehiscences.[3] As a result a marginal gingiva can, without

Figure 1. *Development of labial gingival recessions during orthodontic treatment: (a) immediately pre-treatment at age 13.8 year and (b) immediately post-treatment, 3 years later*

proper alveolar bone support, migrate apically, leading to root exposure. Furthermore, a fixed orthodontic appliance creates retention areas for dental plaque. In case of inadequate removal of plaque, gingival inflammation could lead to periodontal breakdown. In addition, a similar effect might be caused by long-term wear of a plaque-accumulating bonded retainer attached to the 6 anterior teeth in patients with poor oral hygiene. Irrespective of the mechanism, the results of a recent systematic review imply that orthodontic therapy can cause a small mean worsening of periodontal status, including the development of gingival recessions.[4]

An understanding of the association between orthodontic treatment and the development of gingival recessions is important because more and more children, teenagers, and adults are being treated orthodontically.[5] For example, data from the United States show that the proportion of children who received orthodontic therapy increased from about 15% to more than 30% for those born in 1950s and 1970s, respectively.[5] Furthermore, most patients desire orthodontic treatment for aesthetic reasons.[6,7] This motivation is independent of the geographic location or the affluence of the country.[6,8,9] However, gingival recessions can negatively affect the aesthetics of the dentition and compromise treatment results.[10-12]

Population-based investigations have demonstrated that the development of gingival recessions depends on age: their prevalence is lower at younger age and increases over time.[13-15] For example, recessions of more than 3 mm were present in 6%, 24%, and 54% of patients aged 14 to 19, 20 to 29, and 30 to 39 years, respectively. In other words, the proportion of patients with severe recessions increased almost 10-fold from the late teenage years to adulthood.[15] To date, studies that focused on the development of gingival recessions in orthodontic patients evaluated samples either immediately,[16] or several years after treatment.[17-19] The latter ones, however, were limited to only one long-term observation. Consequently, the dynamics of the development of gingival recessions could not have been evaluated. Moreover, most investigations were limited to the assessment of incisors and canines,[16-20] with little attention given to other teeth.[2,21] Therefore, the aim of this study was threefold: (1) to assess the change of prevalence of gingival recessions in a large representative cohort of patients during and 2 and 5 years after orthodontic treatment, (2) to evaluate the development of recessions in various regions of the dental arches, and (3) to identify variables associated with the development of gingival recessions.

5.2 Materials and Methods

5.2.1 Materials

A cohort of 302 patients was selected from the archives of the Department of Orthodontics and Craniofacial Biology, Radboud University Medical Centre Nijmegen, the Netherlands, according to the following inclusion criteria: (1) treated with full fixed appliances, (2) a bonded lingual retainer placed directly after active orthodontic treatment, (3) no orthodontic retreatment, and (4) good-quality dental casts available before treatment, after treatment, 2 years after treatment, and 5 years after treatment. All patients had a lingual retainer either bonded only to the mandibular canines (type I retainer) (Figure 2) or bonded to all 6 mandibular anterior teeth (type II retainer) (Figure 3) during the entire post-treatment period. In all patients, 4 mandibular incisors were present before treatment, and 5 years after treatment.

Figure 2. Type I retainer: 0.0215 x 0.027-inch stainless steel rounded rectangular wire bonded to the mandibular canines only

Gender, age at the 4 assessment times, information on extraction *versus* non-extraction treatment alternative, and type of retainer were obtained from the patient files. Angle classification was determined on the right side of the pre-treatment (T_0) plaster models. The type of retainer was confirmed by inspection of the plaster models made after treatment.

Figure 3. *Type II retainer: 0.0195-inch, 3-strand, heat-treated twisted wire, bonded to all 6 mandibular anterior teeth*

In the 302 subjects, 117 (38.7%) were male and 185 (61.3%) were female. The distribution of the Angle classifications at pre-treatment was: 51 patients (16.9%) were Class I, 247 patients (81.8%) were Class II, and 4 patients (1.3%) were Class III. The mean ages were 13.6 years at the beginning of orthodontic treatment and 16.2 years at the end of treatment (Table 1). The mean treatment duration was 2.6 years. One hundred ninety-five patients (64.6%) were treated without extractions, 52 (17.2%) had extractions of 4 teeth (1 tooth in each quadrant), 29 (9.6%) had extractions of only 2 maxillary teeth, and 26 (8.6%) had other types of extractions. In 167 patients (55.3%), a lingual retainer was bonded only to the mandibular canines (type I retainer), whereas 135 patients (44.7%) had a retainer bonded to all 6 mandibular anterior teeth (type II retainer).

Table 1. *Characteristics of the sample (N = 302); all values are in years*

	Mean	SD	Minimum	Maximum
Age start of treatment	13.6	3.6	9.5	32.7
Age end of treatment	16.2	3.5	11.7	35.1
Age 2 years after treatment	18.6	3.6	13.7	37.2
Age 5 years after treatment	21.6	3.5	16.6	40.2
Duration of treatment	2.6	0.8	1.0	6.0
Post-treatment period	5.4	0.4	4.6	6.4

5.2.2 Methods

Labial gingival recessions in all teeth were scored (*Yes* or *No*) on initial (Ts), end-of-treatment (To), 2 years post-treatment (T2), and 5 years post-treatment (T5) plaster models. A recession was noted (scored *Yes*) if the labial cemento-enamel junction was exposed. The judgment was done independently by two calibrated observers (AMR and AR) after meticulous inspection of the plaster models.

The recessions were analyzed as (1) recessions in the mandibular incisors, (2) recessions in the rest of dentition, and (3) recessions in all teeth.

5.2.3 Statistical analysis

Descriptive statistics with means and standard deviations were calculated to report the findings at the 4 assessment times. The presence of a recession is a dichotomous variable—therefore, kappa statistics were used to assess observer performance. In the pilot study, the kappa values were computed to express agreement between the 2 scores for the gingival recessions: one obtained by clinical examination, and the other obtained by scoring plaster models. In the main study, the kappa values were calculated for inter-observer and intra-observer concordance.

Fisher's exact tests were run to identify differences in the development of recessions between (1) male and female subjects, (2) those younger than 16 years of age *versus* those of 16 years or older at the end of treatment, (3) subjects with extraction *versus* non-extraction treatment, (4) subjects with type I *versus* type II retainers, and (5) subjects with the various Angle classifications.

Regression analyses were carried out to investigate an association between the increase of the presence of gingival recessions from To to T5 in the whole dentition, in the mandibular incisor region, in the remaining teeth, and in the 6 teeth with the highest prevalence of recessions (maxillary right and left first premolars, mandibular right and left first premolars, and mandibular right and left central incisors) (dependent variables), and age at the end of treatment, gender, and extraction *versus* non-extraction treatment alternative (independent variables).

5.2.4 Methods error

The validity of the use of plaster casts for scoring recessions was assessed in a *pilot study* with 30 randomly selected adult patients (mean age 42.0 years; SD, 10.4; range: 18.1 – 54.8 years). First, an observer (AMR) scored (*Yes* or *No*) the presence of gingival recessions in all regions of the dental arches during clinical examinations. Then, maxillary and mandibular alginate impressions were taken to make plaster casts. Finally, the same observer determined the presence of gingival recessions on the plaster models 3 months after the clinical examinations.

Clinically, 147 recessions were identified (scored *Yes*) in 20 of the 30 patients, whereas 137 recessions were identified on 20 of the 30 plaster models. In 21 teeth, the clinical and model scores were identical (kappa = 1). The scores were different for 7 teeth (once for the maxillary right second premolar, the maxillary left canine, the mandibular left second molar, and the mandibular right central incisor; twice for the maxillary right canine, the maxillary left central incisor, and the mandibular right second molar). However, the mean kappa was greater than 0.800, suggesting a good level of agreement.[22]

To determine intra-observer agreement for the judgment of gingival recessions in the *main study*, 80 randomly selected dental casts of 20 patients were re-evaluated by both observers (AMR and AR). The kappa values for the presence of recessions were calculated for each tooth and each time point. At pre-treatment and end of treatment, perfect agreement was found (kappa = 1) for all scored teeth. At 2 years after treatment, the agreement was perfect for 28 teeth (kappa = 1) and good or very good for the remaining teeth (kappa values of 0.67 - 0.93). At 5 years after treatment, the concordance was perfect (kappa = 1) for 26 teeth and very good for the remaining teeth (kappa values of 0.80 - 0.95). Because of the high inter-observer concordance, the scores of observer 1 (AMR) were used for further analysis. Intra-observer agreement ranged from 0.798 (for the mandibular right second molar) to 1. The mean kappa was 0.98.

5.3 Results

The prevalences of gingival recessions at the 4 assessment times are shown in Table 2. The frequencies of gingival recessions per tooth at all time points are given in Figure 4.

The overall increase of gingival recessions from pre-treatment to the end of treatment was similar in males and females ($P = 0.462$). Also, patients who had been treated without extractions showed an overall development of gingival recessions at post-treatment comparable with patients who had had extraction treatment ($P = 0.320$).

Table 2. *Gingival recessions in the region of lower incisors (Rec_Lower_Inc), the rest of the dentition (Rec_Rest), and in all teeth (Rec_All) pre-treatment (T_S), at the end of treatment (T_0), 2 years (T_2), and 5 years (T_5) after treatment*

		Rec_Lower_Inc				*Rec_Rest*				*Rec_All*			
		T_S	T_0	T_2	T_5	T_S	T_0	T_2	T_5	T_S	T_0	T_2	T_5
N without recessions		301	294	281	259	297	286	249	199	297	282	241	188
N with recessions		1	8	21	43	5	16	53	103	5	20	61	114
% with recessions		0.3	2.6	7	14.2	1.7	5.3	17.5	34.1	1.7	6.6	20.2	37.7
Number of subjects with	1 recession	1	6	15	22	2	8	20	29	2	11	21	32
	2 recessions	-	1	4	13	2	5	14	29	1	4	18	25
	3 recessions	-	1	1	5	1	2	5	15	2	2	7	20
	4 recessions	-	-	1	3	-	1	6	12	-	2	5	14
	5 recessions	-	-	-	-	-	-	4	6	-	-	2	6
	6 recessions	-	-	-	-	-	-	-	1	-	1	2	3
	7 recessions	-	-	-	-	-	-	1	2	-	-	1	2
	8 recessions	-	-	-	-	-	-	-	5	-	-	2	2
	9-14 recessions	-	-	-	-	-	-	3	4	-	-	3	10
Total number of recessions		1	11	30	75	9	28	143	315	10	39	173	390

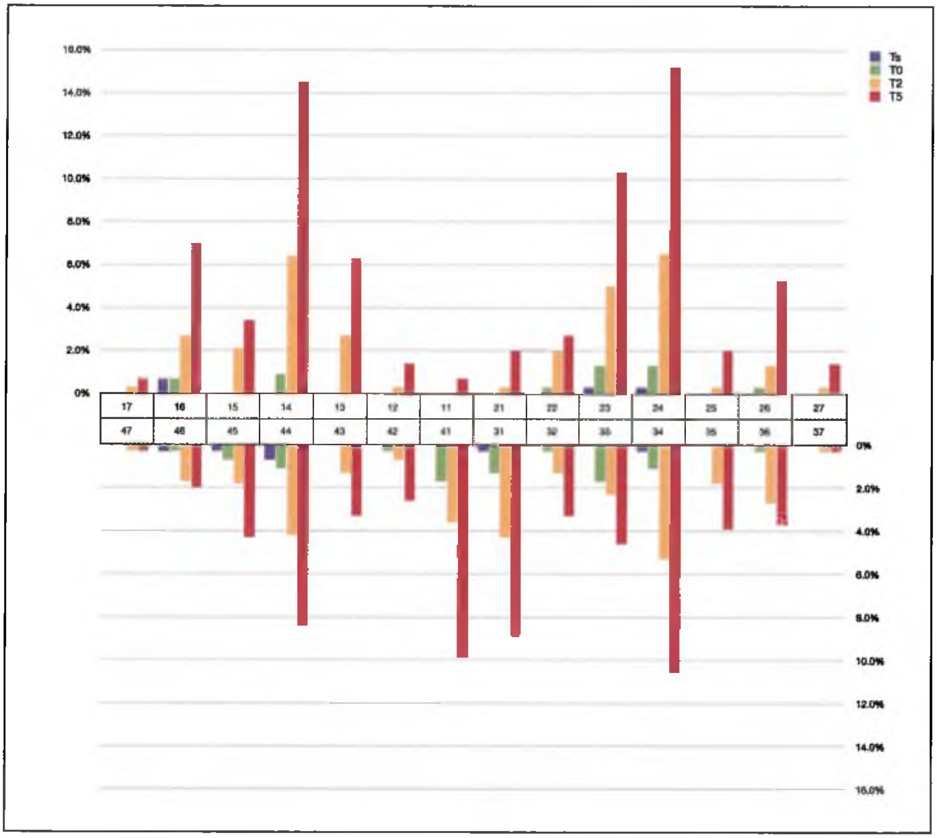

Figure 4. Frequencies (%) of gingival recessions per tooth at Ts, start of treatment; T0, end of treatment; T2, 2 years post-treatment; and T5, 5 years post-treatment

Age at the end of treatment was associated with an increased number of recessions. Patients who were younger than 16 years of age at completion of orthodontic treatment were less likely to develop recessions than patients who were 16 years or older at the end of treatment ($P = 0.013$). The type of fixed retainer—bonded to the canines only, or bonded to all 6 front teeth—did not influence the development of recessions in the mandibular front region ($P = 0.231$). Also, pre-treatment Angle classification demonstrated no association with the number of recessions at 5 years post-treatment ($P = 0.523$).

The results of the regression analyses estimating the effects of age at the end of treatment, gender, and extraction *versus* non-extraction treatment on the increased number of recessions from the end of treatment to 5 years later are presented in Table 3. The age at pre-treatment was associated with the increase of the overall number of recessions after treatment. The value of the odds ratio (OR = 1.097; *P* = 0.014) can be interpreted as follows: the risk of an increased number of recessions grows by 9.7% with each subsequent year after the end of treatment. In other words, an 18-year old patient has a 9.7% higher chance to develop more recessions 5 years after treatment than a 17-year old.

The age at the end of treatment, however, was not associated with the increase of the number of recessions in the mandibular incisor region (*P* = 0.576). Extraction treatment was found to be related to the development of recessions in the mandibular left first premolar (OR = 2.501; *P* = 0.047). No analogous relationship was found between the development of recessions in other teeth (maxillary right and left first premolars; mandibular right first premolar, and mandibular right and left central incisors) and extraction treatment (Table 3).

Table 3. *Regression models demonstrating the effects of age, gender, and treatment alternative (extraction versus non-extraction) on prevelance of gingival recessions (P = p-value; bold denotes statistical significance; OR = odds ratio; 95% CI = 95% confidence interval; F = females; M = males; Y = Yes; N = No)*

Increase in the number of recessions from T0 to T5	Independent variables	P	OR	95% CI
Overall	Age end of treatment	**0.014**	**1.097**	**[1.019...1.181]**
	Gender (F = 0; M = 1)	0.338	1.268	[0.780 ... 2.060]
	Extraction (*Y* or *N*)	0.983	0.994	[0.584 ... 1.693]
Mandibular incisors	Age end of treatment	0.576	1.026	[0.937 ... 1.123]
	Gender (F = 0; M = 1)	0.468	0.768	[0.376 ... 1.568]
	Extraction (*Y* or *N*)	0.388	1.385	[0.661 ... 2.902]
Teeth other than mand. incisors	Age end of treatment	**0.023**	**1.088**	**[1.012...1.170]**
	Gender (F = 0; M = 1)	0.058	1.617	[0.983 ... 2.659]
	Extraction (*Y* or *N*)	0.699	1.113	[0.646 ... 1.918]
Mandibular right central incisor	Age end of treatment	0.407	0.943	[0.820 ... 1.084]
	Gender (F = 0; M = 1)	0.225	0.569	[0.229 ... 1.414]
	Extraction (*Y* or *N*)	0.218	1.748	[0.719 ... 4.254]
Mandibular left central incisor	Age end of treatment	0.298	1.056	[0.953 ... 1.169]
	Gender (F = 0; M = 1)	0.732	0.855	[0.348 ... 2.101]
	Extraction (*Y* or *N*)	0.411	1.478	[0.582 ... 3.750]
Maxillary right first premolar	Age end of treatment	0.555	1.043	[0.907 ... 1.199]
	Gender (F = 0; M = 1)	0.789	1.112	[0.512 ... 2.416]
	Extraction (*Y* or *N*)	0.998	0.999	[0.352 ... 2.837]
Maxillary left first premolar	Age end of treatment	0.943	0.994	[0.840 ... 1.176]
	Gender (F = 0; M = 1)	0.607	1.222	[0.569 ... 2.627]
	Extraction (*Y* or *N*)	0.575	0.712	[0.217 ... 2.331]
Mandibular left first premolar	Age end of treatment	0.220	1.069	[0.961 ... 1.190]
	Gender (F = 0; M = 1)	0.331	1.531	[0.649 ... 3.614]
	Extraction (*Y* or *N*)	**0.047**	**2.501**	**[1.014...6.167]**
Mandibular right first premolar	Age end of treatment	**0.043**	**1.122**	**[1.004...1.253]**
	Gender (F = 0; M = 1)	0.811	1.129	[0.419 ... 3.044]
	Extraction (*Y* or *N*)	0.762	1.186	[0.392 ... 3.590]

5.4 Discussion

The aim of this investigation was to evaluate the prevalence of post-orthodontic gingival recessions and to identify variables associated with their development. Our findings demonstrate a continuous increase in the number of recessions from the beginning of orthodontic treatment to 5 years after active therapy. At baseline, 1.7% of the patients had gingival recessions; at the end of active treatment, 6.6% had them; 2 years after treatment, 20.2% had them; and 5 years after treatment, 37.7% of the patients had gingival recessions. Our results are consistent with the findings of other authors.[21,23] Thomson[21] found gingival recessions in approximately 66% of adults 8 years after orthodontic therapy. The prevalence of recessions in the present study is lower than Thomson's result, this could be due to a shorter observation time in our investigation (5 years *versus* > 8 years). Vasconcelos *et al*[23] found a higher prevalence of recessions than we observed in our study. They noticed that 10.3% of the subjects at 13.1 years of age had gingival recessions in the mandibular incisors compared with 2.6% of 16 year olds in our investigation. The discrepancy might be explained by the method of scoring: Vasconcelos *et al* assessed the presence of recessions on color slides, while we evaluated them on plaster casts.

In our cohort, gingival recessions were not equally distributed in the dental arches. Some teeth demonstrated a significantly higher prevalence of recessions than others. For example, 14% of the maxillary first premolars, as opposed to only 2 to 3% of the maxillary lateral incisors showed labial gingival recessions at 5 years post-treatment (Figure 4). Our findings are consistent with investigations of both orthodontic[2,17,18] and non-orthodontic samples,[13-15,24-26] which showed that some regions of maxillary and mandibular dental arches are *loci minores resistentiae* for the development of recessions. Typical regions where recessions develop are the maxillary first premolars and first molars and the mandibular central incisors and first premolars.

Discrepancies such as a relatively low prevalence of gingival recessions in the maxillary second premolars observed in the present study *versus* high prevalence found by Susin *et al*,[15] or the high prevalence of recessions in the mandibular central incisors in our investigation *versus* the low prevalence reported by Ainamo *et al*,[13] can be explained by differences in age at assessment, methods of evaluation, or various behavioral influences (hygiene, diet, smoking, *etc.*) that had not been controlled.

In our sample, all subjects had either a type I (Figure 2) or a type II (Figure 3) bonded retainer. The presence of a fixed retainer as an inclusion criterion was influenced by a growing trend among clinicians to use compliance-free permanent retention.[27,28] Fixed retainers are associated with increased plaque accumulation,[29,30] which can result in gingival inflammation, and, eventually, the development of gingival recessions.[31] Prevention of plaque accumulation by tooth brushing and flossing is more effective when a type I retainer is *in situ*.[32] However, we found that subjects having type I or type II retainers demonstrated comparable prevalences of labial gingival recessions in the mandibular anterior region. The lack of difference suggests that both types of retainers similarly affect the development of recessions. However, fixed retainers are attached to the lingual surfaces of the teeth, and their influence might be restricted to lingual recessions that were not assessed here.[31] Also, the 5-year observation period might have been too short to notice differences between patients wearing type I and II retainers.

The increase of gingival recessions with age, in orthodontic patients, was similar to that observed in other examined groups.[13,15,24,33] Epidemiologic studies demonstrated an age-related steady rise in the frequency and extent of recessions in populations from both more affluent[24,25,33] and poorer areas.[26,33] For example, recessions occurred in 10% of Finnish 15- to 17-year olds and in 52% of 18- to 20-year olds; i.e., their prevalence increased about 5-fold.[24] A similar trend was noticed in Brazilians; recessions were found in 30% of the 14- to 19-year olds and in 77% of the 20- to 29-year olds.[15] The data from countries in which subjects were deprived of dental care showed similar tendencies.[26,33] Our findings generally agree with the results of these studies and demonstrate the time-dependent change of the prevalence of gingival recessions (Table 3). It is noteworthy that the frequency of recessions in our cohort was overall somewhat lower than those in non-orthodontic samples.[13,24,25] This could indicate that orthodontic treatment does not pose a risk for the development of gingival recessions. Unfortunately, methodological differences (e.g. clinical *versus* plaster cast evaluations), a wide range of ages at the assessments, and other confounders (diet, hygiene, *etc.*) preclude this conclusion.

Our study showed that males and females have similar risks of developing gingival recessions. Our findings agree with those of Ainamo *et al*[13] and Susin *et al*[15] who found that the prevalence of recessions after adolescence is independent of gender. Several studies, however, demonstrated that males develop more recessions than females.[14,24,34] Paloheimo *et al*[24] observed that male subjects between 17 and 20 years of age had a higher prevalence of recessions in comparison with females, but the difference gradually diminished. Brown *et al*[34] and Albandar and Kingman,[35] showed, on the basis of the NHANES III survey, that the prevalence of recessions was significantly higher in males than in females after adjusting for age and race or ethnicity. The disagreement between our results and those of Brown *et al* and Albandar and Kingman may result from age during assessment: 21.6 years in our study *versus* over 30 years in the studies mentioned above.

To our knowledge, this is the first study of gingival recessions in a large sample of patients treated with contemporary orthodontic methods, with multiple assessments after treatment, and a long follow-up period. However, a retrospective study design, a relatively wide age range in the cohort, evaluations of plaster casts only, and a lack of assessment of periodontal parameters are limitations of this study. Furthermore, the type of tooth movement relative to the different malocclusions or regions of the jaw was not included in the analysis. Consequently, caution should be exercised during interpretation of the current findings. The shortcomings of this study, but also of other published investigations, indicate the necessity for a prospective study with (1) clinical examination before, during and after treatment, (2) stratification for gingival biotype and other variables such as hygiene, diet, smoking, and (3) a long follow-up.[36]

5.5 Conclusions

On the basis of our findings the following conclusions can be made:

1. The prevalence of labial gingival recessions depends on age and increases from the start of orthodontic treatment to 5 years after therapy.
2. Overall, the pattern of development of labial gingival recessions in orthodontic patients is similar to that observed in epidemiologic studies.
3. Canines, first premolars, and first molars in the maxilla, and central incisors and first premolars in the mandible are at the highest risk for labial gingival recessions.
4. Neither gender nor the type of retainer—plain, single wire bonded to the mandibular canines only *versus* multi-stranded wire, bonded to all mandibular anterior teeth—is associated with the development of labial gingival recessions.

5.6 References

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Chapter 6

Gingival recessions and the change of inclination of mandibular incisors during orthodontic treatment

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Eur J Orth 2013;35:249-255

Summary

A recent systematic review demonstrated that, overall, orthodontic treatment might result in a small worsening of periodontal status.

The aim of this retrospective study was to test the hypothesis that a change of inclination of the mandibular incisors promotes development of labial gingival recessions.

One hundred and seventy-nine subjects who met the following inclusion criteria were selected: age 11 to 14 years at the start of orthodontic treatment (Ts), bonded retainer placed immediately after treatment (T0), dental casts and lateral cephalograms available pre-treatment (Ts), post-treatment (T0), 2 years post-treatment (T2), and 5 years post-treatment (T5). Depending on the change of lower incisor inclination during treatment (Δ Inc_Incl), the sample was divided into three groups: *Retro* (n = 34; Δ Inc_Incl $\leq -1^{\circ}$), *Stable* (n = 22; Δ Inc_Incl $> -1^{\circ}$ and $\leq 1^{\circ}$), and *Pro* (n = 123; Δ Inc_Incl $> 1^{\circ}$). Clinical crown heights of mandibular incisors and the presence of gingival recessions in this region were assessed on plaster models. Fisher's exact tests, one-way analysis of variance, and regression models were used for analysis of inter-group differences.

The mean increase of clinical crown heights (T0 to T5) of mandibular incisors was 0.60 mm, 0.88 mm and 0.91 mm in the *Retro*-, *Stable*-, and *Pro*-group, respectively; the difference was not significant ($P = 0.103$). At T5, gingival recessions were present in 8.8%, 4.5%, and 16.3% of the patients from the *Retro*-, *Stable*-, and *Pro*-group, respectively. The difference was not significant ($P = 0.265$).

The change of mandibular incisor inclination during treatment did not affect the development of labial gingival recessions in this patient group.

6.1 Introduction

A *gingival recession* (Figure 1a and 1b) is defined as the displacement of the marginal tissue apical to the cemento-enamel junction.[1] Recessions are relatively common in Caucasian populations and their development is age-dependent—they are more prevalent in older than in younger persons. Furthermore, they are more frequently observed in maxillary than in mandibular teeth.[2] Gingival recessions negatively affect the appearance of the dentition and may cause tooth hypersensitivity and lead to root caries.[2,3]

Figure 1. Development of labial gingival recessions after orthodontic treatment: (a) immediately post-treatment and (b) 5 years later

Orthodontic treatment may promote development of recessions.[4,5] Slutzkey and Levin[4] observed that the prevalence and extent of recessions correlated with past orthodontic treatment. For example, young adults (18 to 22 years old) who had been treated orthodontically many years before showed a twice as high risk of developing gingival recessions than their untreated peers (22.9% *versus* 11.4%, respectively). Also, Bollen *et al*[5] concluded in their review that the evidence suggested a small mean worsening of periodontal status after orthodontic therapy.

The precise mechanism by which orthodontic treatment influences the occurrence of recessions remains unclear. Nonetheless, it has been assumed that the presence of a bony dehiscence is a prerequisite for the development of a gingival recession.[6] Because a bony dehiscence does not always lead to a recession,[7] other factors such as thin gingival biotype, prolonged gingivitis, or mechanical trauma during tooth brushing must coincide.[6] From the orthodontic perspective, however, a possibility of formation of alveolar bone dehiscences during treatment and the presence of gingivitis during and after therapy is most important.

Animal experiments with labial movement of lower incisors in monkeys[8,9] demonstrated the development of bone dehiscences and subsequent loss of periodontal attachment. Although other experiments were less unequivocal,[10] it seems possible that labial movement of incisors in humans may be a risk factor for gingival recessions. Several studies addressed this problem, but their conclusions were contradictory. Some publications showed an association between incisor proclination and development of recessions[11,12,13] and others demonstrated the lack of such correlation.[14,15] Most of them, however, assessed periodontal status immediately or within a few months after orthodontic therapy.

Orthodontic treatment is followed by a period of retention. Fixed retainers, a common type of retention device,[16] are associated with increased accumulation of bacterial plaque.[17] Observations that teeth with loss of periodontal attachment showed signs of gingival inflammation,[9,18] suggest the association between a plaque-induced gingivitis and development of recessions.

The objective of this study was to test the research hypothesis that an increase or decrease of lower incisor inclination during treatment followed by permanent retention with fixed retainers results in an increase of the clinical crown heights and development of gingival recessions.

6.2 Materials and Methods

6.2.1 Materials

The post-treatment archive in the Department of Orthodontics and Craniofacial Biology of the Radboud University Medical Centre Nijmegen, the Netherlands, was searched to identify all subjects meeting the following inclusion criteria: (1) age from 11 to 14 years at the start of orthodontic treatment (Ts), (2) presence of four fully erupted lower incisors before and after treatment, (3) a bonded canine-to-canine retainer placed directly after active orthodontic treatment with full fixed appliances, (4) no visible wear of lower incisal edges, (5) no retreatment, and (6) dental casts and lateral cephalometric radiographs available before treatment (Ts), after treatment (T0), 2 years after treatment (T2), and 5 years after treatment (T5).

One hundred and seventy-nine subjects (77 males and 102 females) met the inclusion criteria. Based on the amount and direction of change of the lower incisor inclination during treatment (Δ Inc_Incl from Ts to T0), the sample was divided into three groups:

1. *Retro*-group ($n = 34$); Δ Inc_Incl ≤ -1° (range: -15° to -1°)
2. *Stable*-group ($n = 22$); Δ Inc_Incl > -1° and ≤ 1° (range: -0.5° to 1°)
3. *Pro*-group ($n = 123$); Δ Inc_Incl > 1° (range: 1.5° to 22.5°)

6.2.2 Methods

The distances between the incisal edges and the deepest points of the curvature of the vestibulo-gingival margin of all four mandibular incisors (Figure 2), corresponding with the *clinical crown heights*, were measured on the plaster models made at Ts, T0, T2, and T5. The measurements were made by one investigator (AMR) with an electronic caliper (Digital 6, Mauser, Winterthur, Switzerland) with an accuracy of 0.01 mm. Pre-existing gingival recessions may indicate high individual susceptibility to the development of recessions. Therefore, the presence of pre-treatment (T_s) recessions in all teeth was scored as *Yes/No* on the plaster models (Figure 2) independently by two calibrated observers (AMR and AR). The presence of gingival recessions 5 years after treatment (at T5) was scored only for the lower incisors. A recession was noted (scored *Yes*) if the labial cemento-enamel junction was exposed.

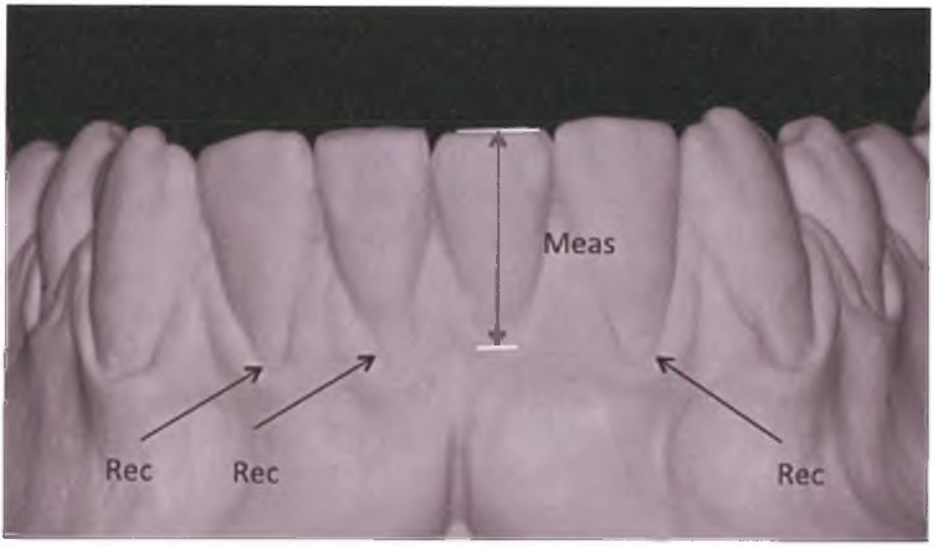

Figure 2. Example of measurement of the clinical crown height (Meas) and gingival recession (Rec) scored as present

The validity of measuring clinical crown heights and identifying gingival recessions on plaster models was assessed in a *pilot study* that was performed in 30 randomly selected adult patients (mean age 42.0; SD, 10.4; range 18.1 to 54.8 years). First, an observer (AMR) measured clinical crown heights of the four lower incisors in a patient—sitting in the dental chair—with the electronic caliper. Then, during this clinical examination, the presence of gingival recessions in all regions of the dental arch was scored as *Yes* or *No*. Finally, upper and lower alginate impressions were taken to make plaster casts. After 3 months, the same assessment—measuring the clinical crown heights and scoring the presence of gingival recessions—was performed on the plaster casts by the same observer (AMR).

The following landmarks were identified and traced on the lateral cephalometric radiographs taken at Ts, T0, T2, and T5: incisal edge (*ie*) and apex (*ap*) of the lower incisor, *menton* (the lowest point of the mandibular symphysis), and *gonion* (the most inferior posterior point of the mandibular angle). The *incisor inclination* was determined at all time points as the angle between the line connecting *ie* and *ap* and the line connecting *menton* and *gonion* landmarks.

Information on gender, age at Ts, T0, T2, and T5, and extraction *versus* non-extraction treatment type was obtained from the patient files.

6.2.3 Methods error

To determine the inter- and intra-observer agreement for the clinical crown height, inclination of the lower incisors, and presence of gingival recessions, 80 dental casts and 20 lateral cephalograms of 20 randomly selected subjects were re-evaluated by two observers (AMR and AR) after more than 1 month.

Spearman's correlation coefficients, duplicate measurement error (DME), and paired *t*-tests were computed to evaluate error of determination of clinical crown heights and lower incisor inclination. The DME was calculated as the SD of the difference between paired scores, divided by $\sqrt{2}$. The kappa statistic was calculated to assess the strength of agreement for scoring the presence of recessions.

6.2.4 Statistical analysis

In the pilot study, Spearman's correlation coefficients and paired *t*-tests were used to analyze the difference between the clinical and model measurements; the kappa statistic was used to express the agreement between the clinical and model assessments for the gingival recessions.

Descriptive statistics (means and SDs) were calculated. Fisher's exact tests were computed to evaluate the inter-group difference in distribution of gender, extraction *versus* non-extraction treatment type, and presence of recessions. One-way ANOVA (analysis of variance) was used to assess the inter-group differences regarding age at Ts, T0, T2, and T5, incisor inclination at Ts, T0, T2, and T5, treatment time, and post-treatment time (from T0 to T2 and from T0 to T5).

Regression analysis was performed to investigate an association between the change of clinical crown heights from T0 to T5 (dependent variable) and age at T0, group (*Retro*, *Stable*, and *Pro*), and gender (independent variables).

6.3 Results

6.3.1 The pilot study

The correlation between the measurements of crown heights performed clinically and on plaster models was 0.986. However, statistically significant differences between clinical and model measurements were found—the crown heights of the lower incisors measured clinically, were approximately 0.1 mm larger than when measured on plaster models.

The level of agreement between scoring recessions clinically and on plaster models was very good. Clinically, 147 recessions in various regions of the dental arch were found in 20 of 30 patients, whereas on plaster models 137 recessions were found. The kappa was > 0.800 suggesting a very good concordance.

6.3.2 Methods error

For the clinical crown height, the coefficients of reliability ranged between 0.973 and 0.995. One statistically significant difference of the clinical crown height measurements between both observers was found at Ts (tooth 42). No differences were found at To, whereas seven differences were identified at T2 and T5. All these differences were small, with a maximum of 0.04 mm. The DME for the clinical crown height ranged between 0.07 and 0.17 mm.

Regarding the Inc_Incl at the four points in time, the reliability between the two observers ranged between 0.985 and 0.988. The difference between the two observers was statistically significant at all points in time, with the mean difference between the observers ranging between 0.23° and 0.46°. The DME for the inclination ranged between 0.81° and 0.91°.

6.3.3 Sample

The proportion of males in the *Pro*-group (62.6%) was higher than in the *Retro*- and *Stable*-group (44.1% and 40.9%, respectively; $P = 0.046$). The proportion of extraction *versus* non-extraction treatment was comparable in the groups ($P = 0.229$). The *Retro*-, *Stable*-, and *Pro*-group were also well-matched regarding age at Ts (mean 12.4 years), age at T0 (mean 15 years), treatment time (Ts to T0, 2.8 years), and post-treatment time (T0 to T2, 2.4 years; T0 to T5, 5.4 years). Other demographic data of the sample are presented in Table 1.

Pre-treatment Inc_Incl was largest in the *Retro*-group (98.3°) and smallest in the *Pro*-group (91.3°), whereas end-of-treatment (T0) Inc_Incl was largest in the *Pro*-group (99.1°) and smallest in the *Retro*-group (94.4°). From T0 to T5, Inc_Incl did not change in the *Retro*- and *Pro*-groups, and increased by 2° in the *Stable*-group. The DME for the inclination ranged between 0.81° and 0.91°.

Table 1. *Characteristics of the Retro-, Stable-, and Pro-group**

	Retro	Stable	Pro	*P* value	Paired differences
Age at Ts	12.52 (0.88)	12.38 (0.86)	12.32 (0.74)	0.415	-
Age at T0	15.31 (1.26)	14.83 (1.24)	14.99 (0.99)	0.193	-
Tx time (Ts-T0)	2.79 (0.75)	2.45 (1.03)	2.67 (0.73)	0.453	-
Time from T0-T2	2.46 (0.49)	2.68 (0.59)	2.40 (0.51)	0.070	-
Time from T0-T5	5.56 (0.43)	5.59 (0.44)	5.39 (0.41)	0.024	-
Inc_Incl at Ts	98.32 (6.20)	97.23 (6.18)	91.33 (6.18)	<0.001	R vs P; S vs P**
Inc_Incl at T0	94.35 (6.48)	97.36 (5.96)	99.09 (6.21)	0.001	R vs P
Inc_Incl at T2	94.66 (6.75)	99.05 (6.45)	99.50 (6.49)	<0.001	R vs S; R vs P
Inc_Incl at T5	94.47 (7.04)	99.34 (6.64)	99.91 (6.73)	0.001	R vs S; R vs P

**All values are in years or degrees. Standard deviations are given in parentheses. Inter-group differences are analyzed with ANOVA tests; paired comparisons are made with post hoc Tukey's tests.* **R = *Retro*; S = *Stable*; P = *Pro*

6.3.4 *Gingival recessions*

No gingival recessions were found before treatment (Ts) in any of the subjects from the *Retro*-, *Stable*-, and *Pro*-group. Five years after treatment (T5), gingival recessions were present in 3 (8.8%), 1 (4.5%), and 20 (16.3%) patients from the *Retro*-, *Stable*-, and *Pro*-group, respectively. However, the difference was not statistically significant ($P = 0.265$).

6.3.5 *Clinical crown height*

The mean increase of clinical crown heights of the lower incisors was 0.60 mm, 0.88 mm and 0.91 mm in the *Retro*-, *Stable*-, and *Pro*-group, respectively (Table 2). The only statistically significant inter-group difference was a larger increase of the clinical crown height of tooth 41 in the *Pro*-group in comparison with the *Retro*-group—0.83 mm in the former and 0.43 mm in the latter group ($P = 0.049$; 95% CI -0.80 ... -0.01). The regression analysis (Table 3) showed that none of the independent variables had an effect on the change of clinical crown heights of lower incisors.

Table 2. *The mean increase (mm) of clinical crown heights of lower incisors after treatment (from To to T5)**

Tooth number	Retro	Stable	Pro	*P* value	95% Confidence interval		
					R *versus* S	R *versus* P	S *versus* P**
32	0.81 (0.76)	0.92 (0 50)	1.05 (0 88)	0 274	[-0.64 to 0 42]	[-0.62 to 0 12]	[-0.59 to 0.31]
31	0.58 (0.61)	0.57 (0.70)	0.79 (0.86)	0.244	[-0.51 to 0.53]	[-0.58 to 0.15]	[-0.66 to 0.21]
41	0 43 (0.71)	0.63 (0 76)	0 83 (0.91)	0.049	[-0.75 to 0 36]	[-0 80 to -0.01]	[-0.68 to 0.27]
42	0.79 (0.67)	0.95 (0.85)	0.97 (0.71)	0.439	[-0.63 to 0.31]	[-0.51 to 0.15]	[-0.41 to 0.38]
Mean	0 60 (0 69)	0 88 (0 80)	0 91 (0.84)	0 103	[-0.54 to 0.31]	[-0.56 to 0.04]	[-0.50 to 0 21]

**Standard deviations are given within parentheses.* ***R = Retro; S = Stable; P =* Pro

Table 3. *Results of regression analysis**

	Coefficients *(B)*	*P* value	Lower limit of 95% CI	Upper limit of 95% CI**
(Constant)	64.23	<0.001	27.97	100.5
Age at Ts***	-3.44	0.612	-16.81	9.93
Gender****	12.82	0.236	-8.45	34.09
Retro-group	-6.25	0.744	-44.04	31.53
Pro-group	22.32	0.174	-9.93	54.57

**The Stable-group was used as a reference group in the regression model. **CI = Confidence interval. ***Age above 11 years. ****Female = 0; male = 1*

6.4 Discussion

Orthodontic treatment is frequently an elective procedure performed mostly for aesthetic reasons.[20] Gingival recessions may compromise therapeutical outcome because they may adversely affect dentofacial aesthetics or cause tooth hypersensitivity. Although their etiology is not clear, occurrence of gingival recessions may be associated with past orthodontic treatment.[4] Given that a gingival recession may be the unwanted effect of orthodontic therapy, identification of factors conducive to development of recessions is of great importance. In this study, we searched for a relationship between the change of inclination of lower incisors during treatment (Δ Inc_Incl) and the development of gingival recessions in the area of mandibular incisors.

Our results show that despite the difference in the amount and direction of lower incisor inclination during treatment, the increase of clinical crown heights was similar in our study groups. Neither proclination nor retroclination of the lower incisors nor maintaining them in the original positions affected the development of recessions 5 years after orthodontic treatment. Although we found that the increase of the clinical crown height in tooth 41 in the *Pro*-group was larger than in the *Retro*-group (Table 2), the difference was limited to only one tooth and the change of clinical crown heights of the remaining incisors was comparable. Moreover, the inter-group difference for tooth 41 resulted from less increase of the clinical crown height in the *Retro*-group rather than larger increase in the *Pro*-group. Thus, the current findings seem to be in agreement with the results of Ruf *et al,*[14] Årtun and Grobéty,[20] and Djeu *et al.*[15] Ruf and associates[14] analyzed the changes in mandibular incisor inclination in teenagers treated with the Herbst appliance and development of gingival recessions 6 months after treatment. They found that the mean proclination of lower incisors by 8.9° did not increase the risk of recessions. Also, the comparison of patients with maximal proclination (mean = 16.4°) and minimal proclination (mean = 2.7°) did not reveal any significant differences for crown height or for the incidence of recession between the subgroups. Djeu *et al*[15] made a similar finding in adolescent and post-adolescent patients treated with fixed appliances in whom lower incisors had been proclined by 5 degrees. They reported that proclination of mandibular incisors was not correlated to gingival recessions. Årtun and Grobéty,[20] in turn, followed the group of 10-year olds with Class II malocclusion, who had been treated with reverse headgear to the mandibular dentition, until 22 years. They reported no difference in the increase in clinical crown height from after treatment to follow-up.

Several other studies, however, found the association between a change of inclination of lower incisors and an increased risk of gingival recessions. Sperry *et al*[21] investigated Class III patients who had been orthodontically treated without surgery 9.2 years earlier. They found more gingival recessions in their group than in a combined Class I/Class II control group. Unfortunately, the large difference in mean age between the groups (9.5 years) makes their finding difficult to interpret. Ngan *et al*[22] observed that retroclination of mandibular incisors in patients, who already had labial recessions, resulted in a decrease of severity of recessions. Årtun and Krogstad[11] found that excessive proclination of lower incisors during the combined orthodontic-surgical treatment of Class III subjects led to retraction of the gingival margin during the 3 years post-treatment—only minimal changes were noted after the next 5 years. Also, Allais and Melsen[12] observed that at the end of orthodontic treatment of adult patients, lower incisors demonstrated more gingival recessions than untreated controls. The discrepancy between our findings and the results of other authors can be explained by inclusion of subjects with recessions in the study group[22] or evaluation of patients with a Class III malocclusion,[11,21] who might have had a thinner gingiva and were more prone to recessions. Allais and Melsen,[12] in turn, found only minimal

(<0.2 mm) differences in crown heights between treated and untreated individuals, which were within the error of measurement.

All subjects in our sample had fixed lower retainers during the whole 5-year post-treatment period. We selected patients with bonded canine-to-canine retainers because it is a popular type of retention of the mandibular dental arch. Furthermore, a growing trend among clinicians is to use compliance-free permanent retainers.[16,23,24] This makes that the evaluation of this group provided clinically relevant information. Increased plaque retention is one of the disadvantages of fixed retainers. This may result in prolonged gingival inflammation and bleeding on probing.[25] Although we did not measure periodontal parameters (indices) in this study, it is likely that many patients had calculus accumulation as shown by Pandis *et al.*[17] How an accumulation of calculus around a bonded retainer promotes gingival recessions is unclear because recessions develop primarily labially, whereas the retainer is bonded lingually. Nonetheless, it has been hypothesized[17] that, if mandibular incisors retained with a bonded appliance for long periods of time are proclined, this may cause attachment loss, leading to gingival recessions. Our findings do not confirm this hypothesis. The increase of clinical crown heights was similar irrespective of the change in inclination. However, it cannot be ruled out that it is possible to identify an association between incisor inclination and development of gingival recessions if the observation period had been longer.

Previous researchers used intraoral photographs for evaluation of periodontal status.[12,20] For example, Allais and Melsen[12] utilized colour slides and found that the number of unreadable teeth was larger when the assessment was performed on casts than when done on slides. They considered intraoral images as a better medium for analyzing gingival recessions. However, we noticed that many of our intraoral photographs were unreadable, usually due to the lip retractor covering the gingiva. Consequently, after validation of the use of plaster models for analysis of gingival recessions in a pilot study, we only used dental casts.

Presence of gingival inflammation, baseline recession, a gingival biotype, and a narrow width of keratinized gingiva were found to affect development of gingival recessions.[26] Particularly, a delicate—thin—gingiva and on-going gingivitis are considered as the crucial factors promoting development of recessions.[6] Wennström[6] stated that labial tooth movement *per se* would not cause recession, but the thin gingiva that would be the consequence of the labial tooth movement might serve as a *locus minores resistentiae*, i.e. a recession might develop in case of improper tooth brushing or bacterial plaque accumulation leading to gingival inflammation. The limitation of this investigation is that the above-mentioned periodontal parameters were not assessed and that we only evaluated the presence of baseline—pre-treatment (Ts)—recessions. Due to the retrospective nature of the current study, it is possible that periodontal variables, unequally distributed in the groups, overrode the effect of the change of incisor inclination on the occurrence of recessions.

Our results indicate the necessity of a prospective study with clinical examination before, during and after treatment, stratification for gingival biotype and various types of malocclusion, and a long follow-up. The recent systematic review identified only studies that provided a low or moderate level of scientific evidence.[26] Most publications included in the review suffered from a retrospective design and examinations of clinical data like gingival height, gingival biotype, or width of attached gingiva on intraoral photographs or plaster casts. A minority of trials included clinical measurements of these gingival parameters but only at the follow-up examination. Because smoking and inadequate hygiene resulting in gingival inflammation are associated with gingival recessions,[6] these parameters should also be monitored during treatment. Furthermore, the sample composition and length of follow-up are of importance. Årtun and Krogstad[20] found that recessions induced by orthodontic treatment developed primarily during the first 3 years after treatment with little progress afterwards. However, they assessed periodontal status in patients treated surgically for Class III malocclusion. Patients with this type of malocclusion and treatment modality are not representative for a typical orthodontic patient population, which comprises subjects with Class I and Class II malocclusions. Extending the observation period over 3 years post-treatment also seems justified in the light of findings that, overall, orthodontic therapy increases the risk of gingival recessions.[4]

It should be stressed that orthodontic treatment *per se* may be conducive to the development of gingival recessions irrespective of the direction of tooth movement. Elucidation of this issue would require a control group comprising subjects not treated orthodontically and, unfortunately, this was beyond the scope of our study.

6.5 Conclusions

Based on the findings of this study, we conclude that the change of lower incisor inclination during orthodontic treatment did not affect the development of labial recessions in this patient group.

A prospective study, that takes into consideration additional factors which could influence the development of gingival recessions, is needed to elucidate the role of change of lower incisor inclination on the development of gingival recessions during orthodontic treatment and permanent retention. The design of such a study should include (1) clinical examination before, during, and after treatment, (2) stratification for gingival biotype, (3) various types of malocclusion, and (4) a long observation period.

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Chapter 7

Labial gingival recessions in orthodontically treated and untreated individuals—a case-control study

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J Clin Period 2013;40:631-637

Summary

Objectives

To evaluate the long-term development of labial gingival recessions during orthodontic treatment and the retention phase.

Methods

In this retrospective case-control study the presence of gingival recession was scored (*Yes* or *No*) on plaster models of 100 orthodontic patients (*cases*) and 120 *controls* at the age of approximately 12 (T12), 15 (T15), 18 (T18), and 21 (T21) years. In the treated group, T12 reflected the start of orthodontic treatment, and T15 the end of active treatment and the start of the retention phase with bonded retainers. Independent *t*-tests, Fisher's exact tests and a fitted two-part "hurdle" model were used to identify the effect of orthodontic treatment/retention on development of recessions.

Results

The proportion of subjects with recessions was consistently higher in *cases* than *controls*. Overall, the odds ratio for orthodontic patients as compared with controls to have recessions is 4.48 ($P < 0.001$; 95% CI: 2.61 ... 7.70).

Conclusions

Within the limits of the present study design, orthodontic treatment and/or the retention phase may be risk factors for the development of labial gingival recessions. In orthodontically treated subjects mandibular incisors seem to be the most vulnerable to the development of gingival recessions.

Clinical relevance

Scientific rationale for the study: although gingival recessions are present in the majority of adults, it remains unclear how orthodontic treatment and/or the retention phase affect their development. *Principal findings:* orthodontic treatment and/or the retention phase may promote the development of labial gingival recessions. Mandibular incisors are relatively more vulnerable to the development of recessions. *Practical implications:* risk factors for the development of gingival recessions should be investigated in a prospective study.

7.1 Introduction

A *gingival recession* is characterized by the displacement of the marginal tissue apical to the cemento-enamel junction with exposure of the root surface.[1] Localized gingival recession and ensuing root exposure may represent an aesthetic problem to the patient, and it is often related to root sensitivity.[2,3]

The occurrence of gingival recessions is age-dependent and their development begins relatively early in life.[4-7] For example, gingival recessions were noticed in more than 60% of Norwegian 20-year-olds and in more than 90% of the older population (above 50 years).[4] Similar trends were found in Brazil[5] and France.[6] In populations deprived of dental care the occurrence of gingival recessions was even higher.[4]

Although the etiology of gingival recessions remains unclear, several predisposing factors have been suggested. A high proportion of individuals with gingival recessions in populations with high standards of oral hygiene[6] implies that mechanical and anatomic factors likely play a role.[8,9] An "improper" tooth brushing method has been proposed as the most important mechanical factor contributing to the development of gingival recessions.[10] An aggressive cleaning technique may lead to mechanical destruction, which is influenced by horizontal scrubbing with excessive force and the use of hard toothbrushes. Among anatomical variables, a thin gingival biotype and a reduced thickness of the alveolar bone due to abnormal tooth position in the arch, individual tooth shape, the presence of dehiscence/fenestration, or an aberrant path of eruption seem particularly relevant.[8]

Another etiological factor of gingival recession may be the active orthodontic treatment and/or retention phase. There are several possible ways how orthodontic therapy can influence the development of gingival recessions. The movement of teeth, especially the movement of teeth to positions outside the labial or lingual alveolar plate could result in thinning of the alveolar plate or even dehiscence formation.[11] Consequently, a marginal gingiva without alveolar bone support can migrate apically leading to root exposure. Moreover, orthodontic patients are strongly advised to maintain ideal oral hygiene to prevent plaque accumulation around orthodontic appliances. Intensive tooth brushing, however, may contribute to mechanical destruction of gingival tissue, particularly if a habit of vigorous tooth cleaning continues indefinitely. Furthermore, an active orthodontic treatment is typically followed by a retention phase. Many clinicians use fixed multi-stranded wire retainers in the anterior regions of the maxillary and mandibular arch, around which plaque may accumulate.[12] As a result, a recession-conducive gingivitis may develop.

Considering that the prevalence of gingival recessions increases with age, the long-term effects of orthodontic treatment on the occurrence of recessions can be assessed only in the context of their natural history in non-treated controls. There are only two publications[12,13] that compared the development of gingival recessions in patients who had been treated more than 5 years before, to non-treated controls. Their results are contradictory—Thomson[13] observed no effect of orthodontic treatment on gingival recessions, whereas Slutzkey and Levin[14] found a positive association between the past orthodontic therapy and the occurrence of gingival recessions. A possible explanation of these conflicting results is that the proportion of gingival recessions at baseline was not evaluated in any of the above investigations. Thus, one cannot exclude that orthodontically treated and untreated subjects differed regarding the prevalence of recessions at the beginning of the observation period in the studies by Thomson[13] and by Slutzkey and Levin.[14]

Therefore, the aim of the present investigation was to evaluate the development of labial gingival recessions in orthodontic patients, 6 years after completion of therapy, in comparison to non-treated controls. Our null hypothesis (Ho) was that the prevalence of gingival recessions after orthodontic therapy is the same as in non-treated controls.

7.2 Material and Methods

In this retrospective case-control study two samples were followed longitudinally: *cases* for 8.2 years and *controls* for 9.6 years.

7.2.1. Study group (cases)

The post-treatment archive at the Department of Orthodontics and Craniofacial Biology of the Radboud University Medical Centre Nijmegen, the Netherlands, was searched for subjects meeting the following inclusion criteria: (1) treated with full fixed appliances, (2) a lingual bonded retainer placed directly after active orthodontic treatment, (3) no orthodontic re-treatment, (4) initial, end-of-treatment, and long-term after treatment dental casts made at the ages of approximately 12 (pre-treatment, T12), 15 (end-of-treatment, T15), 18 (long-term, T18), and 21 (long-term, T21) years available. The choice of age range resulted, on one hand, from timing of initiation of typical orthodontic treatment, and, on the other hand, was influenced by timing of collection of records in the control group. All patients in the study group had a lingual retainer—either bonded to the mandibular canines only or bonded to all six mandibular anterior teeth—during the entire post-treatment period. In all patients, four mandibular incisors were present at T12 and T21. Exclusion criteria were: (1) combined orthodontic/surgical treatment, (2) restorative treatment (except for single crowns) after orthodontic treatment, and (3) dental casts of poor quality, particularly in the area of the gingival margin.

Demographic data, such as gender, age at T12, T15, T18, and T21, and type of retainer were obtained from the patient files. Angle classification was determined on the right side of the initial (T12) plaster models. All *cases* were born between 1967 and 1986.

7.2.2 Control group

The control group consisted of healthy subjects drawn from the archives of the Nittedal Growth Material, a longitudinal study conducted by the Department of Orthodontics, University of Oslo, Oslo, Norway, and described in detail in previous articles.[15,16]

In summary, the records—dental models, cephalometric radiographs, and facial photographs—were collected within a 20-year period from subjects born between 1958 and 1972 and called for dental examination at 6 years and then every 3 years until the age of twenty-one. All participants were Norwegian Caucasians with a normal occlusion in the sagittal, transversal, and vertical dimensions with only minor deviations such as rotations and/or spacing at the age of 18 years, and no apparent facial disharmony. None of the participants had undergone orthodontic treatment.[16] Inclusion criteria for the purpose of this study were: (1) dental casts made at the age of 12 (T12), 15 (T15), 18 (T18), and 21 (T21) available, and (2) presence of full dentition at T21 (except for wisdom teeth). Exclusion criteria were: (1) missing tooth/teeth, (2) restorative treatment (except for single crowns) and (3) dental casts of poor quality, particularly in the area of the gingival margin.

Study size analysis was not performed before initiation of the investigation. Instead, all eligible subjects were included in the study.

7.2.3 Measurements

The outcome variable was the presence of gingival labial recessions in all teeth, which was scored (*Yes* or *No*) on plaster models at T12, T15, T18, and T21 in *cases* and *controls*. A recession was noted (scored *Yes*) if the labial cemento-enamel junction was exposed. The judgment was done independently by two calibrated observers (AMR and AR) after meticulous inspection of the models.

It was agreed that in case of doubt whether a recession is present, it was scored "No recession". Observers were not blinded to the origin of dental casts (i.e. whether they scored *cases* or *controls*). Potentially confounding variables such plaque accumulation, bleeding on probing of gingival pockets, smoking, tooth-brushing habits were unknown to the authors and were not included in the analysis.

7.2.4 Method validation and examiners' calibration

The validity of the use of plaster casts for scoring recessions was performed in 30 randomly selected adult patients (mean age 42.0 years; SD = 10.4; range: 18.1 - 54.8 years). First, one observer (AMR) scored (*Yes* or *No*) the presence of gingival recessions in all regions of the dental arch during clinical examination. Then, upper and lower alginate impressions were taken to make plaster models. Finally, the same observer determined the presence of gingival recessions on plaster models three months after clinical examination. The kappa statistic was used to assess agreement between clinical and plaster model ratings.

To determine intra-observer agreement for the judgment of gingival recessions, 80 randomly selected dental casts of 20 patients were re-evaluated by both observers (AMR and AR).

7.2.5 Statistical analysis

Fixed retainers bonded to mandibular anterior teeth might have influenced the development of recessions. As a result, the recessions were analyzed as: (1) recessions in the lower incisors (*Rec_Lower_Inc*), (2) recessions in the rest of dentition (*Rec_Rest*), and (3) recessions in all teeth (*Rec_All*).

Descriptive statistics with means and standard deviations were calculated to report the findings at T12, T15, T18, and T21. The kappa statistic was used to assess the agreement between the two scores for the gingival recessions, one obtained by clinical examination and the other obtained by scoring plaster models (method validation), and for inter- and intra-observer concordance (the main study).

Independent *t*-tests were used to identify inter-group differences in age at T12, T15, T18, and T21. Fisher's exact tests were run to identify the difference in gender proportion between the groups and the difference in prevalence of recessions between cases and controls at T15, T18, and T21. Because no recessions were found at T12 for this group no comparisons were made. Moreover, Fisher's exact tests were used to identify an association between the Angle classification and prevalence of recessions in cases at T21.

To estimate the influence of age and orthodontic treatment on the prevalence of recession, a two-part "hurdle" model was fitted.[16] The first part is a logistic regression model estimating the chance of having recessions (the hurdle). The second part is a truncated negative binomial model, which estimates the number of recessions, in case the hurdle is passed. For both parts of the model, orthodontic treatment *versus* no treatment and age were used as independent variables. Sensitivity analyses were not carried out.

7.3 Results

7.3.1 Method validation and examiners' calibration

Clinically, 147 recessions were identified in 20 of 30 patients, whereas 137 recessions were identified in 20 of 30 plaster models. Looking per type of tooth, in 21 of 28 teeth the clinical and model scores were identical (kappa = 1). The mean kappa for all teeth was > 0.800 suggesting a very good level of agreement.[18]

7.3.2 Inter- and intra-observer agreement

The kappas for the presence of recessions were calculated for each tooth and each time point. The mean kappa for inter-observer agreement for all teeth > 0.850 (range: 0.67 – 1) suggests almost perfect agreement. Consequently, the scores of observer 1 (AMR) were used for further analysis. Intra-observer agreement ranged from 0.798 (for tooth 47) to 1. The mean intra-observer kappa was 0.98.

7.3.3 Sample

Of the 500 potentially eligible *Treated* subjects, 100 were confirmed eligible and included in the study. Of the 4229 potentially eligible *Untreated* subjects, 120 had dental casts made at T12, T15, T18, and T21 available. All of them met inclusion/exclusion criteria, were confirmed eligible, and included in the investigation. The proportion of males was slightly higher in the *Treated* than in the *Untreated* group (42% *versus* 34.2%, respectively) but the difference was statistically insignificant (P = 0.265). Both groups were not perfectly matched regarding the age of assessment (Table 1). At T12, the *cases* were 4 months older in comparison to the controls. At T18 and T21, however, *cases* were younger than *controls* by 11 and 12 months, respectively.

Initial orthodontic diagnosis (at T12) was different in the *Treated*- and *Untreated*-group—13% of the *cases* and 50.8% of the *controls* had Angle Class I malocclusion, whereas 87% of the *cases* and 46.7% of the *controls* had Angle Class II malocclusion. None of the *cases* and 2.5% of the *controls* was diagnosed with Angle Class III malocclusion. No association between Angle Class and number of recessions in *cases* was found (P = 0.938).

Table 1. *Age at the time of evaluation in **cases** (Treated) and **controls** (Untreated) assessed with a t-test*

	Treated (N = 100)		Untreated (N = 120)				
	Mean	SD	Mean	SD	Difference	P	95% CI
T12	12.13	0.54	11.82	0.38	0.31	<0.001	[0.190...0.436]
T15	14.86	0.68	14.80	0.38	0.06	0.368	[-0.078...0.209]
T18	17.24	0.84	18.13	0.37	-0.89	<0.001	[-1.051...-0.714]
T21	20.37	0.86	21.37	0.55	-1.00	<0.001	[-1.183...-0.804]

SD = *Standard deviation*; P = *P-value*; CI = confidence interval

The orthodontic treatment in *cases* was started at T12 and completed at T15. The mean length of orthodontic treatment was 2.8 years and ranged from 1.4 to 4.4 years.

7.3.4 Labial gingival recessions

The proportion of subjects with at least one recession in the *Treated-* and *Untreated*-group is presented in Table 2. Because no recessions were found at T_{12}, this age group was not analyzed. At the remaining points in time, the proportion of subjects with (a) recession(s) was consistently higher in orthodontically treated than in untreated subjects.

The prevalence of gingival recessions in the *Rec_All, Rec_Lower_Inc*, and *Rec_Rest* regions at T15, T18, and T21 is shown in Table 3a, 3b, and 3c. In each region, gingival recessions were more prevalent in *cases* than *controls*. Also, there is a trend for orthodontic patients to have more recession sites.

Table 2. *Proportion of subjects with at least one recession (in %) in **cases** (Treated) and **controls** (Untreated) assessed with a Fisher's exact test*

	Treated (N = 100)	Untreated (N = 120)	P-value
T12	0	0	*
T15	5	0	0.018
T18	15	5	0.019
T21	35	16.7	0.003

Table 3a, 3b, and 3c. *Development of labial gingival recessions in **cases** (Treated) and **controls** (Untreated); N = number of subjects*

Table 3a	*Recessions in all teeth*					
	Treated (N = 100)			Untreated (N = 120)		
	T15	T18	T21	T15	T18	T21
N with recessions	5	15	35	0	6	20
% with recessions	5	15	35	0	5	16.7
N with 1-2 recessions	4	10	18	0	5	14
N with 3-4 recessions	1	4	14	0	1	5
N with 5 or more recessions	0	1	3	0	0	1
Total number of recessions	***9***	***35***	***105***	***0***	***8***	***39***

Table 3b	*Recessions in lower incisors*					
	Treated (N = 100)			Untreated (N = 120)		
	T15	T18	T21	T15	T18	T21
N with recessions	1	2	13	0	0	2
% with recessions	1	2	13	0	0	1.7
N with 1-2 recessions	1	2	11	0	0	2
N with 3-4 recessions	0	0	2	0	0	0
N with 5 or more recessions	0	0	0	0	0	0
Total number of recessions	***1***	***4***	***21***	***0***	***0***	***2***

Table 3c	*Recessions in rest of the dentition*					
	Treated (N = 100)			Untreated (N = 120)		
	T15	T18	T21	T15	T18	T21
N with recessions	4	14	31	0	6	20
% with recessions	4	14	31	0	5	16.7
N with 1-2 recessions	3	10	19	0	5	15
N with 3-4 recessions	1	3	9	0	1	4
N with 5 or more recessions	0	1	3	0	0	1
Total number of recessions	***8***	***31***	***84***	***0***	***8***	***37***

For example, in the *Rec_All* region, approximately twice as many *cases* as *controls* had recessions at T21—the inter-group difference was particularly large for subjects with more than 2 recession sites. At T21, 14% *cases* and 4.2% *controls* had 3-4 teeth with recessions and 3% *cases* and 0.8% *controls* developed 5 or more sites with a gingival recession. The difference was smaller for subjects with < 3 teeth with recessions—18% cases and 11.7% controls had 1-2 sites with gingival recessions (Table 3a).

Using the hurdle model, overall, the odds ratio (OR) for *cases* as compared to *controls* to have recessions is 4.48 ($P < 0.001$; 95% CI: 2.61 ... 7.70). The OR for the increase of age by one year to have recessions is 1.53 ($P < 0.001$; 95% CI: 1.38 ... 1.70). For those estimated to have recessions, the mean number of recessions for *cases* is estimated to be 142% higher than for *controls* ($P = 0.013$; 95% CI: 21% ... 385%). The estimated increase in the number of recessions by increasing age, for those with recessions, was not statistically significant. This increase was estimated to be 10% ($P = 0.231$; 95% CI: -6% ... 28%) (Figure 1).

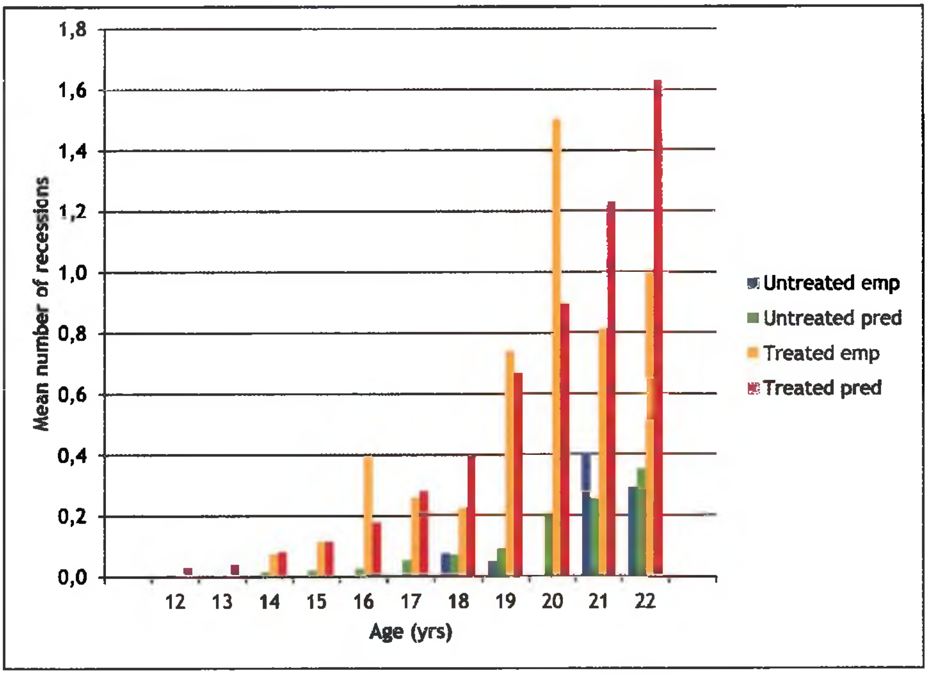

Figure 1. Mean number of labial gingival recessions in the Treated and Untreated subjects, both empirical (Treated emp, Untreated emp) and as predicted by the hurdle model (Treated pred, Untreated pred)

7.4 Discussion

Orthodontic treatment has long been implied to affect periodontal status. On one hand, the American Association of Orthodontists has claimed that untreated malocclusion may lead to "gum disease" and has suggested that orthodontic therapy might prevent it.[19] On the other hand, some investigators demonstrated increased alveolar bone loss[20] or larger gingival recessions[14,21] in orthodontically treated patients in comparison to untreated controls.

In our study, the null hypothesis (Ho) was that the orthodontic therapy would have no association with the development of labial gingival recessions. The present findings showed that orthodontic treatment promotes the development of gingival recessions, thus Ho was rejected. Overall, orthodontically treated patients demonstrated a higher prevalence of recessions than untreated controls at all time points. Moreover, the OR for *cases* to have recessions in comparison to *controls* is 4.48. Furthermore, the extent of recessions (i.e. number of teeth with recessions) was larger in cases in comparison to controls. For example, 17% of the cases demonstrated 3 or more recession sites at T21, whereas only 5% of the controls had 3 or more recession sites. Our results corroborate the findings of Allais and Melsen[22] and Slutzkey and Levin.[14] Allais and Melsen[22] noticed that the prevalence of gingival recessions in at least one lower incisor was significantly higher in orthodontically treated adults than in controls.

Slutzkey and Levin,[14] in turn, observed that past orthodontic treatment was positively correlated with the development of overall gingival recessions—orthodontically treated young adults (18 - 22 years old) had a twice as high proportion of recessions in comparison to untreated individuals (22.9% *versus* 11.4%, respectively). Moreover, the authors found that orthodontic therapy was conducive to the occurrence of more severe (> 3 mm) and more extensive (3 or more recession sites) gingival recessions. Our results are in agreement with their findings.

A contrary conclusion was made by Thomson,[13] who did not identify differences in occurrence of gingival recessions between those who had and had not been treated orthodontically. The disagreement between his and our findings may result from the lack of assessment of periodontal status at baseline in the cohort of Thomson.[13] It is possible that in subjects not treated orthodontically, dental plaque accumulation or bleeding was more prevalent than in orthodontically treated patients. As a result, a recession-promoting effect of orthodontic treatment could not have been detected.

Our results suggest that lower incisors are particularly vulnerable to the development of recessions in orthodontic patients. For example, 31% of the *cases* and 16.7% of the *controls* demonstrated at least 1 recession site at T_{21} in all the teeth except lower incisors (**ratio – 2:1**, Table 3c), whereas 13% *cases* and 1.7% *controls* had at least 1 lower incisor with a recession at T_{21} (**ratio – 8:1**, Table 3b). The current findings agree with the results of Slutzkey and Levin[14] who also noticed a relatively high prevalence of gingival recessions in mandibular incisors. However, it remains unclear what element of orthodontic treatment—position of incisors, orthodontic appliance itself, or retention—had a predominant effect on the occurrence of recessions in lower incisors. A change of incisor inclination during treatment has been extensively investigated but conflicting findings have been reported. Some authors—Allais and Melsen[22]—showed an association between proclination of mandibular incisors and development of gingival recessions, whereas others—Årtun and Grobéty[23] and Renkema *et al*[24]—could not confirm such a relationship. In this study *all cases* had a canine-to-canine bonded retainer placed immediately after completion of active orthodontic therapy. Fixed retainers were *in situ* during the entire observation period (from T_{15} to T_{21}). It was found that the presence of a fixed retainer is associated with increased plaque accumulation[12] and may result in gingival inflammation, and, eventually, the development of gingival recessions.[25] Unfortunately, it was beyond the scope of this study to determine whether the development of gingival recessions in mandibular incisors depends more on active orthodontic treatment or on the presence of fixed retention.

In this study, we scored a gingival recession as present (*Yes*) or absent (*No*). Many researchers used the 4-grade Miller's classification of gingival recessions.[26] The Miller's classification was not applied in the current investigation because, according to Miller, a clearly visible mucogingival junction (MG) is important for rating the severity of recession. Unfortunately, the position of the MG could not always be determined accurately on plaster models. Moreover the Miller's classification distinguishes recession-type defects with only soft tissue damage on the labial aspect of the teeth (classes I and II) from those associated with inter-proximal soft tissue and bone loss (classes III and IV).[27] A scoring of loss of interproximal tissue on dental casts is possible, but our *cases* and *controls* were young at T21 and identification of Miller class III or IV had been deemed as rather unlikely. Furthermore, the Miller classification has not been validated.[27] As a result, Miller's system was inapplicable here. However, as demonstrated in the method validation section, our scoring method showed adequate reliability.

It should be stressed that—based on the design of this study—it is not possible to differentiate between effects of the active treatment phase and the retention phase on the development of gingival recessions. In this investigation the retention phase always followed the active treatment phase, and only combined effects of both phases, treated as one exposure, could have been studied.

Recent systematic reviews[28,29] showed that no high-quality evidence regarding the association between orthodontic treatment and the development of gingival recessions is available. The major weak point of the studies to date is related to the retrospective study design used. Consequently, factors potentially related to recessions—e.g. a thin gingival biotype, hygiene, diet, smoking, *etc.*—could not have been controlled for. The present investigation studied the development of gingival recessions in a large sample of patients treated with contemporary orthodontic methods and non-treated controls, with multiple assessments after treatment, and a long follow-up period. It has, however, certain limitations resulting from a retrospective design such as evaluation of plaster casts only, the lack of assessment of other periodontal parameters, a control group derived from a different population, and no information concerning the diet, oral hygiene, piercings, and smoking habits of the patients. All these factors reduce the external validity of our findings. Thus, caution should be exercised in interpreting our results. This study also indicates that there is an urgent necessity for a prospective study with clinical examination before, during, and after treatment, stratification for gingival biotype and other potential confounders.

7.5 Conclusions

Within the limits of the present research design, orthodontic treatment and/or the retention phase may be risk factors for the development of labial gingival recessions. Overall, the odds ratio for orthodontic patients as compared with untreated controls to have recessions is 4.48 ($P < 0.001$; 95% CI: 2.61 ... 7.70).

In orthodontically treated subjects, mandibular incisors seem to be the most vulnerable to the development of gingival recessions.

7.6 Acknowledgments

The authors wish to thank Prof. Lisen Espeland and Prof. Vaska Vadevska-Radunovic from the Department of Orthodontics, University of Oslo, Oslo, Norway, for allowing access to the archives of the Nittedal Growth Material and for their very kind hospitality.

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Chapter 8

General discussion

8.1 Introduction

Recent publications showed a high popularity of fixed retainers worldwide. For example, the majority of Norwegian orthodontists[1] and all Swiss orthodontists[2] use bonded retainers for their patients. Also, it was demonstrated in a survey of retention procedures used in orthodontic practices in the Netherlands that the vast majority (97%) of the Dutch specialists in orthodontics use bonded retainers.[3] This worldwide trend served as the starting point for this thesis.

The overall objective of the study was to evaluate the effectiveness of lower bonded retainers in maintaining the alignment of teeth and to elucidate the role of orthodontic treatment—followed by permanent retention with lower bonded retainers—in the development of labial gingival recessions. In this chapter some methodological issues as well as results are discussed. Subsequently clinical implications and suggestions for further research are given. Finally general conclusions are enumerated.

8.2 Strengths and limitations of the study

8.2.1 Study design

During the past decade there has been an increase in understanding and adopting the principles of evidence-based medicine. It is defined as "... *use of current best evidence in making decisions about the care of the individual patient*[4]" and provides a basis for optimal therapy. The concept of best evidence has been formalized and a hierarchy of sources of evidence has been widely accepted. For example, the Centre for Evidence Based Medicine (CEBM) of the University of Oxford[5] ranks the quality of scientific evidence from 1 (highest) to 5 (lowest). Grade 1 corresponds with systematic reviews of randomized clinical trials (RCTs) (1a), or individual RCTs with narrow confidence interval (1b), grade 2 with systematic reviews of cohort studies (2a), individual cohort studies and low quality RCTs (2b), and outcomes research (2c), grade 3 with systematic reviews of case-control studies (3a), and individual case-control studies (3b), grade 4 with case-series (and poor quality cohort and case-control studies), and grade 5 with expert opinions without explicit critical appraisal. According to the U.S. Preventive Services Task Force[6]—an independent panel of experts that systematically reviews the evidence of effectiveness of various therapeutical modalities and develops recommendations for their clinical use—*the highest level in the hierarchy* of research designs have (I) a properly powered and conducted randomized controlled trial (RCT), or a well-conducted systematic review, or meta-analysis of homogeneous RCTs; *the intermediate level in the hierarchy* occupies (II-1) a well-designed controlled trial without randomization, (II-2) a well-designed cohort or case-control analytic study, and (II-3) a multiple time series with or without the intervention and/or uncontrolled experiments with dramatic results; whereas, *the lowest level in the hierarchy* of study design occupy (III) opinions of respected authorities based on clinical experience, descriptive studies, or case reports, and reports of expert committees. Thus there is agreement that RCTs and systematic reviews of RCTs provide best scientific evidence, and expert opinions constitute the weakest evidence.

An RCT is preferred because only this study design allows conclusions on cause and effect relationships of a particular treatment modality and outcome. The advantage of an RCT is that the compared study groups are balanced regarding various types of biases, both known and unknown factors influencing the outcome. Furthermore, blinding of investigators and patients to the type of intervention, and concealment of random allocation guard against additional bias. Consequently, if a treatment effect is observed, there will be more confidence in concluding that one intervention is better than the other. Moreover, well-designed RCTs have high internal validity and good generalizability, i.e. their results may be extrapolated beyond the study group to the general population.[7,8] However, there has been no published RCT evaluating the long-term performance of bonded orthodontic retainers in a large group of patients; available evidence in this field comes from retrospective studies. The studies in this thesis also had a retrospective design with possible associated biases limiting the validity of conclusions. Of particular importance seems to be a selection bias related to collecting the sample. The material was obtained from the post-treatment archive housed at the Department of Orthodontics and Craniofacial Biology, Radboud University Medical Centre Nijmegen, the Netherlands. At the university clinic, residents, who are less experienced clinicians, usually carry out orthodontic treatment. Therefore treatment duration, failure rates or unwanted side effects in the current sample may differ from a patient population at large.

8.2.2 Sample size and length of follow-up

The performance of bonded retainers was evaluated on the basis of 456 consecutively treated subjects, who were followed for at least 5 years after active orthodontic treatment. All patients were treated orthodontically according to similar protocols used in the clinic. In the present investigation, both sample size and length of follow-up were significantly more extensive than in most other publications. With the exception of the study by Andrén *et al*,[9] other authors followed either few patients[10,11] or followed patients relatively short-term.[12,13]

Andrén *et al*,[9] in turn, examined the effectiveness of fixed retainers more than 5 years post-treatment in 100 patients. However, they evaluated 4 different types of bonded retainers (3-strand FSW 0.0175-inch, 5-strand FSW 0.015-inch, 5-strand FSW 0.0175-inch, and 5-strand FSW 0.0195-inch). As a result, the sample size for each retainer type was small and ranged from 15 to 33 subjects. The large sample size combined with the extended observation period of this study are unique in comparison with other investigations and allow—within the limitations of the retrospective study design—the authors to draw relatively confident conclusions.

8.3 Results and clinical implications

The present findings suggest that retainers bonded to the mandibular canines only (33-43) and to all 6 mandibular anterior teeth (33-32-31-41-42-43) are effective in maintaining the alignment in the mandibular anterior region after active orthodontic treatment in a high percentage of the patients. However, retainer failures were noted in a number of patients. In case of the 33-43 bonded retainer, approximately 1 out of 5 patients (20.4%) experienced bond failures, whereas in case of the 33-32-31-41-42-43 bonded retainer almost 1 out of 3 patients (32.2%) experienced bond failures. The yearly failure rate was higher during the first 2 years post-treatment than during 3 to 5 years post-treatment. The retainer wire was broken in only one case.

The relatively high percentage of retainer failures may seem to be in contradiction with the high effectiveness of bonded retainers in preventing post-treatment changes. Although each bond failure puts an additional burden on the patient—for repair a patient must arrange time to visit the orthodontic practice and may need to cover the cost—not each retainer failure leads to misalignment of the teeth. When a detached retainer is detected and reattached early, the likelihood of post-treatment increase in irregularity is minimal.

A practical problem related to the long-term wear of bonded retainers is: *Who is responsible for their check-ups and repairs*? An answer to this question is growing more and more urgent, particularly in the light of findings that many orthodontists recommend permanent retention. Moreover, bonded retainers may cause undesired effects, such as a torque difference between adjacent teeth. To all appearances, a reply is simple—the orthodontist who has treated the patient and placed the retainer bears responsibility. This model, in practice, might inconvenience the patient because it takes more time for an appointment with the orthodontist in addition to regular check-ups by the dentist. From the patient's point of view, it seems rational if a check-up of the retainer is performed during the routine inspection by the dentist. This is possible provided that (i) there is communication between the orthodontist and dentist regarding this subject, (ii) the dentist is trained how to carry out retainer check-ups and to perform repairs effectively and, above all, (iii) the dentist is aware of potential unwanted side-effects of bonded retainers. Some responsibility for retainer control would be shifted from orthodontist to the dentist in this model, especially 1 year after orthodontic treatment. Although some dentists might be hesitant to take over the extra duty, the combination of a routine dental check-up with a retainer check-up is desirable from the patient's perspective. This would also be in accordance with the recommendations of the Institute of Medicine (IOM)[14]—the health branch of the National Academy of Sciences of the U.S.A.—to organize provision of health care services within a patient-centered system. The IOM defines patient-centered care as "*...care that is respectful of and responsive to individual patient preferences, needs, and values, and ensuring that patient values guide all clinical decisions.*" Thus the system of long-term supervision of orthodontic retention, in which check-ups of bonded retainers are performed by the dentist during a routine dental check-up, would certainly meet the requirements of a *patient-centered* approach.

An important finding of this investigation was that orthodontic patients might be at increased risk of occurrence of labial gingival recessions in comparison to untreated subjects. It was shown that, overall, patients treated orthodontically are approximately 5 times more likely to develop recessions than subjects who have never undergone orthodontic therapy. However, it is unclear which element of therapy—active phase of treatment, or retention phase, or both—is responsible for the occurrence of recessions. In this study, the retention phase always followed active treatment. As a result, only combined effects of both phases could have been investigated. Previous publications implied that both active treatment and retention phase might promote the development of gingival recessions. In fact, similar causative factors may be involved in both phases such as movement of roots toward cortical plates, gingival inflammation due to dental plaque build-up, or mechanical trauma.

An encroachment of roots upon alveolar plates can take place during active treatment. Animal experiments showed that orthodontically-induced excessive proclination of incisors might lead to gingival recessions accompanied by significant bone dehiscences.[15,16] Gingival recessions developed despite thorough plaque control and application of antibiotic.[15] It was speculated that movement of roots, especially the movement to positions outside the alveolar plates, might induce dehiscence formation and subsequently the development of a gingival recession.[17] Unfortunately, human studies were less unambiguous in showing a correlation between proclination of teeth and formation of recessions—some found a positive correlation[18,19] and others found no effect of incisor tipping on the occurrence of recessions.[20,21] The same mechanism might be in effect during the retention phase.

Bonded retainers are placed to prevent post-treatment alterations. Despite this, undesirable changes in tooth position still occur in 2.7% - 5% of patients with bonded retention.[22] Orthodontic relapse has been a suggested reason for these undesirable changes.[23] However, teeth most often move in a direction away from their pre-treatment position.[22] This suggests that active force generated by the retainer might play a role. A fixed retainer should always be perfectly adapted to the lingual surfaces of a working model during fabrication. If this is not the case and a poorly adapted retainer is attached to the teeth, the pressure applied to a wire during the bonding procedure will induce elastic deflection of the wire, and the retainer will become active.[23] For example, a deflection of as little as 0.2 mm may generate a force in excess of 1 N.[24] This, in the absence of bond failures, will result in uncontrolled tooth movement. In extreme situations an active retainer might bring the root completely out of the bone, causing extensive gingival recession[25] (Figure 2). Also, the parts of the lingual retainer not covered with composite adhesive material are subject to masticatory forces. These forces could result in mechanical deformation of the wire, which might cause tooth movement.[26] Furthermore, whenever pressure is applied to reposition a *debonded* retainer, it will inevitably undergo elastic deflection leading to uncontrolled but expected tooth movement.

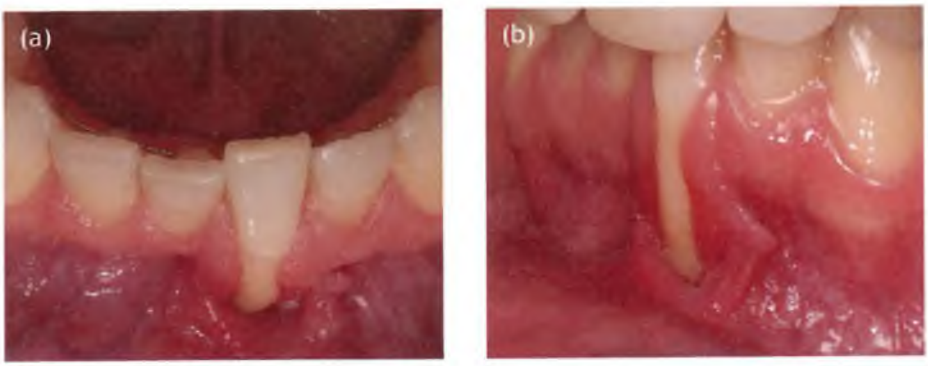

Figure 1. Frontal (a) and lateral (b) view of a lower left central incisor with excessive labial root torque; the prognosis of this tooth is very poor

Accumulation of dental plaque is frequently encountered in orthodontic patients with inadequate oral hygiene. It has been found that poor oral hygiene in combination with retentive sites facilitate plaque build-up. Also, during the retention phase, especially when bonded retainers are used for a prolonged period of time, accumulation of plaque around the bonded retainers can be observed.[27] Plaque accumulation results from the increased availability of retentive sites for microbial colonization, which calcifies at a later stage. It is probable that retainers promote calculus accumulation beyond the resin margins, causing the calculus to extend lingually to the free gingiva and favouring biofilm formation.[27] Because dental plaque/calculus accumulation has been found to promote recessions in orthodontically untreated subjects,[28,29] this association might be in effect in patients *both* during active orthodontic treatment *and* the retention period.

Vigorous tooth brushing can cause trauma to the gingiva and is considered to be a predominant causative factor for the development of recessions, particularly in young individuals. Traumatizing tooth brushing and tooth malposition are the factors most frequently found to be associated with marginal tissue recession.[30,31] In addition, Khocht *et al*[32] showed that recessions are related to the use of hard toothbrushes. Orthodontic patients are strongly recommended to maintain ideal oral hygiene to prevent plaque accumulation around orthodontic appliances and bonded retainers. Intensive tooth brushing, however, may contribute to mechanical destruction of gingival tissue, particularly if a habit of vigorous tooth cleaning continues indefinitely.

Irrespective of the specific mechanisms or factors predisposing to gingival recessions, many of them seem to act *not only* during the period when a patient is treated orthodontically *but also* during the retention period. Moreover, it is likely that these factors work synergistically, i.e. the effect of two predisposing factors acting separately can be relatively small but in case of joint action, the result could be considerably larger. This could partly explain the numerous conflicting data found in various publications concerning the development of recessions in orthodontic patients.

8.4 Further research

As in all investigations, the current study not only answered the formulated research questions and elucidated several clinical problems, but it also delineated areas requiring attention and warranting research in the future.

The results of the survey regarding retention procedures used in orthodontic practices in the Netherlands—Chapter 2—as well as data from other countries suggest that many orthodontists use bonded retainers for a prolonged period of time—often permanently. It was found that retainers bonded to all anterior mandibular teeth might cause unwanted effects. Because the development of these complications is almost always painless, there is little probability that they will attract the attention of the patient before they become severe. Therefore it seems imperative to strongly advise the patient to attend regular retainer check-ups. Although it was mentioned that according to the principle of *patient-centered care* the dentist would be the most appropriate professional to check retention appliances in the long run, alternative arrangements are also possible provided a patient's retainer is periodically controlled. Considering new research goals, it seems important to investigate how often patients experience complications caused by bonded retainers and which factors associated with retainer design (e.g. type of wire, method of placement, *etc.*) could contribute to the occurrence of undesired effects.

Orthodontic treatment is usually an elective therapy performed to improve dentofacial aesthetics.[33] The development of labial gingival recession may compromise aesthetics and cause dissatisfaction for the patient. The present study demonstrated that orthodontic patients are more likely to develop gingival recessions in comparison to orthodontically untreated individuals. Partly due to the retrospective study design of the current investigation, it was impossible to identify which element—treatment or retention—was conducive to the development of recessions. Due to the gravity of the problem it is highly advisable to conduct a randomized controlled clinical trial aiming to elucidate the role of various elements during active orthodontic treatment and the retention phase in the pathogenesis of gingival recessions. Such a trial should include evaluation of general health and habits, treatment modality, and long-term clinical examination of oral hygiene and gingival condition.

8.5 Conclusions

This study showed that two frequently applied fixed retainers—the one bonded only to the mandibular canines and the other bonded to all mandibular anterior teeth—are effective in maintaining the orthodontic alignment of the mandibular anterior region. However, (1) relatively high failure rates of both fixed retainer types, (2) undesirable changes caused by flexible spiral wire retainers, and (3) an increased risk for developing gingival recession associated with orthodontic treatment and/or retention with these retainers, make it necessary to perform prospective research in these particular areas.

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Chapter 9

Summary

Chapter 1 gives a brief introduction about orthodontic relapse, post-treatment changes, orthodontic retention in general, and more specific, retention with bonded retainers. Bonded retainers have been widely used as an orthodontic retention appliance for the past four decades. It addresses the need for prolonged retention with minimum patient compliance. Definite disadvantages of bonded retainers include the risk of retainer failures and the accumulation of plaque. Studies reporting on the effectiveness, failure rates and detrimental effects of bonded retainers are based on small patient groups and/or short observation periods. The overall objective of this thesis and specific aims are presented.

The aim of the survey described in Chapter 2 was to get more insight into retention strategies applied in Dutch orthodontic practices. The overall response rate was 91 per cent. Most orthodontists placed a bonded retainer in the upper and lower arch, except when the upper arch was expanded during treatment or when extractions were performed in the upper arch, in which case they placed a removable retainer. Opinions regarding the use of removable retainers varied in terms of daily wear and the duration of the retention phase. Contra-indications for bonded retainers were given by 96% of the orthodontists, with poor oral hygiene being the most commonly mentioned. Orthodontists who only used bonded retainers (5%) did not want to depend on patient compliance. The few who only used removable retainers (3%) quoted bond failures and breakages as main reason for not using bonded retainers. As far as bonded retainers are concerned, 84% of the orthodontists preferred permanent retention. Almost 60% of the orthodontists believed that a practice guideline for retention after orthodontic treatment is needed, which was indicated by the varied responses in this survey.

Chapter 3 describes a study to assess the long-term effectiveness of the 33-43 lingual (0.0215 x 0.027-inch stainless steel) retainer in preventing orthodontic relapse. In a group of 235 patients a 33-43 lingual retainer was placed after active treatment. During orthodontic treatment the mean irregularity index decreased significantly from 7.2 mm (SD, 4.0) to 0.3 mm (SD, 0.5); it increased significantly to 0.7 mm (SD, 0.8) at 2 years post-treatment and 0.9 mm (SD, 0.9) at 5 years post-treatment. During the

5-year post-treatment period the irregularity index was stable in 141 patients (60%) and increased by 1.0 mm (SD, 0.8) in 94 patients (40%). The 33-43 lingual stainless steel retainer was effective in preventing relapse in the mandibular anterior region in 60% of the patients. A relatively high percentage experienced a small to moderate increase in mandibular incisor irregularity. Twenty per cent of the patients encountered retainer failures in this study. The number of failures negatively influenced the alignment of the mandibular anterior region.

In Chapter 4 the results of a study to assess the long-term effectiveness of the FSW (0.0195-inch, 3-strand) retainer in maintaining orthodontic alignment are presented. In a group of 221 patients an FSW lingual retainer was bonded to the 33-32-31-41-42-43 following active treatment. During orthodontic treatment the mean irregularity index decreased significantly from 5.35 mm (SD, 3.47) to 0.08 mm (SD, 0.23). Alignment of the mandibular anterior teeth was stable in 200 patients (90.5%) up to 5 years post-treatment; in 21 patients (9.5%), a mean increase of 0.81 mm (SD, 0.47) was observed. The increase of the irregularity was strongly related to bond failures. Undesirable post-treatment complications—torque differences of the incisors or an increased buccal canine inclination—were observed in 6 patients (2.7%). The 33-32-31-41-42-43 lingual FSW retainer was very effective in maintaining the alignment of the mandibular anterior region after active orthodontic treatment. It was concluded that, in patients with a FSW lingual retainer, regular check-ups are necessary to determine bond failures, post-treatment changes, and complications as early as possible.

The aim of the study described in Chapter 5 was threefold: (1) to assess the prevalence of gingival recessions in orthodontic patients before, immediately after, 2 years, and 5 years after orthodontic treatment, (2) to evaluate the development of recessions in various regions of the dental arches, and (3) to identify variables associated with the development of gingival recessions. Vestibular gingival recessions were scored for all teeth using initial, end-of-treatment, 2- and 5-years post-treatment plaster models of 302 orthodontic patients. All patients had a fixed retainer bonded lingual to either the mandibular canines only, or to all six mandibular front teeth. A continuous increase in gingival recessions after treatment was found from 7% at the end of treatment to 20% at 2 years post-treatment, and to 38% at 5 years post-treatment. Patients younger than 16 years of age at the end of treatment were less likely to develop recessions than patients older than 16 years at the end of treatment. The prevalence of recessions was not associated with gender or extraction treatment. The type of fixed retainer did not influence the development of recessions in the mandibular front region. The prevalence of gingival recessions steadily increased after orthodontic treatment, and was higher in older than in younger patients. No variable, except for age at the end of treatment, seemed to be associated with the development of gingival recessions.

The aim of the study described in Chapter 6 was to test the hypothesis that a change of the inclination of the lower incisors promotes development of labial gingival recessions. The study group consisted of 197 subjects—11 to 14 years at the start of orthodontic treatment—with a mandibular retainer bonded immediately after treatment. Clinical crown heights of mandibular incisors and the presence of gingival recessions in this region were assessed on pre-treatment, post-treatment, 2-years and 5-years post-treatment plaster models, and on lateral cephalometric radiographs mandibular incisor inclination at the 4 stages was determined. The sample was divided—depending on the change of lower incisor inclination by orthodontic treatment—into three groups: *Retro*, *Stable*, and *Pro*. The mean increase of clinical crown heights of mandibular incisors from the end-of-treatment to the 5-years post-treatment stage was 0.60 mm, 0.88 mm and 0.91 mm in the *Retro*-, *Stable*-, and *Pro*-group, respectively; the difference was not significant. At 5-years post-treatment, gingival recessions were present in 8.8%, 4.5%, and 16.3% of the patients from the *Retro*-, *Stable*-, and *Pro*-group, respectively. The difference was not significant. The changes in lower incisor inclination during treatment did not affect the development of labial gingival recessions in this group of patients.

In Chapter 7 the results of a study evaluating the long-term development of labial gingival recessions in orthodontically treated and untreated individuals are presented. In this retrospective case-control study the presence of gingival recession was scored on plaster models of 100 orthodontic patients (*cases*) and 120 *controls* at the age of approximately 12 (T12), 15 (T15), 18 (T18), and 21 (T21) years. In the treated group, T12 reflected the start of orthodontic treatment, and T15 the end of active treatment and the start of the retention phase with bonded retainers. The proportion of subjects with recessions was consistently higher in *cases* than in *controls*. Orthodontic treatment and/or the retention phase are risk factors for the development of labial gingival recessions. In orthodontically treated subjects mandibular incisors seem to be the most vulnerable to the development of gingival recessions. Risk factors for the development of gingival recessions should be investigated in a prospective study.

Finally, in Chapter 8 a general discussion of the methodological issues are presented. It describes the limitations and strengths, the results and clinical implications of the thesis. This chapter ends with suggestions for further research, particularly to reduce bond failures of fixed retainers, and to elucidate risk factors for the development of undesired post-treatment changes and gingival recessions. Lastly, general conclusions are enumerated.

Chapter 10

Samenvatting

Hoofdstuk 1 beschrijft een korte inleiding over orthodontische relaps, post-orthodontische veranderingen, orthodontische retentie in het algemeen, en meer specifiek retentie met vaste spalken. De afgelopen vier decennia zijn orthodontische spalken veelvuldig toegepast. Hiermee wordt tegemoet gekomen aan de behoefte tot langdurige retentie, waarbij een minimum aan medewerking van de patiënt is vereist. Onmiskenbare nadelen van vaste spalken zijn het risico van loslaten of breuk van de spalk en accumulatie van plaque rondom de spalk. Onderzoeken naar effectiviteit, loslaten of breuk, en schadelijke effecten van vaste spalken zijn gebaseerd op kleine patiëntenaantallen of een beperkte observatieperiode. In dit hoofdstuk worden tevens de doelstellingen van het onderzoek beschreven.

Het doel van het onderzoek beschreven in **Hoofdstuk 2** was het verkrijgen van meer inzicht in de toegepaste retentieprocedures door orthodontisten werkzaam in Nederland. De totale respons was 91 procent. Het merendeel van de orthodontisten plaatste na de actieve orthodontische behandeling een spalk in het boven- en onderfront. Wanneer de bovenboog was geëxpandeerd of wanneer er extracties waren uitgevoerd, werd een uitneembare retainer geplaatst. De meningen ten aanzien van het aantal draaguren voor uitneembare retainers, en de duur van de retentieperiode liepen erg uiteen. Door 96% van de orthodontisten werden contra-indicaties aangegeven voor wat betreft het plaatsen van een spalk; een slechte mondhygiëne werd hierbij het meest frequent genoemd. De orthodontisten die nooit uitneembare retainers plaatsten (5%), verklaarden dat ze niet afhankelijk willen zijn van de medewerking van de patiënt. Zij die nooit orthodontische spalken plaatsten (3%) waren van mening dat deze vaak loskomen of breken. Wanneer geretineerd werd met een spalk, gaf 84% van de orthodontisten de voorkeur aan permanente retentie. Bijna 60% van de orthodontisten was van mening dat er een praktijkrichtlijn voor retentie na de orthodontische behandeling moet worden ontwikkeld. De behoefte aan een praktijkrichtlijn werd mede bevestigd door de uiteenlopende opinies van de participanten in dit onderzoek.

In Hoofdstuk 3 worden de resultaten gepresenteerd van een studie naar de effectiviteit van de 33-43 linguale retainer (0.0215 x 0.027-inch stainless steel) ter voorkoming van orthodontische relaps. In een patiëntengroep (n = 235) was na het afronden van de actieve behandeling ter retentie een linguale 33-43 retainer geplaatst. De gemiddelde “irregularity index“ was tijdens de orthodontische behandeling significant verlaagd van 7.2 mm (SD, 4.0) naar 0.3 mm (SD, 0.5); 2 en 5 jaar na de orthodontische behandeling bedroeg de “irregularity index“ gemiddeld respectievelijk 0.7 mm (SD, 0.8) en 0.9 mm (SD, 0.9). De toename was statistisch significant. Bij 141 patienten (60%) was de “irregularity index“ vijf jaar na de orthodontische behandeling stabiel; bij 94 patiënten (40%) was de “irregularity index” na vijf jaar met gemiddeld 1.0 mm (SD, 0.8) toegenomen. De 33-43 linguale retainer bleek effectief in het voorkomen van relaps bij 60% van de patiënten. Bij een relatief hoog percentage vond een geringe tot matige toename van de “irregularity index“ plaats. Bij 20% van de patiënten was er sprake van falen (losraken) van de spalk, hetgeen een negatieve invloed had op de stabiliteit van het onderfront.

Hoofdstuk 4 geeft een beschrijving van de resultaten van een onderzoek naar de effectiviteit van de 33-32-31-41-42-43 retainer (0.0195-inch, 3-strand, heat-treated) ter voorkoming van orthodontische relaps. In een patiënten groep (n = 221) was na het afronden van de actieve behandeling ter retentie een linguale twistflex 33-32-31-41-42-43 spalk geplaatst. De gemiddelde “irregularity index“ was gedurende de orthodontische behandeling significant verlaagd van 5.35 mm (SD, 3.47) naar 0.08 mm (SD, 0.23). Bij 200 patiënten (90.5%) was de “irregularity index“ 5 jaar na de orthodontische behandeling stabiel; bij 21 patiënten (9.5%) werd een toename gemeten van gemiddeld 0.81 mm (SD, 0.47). De toename van de “irregularity index“ was sterk gerelateerd aan het losraken van de spalk. Bij 6 patiënten (2.7%) werden complicaties—een bucco-inclinatie van een cuspidaat of torqueverschil bij de incisieven—waargenomen. De linguale twistflex spalk bevestigd aan alle 6 elementen in het onderfront is zéér effectief in het retineren van het resultaat van de orthodontische behandeling in deze regio. Het is evenwel noodzakelijk deze spalk regelmatig te controleren om eventueel losraken en complicaties tijdig te kunnen vaststellen.

Het doel van het in Hoofdstuk 5 beschreven onderzoek was het bepalen van de prevalentie van gingivarecessies bij een groep orthodontisch behandelde patiënten vóór, direct na, en 2, en 5 jaar na behandeling, en zo mogelijk variabelen geassocieerd met de ontwikkeling van gingivarecessies te identificeren. Bij 302 patiënten werden labiale gingivarecessies van alle aanwezige gebitselementen gescoord aan de hand van gebitsmodellen vervaardigd tijdens bovengenoemde vier stadia. Alle patiënten hadden een linguale orthodontische spalk, die hetzij alleen op de ondercuspidaten, dan wel op alle 6 onderfrontelementen was geplakt. Er werd een continue toename van gingivarecessies gevonden met een prevalentie van 7% direct na het afronden van de orthodontische behandeling, 20% na 2 jaar retentie en 38% na 5 jaar retentie. Patiënten die jonger waren dan 16 jaar ten tijde van het afronden van de orthodontische behandeling, hadden minder kans op het ontwikkelen van gingivarecessies dan patiënten die op dat moment 16 jaar of ouder waren. De prevalentie van gingivarecessies was niet geassocieerd met het geslacht van de patiënt, of het type behandeling—extractie of non-extractie. Het type retainer had geen invloed op de ontwikkeling van recessies in het onderfront. De prevalentie van gingivarecessies nam gestaag toe na een orthodontische behandeling, en was hoger bij oudere dan bij jongere patiënten. Behalve de leeftijd van de patiënt ten tijde van het afronden van de orthodontische behandeling, leek geen enkele variabele geassocieerd met de ontwikkeling van gingivarecessies.

Met het in Hoofdstuk 6 beschreven onderzoek werd de volgende hypothese getoetst: "*De verandering van de inclinatie van de onderincisieven bevordert het ontstaan van labiale gingivarecessies*". Bij het onderzoek waren 197 patiënten betrokken die aan het begin van de orthodontische behandeling 11-14 jaar oud waren. Bij alle patiënten was ter retentie een mandibulaire linguale spalk geplaatst. Op de gebitsmodellen, vervaardigd vóór, direct na, en 2, en 5 jaar na het afronden van de orthodontische behandeling werd de klinische kroonhoogte van de onderincisieven gemeten en de aanwezigheid van labiale gingivarecessies in deze regio bepaald. Op de laterale schedelprofielfoto's werd de inclinatie van de onderincisieven op de bovengenoemde vier stadia bepaald. De groep werd—op basis van de verandering in de inclinatie van de onderincisieven tijdens de orthodontische behandeling—verdeeld in 3 groepen: *Retro*, *Stable*, en *Pro*. De gemiddelde toename van de klinische kroonhoogte van de onderincisieven bedroeg 5 jaar na het afronden van de orthodontische behandeling respectievelijk 0.60 mm, 0.88 mm en 0.91 mm in de *Retro-*, *Stable-*, en *Pro*-groep; het verschil in toename tussen de 3 groepen was echter niet significant. Vijf jaar na het afronden van de orthodontische behandeling werden bij respectievelijk 8.8%, 4.5%, and 16.3% van de patiënten van de *Retro-*, *Stable-*, en *Pro*-groep gingivarecessies aangetroffen. Het verschil in prevalentie tussen de 3 groepen was niet significant. De verandering in inclinatie van de onderincisieven tijdens de orthodontische behandeling had geen invloed op het ontstaan van labiale gingivarecessies in deze patiëntengroep.

In Hoofdstuk 7 worden de resultaten gepresenteerd van een studie naar de ontwikkeling van labiale gingivarecessies bij orthodontisch behandelde en niet-orthodontisch behandelde individuen. In dit retrospectieve onderzoek werd de aanwezigheid van gingivarecessies gescoord aan de hand van gebitsmodellen van 100 orthodontisch behandelde patiënten (*testgroep*), en 120 individuen (*controlegroep*) op de leeftijd van ongeveer 12 (T12), 15 (T15), 18 (T18), en 21 (T21) jaar. Bij de testgroep viel T12 samen met de start van de orthodontische behandeling; T15 viel samen met het einde van de behandeling/begin van de retentiefase, waarbij een mandibulaire linguale spalk was geplaatst. Het aantal patiënten met recessies was telkens groter in de testgroep dan in de controlegroep. De orthodontische behandeling en/of de retentiefase vormen risicofactoren voor het ontwikkelen van labiale gingivarecessies. Bij orthodontisch behandelde patiënten lijken de onderincisieven het meest gevoelig te zijn voor het ontwikkelen van gingivarecessies. Risicofactoren voor de ontwikkeling van gingivarecessies dienen verder te worden onderzocht in een prospectieve studie.

Tenslotte worden in Hoofdstuk 8 de methodologische aspecten, sterke punten, tekortkomingen, resultaten en klinische implicaties van het onderzoek besproken. Er worden suggesties gedaan voor verder onderzoek, in het bijzonder ten aanzien van het voorkómen van losse en actieve spalken, en de rol van de orthodontische behandeling en retentie-spalken als risicofactoren voor het ontwikkelen van gingivarecessies. Het hoofdstuk wordt afgesloten met de conclusies van het onderzoek.

Appendices

I. Acknowledgements

With this thesis a pleasant time of research has come to an end. I would like to extend my thanks to several individuals whose guidance contributed in one way or another to this manuscript. The majority will remain nameless here.

First and for all, I have to thank *all patients* involved in this research who were – time after time – willing to come back for post-treatment check-ups and impression taking. Without these patients it would have been impossible to perform research over such a long period of time.

Secondly, I want to thank *all colleagues* – dental nurses, laboratory staff, secretaries, postgraduates, dentists and orthodontists – of our and other departments, and the “Orthodontistenpraktijk Meppel” for their cooperation and kindness during my research years. Working with so many wonderful people created the perfect circumstances to brighten the solitude of being a researcher.

To *Prof. dr. Christos Katsaros*, my first promoter. Christos, your guidance as my first research mentor was essential to me. Thank you so much for the time and effort you have invested in – especially the first part – of this thesis. Working with you was not just fruitful, it also was enjoyable due to your special sense of humor. Thanks to your move to Bern you brought me to Azzurro. Now, whenever I go to Bern, I go to Azzurro. I am also very grateful for your and Alexandra’s hospitality whenever I stayed in Bern.

To *Prof. dr. Anne Marie Kuijpers-Jagtman*, my second promoter and head of our department. Anne Marie, I will not enumerate all your qualities, because I want to keep it short. Thanks to your adaptive power you have achieved whatever possible in orthodontics. Your selfless commitment regarding education, research and cleft patients – not only in our country but also far abroad – is amazing. You gave me the opportunity to learn. Most important to me: I could always, anytime, night and day, knock on your door for advice and assistance. I’m very grateful to you for all of this.

To *dr. Piotr Fudalej,* my co-promoter. Piotr, you gave me the boost I needed in the completion of this research work. The boost is inextricably linked to gingival recessions. I want to tank you for that a thousand times. Because you regarded the combination of family and work as your highest priority, you had to leave Nijmegen. A loss. I wish you all the best in your future career.

To *dr. Ewald Bronkhorst*, our statistician. Ewald, thanks for your apparently never ending patience. The first time I came to you my statistical knowledge had more or less faded away. Meanwhile I can say that I will never ever be a statistical miracle, but at least now I know what we are talking about.

To *drs. Elke Sips*, colleague and former postgraduate at our department. Elke you did the hard work regarding the survey on orthodontic retention procedures in the Netherlands. For this you have my sincere gratitude.

To *Prof. dr. P.J. Slootweg*, *Prof. dr. F. Abbas*, and *dr. E.M. Ongkosuwito*, the members of the reading committee. I greatly appreciate the time you took and the effort you made in reviewing this thesis. I wish to thank you all.

To *Prof. dr. V. Vandevska-Radunovic,* my host in Oslo. Vaska, thank you so much for your hospitality. Your confidence in me to stay in your house even while you and your family were away meant a lot to me.

To *Faye Klein Meulekamp*, *Jens Padmos* and *Alianne Renkema*, my proof-readers. Thanks for the meticulous way you fulfilled the job and detected Djunglish, a variety of small flaws, and all kinds of important trivia.

To *dr. Rosemie Kiekens*, *dr. Barbara Oosterkamp* and *drs. Hardus Strydom*, my roommates. A special thanks for your useful comments and friendship.

Daniel: think I owe you something :)
Arne: thanks for the Excel-file©arne ;)
Jens: hope you'll be a dentist soon ;)

Nijmegen, 13-09-13

II. Curriculum Vitae

Anne-Marie Renkema was born on February the second, 1953, van Doornlaan 4 in Oost- en West-Souburg in the province of Zeeland (the Netherlands), one day after the flood disaster. When she was a toddler, the family moved to the other extreme of the Netherlands: Winschoten in the province of Groningen. After secondary school from 1965 - 1970, she obtained a degree as zoological laboratory technician (polytech Amsterdam) in 1975. From 1975 - 1981 she studied dentistry—6-year program—at the University of Groningen. She worked as a general practitioner in a private practice in Germany (Papenburg) for a year-and-a-half. In this practice some orthodontic treatment was performed. Anne-Marie experienced that qualified does not automatically mean capable. Therefore she decided to follow a postgraduate training in orthodontics. The training was fulfilled in Germany (Osnabrück and Bonn). In March 1986 she passed the final examination in Aachen, with professor Diedrich as examiner. In July 1986 she started a full-time private practice in orthodontics in Meppel, the Netherlands. Since 1998 she works as a part-time faculty member at the Department of Orthodontics and Craniofacial Biology of the Radboud University Medical Centre Nijmegen, the Netherlands. In September 2007 she entered a partnership in her orthodontic office with Aniek Jonker-Derks, former postgraduate at the same department. In October 2011 Anne-Marie transferred her part of the partnership to Alianne Renkema, and subsequently extended her activities at the Radboud University Medical Centre Nijmegen.

III. Publications

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Festina lente!