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Evaluation of orthodontic treatment after 1 year of retention—a randomized controlled trial

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SUMMARY The aim of this study was to use a randomized controlled trial methodology to evaluate and compare three different retention methods. The capacity of the retention methods to retain orthodontic treatment results was in this first phase analysed on a short-term basis, i.e. after 1 year of retention.

The subjects were recruited from adolescents undergoing fixed appliance treatment at an orthodontic clinic in the National Health Service (NHS) in Sweden between 2001 and 2007. Seventy-five patients (45 girls and 30 boys with a mean age of 14.4 years at the start of retention) were randomized into three retention systems; a vacuum-formed retainer in the maxilla and bonded canine-to-canine retainer in the mandible (group V-CTC), a vacuum-formed retainer in the maxilla combined with stripping of the 10 proximal surfaces of the lower mandibular anterior teeth (group V-S), and a prefabricated positioner covering the teeth in the maxilla and mandible (group P). The main outcome measures were: Little's irregularity index (LII), intercanine and intermolar width, arch length, overjet, and overbite. Registrations were made before orthodontic treatment, when the fixed orthodontic appliance was removed, and after 12 months in retention. Differences in means between groups were tested by one-way analysis of variance.

After 1 year of retention, no clinically significant difference in retention capacity was found between the three retention methods. Small but significant differences ($P<0.05$) were observed between the V-CTC and V-S groups regarding mandibular canine width, mandibular arch length, and overbite. In group P, two patients failed to co-operate.

Introduction

The aim of orthodontic treatment is to correct malocclusions and maintain stability of the corrections. During the 1960s and 1970s, the long-term stability of various types of orthodontic treatment was presented in several retrospective studies. In the 1980s and 1990s, the different retention strategies were analysed (Boese, 1980; Little, 1990; Zachrisson, 1997; Melrose and Millett, 1998). In 2006, the Cochrane Collaboration group selected and analysed all available literature with regard to various retention methods and focused on the effectiveness of different strategies. While solely randomized or pseudorandomized study designs were accepted, only five studies fulfilled the preset inclusion criteria. The Cochrane group reached the conclusion that no evidence existed concerning the most appropriate retention strategy following orthodontic treatment (Littlewood *et al.*, 2006). They recommended that future research should include true randomization, reporting of dropouts, adequate sample size calculation, and a minimum of 3 months follow-up. In view of this, it seems desirable to conduct well-designed randomized controlled trials (RCTs) to compare the effectiveness of different retention methods since such studies are rare.

In 2007, two RCT studies were published with focus on the efficiency of appliances to retain orthodontic treatment. These showed equal retention capacities of Hawley and vacuum-formed retainers in the maxilla after 6 months, but in the lower arch there was statistically significantly more relapse in the Hawley group (Rowland *et al.*, 2007) and that full-time wear of Essix retainers had the same capacity as part-time wear after 6 months (Gill *et al.*, 2007). Few studies have analysed the capacity of various retention methods to retain orthodontic treatment results after 1 year. The aim of this research therefore was to use RCT methodology to evaluate and compare three different retention methods. The capacity of the retention methods to retain orthodontic treatment results was in this first phase analysed on a short-term basis, i.e. after 1 year of retention. The null hypothesis tested was that there would be no difference in retention capacity between any of the three retention methods.

Subjects and methods

The Ethics Committee of Lund/Malmö University, Sweden, approved the protocol and the informed consent form (LU515-01). Each patient and parent were given oral as well as written information and had to sign the written consent before being included in the trial.

The study was carried out on patients referred to an orthodontic clinic in the National Health Service (NHS), Ystad, Sweden. The NHS clinic is responsible for

treatment of malocclusions of patients in the southeast County Council of Scania. The NHS in Sweden offers free dental care, including orthodontic treatment, to patients with a certain degree of malocclusion up to the age of 20 years. One experienced orthodontist treated all the patients who underwent orthodontic treatment between 2001 and 2007. The following inclusion criteria were met: no previous experience of orthodontic treatment, permanent dentition, space deficiencies in both jaws, normal skeletal and dentoalveolar sagittal, vertical, and transverse relationships, Class I molar relationship or 3 mm anterior or posterior deviation, and a treatment plan involving extraction of four premolars followed by fixed straight wire appliances (0.022 inch, MBT) in both jaws.

The generation of randomization was performed in blocks of five to ensure that equal numbers of patients were allocated to each of the three retention groups. Fifteen paper sheets, five ballots with maxillary vacuum-formed retainer and bonded mandibular canine-to-canine retainer, five with maxillary vacuum-formed retainer and mandibular interproximal enamel reduction (stripping), and five with a positioner were placed in a basket. The patient then decided the retention treatment by picking a ballot from the basket.

Retention methods

The three retention methods of choice were as follows:

1. a removable vacuum-formed retainer covering the palate and the maxillary anterior teeth from canine-to-canine and a bonded canine-to-canine retainer in the lower arch (group V-CTC; Figure 1a)
2. an identical maxillary vacuum-formed retainer as in group V-CTC was combined with stripping (Boese, 1980; Joseph *et al.*, 1992) of the lower anterior teeth (group V-S; Figure 1b)
3. a prefabricated positioner (Keski-Nisula *et al.*, 2008) covering all erupted teeth in the maxilla and the mandible (group P; Figure 1c)

The vacuum-formed retainers were made of 2 mm Biolon (Dreve Dentamid GmbH, Unna, Germany) in a Scheu Ministar press (Scheu-Dental GmbH, Iserlohn, Germany). The canine retainers consisted of 0.7 mm spring hard wire (Dentaurum noninium; Dentaurum, Ispringen, Germany) bonded with Transbond LC (3M Unitek Orthodontic Products, Monrovia, California, USA) to the lower canines. Mechanical stripping of the lower incisors and canines was performed either by hand with single-sided medium and fine metal blades (TP Orthodontics, La Porte, Indiana, USA) or with

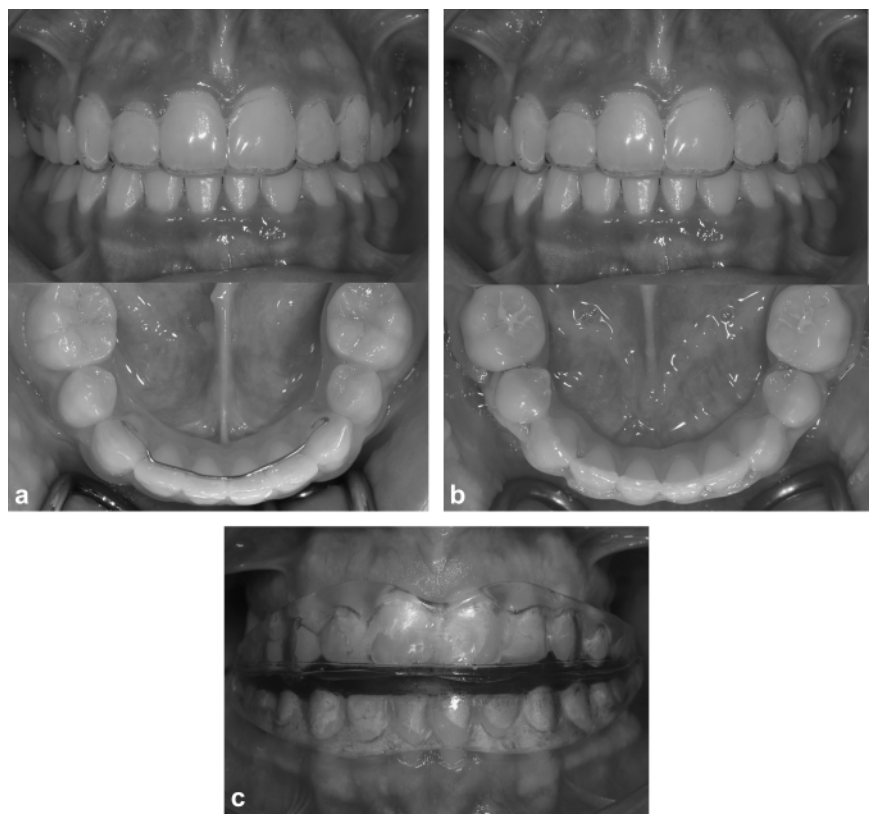

Figure 1 Vacuum-formed retainer in the maxilla and canine-to-canine retainer in the mandible (**a**), vacuum-formed retainer in the maxilla and stripping of the mandibular incisors and canines (**b**), and positioner covering all erupted teeth in the maxilla and mandible (**c**).

Ortho-Strips for the EVA system (Intensiv SA, Swiss Dental products, Grancia, Switerland). The method of stripping was dependent on tooth form, non-triangular or triangular, respectively, and was either performed on the visit 5–6 weeks prior to debonding or at debonding. The aim of stripping was to obtain small but distinct enamel flattening of the contact surfaces. The reduction of any contact point between two teeth amounted approximately to the thickness of the coarse blade of either system, i.e. 0.22 mm for hand stripping or 0.34 mm for EVA stripping. The preformed positioner (Ortho-Tain Positioner; Ortho-Tain Inc., Toa Alta, Puerto Rico, USA) was a soft plastic device covering all erupted teeth.

All retention appliances were distributed within 1 hour after debonding. The patients in groups V-CTC and V-S were instructed to wear the vacuum-formed retainer 22–24 hours/day for 2 days and nights and then during the night for 12 months. In group P, the positioner was to be worn for 30 minutes during the daytime and during sleep for 12 months. During day-time wear, patients were instructed to actively chew into the positioners. All patients visited the clinic twice for control of co-operation and of the appliances.

Documentation

Dental casts were obtained on three occasions, i.e. before orthodontic treatment, when the fixed orthodontic appliance was removed, and after 12 months in retention. The following linear measurements on dental casts were made by the same examiner (GET) with an electronic digital calliper (Mauser Digital 6, Winterthur, Switzerland) to a precision of 0.01 mm.

1. Little's irregularity index (LII) in the maxilla and mandible—the summed displacement of the anatomic contact points of the upper and lower incisors and canines (Little, 1975)
2. Intercanine width in the maxilla and the mandible—the distance between the maxillary and mandibular canine cusp tips
3. Intermolar width in the maxilla and the mandible—the distance between the mesiobuccal cusp tips of the first maxillary and mandibular molars
4. Arch length in the maxilla and the mandible—the perpendicular distance from the midpoint of the incisal edges of the central incisors to a line joining the mesial anatomic contact points of the first molars in the maxilla and mandible
5. Overjet—the distance parallel to the occlusal plane from the incisal edge of the most labial maxillary incisor to the opposing mandibular central incisor
6. Overbite—the overlap of upper to lower central incisors

Patient ages and treatment times were documented according to the dental records.

Statistical analysis

The sample size for each group was calculated based at a significance level of 0.05 and 80 per cent power to detect a clinically meaningful difference of 2.0 mm (SD = 2.0 mm) of the LII. The power analysis showed that 16 patients in each group were sufficient. To compensate for dropouts in future follow-up studies, 25 patients were enrolled in each group.

Arithmetic means and standard deviations (SDs) at group level at times corresponding to pre-treatment, start of retention, and after 1 year of retention were calculated for each variable. Significant differences in means between groups were tested by one-way analysis of variance using the Statistical Package for Social Sciences (version 14.0; SPSS Inc., Chicago, Illinois, USA). *P*-values less than 5 per cent ($P < 0.05$) were considered statistically significant.

Error of method

Twenty randomly selected dental casts were measured on two separate occasions with a 4 week interval by the same examiner. The method error (Dahlberg, 1940) did not exceed 0.45 mm for any of the 10 measurements. No significant mean differences between the two series of records were found using paired *t*-test. All results were also tested for normality.

Results

A total of 82 patients fulfilled the inclusion criteria. Seven patients (six girls and one boy) declined to participate, and thus, 75 patients were randomized. There were two dropouts during the 12 month period and consequently the study included 73 patients at the end of the trial (Figure 2).

In group V-CTC (18 girls and 7 boys), the mean age at the start of retention was 14.1 years (SD 1.3), in group V-S (14 girls and 11 boys) 14.7 years (SD 1.8), and in group P (13 girls and 12 boys) 14.3 years (SD 1.5). The mean active orthodontic treatment period in the V-CTC group was 1.6 years (SD 0.3), in the V-S group 1.8 years (SD 0.5), and 1.6 years (SD 0.3) in group P. There were no significant differences between any of the three retention groups regarding age or active treatment time. In addition, there were no significant differences between any of the retention strategies when measuring the study casts before and after active treatment.

Retention capacity

Maxilla. Small but insignificant differences were found between the three maxillary retention methods (Table 1). During the retention period the mean LII increased between 0.5 and 0.8 mm. The mean intercanine widths were reduced in all three groups, more for those wearing the positioner (1.6 mm) and less in the two groups wearing the vacuum-formed retainer (0.6–0.7 mm). The mean intermolar width

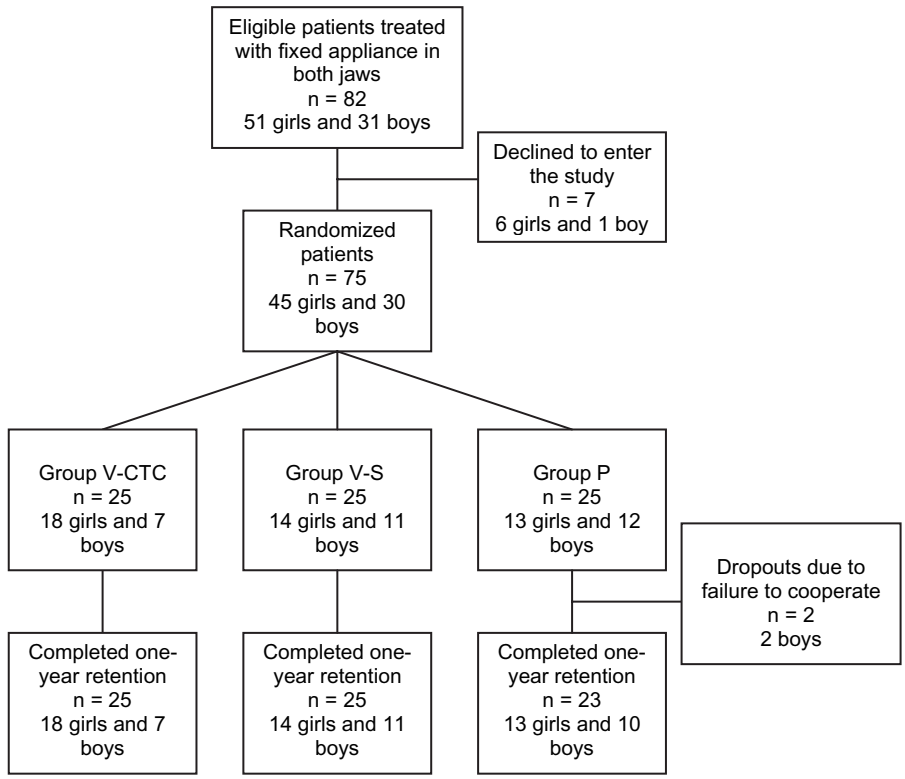

Figure 2 Consort diagram of the trial. Vacuum-formed retainer in the maxilla and canine-to-canine retainer in the mandible (group V-CTC), vacuum-formed retainer in the maxilla and interproximal enamel reduction in the mandible (group V-S), and positioner (group P).

decreased between 0.8 and 1.0 mm while a minimal increase in mean arch length (0.1–0.3 mm) was measured in all three groups (Table 1).

Mandible. Small but insignificant differences were seen in the mean LII between the three groups. The mean increase in LII was largest in group P at 1.1 mm followed by the V-S and V-CTC groups at 0.8 and 0.6 mm, respectively (Table 1).

A significant difference in the mean intercanine width between groups V-CTC and V-S was found ($P<0.001$). The mean intercanine width in the V-CTC group was unchanged and the mean reduction in group V-S was −1.0 mm. In group P, the mean reduction was −0.7 mm (Table 1).

Small but insignificant differences were seen in the mean intermolar width between the three groups. In group V-CTC, it was unchanged while in groups V-S and P it decreased by 0.6 and 0.8 mm, respectively (Table 1).

A significant difference in mean arch length was present between the V-CTC and V-S groups ($P<0.05$). It remained unchanged in the V-S group but increased in the V-CTC group to 0.7 mm. In group P, the mean change was 0.5 mm (Table 1).

Overjet and overbite. The mean overjet was stable in all three groups with a range of 0.0–0.3 mm. There was a small but significant change in overbite between groups V-CTC and V-S at −0.4 and +0.2 mm, respectively ($P<0.05$). In group P, the mean change was −0.2 mm (Table 1).

Successful retention. Overall, it was considered that in the V-CTC and V-S groups all patients had successful retention and 23 of 25 patients in group P were successful. The unsuccessful retention of the two patients in group P was due to failure to co-operate.

Discussion

On a short-term basis of 1 year and from a clinical point of view, all three retention methods had a good capacity to retain the orthodontic treatment results. Thus, the null hypothesis could not be rejected for the patient groups corresponding to the inclusion criteria.

The majority of relapse after orthodontic treatment occurs quite soon following debond and 50 per cent is seen within a few days due to stretching of the gingival tissues (Reitan, 1967; Taner *et al.*, 2000; Aasen and Espeland, 2005). The fibres within the periodontal membrane have a turnover rate of weeks while remodelling of supragingival fibres take months (Reitan, 1967; Boese, 1980). Accordingly, a retention method must have the capacity to stabilize the orthodontic result during these tissue-remodelling phases. From this perspective, it was found that all three retention strategies evaluated in this trial had equal capacity to resist

Table 1 The mean measurements (mm) for the three retention groups [removable vacuum-formed retainer and bonded lower canine-to-canine retainer (V-CTC), removable vacuum-formed retainer and lower anterior stripping (V-S) and positioner (P)] and the mean changes from the start and after 1 year's retention.

	V-CTC (n=25)		V-S (n=25)		P (n=23)		Analysis of variance
	Mean	SD	Mean	SD	Mean	SD	
Maxilla							
Little's irregularity index	1.1	1.1	1.0	1.0	1.3	1.1	NS
Change	0.6	1.0	0.5	1.0	0.8	1.2	NS
Intercanine width	35.9	1.8	35.9	2.2	35.1	3.1	NS
Change	−0.7	0.7	−0.6	0.6	−1.6	2.4	NS
Intermolar width	48.3	2.6	48.0	3.0	48.5	2.2	NS
Change	−0.8	1.7	−0.8	1.0	−1.0	1.1	NS
Arch length	23.5	1.5	22.7	1.8	23.1	1.6	NS
Change	0.3	1.1	0.1	0.4	0.3	2.5	NS
Mandible							
Little's irregularity index	1.0	0.6	1.1	1.1	1.5	1.1	NS
Change	0.6	0.6	0.8	0.9	1.1	1.0	NS
Intercanine width	27.4	1.5	26.4	2.1	26.8	1.6	NS
Change	0.0***	0.4	−1.0***	0.9	−0.7	1.0	0.000 V-CTC/V-S
Intermolar width	42.2	1.5	41.7	2.5	42.2	1.9	NS
Change	0.0	1.1	−0.6	1.8	−0.8	1.8	NS
Arch length	18.6	1.3	17.7	1.4	18.2	1.4	NS
Change	0.7*	1.0	0.0*	0.8	0.5	0.8	0.024 V-CTC/V-S
Overjet	3.0	0.9	3.3	1.2	3.4	0.9	NS
Change	0.0	0.9	0.3	1.0	0.3	0.9	NS
Overbite	1.8	0.9	2.2	1.1	2.2	1.0	NS
Change	−0.4*	0.8	0.2*	0.7	−0.2	1.0	0.038 V-CTC/V-S

*P<0.05, ***P<0.001, NS, not significant.

residual forces and retain the orthodontic treatment result during the first year.

Only a few RCTs of short-term stability of orthodontic treatment results have been published (Lindauer and Shoff, 1998; Gill *et al.*, 2007; Rowland *et al.*, 2007). These also demonstrated small but insignificant movement of the teeth. On the second day after debonding, the patients wore their vacuum-formed retainers only at night in this study. This regimen was chosen since equal stability of treatment results following full- or part-time wear of Essix retainers has been presented (Gill *et al.*, 2007). Vacuum-formed retainers have been shown to be superior to Hawley retainers in retaining the maxillary anterior teeth (Rowland *et al.*, 2007) and were thus the method of choice. The fact that the LII increased in patients with canine-to-canine retainers in the present study is supported by Atack *et al.* (2007). In group V-CTC it was obvious that the canine-to-canine retainers held the intercanine width but the extraction sites opened up significantly, i.e. the arch length increased compared with group V-S.

The finding that stripping without any conjunctive methods was sufficient to retain the treatment result on a short-term basis has not been demonstrated previously in a RCT study. In a retrospective study, it has been shown that stripping of lower anterior teeth in combination with overcorrection of rotated teeth was sufficient to prevent relapse during a 3 year period (Aasen and Espeland, 2005). Naturally, the reduction of enamel diminished the distance between the canines and was probably the explanation why small but significant differences in mandibular canine width and overbite could be seen between groups V-CTC and V-S. Stripping of the lower anterior teeth after debonding rather than the wearing of fixed or removable retention appliances would probably provide advantages not only for the patient but also for the clinician with regard to costs, chair-time, and problems with lost appliances.

The positioner is an eruption guidance appliance that is used in the early mixed dentition (Keski-Nisula *et al.*, 2008). No research has been presented about the effectiveness of prefabricated positioners to retain orthodontic treatment results. This trial showed that the appliance can be used in the permanent dentition as a retention device on a short-term basis. Because it is prefabricated it is a more cost-effective alternative to appliances made by technicians. One drawback, however, is that the fitting cannot be as precise as retention appliances made on individual dental casts.

The RCT was the study design of choice since a high level of evidence was desirable when the retention capacity was evaluated in a comparison between the three retention methods. The randomization process confirmed that subject characteristics were equally distributed in the three groups. Strict inclusion criteria, power calculation, and minimal dropouts during the trial limited bias.

A drawback with removable appliances is that compliance is compulsory but since the patients were randomly allocated, the compliance rate was evenly distributed between the groups.

The use of LII for measuring relapse of tooth positions may have some limitations as it has a tendency to exaggerate cases with considerable irregularity but little length shortage, i.e. a rotated tooth without crowding (Little, 1975). In this study, the LII never exceeded 1.1 mm and such a small irregularity might not be of clinical significance.

Only the short-term retention capacity between the three retention methods was evaluated in this trial. Littlewood *et al.* (2006) highlighted other variables such as adverse effects on health and survival of retainers in connection with research in this field. However, studies on the same patient material are ongoing to determine long-term retention capacity, cost-effectiveness, and side-effects.

Conclusions

On a short-term basis of 1 year's retention and from a clinical point of view, it was found that the three retention methods were successful in retaining the orthodontic treatment results for the patient groups corresponding to the inclusion criteria.

Funding

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