Original Article

Anterior tooth alignment:

A comparison of orthodontic retention regimens 5 years posttreatment

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ABSTRACT

Objective: To assess orthodontic treatment outcome at debonding and at 3 and 5 years after orthodontic treatment and to investigate the influence of different retention protocols on anterior tooth alignment.

Materials and Methods: Using the Peer Assessment Rating (PAR) Index, 169 patients (74 boys, 95 girls) were analyzed at four stages: pretreatment (T0), posttreatment (T1), 3 years posttreatment (T3), and 5 years posttreatment (T5). The PAR anterior component scores (ACSs) were compared between groups with different retention protocols. In the maxilla, protocols were removable retainer until T3 (MAX1), removable and fixed retainer until T3 (MAX2), and removable retainer until T3 and fixed retainer until T5 (MAX3). In the mandible, protocols were no retainer (MAND1), fixed 3-3 retainer until T3 (MAND2), and fixed 3-3 retainer until T5 (MAND3).

Results: Mean weighted improvement in PAR score was 88.3% at T1, 86.4% at T3, and 82.1% at T5. The ACS for the maxilla showed no significant differences between the retention protocols at any time point. In the mandible, the group without retention showed a gradual but not significant deterioration in ACS throughout the posttreatment period. At T5 there was a significant difference in ACS between the group that had the retainer removed at T3 and the group that kept the retainer.

Conclusion: The 5-year treatment outcome, as measured by the PAR Index, was good. Stability of the maxillary anterior alignment 5 years posttreatment did not appear to be influenced by choice of retention protocol. Mandibular anterior alignment was significantly better for the group using a fixed retainer compared with the group where the retainer was removed 3 years posttreatment. (*Angle Orthod.* 2015;85:353–359.)

KEY WORDS: Retention; Alignment; Stability; PAR Index

INTRODUCTION

Retention after orthodontic treatment has been a much discussed topic for decades. In 1934, Oppenheim[1] stated that ''Retention is the most difficult problem in orthodontia; in fact, it is the problem.'' About 70 years later, a systematic review of retention procedures[2] concluded that there is a lack of research on the influence of different retention protocols on posttreatment relapse. Another systematic review[3] evaluated the morphologic stability and changes in occlusion at least 5 years posttreatment and reported that few evidence-based conclusions can be made, despite a large number of studies on this subject. Long-term stability after orthodontic treatment has been found to be unpredictable at the individual level[3] as growth and dental tissue changes may interfere with an otherwise good treatment result.

The rationale behind retention after orthodontic tooth movement is well-known. Research has shown that the periodontal ligament needs 3–4 months to remodel.[4] The collagenous fiber networks need 4–6 months to reorganize, and the elastic supracrestal fibers may need up to 1 year to settle. Because of these factors, relapse tendency is highest immediately after debonding and in the first 12 months posttreatment.[5]

To prevent posttreatment changes, extensive use of retention, both removable and fixed, is widely

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accepted.[6–10] However, studies reveal that preferred methods of retention are highly variable and largely dependent on the orthodontists' personal preferences. Some orthodontists desire common retention guidelines.[6,10] If this is to be realized, more information is required on the effect of varying retention protocols on posttreatment changes. Maintenance of maxillary and mandibular incisor alignment is of highest esthetic priority. Although posttreatment incisor relapse in the mandible has been highlighted,[11] fewer studies have investigated the influence of retention on maxillary anterior alignment with a follow-up period exceeding 12 months.[5,12] The aim of this longitudinal retrospective study was to evaluate the orthodontic treatment outcome immediately after removal of the orthodontic appliance and 3 and 5 years posttreatment and, more specifically, to investigate the effect of different retention protocols on stability of maxillary and mandibular anterior tooth alignment.

MATERIALS AND METHODS

The study sample comprised 169 patients (74 boys, 95 girls) from the retention archives at the Department of Orthodontics, University of Oslo. Approval was granted by the Norwegian Ethical Research Committee. All patients were treated with fixed appliances at the postgraduate clinic. Study casts available at pretreatment (T0), posttreatment (T1), 3-year follow-up (T3), and 5-year follow-up (T5) were analyzed. Because of lack of attendance, study casts were missing for 27 patients at T3 and 29 patients at T5. Records were present at every time stage for 116 of the patients. Information regarding sex, age, treatment need, length of treatment, and type and duration of retention was extracted from the patients' records. Patients with agenesis or extraction of anterior teeth, patients treated with orthognathic surgery, adult patients (19 years or older at treatment start), and retreated patients were excluded. One hundred patients (59.2%) had no extraction, and 46 (27.2%) patients were treated with extractions of four premolars.

Mean pretreatment age was 12.2 years (±1.6 years). Mean treatment duration was 2.5 years (±0.83 years). Average follow-up period was 3.1 years (± 4.4 months) at T3 and 5.3 years (± 6.9 months) at T5. The Peer Assessment Rating (PAR) Index[13] was used to assess occlusion at the different time stages. Treatment changes were measured using the PAR score percentage improvement method. The anterior component score (ACS) of the PAR Index, scoring contact point displacements, was extracted from the total score and used to evaluate anterior tooth alignment. Retrospective evaluation of the sample identified three different retention protocols in each jaw. In the maxilla protocols were removable retainer until T3 and no retention after T3 (MAX1); removable and fixed retainer until T3, with both removed at T3 (MAX2); and removable retainer until T3 combined with fixed retainer until T5 (MAX3). In the mandible protocols were no retention (MAND1); fixed 33–43 retainer until T3, and retainer removed at T3 (MAND2); and fixed 33–43 retainer until T5 (MAND3).

The retainers, both removable and fixed, were applied at appliance debonding; the patients were instructed to wear the removable retainer according to the routines at the postgraduate clinic: full-time wear the first 3 months, every night the following 21 months, and 2–3 nights a week the last 12 months. Approximately 54% received a vacuum-formed retainer, 30% a Hawley retainer, and 16% a Jensen retainer. Removable retainers were not provided for the mandible. Any removal of fixed retainers at T3 was done because of hygiene issues, breakage, or the patient's wishes.

Statistical Analysis

A paired *t*-test was used to assess changes in mean ACS for the time periods T0–T1, T1–T3, T3–T5, T1–T5, and T0–T5 for each retention group. For the maxilla, mean ACS for the three retention groups were tested against each other at each time stage using one-way analysis of variance with Tukey correction. For the mandible, mean ACSs were tested only for MAND2 and MAND3, using an independent *t*-test at all stages, as MAND1 differed significantly from the other groups at T0 and was excluded from further statistical analysis.

Unpaired *t*-tests were used to examine the groups for differences in the following variables: age at T0, pretreatment ACS, time lapse from T1 to T3, time lapse from T3 to T5, and type of removable retainer. Differences in distribution of sex between the groups were tested using χ^2. A P value $\leq .05$ was regarded as statistically significant.

All measurements were done by one operator, who was first trained in using the PAR Index by more experienced examiners. Error of method was assessed using intraclass correlation coefficient, which was 0.96. Intraexaminer reliability was determined by scoring 30 randomly selected sets of models twice, 4 weeks apart; reliability was 0.98. All analyses were done using SPSS (version 20.0.0) (SPSS Inc, Chicago, IL, USA).

RESULTS

Mean weighted PAR (wPAR) score at pretreatment was 24.71 (± 8.80) for the total group, which reduced to 2.88 (± 3.39) posttreatment (T1). The wPAR score

Table 1. Mean Weighted Peer Assessment Rating (PAR) Scores and Anterior Component Scores at Pretreatment (T0), Posttreatment (T1), 3-Year Follow-up (T3), and 5-Year Follow-up (T5)[a]

		T0		T1		T3		T5	
Weighted PAR Scores									
Total group		24.71	(169)	2.88	(169)	3.36	(142)	4.43	(140)
Anterior Component Scores									
Maxilla									
MAX1	Removable retainer until T3 and no retention after T3	3.89	(95)	0.03	(95)	0.20	(83)	0.32	(78)
MAX2	Removable and fixed retainer until T3, with both removed at T3	4.64	(25)	0.08	(25)	0.25	(24)	0.62	(13)
MAX3	Removable retainer until T3 combined with fixed retainer until T5	4.53	(49)	0.02	(49)	0.03	(35)	0.18	(49)
Mandible									
MAND1	No retention	0.91	(23)	0.35	(23)	0.53	(19)	1.00	(18)
MAND2	Fixed 33–43 retainer until T3, with retainer removed at T3	2.37	(68)	0.03	(68)	0.21	(61)	0.67	(45)
MAND3	Fixed 33–43 retainer until T5	2.96	(78)	0.00	(78)	0.06	(62)	0.08	(77)

[a] Values in parantheses are number of cases (n).

increased to 3.36 (± 4.02) at T3 and 4.43 (± 4.78) at T5 (Table 1). Orthodontic treatment led to 88.3% improvement at T1. The percentage improvement dropped to 86.4% at T3 and 82.1% at T5.

At T0, the anterior contact point displacement score ranged from 3.89 to 4.64 for the maxilla and from 0.91 to 2.96 for the mandible (Table 1). Posttreatment (T1), the ACSs were close to zero for all the groups except for MAND1, the no-retention group, which showed a score of 0.35 (Figures 1 and 2). A gradual increase in ACSs was recorded from T1 to T5 for all the groups; however, MAND1 was the only group that reached a score of 1.00 (Figures 1 and 2).

The paired *t*-test showed a statistically significant change in ACS for all the groups from T0 to T1 (Table 2). From T0 to T5, all groups maintained the statistically significant improvement, whereas MAND1 displayed insignificant deterioration.

Analysis of variance for the maxillary retention protocols showed no significant differences in ACS between any of the three groups at any of the four time stages (Table 3). Analyses of mean changes in ACS from T1 to T3 and T3 to T5 showed no significant differences between the groups.

Independent *t*-test of the mandibular retention protocols showed significant differences between

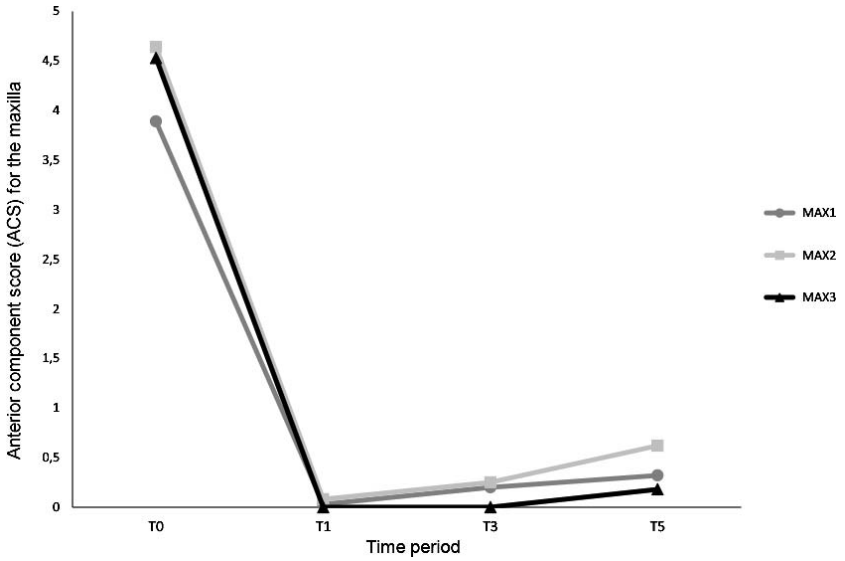

Figure 1. Graphic illustration of mean anterior component score on the Peer Assessment Rating Index for three groups with different posttreatment maxillary retention protocols, showing how the score changed from pretreatment (T0) to posttreatment (T1), 3 years posttreatment (T3), and 5 years posttreatment (T5). MAX1 indicates removable retainer until T3 and no retention after T3; MAX2, removable and fixed retainer until T3 with both removed at T3; MAX3, removable retainer until T3 combined with fixed retainer until T5.

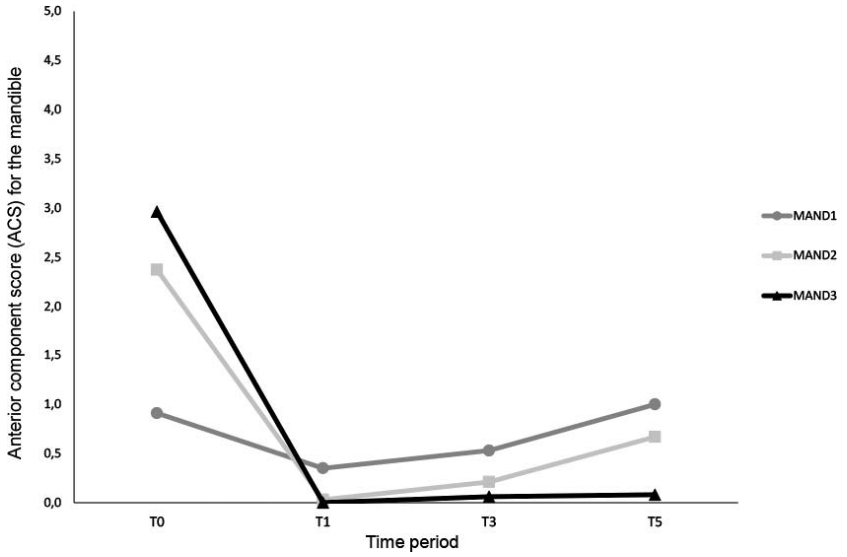

Figure 2. Graphic illustration of mean anterior component score on the Peer Assessment Rating Index for three groups with different posttreatment mandibular retention protocols, showing how the score changed from pretreatment (T0) to posttreatment (T1), 3 years posttreatment (T3), and 5 years posttreatment (T5). MAND1 indicates no retention; MAND2, fixed 33–43 retainer until T3, with retainer removed at T3; MAND3, fixed 33–43 retainer until T5.

MAND2 and MAND3 at T3 and T5 (Table 4). When tested for differences in mean change in ACS from T1 to T3 and T3 to T5, significant differences were found between the groups in the period T3 to T5 ($P = .002$). MAND1, in which there was no posttreatment retainer, ended up at T5 with an ACS similar to that at pretreatment.

There were no significant differences between the retention protocol groups for either the maxilla and the mandible for the following variables: sex, age at T0, pretreatment ACS, extraction/nonextraction treatment, type of removable retainer, time lapse from T1 to T3, and time lapse from T3 to T5.

DISCUSSION

The mean wPAR score was 24.71 before treatment, which is similar to score in other studies using the same methodology.[14–16] However, the posttreatment wPAR score was slightly lower and the percentage improvement slightly higher than the data reported in other studies.[14,17,18] Furthermore, the percentage improvement from T0 to T5 (82.1%) was rather high compared with existing literature that had a 5-year follow-up[14,16–20] (Table 5). One possible explanation for this could be the fact that most of the patients who received fixed retention posttreatment kept the retention

Table 2. Paired Sample *t*-Test of Mean Changes in Anterior Component Scores for All Retention Protocol Groups[a,b]

		T0–T1		T1–T3		T3–T5		T1–T5		T0–T5	
Maxilla											
MAX1	Removable retainer until T3 and no retention after T3	−3.86 ****	(95)	.17 **	(83)	.09	(67)	0.28**	(78)	−3.53 ****	(78)
MAX2	Removable and fixed retainer until T3, with both removed at T3	−4.56 ****	(25)	.17	(24)	.25	(12)	0.46	(13)	−3.92 ****	(13)
MAX3	Removable retainer until T3 combined with fixed retainer until T5	−4.51 ****	(49)	.03	(35)	.14 *	(35)	0.16**	(49)	−4.35 ****	(49)
Mandible											
MAND1	No retention	−.57 **	(23)	.32	(19)	.43	(14)	0.61	(18)	.06	(18)
MAND2	Fixed 33–43 retainer until T3, with retainer removed at T3	−2.34 ****	(68)	.18 **	(61)	.50 ***	(38)	0.64****	(45)	−1.47 ***	(45)
MAND3	Fixed 33–43 retainer until T5	−2.96 ****	(77)	.07 *	(62)	.02	(62)	0.08*	(77)	−2.88 ****	(77)

[a] Values in parantheses are number of cases (n).

[b] Groups were tested at five time periods: pretreatment (T0) to posttreatment (T1), T1 to 3-year follow-up (T3), T3 to 5-year follow-up (T5), T1 to T5, and T0 to T5.

* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$; **** $P \leq .0001$.

Table 3. *P* Values from Analysis of Variance Comparing Mean Upper Anterior Component Scores on the Peer Assessment Rating Index for Different Retention Protocols at Pretreatment (T0), Posttreatment (T1), 3-Year Follow-up (T3), and 5-Year Follow-up (T5)

Protocols Compared	*P* Value			
	T0	T1	T3	T5
MAX1 vs MAX2	.407	.586	.928	.363
MAX1 vs MAX3	.344	.951	.228	.553
MAX2 vs MAX3	.984	.503	.259	.138

[a] MAX1, removable retainer until T3 and no retention after T3; MAX2, removable and fixed retainer until T3, with both removed at T3; MAX3, removable retainer until T3 combined with fixed retainer until T5.

* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

Table 4. *P* Values from Independent Samples *t*-Test Comparing Lower Anterior Component Scores on the Peer Assessment Rating Index for Two Groups with Different Retention Regimens at the 5-Year Follow-up (T5)

Protocols Compared	*P* Value			
	T0	T1	T3	T5
MAND2 vs MAND3	.152	.159	.047*	.000***

[a] T0 indicates pretreatment; T1, posttreatment; T3, 3-year follow-up; T5, 5-year follow-up; MAND2, fixed 33–43 retainer until T3, with retainer removed at T3; MAND3, fixed 33–43 retainer until T5.

* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

until T5. Other studies reported on shorter retention periods,[14,16] and it is very likely that this has influenced the overall PAR score. In this respect, our findings support the view that prolonged retention is beneficial for maintaining the obtained treatment result. This is in accordance with Lagerström et al.,[18] who in a long-term follow-up found significantly lower wPAR scores for patients wearing retainers compared with patients without retainers.

Maxillary and mandibular mean ACSs were significantly lower at the 5-year follow-up compared with pretreatment. The only exception was the no-retainer group (MAND1), which deteriorated slightly at T5. The patients in this group started off with significantly better tooth alignment than patients in the other groups, which was the reason for not receiving any mandibular retainer. However, despite deterioration of tooth alignment at the 5-year follow-up, the mean ACS in this group was so small that the clinical significance is questionable. The removal of the mandibular retainer 3 years posttreatment had a negative impact on tooth alignment at T5 (MAND2), and the group that maintained the retainer (MAND3) had significantly better ACS than the group that had the retainer removed (MAND2). Therefore, it may be speculated that an optimal mandibular alignment is best maintained with a fixed canine-to-canine retainer. This has been confirmed in other long-term studies where stable posttreatment tooth alignment has been ensured with canine-to-canine retainers bonded to all six anterior teeth or only to the canines.[21,22] No removable retainers were prescribed for the mandible in this sample. However, it cannot be ruled out that a mandibular removable retainer could have had a similar effect on tooth alignment.[23]

In the maxilla, the retention groups showed no significant differences at any of the investigation periods. The three groups had removable retainers in the maxilla, and the combination with a fixed retainer for 3 years (MAX2) or 5 years (MAX3) did not appear to have a significant influence on the ACS. This suggests that the three retention protocols were equally efficient in preserving upper incisor stability for 5 years posttreatment. This is in accordance with previous findings that show that different retention protocols can be equally effective in controlling anterior tooth alignment posttreatment.[5,12,24] Moreover, it has been shown that part-time wear of removable retainers is equally effective in preventing posttreatment relapse compared with full-time wear.[25,26] Therefore, it is unlikely that the use of different removable retainers in this study, either part-time or full-time, could have had any significant influence on the posttreatment maxillary changes.

Increased incisor irregularity, particularly in the mandible, may occur in both treated[27] and untreated patients.[28] The strongest tendency is reported to occur between the ages of 13 and 18,[28] which partly coincides with the posttreatment period in this investigation. This might account for the deterioration of

Table 5. Overview of Mean Weighted Scores from Studies with Comparable Follow-up Period Using the Peer Assessment Rating Index for Assessing Orthodontic Treatment Outcome

	Year	Pretreatment	Posttreatment	5-Year Follow-up	Sample Size	Remark
Richmond and Andrews[19]	1993	23.8	4.4		220	
O'Brien et al.[20]	1993	28.8	8.3		1630	
Birkeland et al.[14]	1997	28.7	6.0	9.6	224	5 years out of retention
Berset et al.[17]	2000	21.8	3.2	6.1	128	
de Freitas et al.[16,a]	2007	27.1	6.2	10.6	87	
Lagerström et al.[18]	2011	20.2	4.3	7.0		
Present study	2014	24.7	2.9	4.4	140	

[a] For de Freitas et al., the mean of the two groups in the study was used.

incisor alignment in the no-retainer group. In the maxilla, relapse occurs to a lesser degree both in the short and the long term. Andrén et al.[12] found minor or no relapse in the maxilla 1 year after removal of fixed retainers and minor relapse 7 years after removal of the retainers. The apparent weaker tendency to relapse and late crowding in the maxilla could explain why all three maxillary retention protocols in this study proved equally efficient. Still, the continuous biological migration of the dentition is unpredictable at the individual level and might lead to further dental crowding.[29] It is therefore understandable why many orthodontists apply fixed retainers for an indefinite period of time.

The material used in this study was collected from a postgraduate clinic and included all types of malocclusions having ''obvious need'' or ''great need'' for orthodontic treatment according to the Norwegian index of orthodontic treatment need.[30] Patients with agenesis or extractions in the anterior segment were excluded from this investigation. This most probably influenced the overall PAR scores but at the same time provided a more coherent sample regarding the maxillary and mandibular anterior segments.

The PAR Index has been extensively used in the evaluation of malocclusions at any stage of treatment.[13] Many studies that evaluate anterior tooth alignment use Little's Irregularity Index in addition to the PAR score. This was considered unnecessary in the current study. As upper and lower ACSs had already been recorded, the scores were extracted from the total PAR score and used for further evaluation. In this way, a uniform application of criteria was ensured and a possible additional source of error was eliminated. Furthermore, Little's Irregularity Index has lately proven to be an index of low reproducibility for measuring contact-point displacement.[31]

The present study is a retrospective, longitudinal, cohort study and as such does not provide the evidence of a prospective clinical trial. Therefore, the conclusions have to be interpreted within its limits.

CONCLUSIONS

- The PAR Index showed that orthodontic treatment reduced malocclusions on average by 88.3%, and good results were maintained at 3 years (86.4%) and 5 years (82.1%) posttreatment.
- Stability of the maxillary anterior segment 5 years posttreatment was not influenced by choice of maxillary retention protocol. Use of removable retainer alone proved equally efficient as a combination of removable and fixed retainer.
- Stability of the mandibular anterior segment 5 years posttreatment was significantly better for the group having fixed retainers all 5 years compared with the group where the retainer was removed 3 years posttreatment.

REFERENCES

1. Oppenheim A. Crisis in orthodontia. Part 1: tissue changes during retention. *Int J Orthod*. 1934;20:639–644.
2. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Retention procedures for stabilising tooth position after treatment with orthodontic braces. *Cochrane Database Syst Rev*. 2006;(1):CD002283.
3. Bondemark L, Holm AK, Hansen K, et al. Long-term stability of orthodontic treatment and patient satisfaction. A systematic review. *Angle Orthod*. 2007;77:181–191.
4. Reitan K. Clinical and histologic observations on tooth movement during and after orthodontic treatment. *Am J Orthod*. 1967;53:721–745.
5. Edman Tynelius G, Bondemark L, Lilja-Karlander E. A randomized controlled trial of three orthodontic retention methods in Class I four premolar extraction cases—stability after 2 years in retention. *Orthod Craniofac Res*. 2013;16(2): 105–115.
6. Renkema AM, Sips ET, Bronkhorst E, Kuijpers-Jagtman AM. A survey on orthodontic retention procedures in The Netherlands. *Eur J Orthod*. 2009;31:432–437.
7. Singh P, Grammati S, Kirschen R. Orthodontic retention patterns in the United Kingdom. *J Orthod*. 2009;36:115–121.
8. Wong PM, Freer TJ. A comprehensive survey of retention procedures in Australia and New Zealand. *Aust Orthod J*. 2004;20:99–106.
9. Pratt MC, Kluemper GT, Hartsfield JK Jr, Fardo D, Nash DA. Evaluation of retention protocols among members of the American Association of Orthodontists in the United States. *Am J Orthod Dentofacial Orthop*. 2011;140:520–526.
10. Vandevska-Radunovic V, Espeland L, Stenvik A. Retention: type, duration and need for common guidelines. A survey of Norwegian orthodontists. *Orthodontics (Chic.)* 2013; 14(1):e110–e117.
11. Little RM. Stability and relapse of dental arch alignment. *Br J Orthod*. 1990;17:235–241.
12. Andrén A, Naraghi S, Mohlin BO, Kjellberg H. Pattern and amount of change after orthodontic correction of upper front teeth 7 years postretention. *Angle Orthod*. 2010;80: 432–437.
13. Richmond S, Shaw WC, O'Brien KD, et al. The development of the PAR Index (Peer Assessment Rating): reliability and validity. *Eur J Orthod*. 1992;14:125–139.
14. Birkeland K, Furevik J, Boe OE, Wisth PJ. Evaluation of treatment and post-treatment changes by the PAR Index. *Eur J Orthod*. 1997;19:279–288.
15. Woods M, Lee D, Crawford E. Finishing occlusion, degree of stability and the PAR index. *Aust Orthod J*. 2000; 16(1):9–15.
16. de Freitas KM, Janson G, de Freitas MR, Pinzan A, Henriques JF, Pinzan-Vercelino CR. Influence of the quality of the finished occlusion on postretention occlusal relapse. *Am J Orthod Dentofacial Orthop*. 2007;132(4):428.e9–e14.
17. Berset GP, Eilertsen IM, Lagerstrom L, Espeland L, Stenvik A. Outcome of a scheme for specialist orthodontic care. *Swed Dent J*. 2000;24:39–48.
18. Lagerström L, Fornell AC, Stenvik A. Outcome of a scheme for specialist orthodontic care, a follow-up study in 31-year-olds. *Swed Dent J*. 2011;35:41–47.

19. Richmond S, Andrews M. Orthodontic treatment standards in Norway. *Eur J Orthod*. 1993;15:7–15.
20. O'Brien KD, Shaw WC, Roberts CT. The use of occlusal indices in assessing the provision of orthodontic treatment by the hospital orthodontic service of England and Wales. *Br J Orthod*. 1993;20:25–35.
21. Renkema AM, Renkema A, Bronkhorst E, Katsaros C. Long-term effectiveness of canine-to-canine bonded flexible spiral wire lingual retainers. *Am J Orthod Dentofacial Orthop*. 2011;139:614–621.
22. Renkema AM, Al-Assad S, Bronkhorst E, Weindel S, Katsaros C, Lisson JA. Effectiveness of lingual retainers bonded to the canines in preventing mandibular incisor relapse. *Am J Orthod Dentofacial Orthop*. 2008;134(2):179e1–8.
23. Atack N, Harradine N, Sandy JR, Ireland AJ. Which way forward? Fixed or removable lower retainers. *Angle Orthod*. 2007;77:954–959.
24. Barlin S, Smith R, Reed R, Sandy J, Ireland AJ. A retrospective randomized double-blind comparison study of the effectiveness of Hawley vs vacuum-formed retainers. *Angle Orthod*. 2011;81:404–409.
25. Shawesh M, Bhatti B, Usmani T, Mandall N. Hawley retainers full- or part-time? A randomized clinical trial. *Eur J Orthod*. 2010;32:165–170.
26. Thickett E, Power S. A randomized clinical trial of thermoplastic retainer wear. *Eur J Orthod*. 2010;32:1–5.
27. Little RM. Stability and relapse of mandibular anterior alignment: University of Washington studies. *Semin Orthod*. 1999;5(3):191–204.
28. Richardson ME. A review of changes in lower arch alignment from seven to fifty years. *Semin Orthod*. 1999; 5(3):151–159.
29. Tsiopas N, Nilner M, Bondemark L, Bjerklin K. A 40 years follow-up of dental arch dimensions and incisor irregularity in adults. *Eur J Orthod*. 2013;35:230–235.
30. Espeland LV, Ivarsson K, Stenvik A. A new Norwegian index of orthodontic treatment need related to orthodontic concern among 11-year-olds and their parents. *Community Dent Oral Epidemiol*. Oct 1992;20(5):274–279.
31. Macauley D, Garvey TM, Dowling AH, Fleming GJ. Using Little's Irregularity Index in orthodontics: outdated and inaccurate? *J Dent*. 2012;40:1127–1133.