Sasan Naraghi

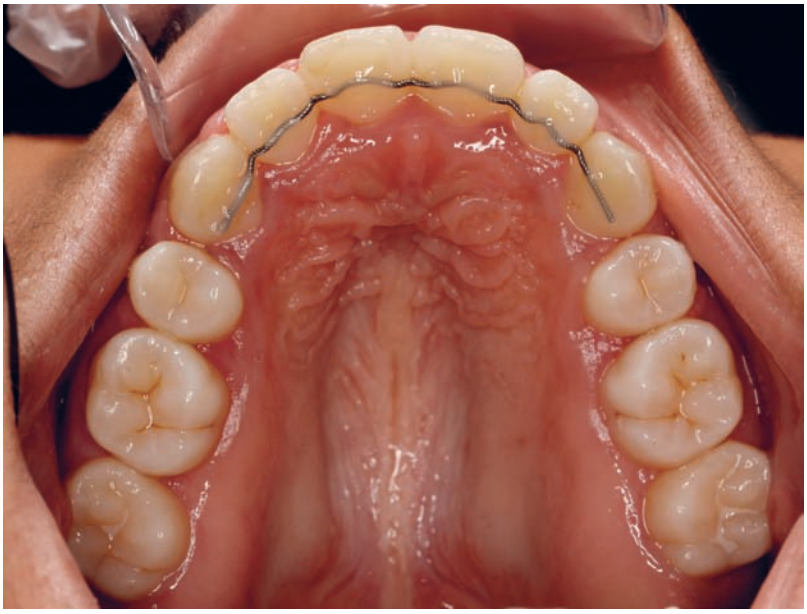
Pattern and amount of change of upper front teeth after retention with a bonded retainer

The Sahlgrenska Academy

2010

Pattern and amount of change of upper front teeth after retention with a bonded retainer

Follow-up one to seven years postretention



Sasan Naraghi

Institute of Odontology
at the Sahlgrenska Academy
University of Gothenburg

UNIVERSITY OF GOTHENBURG

Pattern and amount of change of upper front teeth after retention with a bonded retainer

Follow-up one to seven years postretention

Sasan Naraghi

Department of Orthodontics
Institute of Odontology at the Sahlgrenska Academy
University of Gothenburg

2010

To my beloved family Peggy, Jasmin and Shirin

To my dear brother Sirus who has been my leading star
and a source of inspiration in my life

ISBN 978-91-633-7846-1

Printed by Intellecta Infolog AB, Göteborg 2010

CONTENTS

PREFACE

This thesis is based on the following two papers, which are referred to as paper I and paper II.

Paper I. Naraghi S, Andrén A, Kjellberg H, Mohlin B. Relapse tendency after orthodontic correction of upper front teeth retained with a bonded retainer. *Angle Orthod.* 2005;76: 570–576.

Paper II. Andrén A, Naraghi S, Mohlin B, Kjellberg H. Pattern and amount of change after orthodontic correction of upper front teeth 7 years postretention. *Angle Orthod.* 2010;80:620–625.

ABSTRACT

Objectives:

To investigate the amount and pattern of relapse of maxillary front teeth previously retained with a bonded retainer for two to four years. Which teeth are more prone to relapse? Is there any difference in behavior between contact point displacement and rotation? What is the magnitude of the relapse in short-term and long-term?

Materials and Methods:

The study group originally consisted of 45 patients, and 27 patients on recall for the second study. Recordings from study models before treatment (T1), at debonding (T2), one year after removal of the retainer (T3) and seven years postretention (T4) were present. All patients had been treated with fixed edgewise appliances by the same operator. The irregularity index (sum of contact point displacement [CPD]), and rotations of front teeth in relation to the Raphe line and intercanine distance, were calculated at T1, T2, T3 and T4.

Statistical analysis:

Paired t-test, Pearson's product-moment correlation and Pearson's product-moment correlation coefficient were applied. For all statistical analyses, the statistical significance level was set to 5%.

Results:

Before treatment (T1), the mean irregularity index was 10.1 (range 3.0–29.9). The largest displacements were recorded between laterals and centrals followed by the displacement between laterals and canines. The smallest deviations were found between the centrals.

After treatment (T2), the mean irregularity index was 0.7 (range 0.0–2.1). There was a significant difference in the index between T1 and T2 ($P < .0001$).

One year postretention (T3), the mean irregularity index was 1.4 (range 0–5.1). There was a significant difference in the index between T2 and T3 ($P < .0001$).

Results from the second study showed that there were no statistically significant differences between the change in mean CPDs for the contacts canines/laterals, laterals/centrals, or centrals/centrals. The mean irregularity

index for the 27 patients examined in the second study was 10.3 (range 3.7-29.9) at T1, 0.9 (range 0.0-2.1) at T2, 1.3 (range 0.0-3.5) at T3 and 2.0 (range 0.0-5.8) at T4.
No correlations were found between the pretreatment and postretention irregularity T1/T3 and T1/T4. There was a significant association between the irregularity index at T3 and T4 ($R = 0.938$, $P < .0001$).
The irregularity index of the maxillary front teeth changed very little or not at all during the first year postretention. Further changes long-term resulted in an irregularity index of mean 2.0 mm (range 0.0 – 5.8). The contact relationship between the laterals and centrals seems to be the most critical. Forty rotated teeth in 21 patients were corrected more than 20 ^{o}. Mean relapse during the first year postretention was 6.7 degrees (range 0.0-14.7). Mean changes during seven years were 8.2 degrees (range 0.0-19.3).

Conclusions:

- Minor or no relapse in short-term follow-up (one year) was noted in the maxillary front after correction of irregularity and a two to four year period of bonded retention. Further, small relapses occurred long-term i.e. at mean seven years postretention.
- No significant relation was found between the amount of correction of contact point displacement and magnitude of relapse neither in one nor seven years postretention.
- There was a strong correlation between irregularity one and seven years postretention. Stable cases one year postretention are stable in the long-term and cases with small changes one year postretention tend to deteriorate with time.
- Most of the rotational relapse was seen one year postretention with small changes long-term.
- There was a significant positive correlation between the amount of correction of incisor rotation and the magnitude of relapse.
- Of the over corrected contacts, only 50 percent returned to perfect alignment.
- Laterals are more prone to relapse. If, after a three year period of retention, a decision is made to use permanent retention of the maxillary front teeth, a retainer bonded to only the incisors seems to be a relevant choice.

KEY WORDS:

Retention; Rotation; Relapse; Irregularity; Incisors; Long-term

POPULÄRVETENSKAPLIG SAMMANFATTNING

Efter en tandregleringsbehandling, måste tänderna fixeras för att de inte ska gå tillbaka mot sina ursprungspositioner. När detta sker säger man att tänderna har gått i recidiv (tillbakagång) eller att de har recidiverat. För att undvika recidiv efter ortodontisk behandling limmas en så kallad retentionstråd bakom sex framtänder för att hålla kvar tänderna i deras nya position tills vävnaden runtom stabiliserats. Tråden får oftast sitta kvar i ca 3 år. Det har tidigare varit vanligast att använda retentionstråd i underkäke men på senare år används det i allt större utsträckning även i överkäken.

Syftet med denna studie var att undersöka storleken på recidivet efter ortodontisk korrektion av överkäkens framtänder efter att de har varit fixerade under ca 3 år med en retentionstråd. Vilka av de sex framtänderna är mest benägna att gå tillbaka till ursprungsläget? Är det skillnad i recidiv mellan kontaktpunktsförskjutningar (avståndet mellan två granntänders kontakt) och rotationer? Finns det skillnader i recidiv på kort och lång sikt? Studien gjordes på avgjutningar av patienters tänder som framställts i gips (studiemodeller). Kontaktpunktsförskjutningarna mellan de sex framtänderna mättes med hjälp av ett digitalt skjutmått. Modellerna skannades och rotationer av överkäkständerna från hörntand till hörntand, mättes mot gommens medellinje (Raphe) som referenslinje. Värdena jämfördes med situationen före behandling (T1), direkt efter behandling (T2) samt ett år (T3) och sju år (T4) efter det att retentionstråden hade tagits bort.

Resultaten visade att kontaktpunktsförskjutningarna mellan granntänder minskade och framtänderna upplinjerades av den ortodontiska behandlingen (T2). Ett år efter att retentionen tagits bort (T3), hade små men signifikanta förändringar skett mellan tandkontakterna. Särskilt förändringsbenägna var 2:or (laterala incisiver), därefter 1:or (centrala incisiver) och minst förändringsbenägna var 3:or (hörntänder). Förändringarna var högst individuella och det skilde sig mycket mellan olika individer. Vissa individer var mer utsatta för recidiv.

Vid överbehandlingar av vissa tandkontakter (kompensatoriska överkorrigeringar), gick inte alla tänder tillbaka till önskat läge. Hälften av överkorrigeringarna kvarstod och vissa blev till och med sämre. De tandkontakter som redan vid andra undersökningstillfället (T3) hade börjat recidivera, förvärrades ytterligare vid långtidsuppföljningen (T4). Mönstret

som beskrivits ovan, att lateraler var mest förändringsbenägna och hörntänder mest stabila, kvarstod på långt sikt.

Slutsatser:

- Mindre recidiv sågs ett år efter retentionens avlägsnande (T3), och förvärrades ytterligare något under långtidsuppföljningen (T4), dock i mindre omfattning.
- Det fanns inget samband mellan hur mycket tänderna hade blivit korrigerade och graden av recidiv.
- Det fanns ett starkt samband mellan recidiv ett och sju år efter borttagning av retentionen.
- Rotationer var mer benägna att gå tillbaka mot ursprungsläget.
- Kontaktrelationen mellan lateraler och centraler är mest recidivbenägna och hörntänderna är mest stabila. Om man vill behålla retentionen efter 3 år, räcker det enligt denna studie med att ha kvar den mellan 12-22.
- Överkorrektioner bör göras med försiktighet då risk finns att tänderna inte spontant går tillbaka till önskad position.

INTRODUCTION

The goal of orthodontic treatment is to produce a normal or so-called ideal occlusion that is morphologically stable and esthetically and functionally well-adjusted. The associations between ideal occlusion, oral health, function and esthetics, however, are still in many aspects unclear.

Orthodontic treatment in the primary and mixed dentition periods mainly tends to eliminate factors which may have a negative effect on occlusal development (interceptive orthodontic treatment). Another aim for treatment at an early age is to prevent tooth damage by reducing a large overjet or correcting ectopic eruption of maxillary canines in individuals, where an increased risk for root resorption is suspected. In certain situations, early treatment is motivated for cost benefit reasons. Examples are congenitally missing teeth and vertically unstable occlusions such as Angle class II:2.

Corrective orthodontic treatments are usually carried out in the permanent dentition (adolescents and adults). An ideal occlusion is supposed to go hand in hand with optimal oral function and health and, not in the least, acceptable esthetics. There is, however, limited evidence supporting the belief that an ideal occlusion improves chewing ability and speech and reduces the risk for development of TMD (temporomandibular disorders). Neither has there been shown significant correlations to caries and periodontitis.[1,2]

Studies have shown that esthetics, no doubt, is the major motivating factor for orthodontic treatment both in adults and adolescents. Trulsson et al.[3] found, in a qualitative study of teenagers on a waiting list for orthodontic treatment, that the treatment decision was forced on the individual. Factors

like being as others, influence from media and not in the least from dentists were important. Shaw[4] reported that visible (frontal) tooth irregularities were the most important treatment motivating conditions.

Even if the concern for esthetics seems to be greatest in young individuals, there is a considerable concern for esthetics in older subjects.[5-10] These studies show that patients are interested in well-aligned front teeth and do not care so much about malocclusions in molar areas. Therefore, from the patient's point of view, esthetics and stability of the upper front teeth after treatment is of considerable importance.[7,11] Young individuals show more of their upper front teeth, but with aging, show less due to the lengthening of the nose and upper lip covering more of the upper front teeth. Instead, they may show even more of the lower incisors.[12] After the orthodontic treatment and retention period, when relapses may occur, it is mainly the front teeth irregularity that causes a lack of satisfaction and calls for new treatment.[3,4,10]

Recent studies indicate that malposition of front teeth may contribute to low self-esteem and a general feeling of dissatisfaction.[3,7,11,13] On the other hand, visible malocclusions do not seem to cause psychological illness.[14-16] Orthodontists, in general, are facing two challenges; the first is the treatment and alignment of the dental arches and the second is maintenance of the treatment results.

Orthodontic relapses are usually described as changes toward the pretreatment status. These changes occur very fast if the teeth are not kept in their new position. That is the reason why, after orthodontic treatment, the result must be stabilized by some kind of retention device to prevent relapse. However, after this first period of remodeling of periodontal structures, comes the later period of changes. The problem is that these

changes generally cannot be distinguished from the normal aging process that occurs, regardless of orthodontic treatment or not.

Anatomy of the Periodontium

The periodontal space is occupied by cells, vessels, fluid and dento-alveolar fibers, called the periodontal ligament (PDL). These periodontal ligaments consist of collagen fibers that are arranged into fiber bundles. The portion of these fibers that is embedded into either cementum or bone is called Sharpey's fibers. These fibers occasionally pass through the bone of the alveolar process to continue as principal fibers of an adjacent PDL. They may also run buccally and lingually to connect with the fibers of the periosteum. Other fibers are: Circular fibers (runs around the tooth in the free gingiva), Dentogingival fibers, Dentoperiostal fibers, Alveologingival and Transseptal fibers[17] (Figure 1).

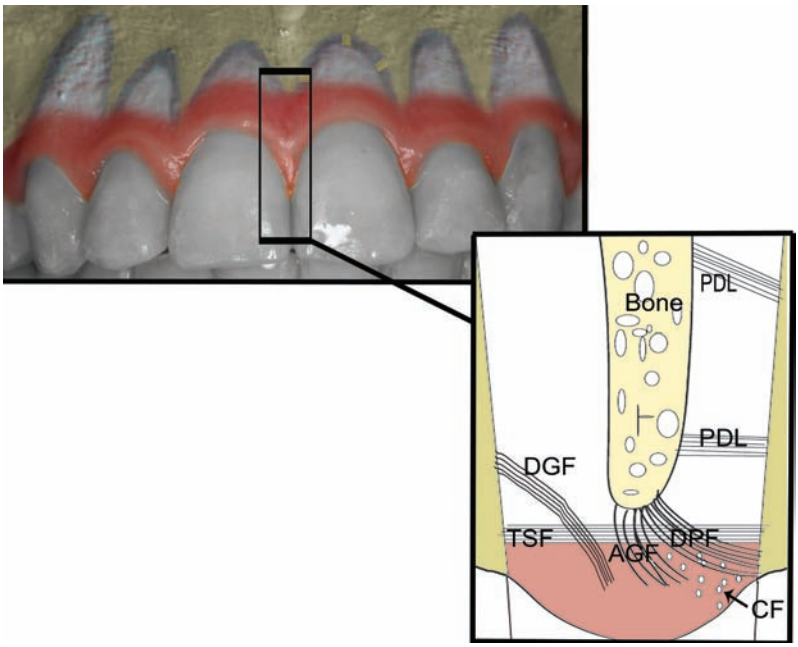


Figure 1. Different fibers surrounding teeth. Periodontal ligament (PDL), Circular fibers (CF), Dentogingival fibers (DGF), Dentoperiostal fibers (DPF), Transseptal fibers (TSF) and Alveologingival fibers (AGF).

Biological and physiological role of periodontium and gingival tissue on relapse

After orthodontic tooth movement, there is a need for remodeling of the supporting tissues around the tooth, to prevent it returning to its former position.[18-21] The periodontal ligaments and Sharpey's fibers act as an anchorage zone for new bone and new cementum. The middle and most apical part of the root are more stable to relapse whereas the marginal third of the root is unstable.[22] Reitan[19] described the relapse that occurred after

tipping of the teeth in dogs without retention. He noticed that some relapse already occurred after two hours, partly caused by the uprighting of the tooth. Relapse continued to occur during the following four days. Thereafter, this process stopped due to the hyalinized zone (cell free zone) on the tension side. A similar pattern was observed in children after tipping teeth without subsequent retention.[19]

The periodontal ligament remodels fast, but the gingival fibers have a slow turnover rate and take as long as 232 days to remodel after experimental tooth rotation.[18] Transseptal and Dentoperiostal fibers of the gingiva, the fibers connecting thick maxillary frenulum to the alveolar process, also need a very long period of remodeling and may be a source of relapse.[23]
Since the supra-alveolar fibers take a long time to remodel, some authors suggest surgical circumferential incision of supra-alveolar structures (fibrotomy) that may prevent or reduce relapse after the experimental rotation of teeth.[24-27]

The retention period is generally longer in adult patients, sometimes even permanent, due to thicker bundles of fibers and the decreased ability of the periodontal and surrounding tissues to remodel after orthodontic tooth movement.[22,28]

When space is closed rapidly in extraction sites, there is a tendency toward reopening. It has been shown that compressed gingival tissue in an extraction site may produce a gingival fold or invagination which is most frequently seen in premolar extraction sites.[29] This hyperplasticity and excessive tissue may cause the reopening of space by pushing teeth apart (Figure 2).

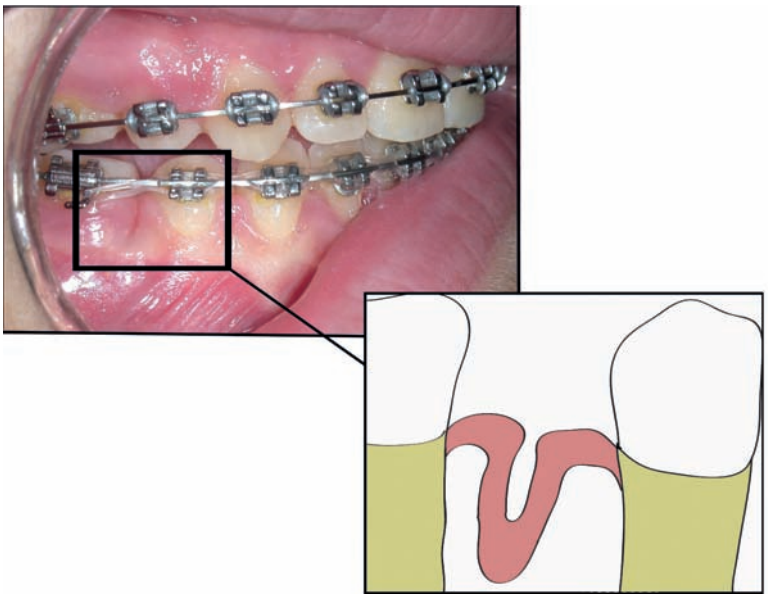


Figure 2. Gingival fold caused by rapid movement of teeth into an extraction site.

According to Reitan[19], there will be little or no relapse following orthodontic movement of an erupting tooth, since its supporting tissues are in a proliferation stage as a result of the eruption process. New fibers will be formed as the root develops, and these new fibers will assist in maintaining the new tooth position.

It seems that the tongue puts more pressure on the teeth than the lips and chin.[30,31] On the other hand, these forces are probably not of the magnitude to move well-supported teeth. When the bone level is reduced, due to periodontitis, some flaring of teeth to the buccal direction might be observed. However, scientific ground for these hypotheses is very low.

Dental arch changes

Henriksson et al.[32] found changes instead of stability in the dental arch form in untreated subjects with normal occlusion, when passing from adolescence into adulthood. They found a significant increase of inter-molar distance in the mandible in male subjects and a significantly more rounded lower dental arch form and reduction in arch depth in both sexes, leading to increased irregularity of the lower incisors.

Thilander,[33] in a longitudinal study of a population with normal occlusion between the ages of 5 and 31 years, found anterior crowding, especially in the mandible. The author explains it as the natural migration of teeth even in the absence of third molars.

In a cast analysis study by Harris,[34] arch size and form were measured in a longitudinal survey of untreated adults, at 20 years of age and again at 55 years of age. During this phase, arch lengths decreased significantly with time. The arch widths increased, especially in the molar area, and even some small expansion occurred in the canine region. These slow changes did not affect inter-arch relationship.

Bishara[35] found the changes that took place from 25 to 45 years of age were, on average, of small magnitude but statistically significant ($p < 0.05$). Both sexes experienced a significant increase in dental crowding in both arches and it was more pronounced in the anterior segments and more severe in the lower front.

In another 20-year longitudinal study by Ward,[36] changes in arch width of the maxillary and mandibular canine and molar in 60 subjects, older than 20 years of age, were examined. Interestingly, approximately half of the subjects were treated orthodontically. When comparing these two groups,

the arch width and length decreased in both groups. Some intercanine expansion occurred in the upper arch but only in the treated group.
The conclusion from these studies is that dental arches change over time and the natural path is the reduction of the arch length and migration of teeth, leading to crowding in front regions, especially in the lower arch, until 55 years of age. Stability or very small changes were observed by Dager et al.,[37] for subjects between 47-58 years of age. The occlusion follows these changes and the result seems to be “stable occlusion”.

Relapse after orthodontic treatment of front teeth

There is a large variation in treatment outcome due to the severity and type of malocclusion, treatment modality, patient cooperation, the growth and adaptation of soft and hard tissue.[38]
Relapse after orthodontic treatment is a well-known problem among orthodontists. Surbeck et al.[39] found that the pattern of pre-treatment rotational displacement of maxillary anterior teeth had a tendency to repeat itself postretention. The authors also claimed that incomplete alignment during treatment was a risk factor for relapse and suggested slight over correction during active treatment of severely rotated teeth. Other studies suggest fiberotomy and over correction to prevent the relapse of rotated teeth.[40,41]
Several studies investigate the relapse of the lower front.[42-51] The arch length decreases [52] and the inter-canine distance also decreases with time, resulting in increasing irregularity in the lower front .[53,54] Some authors recommend having retainers in place permanently.[42,51,55,56] One study shows an acceptable effect of leaving a canine-to-canine retainer up to 20

years. The author's conclusion was that long-term retention with this kind of device of mandibular incisor alignment is acceptable for most patients and quite compatible with periodontal health.[57]

The present study focuses on upper front teeth. As mentioned before, malalignment of maxillary front teeth is often the reason why patients seek orthodontic treatment. There are different types of retention devices to keep the upper front teeth stable after orthodontic treatment.

Retention methods of upper front teeth

A number of different removable or fixed retainers have been used to retain upper front teeth after orthodontic treatment (Figures 3-8). The choice depends on the initial malocclusion, expected growth and occlusal development and the expected cooperation with use of retainers. Bonded retainers seem to be popular as they fairly effectively prevent tipping and rotation of the teeth. They are rather independent of cooperation and can be used for long periods,[39,54,58-60] although there are few studies on real long-term use. Some appliances, such as positioners and spring retainers, can be used for minor tooth movements. Some, like the Jensen plate and the Hawley retainer, are designed to allow vertical tooth movements.

Figure 3. Positioner

Figure 4. Spring retainer

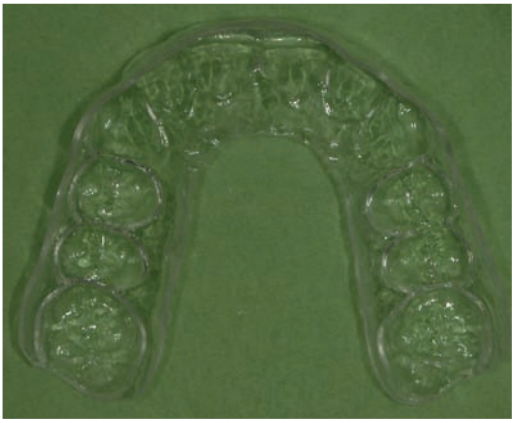


Figure 5. Essix 16-26

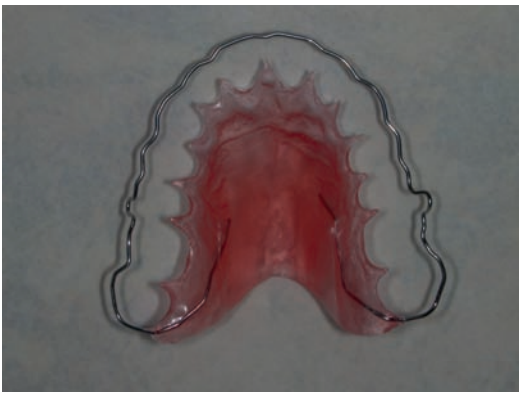


Figure 6. Hawley retainer

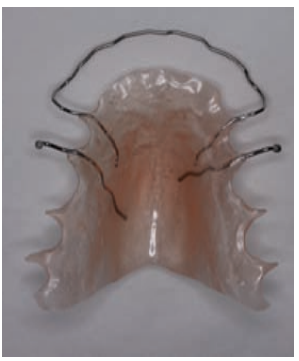


Figure 7. Jensen Plate

Figure 8. Bonded retainer

AIMS

- The aims of the studies included in this thesis are to:
- Study the amount of relapse and long-term changes in alignment of the maxillary front teeth after retention with a bonded retainer.
- Investigate the pattern of relapse regarding the type of movement after the correction of rotations and labial/lingual displacements.
- Examine the effect of over correction of contact point displacement (CPD) in stability outcome.
- Analyze the influence of expansion of the intercanine distance on stability outcome.

MATERIALS AND METHODS

Materials

The study group consisted of 45 patients treated with fixed orthodontic edgewise appliances. The patients were selected from the County Orthodontic Clinic in Mariestad, Sweden, when their upper bonded retainers were removed.

The wire used was 0.0195-inch Wildcat (GAC International Inc., Central Islip, NY). Their mean age at the one year follow-up after removal of the retainer was 18.8 years of age (range 15.8–21.5).

Extraction or nonextraction cases, with various diagnoses and where upper arches were retained with a bonded retainer only, were included. The mean duration of the retention period was 33 months (range 23–48 months)

All six front permanent teeth had to be present before treatment and presenting irregularity. Spacing of the upper front teeth and treatments started as adults were excluded.

Study models before treatment (T1), after active treatment (T2), and one year out of upper retention (T3) had to be available.

From the former group of 45 patients, a group of 27 patients were reexamined in the second study. Study models were collected at mean 7.6 years (range 6.7–10.9 years) out of retention (T4). The mean age of the patients was 25.3 years of age (range 21.7–30.4 years of age). Considering treatment and duration of retention and the mean irregularity index, this group was similar to the former group of 45.

Method for studying rotations and intercanine distance

In order to investigate individual rotational changes of the upper front teeth in relation to the Raphe line and to measure the intercanine distance, a new modified method was developed and tested.

Forty-five scanned pictures of study casts from 15 patients were randomly selected. These pictures represented study casts taken before treatment (T1), at treatment end (T2) and one year postretention (T3).

An Agfa DuoScan F40 (Agfa-Gevaert N.V. Septestraat 27, B-2640 Mortsel, Belgium) scanner was used to scan the casts. A computer program, the Scion Image Beta 4.02 for Windows, was used to measure angles and distances. It is a free program and can be downloaded from http://www.scioncorp.com.

To eliminate possible quality differences of the scanned area, casts were placed on the upper third part of the glass and the scanned area of almost the same size was used. The optimal quality for the pictures was set to 300 DPI since the 2-3 times enlargement did not influence the quality other than better details of the pictures, when plotting.

Sixteen points were plotted in order from A to S. The letter (O) was not used to eliminate the risk for mistaking it as zero. The positions of these 16 points were oriented to the X- and Y-Axis of the scanned picture. These points, two and two, make a line representing the incisor line of the tooth (A-L), Raphe line (MN) and intercanine distance (RS). The rotations were measured as the angle between a line through two points on the incisal edge of the teeth and the Raphe line. The intercanine distance was measured between the cusp tips of the upper canines (Figure 9).

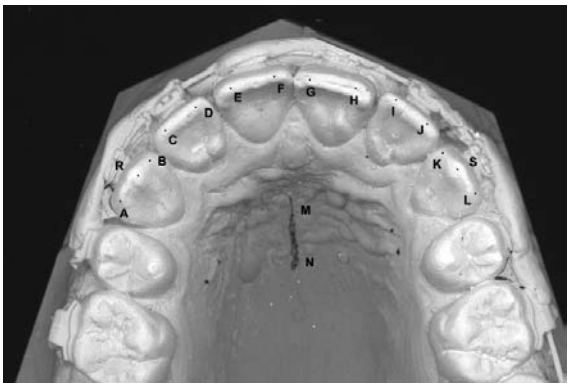


Figure 9. Reference points

For example, to measure the upper right cuspid's angle to the Raphe line, the program constructed a line by connecting points A and B (canine line) and the points M and N (Raphe line) virtually. The following lines could be achieved after plotting the points on the digitalized picture: AB= upper right cuspid line, CD= upper right lateral incisor line, EF= upper right central incisor line, GH= upper left central incisor line, IJ= upper left lateral incisor line, KL= upper left cuspid line, MN = Raphe line and RS = intercanine distance (Figure 10).

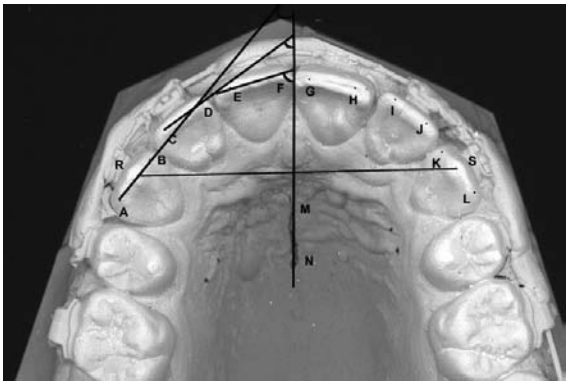


Figure 10. Showing the tooth angles on right side to Raphe line and intercanine distance.

All three scanned pictures (T1= before, T2= end of treatment, and T3= one year postretention) of each patient were opened simultaneously in separate windows and each point was marked as accurately as possible in all three images. Sixteen points (A-S) were marked on each picture (Figure 11 a-c).

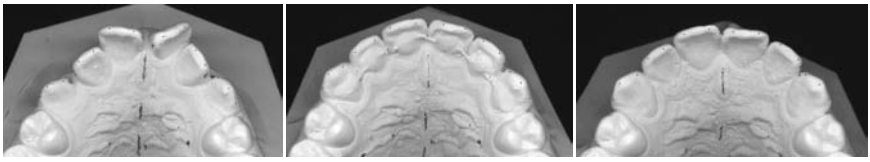


Figure 11 (a-c). T1, T2 and T3 of the same patient.

The pictures, with all points marked, were saved. All three pictures were reopened one by one in Scion image and the points were plotted for measurements. The results were transferred and calculated in StatView ® version 4.51, Abacus Concepts. Inc.

Different formulas were used to calculate the correct angular measurements and the intercanine distance.

Method for studying contact point displacement (CPD)

Labiolingual displacements of the anatomic contact points of all front teeth from the mesial of the right canine to the mesial of the left canine, were measured with a digital caliper on the casts from T1, T2, and T3, with 0.1 mm accuracy. CPDs less than 0.5 mm were judged to be zero. The irregularity index, i.e. the sum of the five CPDs (Figure 12), was calculated as described by Little.[61]

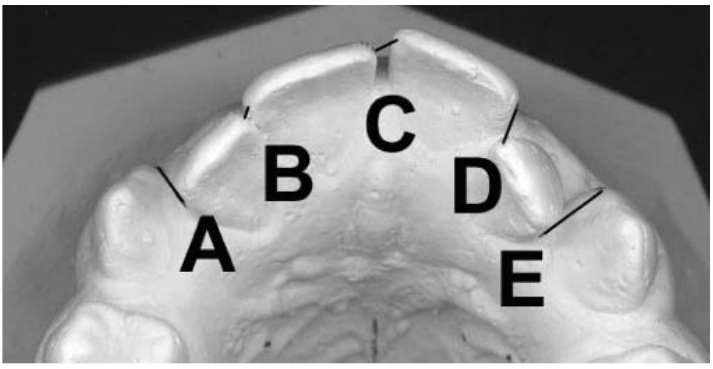


Figure 12. Irregularity index: The sum of five frontal contact displacements in millimeters (A+B+C+D+E).

Measurement errors

To study measurement errors for rotational changes and intercanine distance, each scanned cast picture was measured twice with one month in-between, with new points marked on fresh pictures. The error of the method was calculated, based on Dahlberg's formula,[62] from the equation:

$$S_x = \sqrt{\frac{\sum D^2}{2N}}$$

Where D is the difference between duplicated measurements and N is the number of double measurements. When measuring rotations to the Raphe line, the standard errors were 3.09° for canines and 2.78° for laterals and 2.35° for centrals. The error of measuring intercanine distance was 1.12 mm. The standard error of around 3° is, however, equal to the standard error for measuring many angles on a Cephalogram.

To calculate the measurement error for the contact point displacement, double measurements of 60 models, in 20 patients, were used. The measurement error for CPD was 0.14 mm.

Statistical analysis

The SAS ® v8.2 program (SAS Institute Inc, Cary, NC) was used for all statistical analyses. For all statistical analyses, the statistical significance level was set to 5%.

Paper I

Paired t-test was applied to test differences in the CPD, rotations, and the intercanine distance between T1, T2, and T3. Pearson's product-moment correlation test was applied to test correlations between the CPD and rotations at T1 and changes during treatment and at follow-up.

Paper II

Pearson's product-moment correlation coefficient was calculated to test for associations between irregularity index at T1/T3, T1/T4, and T3/T4. The same analysis was also used to test for correlations between correction of rotations/relapse of rotations and the change in mean CPD T2/T4 for the canine/lateral contact, the lateral/central contact, and the central/central contact.

RESULTS

Contact point displacements

Before treatment (T1). The mean irregularity index at T1 was 10.1 (range 3.0–29.9). The largest displacements were recorded between laterals and centrals followed by the displacement between laterals and canines, whereas the smallest deviations were found between the centrals.

After treatment (T2). The mean irregularity index was 0.7 (range 0.0–2.1). There was a significant difference in the index between T1 and T2 (P <.0001). Forty-three contacts were over corrected. Eighteen over corrections were less than 0.5 mm (all were non measurable) and could only be detected at close inspection.

After retention (T3). The mean irregularity index at T3 was 1.4 (range 0–5.1), i.e. 14% of the irregularity at T1. There was a significant difference in the index between T2 and T3 (P <.0001).

Results from the second study showed that there were no statistically significant differences between the change in mean CPDs for the contacts canines/laterals, laterals/centrals, or centrals/centrals. The mean irregularity index for the 27 patients examined in the second study was 10.3 (range 3.7-29.9) at T1, 0.9 (range 0.0-2.1) at T2, 1.3 (range 0.0-3.5) at T3 and 2.0 (range 0.0-5.8) at T4. No correlations were found between the pretreatment and postretention irregularity T1/T3 and T1/T4. There was a significant association between the irregularity index at T3 and T4 (R = 0.938, P < .0001), (Figure 13).

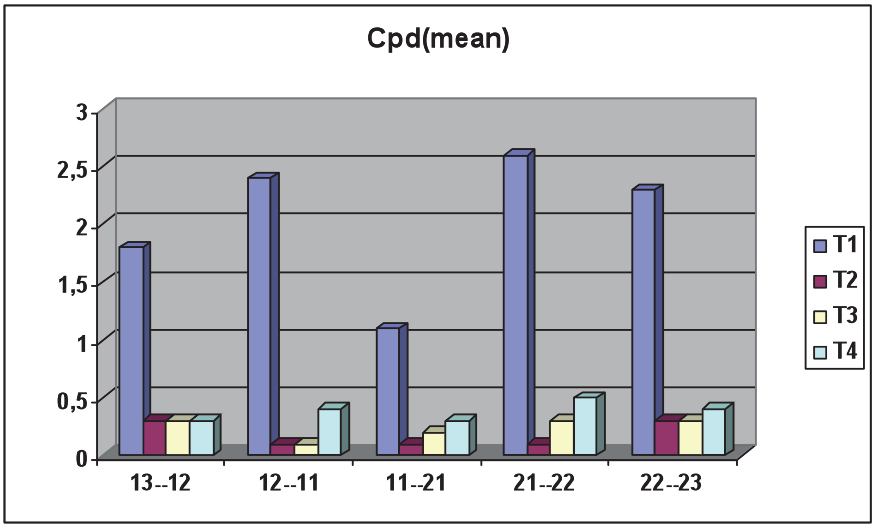


Figure 13. Contact Point Displacements at T1, T2, T3 and T4.

Twenty over corrected contacts were noted. Of the 20 over corrected CPDs, 10 showed perfect contacts at T4 and four were to some degree still over corrected. Six contacts had relapsed 0.8–2.1 mm (Figure 14).

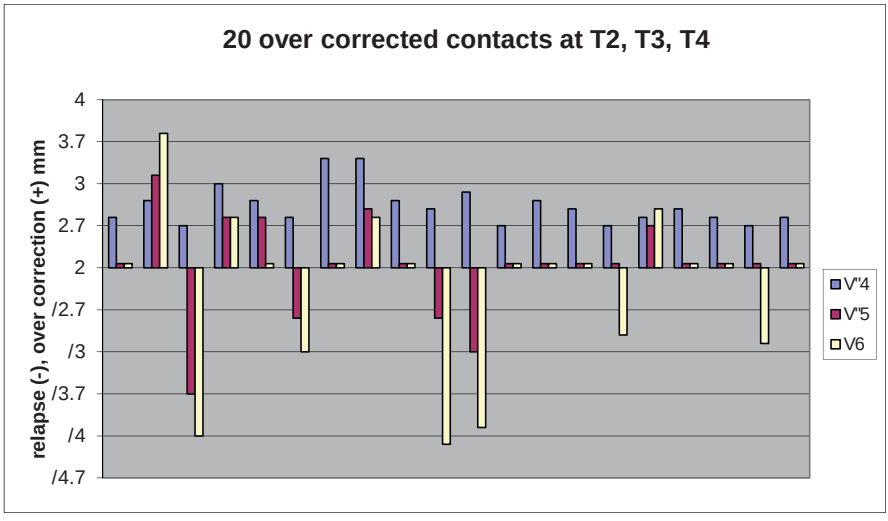


Figure 14. Twenty over corrected contacts at T2, T3 and T4.

Rotations

There was a significant correlation between the amount of rotational change (for all six teeth) due to treatment and relapse (P< .0001). However, when looking at each tooth group, centrals (P< .0130) and laterals (P< .0001) showed significant correlations but not the canines (P < .0622).

A total of 40 rotated teeth in 21 patients were corrected more than 20° during treatment (range 20.3°–51.9°). Mean relapse during the first year postretention (T2–T3) was 6.7° (range 0.0°–14.7°). Seven years postretention (T2–T4), the mean relapse was 8.2° (range 0.0°–19.3°).

Most of the changes were seen at one year postretention (T3). Positive correlation between rotational correction in treatment and long-term relapse was statistically significant for centrals (P = .0004), laterals (P = .0007) and the canines (P = .0056).

Intercanine distance

In 14 patients, the intercanine distance was expanded equal to or more than 1.5 mm from T1-T2 (range 1.5–6.4). Four of these 14 patients showed a reduction of the intercanine width at T3 of 1 mm or more (range 1.0–2.3). Five of nine individuals followed to T4, showed a relapse of 1 mm or more (range 1.1–2.3) of the intercanine distance. Among the patients without increased intercanine distance during treatment, three showed a decreased intercanine distance of 1.5–2.3 mm at T4.

DISCUSSION

When measuring the contact point displacement, a calliper is a common tool, but other methods such as a reflex microscope have also been used.[63] However, to measure rotations on a study model is a more challenging task and some different methods have been described.

In general, two different methods have been used earlier to identify and compare changes after orthodontic treatment. The first method measures plain rotations of the upper six front teeth to the Raphe line on a photocopy of casts.[64-66] With this method, difficulty in locating the Raphe line equally on the pretreatment, post treatment and postretention study models causes measurement errors. The variation in the quality of the plaster casts is another factor that may increase the measurement error.

The second method is based on the arch form and its changes during and after treatment.[32,39,47,67,68] The second method does not distinguish changes of each individual tooth because it is aimed to investigate the arch shape and form and its changes over time. Rotations of teeth are measured relative to a computer generated arch form in this method. Surbeck et al.[39] stated that their method might indicate CPD and incisor rotations even in a group selected for perfect alignment. This shows that a computer generated arch form may not represent the actual dental arch, and teeth may be rotated, but the computer generated arch form does not show it.

It was considered to be of interest to investigate the individual tooth and its rotational change to previous position and to distinguish between rotation and contact point displacement. Therefore, the first method was chosen but instead of doing measurements manually on a photocopy paper, it was

decided to produce and test a new modified and computer-aided method, to study rotational changes of six upper front teeth to the Raphe line.

In the first study, 89% of the patients had a score of less than 3 mm for the maxillary irregularity index, one year out of retention. The change from a mean irregularity index of 0.7 mm after treatment to 1.4 mm after retention can be regarded as a minor relapse compared with the original irregularity index of 10.1 mm. The irregularity one year after retention was 14% of the value before treatment. In comparison with other studies using Hawley retainers,[27,46,69,70] these results seem to be favorable; i.e. less postretention changes were observed in this study. No correlations were observed between the severity of pretreatment irregularity and the amount of relapse. This means that severe cases did not relapse more compared to the cases with less initial irregularity one year postretention.

Since the follow-up period was only one year, the results were considered as short-term. A recall visit one year out of retention was, in most cases, the patient's last visit to the orthodontist. However, small contact displacements one year after retention may be potential starting points for increasing irregularity. It was of interest to learn if this was the case in the second study.

At the long-term follow-up in the second study, the irregularity index of the maxillary front teeth increased among patients. But still 70 percent of the patients had an irregularity index of less than 3 mm. A weakness in this material is the relatively small number of patients (n= 27) with records one and seven years postretention. But the 27 patients that were examined long-term were, in all aspects, similar to the larger group of 45 subjects (initial irregularity, treatment, duration of retention).

A strength with this study is that the original 45 patients reported in the one year study were selected at the appointment when the retainer was

removed. Most other studies are based on retrospective materials[27,38,39,46,66,69,71] selected from larger collections. All of the patients in this study had the same method of retention, i.e. upper bonded retainer, and the length of the retention period and the postretention period is specified. These variables have a wider range in many studies or are not reported at all.[38,39,46,66,69,71,72]

Most of the patients, who showed minor irregularities one year postretention, were more irregular at the long-term follow-up, resulting in that 14% of the contacts were displaced more than 1 mm, maximum 2.2 mm. There was a strong correlation between irregularity one year postretention and long-term seven years postretention, but the findings of Surbeck et al.[39], that pretreatment irregularity is a significant risk indicator for postretention relapse, could not be confirmed. However, half of the group of 27 patients did not change at all and they were stable during the whole postretention period. Concerning corrected rotations, almost all relapse was seen one year postretention with very small further changes.

The contact relationship between laterals and centrals showed the largest CPD at T1, which is in accordance with the earlier findings.[69] Regarding alignment of the maxillary anterior teeth, the contact relationship between the lateral and central seems to be most critical. The correction of a bodily displaced tooth, often laterals, includes selective root torque to minimize the relapse tendency. Otherwise, only the crown is tipped buccally and the root is still on the palatal side.

The laterals showed more rotational mean relapse than centrals and canines, and of the 12 rotations that relapsed more than 10°, eight were laterals. The data confirmed the findings of Surbeck et al.[39], that most rotational relapses of the maxillary incisors are approximately 10°. Half of the over corrected contacts were nicely aligned at T4. The over corrections

that were noticed to have relapsed, one year postretention, had a tendency of continued relapse.

The irregularity index is not always reflecting the esthetic impression of the teeth; evenly distributed small CPDs are probably better than one or two major displaced contacts with the lateral/central contact often being the most critical. The experience is that rotations of up to 10° are not visible. A relapse in the range of 15° to 20° can be detected at close examination. Of the 40 severe rotations in this study, 15% relapsed within that range (15.6°–19.3°).

From an esthetic point of view, a slightly disto-buccally rotated upper canine is not likely to be disturbing due to the curved buccal surface. A rotation that causes a broken contact may be more displeasing. The clinical impression is that the contact between lateral and central is the most critical concerning correction and stability. If, after a 3-year period of retention, a decision is made to use permanent retention of the maxillary front teeth, a retainer bonded to only the incisors seems to be a relevant choice.

Bond failures for the 306 teeth with bonded retainer were recorded in six teeth in five patients during the retention period. There are different reasons mentioned in the literature affecting the results such as material, dimension and shape of the retainer, method, operator skills, patient habits, patient intercuspidation and so on.[58-60,73-77] In this study, most patients achieved a proper overbite with almost no interferences. In patients with short upper clinical crowns, the wire was placed more cervically. All the patients in this study had the same operator.

The failure rate of upper bonded retained teeth (2%) in the present studies is consistent with the findings of Zachrisson[58] and must be considered very good since some studies show that bond failure is higher in the upper front than the lower front.[75,78] In addition, four of six retainer failures in this

study affected premolars (48 premolars were involved), which are considered to have even higher failure rates.

Only a few individuals exhibited an increased intercanine width during treatment. No obvious changes could be recorded in the intercanine distance between T2 and T3. Since four subjects showed a decreased width, no safe conclusions can be drawn from these findings.

Fiberotomy was performed on only nine incisors. Their degree of relapse was not different from the remaining 46 teeth corrected more than 20°. Studies that used Hawley retainers as retention found less relapse in a group with fiberotomies as compared with a group without.[24]

Of the 25 measurable over corrections at T2, 14 had returned to zero CPD at T3. It is not known if the four over corrections that relapsed toward the original position (T1) would have been of a different magnitude without over correction. The seven remaining over corrections were so small (0.5–1.1 mm) that they probably did not cause the patients any dissatisfaction.

It can be concluded that over corrections should be small since there is a risk that some do not rebound to zero CPD. It is uncertain how much the result can be improved by over correction.

Using implants as reference points could be regarded as the most stable and reliable method when measuring rotations. As they can only be used in specific situations, the Raphe line can be considered relatively easy to use as reference to measure rotations of the upper front teeth.

In recent years, laser scanning of study models has given us a more accurate picture of changes during treatment and postretention. However, it is still expensive to acquire these machines, but they may have a future for the evaluation of the treatment and relapse after orthodontic treatment.

CONCLUSIONS

- Minor or no relapse in short-term follow-up (1 year) was noted in the maxillary front after correction of irregularity and a two to four year period of bonded retention. Further, small relapse occurred long-term i.e. at mean seven years postretention.
- No significant relation was found between the amount of correction of contact point displacement and magnitude of relapse neither in one, nor seven years postretention.
- There was a strong correlation between irregularity one and seven years postretention. Stable cases one year postretention are stable in the long-term and cases with small changes one year postretention tend to deteriorate with time.
- Most of the rotational relapse was seen one year postretention with small changes long-term.
- There was a significant positive correlation between the amount of correction of incisor rotation and the magnitude of relapse.
- Of the over corrected contacts, only 50 percent returned to perfect alignment.
- Laterals are more prone to relapse. If, after a three year period of retention, a decision is made to use permanent retention of the maxillary front teeth, a retainer bonded to only the incisors seems to be a relevant choice.

ACKNOWLEDGMENTS

I wish to express my deepest and sincerest thanks to everyone who has helped and supported me during these years with my project. Especially, I would like to thank:

Professor Bengt Mohlin, my supervisor and co-author. Thank you for your kindness and knowledge in the subject. I have learned much during these years, talking to you and learning how to be an open-minded researcher and human being.

Associate professor Heidrun Kjellberg, my supervisor and co-author. Thank you for your speed on returning manuscripts, all your wise comments and your sharp eyes.

Dr. Anders Andrén as a co-author of both papers. I am grateful that we could use your data material for this thesis. It has been a pleasure to know you and work with you.

The Orthodontic Department in Växjö, Kronoberg Region, for all the support during these years and encouraging me to finish my project.

Odont Dr. Tailun He, for all his help with the mathematical formulas to calculate angles in the computer program.

Sandra Ståhlberg, for revision of the English text.

And finally, I am deeply grateful to my wife Peggy and my daughters Jasmin and Shirin for their understanding and acceptance of my involvement in this project.

These studies were supported financially by the following grants: Public Dental Health Service, and FOU centre in both the Kronoberg and Västra Götalands Region.

REFERENCES

1. Mohlin B, Kurol J. To what extent do deviations from an ideal occlusion constitute a health risk? Swed Dent J 2003;27:1-10.
2. SBU. Bettavikelser och tandreglering i ett hälsoperspektiv, 176-2005.
3. Trulsson U, Strandmark M, Mohlin B, Berggren U. A qualitative study of teenagers' decisions to undergo orthodontic treatment with fixed appliance. J Orthod 2002;29:197-204.
4. Shaw WC. Factors influencing the desire for orthodontic treatment. Eur J Orthod 1981;3:151-162.
5. Ingervall B, Mohlin B, Thilander B. Prevalence and awareness of malocclusion in Swedish men. Community Dent Oral Epidemiol 1978;6:308-314.
6. Mohlin B. Need and demand for orthodontic treatment in a group of women in Sweden. Eur J Orthod 1982;4:231-242.
7. Helm S, Kreiborg S, Solow B. Psychosocial implications of malocclusion: a 15-year follow-up study in 30-year-old Danes. Am J Orthod 1985;87:110-118.
8. Salonen L, Mohlin B, Gotzlinger B, Hellden L. Need and demand for orthodontic treatment in an adult Swedish population. Eur J Orthod 1992;14:359-368.
9. Stenvik A, Espeland L, Berset GP, Eriksen HM. Attitudes to malocclusion among 18- and 35-year-old Norwegians. Community Dent Oral Epidemiol 1996;24:390-393.
10. Stenvik A, Espeland L, Berset GP, Eriksen HM, Zachrisson BU. Need and desire for orthodontic (re-)treatment in 35-year-old Norwegians. J Orofac Orthop 1996;57:334-342.
11. Espeland LV, Stenvik A. Perception of personal dental appearance in young adults: relationship between occlusion, awareness, and satisfaction. Am J Orthod Dentofacial Orthop 1991;100:234-241.
12. Burrow SJ. Biomechanics and the paradigm shift in orthodontic treatment planning. J Clin Orthod 2009;43:635-644.
13. de Oliveira CM, Sheiham A. The relationship between normative orthodontic treatment need and oral health-related quality of life. Community Dent Oral Epidemiol 2003;31:426-436.
14. Albino JE, Tedesco LA, Conny DJ. Patient perceptions of dental-facial esthetics: shared concerns in orthodontics and prosthodontics. J Prosthet Dent 1984;52:9-13.

15. Albino JE, Lawrence SD, Tedesco LA. Psychological and social effects of orthodontic treatment. J Behav Med 1994;17:81-98.
16. Kenealy P, Frude N, Shaw W. The effects of social class on the uptake of orthodontic treatment. Br J Orthod 1989;16:107-111.
17. J. Lindhe, T. Karring, N.P. Lang. The Anatomy of Periodontal Tissues, Clinical Periodontology and Implant Dentistry: Blackwell Munksgaard, a Blackwell publishing company; 2008. p. 21-29.
18. Reitan K. Tissue rearrangement during retention of orthodontically rotated teeth. The Angle Orthodontist 1959;29:9.
19. Reitan K. Clinical and histologic observations on tooth movement during and after orthodontic treatment. Am J Orthod 1967;53:721-745.
20. Reitan K. Principles of retention and avoidance of posttreatment relapse. Am J Orthod 1969;55:776-790.
21. Ericsson I, Thilander B. Orthodontic relapse in dentitions with reduced periodontal support: an experimental study in dogs. Eur J Orthod 1980;2:51-57.
22. Thilander B. Biological Basis for Orthodontic Relapse Seminar of Orthodontics; 2000: p. 195-205.
23. Edwards JG. The diastema, the frenum, the frenectomy: a clinical study. Am J Orthod 1977;71:489-508.
24. Boese LR. Increased stability of orthodontically rotated teeth following gingivectomy in Macaca nemestrina. Am J Orthod 1969;56:273-290.
25. Brain WE. The effect of surgical transsection of free gingival fibers on the regression of orthodontically rotated teeth in the dog. Am J Orthod 1969;55:50-70.
26. Parker GR. Transseptal fibers and relapse following bodily retration of teeth: a histologic study. Am J Orthod 1972;61:331-344.
27. Edwards JG. A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse. Am J Orthod Dentofacial Orthop 1988;93:380-387.
28. Taner TU, Haydar B, Kavuklu I, Korkmaz A. Short-term effects of fiberotomy on relapse of anterior crowding. Am J Orthod Dentofacial Orthop 2000;118:617-623.
29. Ronnerman A, Thilander B, Heyden G. Gingival tissue reactions to orthodontic closure of extraction sites. Histologic and histochemical studies. Am J Orthod 1980;77:620-625.
30. Proffit WR, Kydd WL, Wilskie GH, Taylor DT. Intraoral Pressures in a Young Adult Group. J Dent Res 1964;43:555-562.
31. Kydd WL. Maximum forces exerted on the dentition by the perioral and lingual musculature. J Am Dent Assoc 1957;55:646-651.

32. Henrikson J, Persson M, Thilander B. Long-term stability of dental arch form in normal occlusion from 13 to 31 years of age. Eur J Orthod 2001;23:51-61.
33. Thilander B. Dentoalveolar development in subjects with normal occlusion. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod 2009;31:109-120.
34. Harris EF. A longitudinal study of arch size and form in untreated adults. Am J Orthod Dentofacial Orthop 1997;111:419-427.
35. Bishara SE, Treder JE, Damon P, Olsen M. Changes in the dental arches and dentition between 25 and 45 years of age. Angle Orthod 1996;66:417-422.
36. Ward DE, Workman J, Brown R, Richmond S. Changes in arch width. A 20-year longitudinal study of orthodontic treatment. Angle Orthod 2006;76:6-13.
37. Dager MM, McNamara JA, Baccetti T, Franchi L. Aging in the craniofacial complex. Angle Orthod 2008;78:440-444.
38. Ormiston JP, Huang GJ, Little RM, Decker JD, Seuk GD. Retrospective analysis of long-term stable and unstable orthodontic treatment outcomes. Am J Orthod Dentofacial Orthop 2005;128:568-574; quiz 669.
39. Surbeck BT, Artun J, Hawkins NR, Leroux B. Associations between initial, posttreatment, and postretention alignment of maxillary anterior teeth. Am J Orthod Dentofacial Orthop 1998;113:186-195.
40. Blake M, Bibby K. Retention and stability: a review of the literature. Am J Orthod Dentofacial Orthop 1998;114:299-306.
41. Boese LR. Fiberotomy and reproximation without lower retention 9 years in retrospect: part II. Angle Orthod 1980;50:169-178.
42. Little RM, Wallen TR, Riedel RA. Stability and relapse of mandibular anterior alignment-first premolar extraction cases treated by traditional edgewise orthodontics. Am J Orthod 1981;80:349-365.
43. Shields TE, Little RM, Chapko MK. Stability and relapse of mandibular anterior alignment: a cephalometric appraisal of first-premolar-extraction cases treated by traditional edgewise orthodontics. Am J Orthod 1985;87:27-38.
44. Little RM, Riedel RA, Artun J. An evaluation of changes in mandibular anterior alignment from 10 to 20 years postretention. Am J Orthod Dentofacial Orthop 1988;93:423-428.
45. Little RM. Stability and relapse of dental arch alignment. Br J Orthod 1990;17:235-241.

46. Sadowsky C, Schneider BJ, BeGole EA, Tahir E. Long-term stability after orthodontic treatment: nonextraction with prolonged retention. Am J Orthod Dentofacial Orthop 1994;106:243-249.
47. de la Cruz A, Sampson P, Little RM, Artun J, Shapiro PA. Long-term changes in arch form after orthodontic treatment and retention. Am J Orthod Dentofacial Orthop 1995;107:518-530.
48. Schutz-Fransson U, Bjerklin K, Kurol J. Long-term development in the mandible and incisor crowding with and without an orthodontic stabilising appliance. J Orofac Orthop 1998;59:63-72.
49. Schutz-Fransson U, Bjerklin K, Kurol J. Mandibular incisor stability after bimaxillary orthodontic treatment with premolar extraction in the upper arch. J Orofac Orthop 1998;59:47-58.
50. Little RM. Stability and relapse of mandibular anterior alignment: University of Washington studies. Semin Orthod 1999;5:191-204.
51. Durbin DD. Relapse and the need for permanent fixed retention. J Clin Orthod 2001;35:723-727.
52. Little RM. Stability and relapse: early treatment of arch length deficiency. Am J Orthod Dentofacial Orthop 2002;121:578-581.
53. Riedel RA, Brandt S. Dr. Richard A. Riedel on retention and relapse. J Clin Orthod 1976;10:454-472.
54. Zachrisson BU. Important aspects of long-term stability. J Clin Orthod 1997;31:562-583.
55. Parker WS. Retention--retainers may be forever. Am J Orthod Dentofacial Orthop 1989;95:505-513.
56. Cerny R. Permanent fixed lingual retention. J Clin Orthod 2001;35:728-732.
57. Booth FA, Edelman JM, Proffit WR. Twenty-year follow-up of patients with permanently bonded mandibular canine-to-canine retainers. Am J Orthod Dentofacial Orthop 2008;133:70-76.
58. Zachrisson BU. Clinical experience with direct-bonded orthodontic retainers. Am J Orthod 1977;71:440-448.
59. Andren A, Asplund J, Azarmidohkt E, Svensson R, Varde P, Mohlin B. A clinical evaluation of long term retention with bonded retainers made from multi-strand wires. Swed Dent J 1998;22:123-131.
60. Zachrisson BU. Long-term experience with direct-bonded retainers: update and clinical advice. J Clin Orthod 2007;41:728-737; quiz 749.
61. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-563.
62. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin Ltd.; 1940.

63. Atack N, Harradine N, Sandy JR, Ireland AJ. Which way forward? Fixed or removable lower retainers. Angle Orthod 2007;77:954-959.
64. Sanin C, Hixon EH. Axial rotations of maxillary permanent incisors. Angle Orthod 1968;38:269-283.
65. Swanson WD, Riedel RA, D'Anna JA. Postretention study: incidence and stability of rotated teeth in humans. Angle Orthod 1975;45:198-203.
66. Jones ML. The Barry Project--a further assessment of occlusal treatment change in a consecutive sample: crowding and arch dimensions. Br J Orthod 1990;17:269-285.
67. Sampson PD. Dental arch shape: a statistical analysis using conic sections. Am J Orthod 1981;79:535-548.
68. Davis LM, BeGole EA. Evaluation of orthodontic relapse using the cubic spline function. Am J Orthod Dentofacial Orthop 1998;113:300-306.
69. Vaden JL, Harris EF, Gardner RL. Relapse revisited. Am J Orthod Dentofacial Orthop 1997;111:543-553.
70. Huang L, Artun J. Is the postretention relapse of maxillary and mandibular incisor alignment related? Am J Orthod Dentofacial Orthop 2001;120:9-19.
71. Sadowsky C, Sakols EI. Long-term assessment of orthodontic relapse. Am J Orthod 1982;82:456-463.
72. Boley JC, Mark JA, Sachdeva RC, Buschang PH. Long-term stability of Class I premolar extraction treatment. Am J Orthod Dentofacial Orthop 2003;124:277-287.
73. Zachrisson BJ. A posttreatment evaluation of direct bonding in orthodontics. Am J Orthod 1977;71:173-189.
74. Zachrisson BU. The bonded lingual retainer and multiple spacing of anterior teeth. Swed Dent J Suppl 1982;15:247-255.
75. Dahl EH, Zachrisson BU. Long-term experience with direct-bonded lingual retainers. J Clin Orthod 1991;25:619-630.
76. Paulson RC. A functional rationale for routine maxillary bonded retention. Angle Orthod 1992;62:223-226.
77. Zachrisson BJ. Third-generation mandibular bonded lingual 3-3 retainer. J Clin Orthod 1995;29:39-48.
78. Lumsden KW, Saidler G, McColl JH. Breakage incidence with direct-bonded lingual retainers. Br J Orthod 1999;26:191-194.

ISBN 978-91-633-7846-1
Printed by Intellecta Infolog, Gothenburg