Mandibular incisor alignment in untreated subjects compared with long-term changes after orthodontic treatment with or without retainers

Ulrike Schütz-Fransson,[a] Rune Lindsten,[b] Krister Bjerklin,[c] and Lars Bondemark[c]
Malmö, Uddevalla, and Jönköping, Sweden

Introduction: The aim of this work was to analyze the dental and skeletal changes in patients treated with fixed orthodontic appliances with or without retention appliances, and to compare the changes with untreated subjects. Specifically, mandibular incisor irregularity was analyzed. **Methods:** A total of 105 children who had undergone orthodontic treatment with fixed appliances in both jaws were examined in 2 groups: 64 had a lingual mandibular retainer and 41 had no retainer. Retention time was 2.7 ± 1.5 years. The untreated group consisted of 25 subjects. Measurements were done on study casts and lateral head radiographs before and after treatment and 6 and 12 years after treatment. The Little irregularity index (LII) was the most important variable. **Results:** No differences were found in LII 12 years after treatment between the group that had a retainer and the group without a retainer after treatment. In the untreated group, LII was increased over time, but not to the same extent as in the treated groups. Correction of overjet and overbite was stable long-term. At the last examination, the amount of overjet was almost the same in all 3 groups. **Conclusions:** The routine use of mandibular retainers for 2 to 3 years does not appear to prevent long-term relapse. If the patient wants to constrain natural development and changes, lifelong retainers are needed. (Am J Orthod Dentofacial Orthop 2019;155:234-42)

After orthodontic treatment, one challenge is to keep the teeth in their new positions and avoid relapse. More specifically, the alignment of the mandibular incisors after treatment has become an issue in orthodontics. After the retainer has been removed, the mandibular incisors tend to move back to nearly the same position they were in before treatment.[1-4] However, some of the posttreatment changes can be explained by relapse, and others explained by the continued growth and compensatory eruption and migration of the teeth.[5] Changes occurring up to 1 year after retention are likely to be a combination of true orthodontic relapse and late-growth changes.

The etiology of the undesirable incisor irregularity changes is complex. Mandibular incisor irregularity is both unpredictable and variable. Many possible interacting factors are likely, such as tooth size, arch form, forces from the periodontal fibers, deflecting occlusal contacts, facial growth patterns, continuing late growth, and a mesially acting force emanating from the back of the dental arch.[6-8]

Increased mandibular incisor irregularity seems to be a continuous process throughout life even in untreated patients.[9-11] The natural physiologic changes during aging cause changes like those that occur after orthodontic treatment and the removal of retainers. Nevertheless, the question remains of whether the posttreatment changes are a result of relapse or the normal aging and maturational process.

Some studies have compared mandibular irregularity in treated and untreated patients over a long term.[12-14]

[a]Faculty of Odontology, Malmö University, Malmö, Sweden; and County Orthodontic Clinic Uddevalla, Västra Götalands Regionen, Uddevalla, Sweden.
[b]Department of Orthodontics, Institute for Postgraduate Dental Education, Jönköping, Sweden.
[c]Department of Orthodontics, Faculty of Odontology, Malmö University, Malmö, Sweden.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Funding: This study was supported by grants from the Gothenburg Dental Society.
The Ethics Committee of Linköping, Sweden, approved the protocol (2014/381-31).
Address correspondence to: Ulrike Schütz-Fransson, Specialistcentrum, Uddevalla Sjukhus, SE 451 80 Uddevalla, Sweden; e-mail, ulrike.schutz-fransson@vgregion.se.
Submitted, October 2017; revised and accepted, March 2018.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2018.03.025

However, very few long-term studies, if any, have compared patients who have had a bonded lingual retainer with a group without a retention appliance after treatment and then compared those patients with an untreated group. The aim of the present retrospective longitudinal study was to analyze the dental and skeletal changes in patients treated with fixed orthodontic appliances with or without retention appliances, and to compare the changes with a group of untreated subjects. Specifically, mandibular incisor irregularity was studied. The hypothesis was that the long-term mandibular incisor irregularity for the treated group without retainers would be higher than for the group with retainers, and that both groups who have had orthodontic treatment would have a higher amount of irregularity than the untreated group.

SUBJECTS AND METHODS

Three different groups were included (Table I), and long-term records were required for participation in the study. Sample exclusions were single arch treatment, orthognatic surgery treatment, cleft lip or palate, and agenesis or extraction of anterior teeth. This was a retrospective investigation, and no cases were added or excluded after applying the inclusion criteria.

The group with retainers consisted of 64 children (23 boys and 41 girls) who had orthodontic treatment with fixed appliance in both jaws. After treatment, the retention appliance for the mandibular anterior segment was either a canine-to-canine retainer (0.028 inch, spring hard wire bonded to the canines only) or a Twistflex retainer (0.0195 inch, bonded to all mandibular incisors and canines). Both retainers were custom-made in the laboratory and were bonded with composite. The 2 different retainer types have been evaluated in an earlier study,[2] and it was reported that no differences were found between them concerning their capacity to keep the mandibular incisors aligned in a long-term perspective. Therefore, in this study the 2 types of bonded retainers were merged into 1 group. The mean retention time for the mandibular incisors was 2.7 ± 1.50 years. The maxillary arch had a removable appliance for retention.

The nonretention group consisted of 41 patients (17 boys and 24 girls) with orthodontic treatment similar to the retention group, except that no retention appliance was used for the mandibular anterior segment after treatment. The decision to leave the treated patients without retention in the mandible was made by the orthodontists who treated the patients. This group also had a removable appliance in the maxilla for retention.

The orthodontic treatments were performed at the Department of Orthodontics, Institute for Postgraduate Dental Education, Jönköping, Sweden, from 1980 to 1995. The patients received orthodontic treatment for Class II malocclusions, large overjet, crowding, or deep bites. The treatment consisted of fixed edgewise appliances (0.018 inch) in both jaws, and both extraction and nonextraction cases were included. Extractions were carried out in 71 patients (68%), and 34 patients (32%) were treated without extractions. There were exactly the same proportions of extraction and nonextraction cases in the groups with and without retainers.

Expansion of the intercanine width during orthodontic treatment was avoided, and no interproximal enamel reduction or circumferential supracrestal fiberotomy was performed in the groups who had undergone orthodontic treatment.

The untreated group comprised 25 patients (14 boys and 11 girls) who were age matched with the subjects in the 2 other groups. In this group, the subjects had Class I occlusion with normal overjet and overbite and with minor or no crowding. This group was also recruited from the same Department of Orthodontics from 1980 to 1995.

Measurements were performed on dental casts with the use of a sliding digital caliper with an accuracy of 0.01 mm (Mitutoyo 500-171, Kanagawa, Japan). The measurements for the treatment groups were taken on 4 occasions: before treatment (T0), immediately after orthodontic treatment and start of retention (T1), 6 years after treatment (T2), and 12 years after treatment (T3).

For the untreated group, study casts were available for the corresponding ages at T0, T2, and T3. In the retention group, no retention appliance was in place at T2 and T3. The mean retention time for the mandibular incisors was 2.7 ± 1.50 years.

The main outcome measures (Figs 1 and 2) were the irregularity index according to Little (LII), the summed displacement of the anatomic contact points of the mandibular anterior teeth,[15] intercanine width, intercanine arch perimeter distance, available mandibular incisor space (intercanine arch perimeter distance minus summed tooth width for the 4 mandibular incisors), lateral arch length, overjet, and overbite. Also, the tooth width of the mandibular incisors was measured at T0 and T3.

Sagittal and vertical relationships between the jaws and incisor inclination were evaluated on lateral head radiographs, and the cephalometric reference points and measurements were assessed according to Björk[16] and Solow[17] (Fig 3). All measurements on lateral head radiographs were made to the nearest half-degree or 0.5 mm

Table I. Mean age (y) and number of subjects (boys and girls) in the retention group, nonretention group, and untreated group at the 4 examination time points

	Retention group					*Nonretention group*					*Untreated group*					
	n			*Age*		*n*			*Age*		*n*			*Age*		
Ttime point	*Total*	*Boys*	*Girls*	*Mean*	*SD*	*Total*	*Boys*	*Girls*	*Mean*	*SD*	*Total*	*Boys*	*Girls*	*Mean*	*SD*	P *value*
T0	64	23	41	12.9	3.27	41	17	24	12.3	1.80	25	14	11	13.4	1.77	NS
T1	64	23	41	15.6	3.44	41	17	24	14.9	2.12	-	-	-	-	-	NS
T2	62	22	40	21.8	3.55	40	17	23	21.3	2.46	21	11	10	20.5	2.97	NS
T3	52	17	35	27.4	3.47	37	16	21	26.2	2.84	25	14	11	27.0	4.82	NS

T0, before treatment; *T1*, after treatment; *T2*, 6 years after treatment; *T3*, 12 years after treatment; *NS*, not significant.

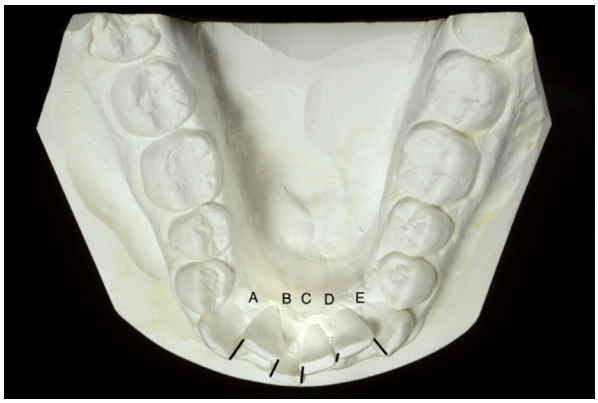

Fig 1. The Little irregularity index = A+B+C+D+E.

with correction for enlargement. No lateral head radiographs were available at T1 for the untreated subjects.

All examinations and measurements were made by 1 author (U.S.-F.), and because there was no retention appliance in place at T2 and T3, a blinded evaluation was possible, meaning that the examiner was unaware of which of the 3 groups the patients belonged to or if the casts were taken at T2 or T3.

Statistical analysis

The sample size estimate was based on a significance level of 0.05 and 80% power to detect a clinically meaningful difference of 1.5 mm (ie, SD 1.5 mm) of LII. The estimate suggested that 22 patients in each group was sufficient.

Arithmetic means and standard deviations at group level were calculated for each variable before treatment (T0), at the end of active treatment and the start of retention (T1), 6 years after treatment (T2), and 12 years after treatment (T3).

The sample was normally distributed according to the Kolmogorov-Smirnov test. Significant differences in means within groups and between groups were tested by means of 1-way analysis of variance, with the use of the Statistical Package for Social Sciences (version 22.0; SPSS, Chicago, Illinois). P values of $<5\%$ ($P < 0.05$) were considered to be statistically significant. When significant differences were found between groups, the Bonferroni correction was used.

A regression analysis was performed for Little's Irregularity Index to assess if LII at T3 was dependent of LII at T0 and to relate mandibular incisor inclination (L1/ML) to changes in Little's Irregularity Index.

Error of the measurements

The same examiner measured 24 randomly selected cases at 2 separate occasions with a ≥4-week interval. The mean error of the measurements according to the Dahlberg formula[18] for the linear variables was 0.1 mm. The largest measurement error was 0.5 mm for intercanine width, 0.5 mm for intercanine perimeter distance, and 0.5 mm for left lateral arch length. Error measurements for the cephalometric angular variables averaged 0.8°. The greatest measurement error was noted for the maxillary incisor inclination: 3.3°.

No significant differences between the 2 series of records were found with the use of paired t test in most the measurements, except for left lateral arch length (range −0.1 to 0.5), available space (range −0.3 to 0.2), tooth width 32 (range −0.1 to 0.1), tooth width 41 (range −0.1 to 0.1), and L1/Apg (range −0.1 to 1.3). The systematic error was within the boundaries given above.

RESULTS

The distribution of age and sex is presented in Table I. No significant difference in age at T0 between the 3 groups could be found; however, there were more girls in the 2 treated groups than in the untreated group.

No significant differences in mandibular incisor irregularity between the retention and nonretention

1. **Intercanine width** (cusp tip to cusp tip of the mandibular canines)
2. **Intercanine arch perimeter distance** (arch perimeter length between the mesial contact points of the canines)
3. **Lateral arch length left 6-2** (from the mesial contact point of the mandibular first molar to the mesial contact point of the canines, left side)
4. **Lateral arch length right 6-2** (from the mesial contact point of the mandibular first molar to the mesial contact point of the canines, right side)

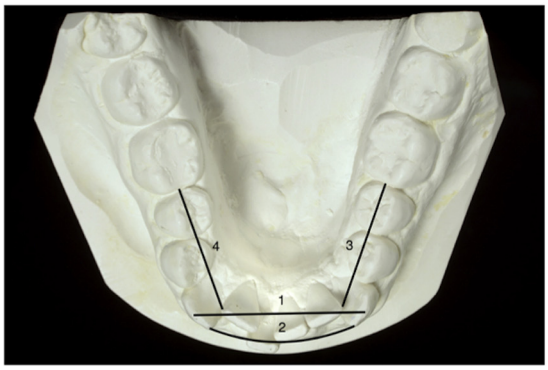

Fig 2. Variables measured on dental casts.

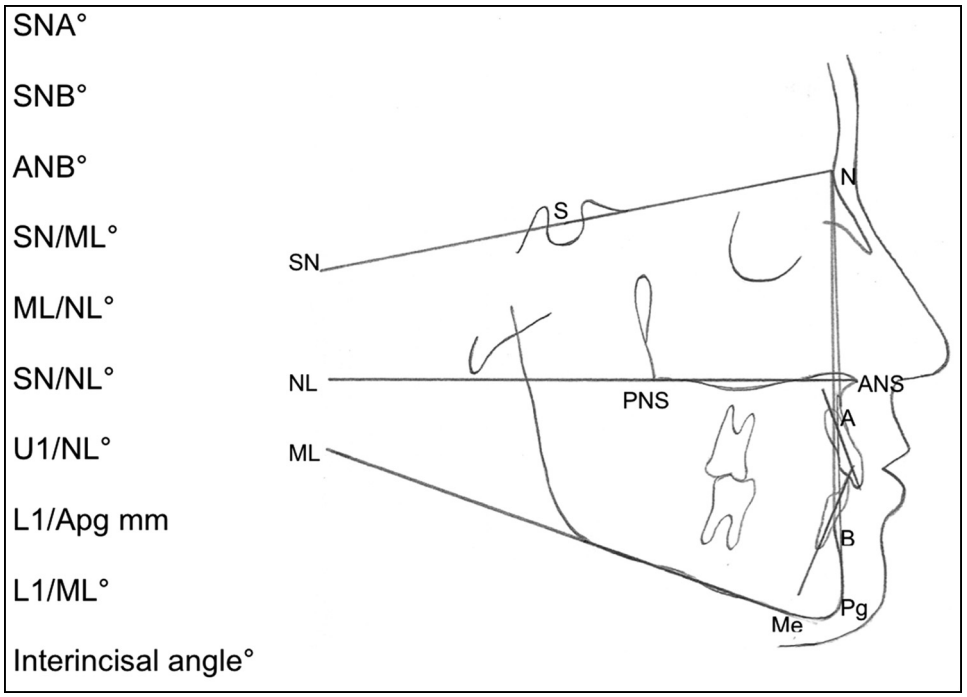

Fig 3. Cephalometric reference points and lines.

groups at T3 (12 years after treatment) were found. However, significant differences were found between the untreated and the 2 treated groups at T3 (Table II). The untreated group had less LII at baseline (T0) and at the last examination (T3). At T0, LII was less for the untreated group compared with the retention group. The multiple regression analysis revealed that LII at T2 was the only variable that could explain LII at T3

Table II. Mean values and number of subjects for 12 variables at the 4 examination time points, measured on study models and the differences in mean values among the 3 groups

		Retention group (1)		*Nonretention group (2)*		*Untreated group (0)*		
Variable	*Time point*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P *value*
Little irregularity index	T0	4.59	3.16	3.86	2.88	1.90	1.38	0≠1*; 0≠2‡
	T1	1.72	1.20	2.01	1.40	–	–	NS
	T2	3.29	2.08	3.82	2.20	2.80	1.82	NS
	T3	4.26	2.39	4.60	2.11	2.87	1.79	0≠1*; 0≠2*
Available space, lower 3-3	T0	−1.98	2.53	−0.83	2.02	−0.03	1.44	0≠2‡; 1≠2*
	T1	−0.10	0.37	0.04	0.07	–	–	NS
	T2	−0.99	1.00	−0.99	1.14	−0.88	1.11	NS
	T3	−1.60	1.26	−1.46	1.35	−0.86	1.24	NS
Intercanine width	T0	25.91	1.83	26.37	1.45	26.69	1.67	NS
	T1	25.96	1.65	26.12	1.30	–	–	NS
	T2	25.40	1.57	25.97	5.28	26.21	1.97	NS
	T3	24.94	1.65	25.04	1.68	25.53	1.95	NS
Intercanine arch perimeter distance	T0	23.85	1.40	24.42	1.67	24.40	1.32	NS
	T1	24.45	1.45	24.51	1.58	–	–	NS
	T2	23.63	1.43	23.48	1.41	23.82	1.15	NS
	T3	23.00	1.61	23.13	1.45	23.08	1.58	NS
Lateral arch length left 2-6	T0	20.29	2.52	20.31	3.18	21.91	1.20	0≠1*; 0≠2*
	T1	19.18	3.45	18.50	3.69	–	–	NS
	T2	18.73	3.54	18.02	3.78	21.45	0.87	0≠1†; 0≠2*
	T3	18.61	3.48	17.68	3.88	20.62	1.23	0≠1†
Lateral arch length right 2-6	T0	19.97	2.44	20.54	2.37	21.98	1.14	0≠1*; 0≠2‡
	T1	19.02	3.47	18.09	3.59	–	–	NS
	T2	18.50	3.55	17.52	3.74	21.44	1.04	0≠1†; 0≠2*
	T3	18.29	3.54	16.95	3.85	19.67	4.38	0≠1*
Tooth width 32	T0	6.18	0.36	6.15	0.38	6.02	0.43	NS
	T3	6.13	0.37	6.19	0.35	5.96	0.43	NS
Tooth width 31	T0	5.61	0.33	5.53	0.34	5.46	0.41	NS
	T3	5.55	0.34	5.51	0.32	5.36	0.39	NS
Tooth width 41	T0	5.56	0.34	5.57	0.39	5.52	0.42	NS
	T3	5.50	0.35	5.53	0.39	5.39	0.42	NS
Tooth width 42	T0	6.12	0.42	6.12	0.36	5.98	0.44	NS
	T3	6.07	0.42	6.13	0.35	5.90	0.49	NS
Overjet	T0	7.00	3.20	6.36	4.41	3.64	1.52	0≠1†; 0≠2‡
	T1	3.26	1.03	3.37	1.20	–	–	NS
	T2	3.77	1.63	3.28	2.07	3.06	1.33	NS
	T3	3.81	1.67	3.30	2.45	3.43	1.95	NS
Overbite	T0	3.59	2.18	2.72	2.55	3.33	1.57	NS
	T1	2.41	1.09	2.34	1.15	–	–	NS
	T2	2.76	1.56	2.38	1.69	2.20	1.32	NS
	T3	2.91	1.51	2.38	1.61	2.57	1.55	NS

*$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

($P = 0.000$). However, the incisor irregularity at T3 could not be predicted by LII at T0.

There was a significant difference at T0 in available space between the nonretention and retention group, with means of −0.8 mm and −2.0 mm, respectively. Also at T0, the available space was significant less in the 2 treatment groups compared with the untreated group. However, after 12 years (T3), no significant differences between the 3 groups were found.

The intercanine width had not increased during the orthodontic treatment. There were no differences found among the 3 groups at baseline or throughout the observation period.

The intercanine arch perimeter distance was slightly increased in the treatment groups from T0 to T1. After T1, the distance decreased in all 3 groups.

Lateral arch length was significantly larger in the untreated group compared with the 2 treatment groups, except at T1 (Table II).

There were no statistical significant differences in tooth width for the 4 mandibular incisors among the 3 groups and over time.

Overjet was reduced during treatment for the 2 treatment groups, and the reduction in overjet corresponded to the amount of overjet for the untreated group at T0. At T2 and T3, the overjet stayed fairly the same in all 3 groups. The same development could also be seen for the overbite.

Results for the cephalometric variables are presented in Table III; a small number of significant intergroup differences were found. After treatment (T1), the mandibular incisors were significantly more proclined in the retention group compared with the nonretention group.

The multiple regression analysis showed that the change in incisor irregularity (LII) from T0 to T3 was explained in 10.4% by the change of incisor inclination (L1/ML) from T0 to T3 ($P = 0.004$).

DISCUSSION

The most important and main result 12 years after treatment was that mandibular incisor irregularity revealed no significant differences between the nonretention and retention groups. Furthermore, in the 2 treatment groups, the irregularity of the incisors was almost at the same level before and 12 years after treatment.

Consequently, the hypothesis that long-term mandibular incisor irregularity for the treated group without retainers would be higher than for the group with retainers could not be confirmed. However, the hypothesis was partly confirmed in that both treatment groups had a higher amount of irregularity than the untreated group at the 12-year follow-up.

Freitas et al[14] also confirmed our findings that post-treatment change of the mandibular anterior crowding was greater in a treated group compared with mandibular crowding caused by physiologic changes in an untreated group, although the observation period was only 5 years. Moreover, another sample of untreated subjects was found to fall in line with our result that incisor irregularity changes were similar in nature but lesser in extent than post-retention changes found in a sample of treated cases.[19]

In the present study, most of the changes in the irregularity of the mandibular incisors in the treated groups occurred from 14.9 to 21.8 years of age. Similar findings were shown in a study[20] of untreated subjects, with most of the mandibular incisor crowding occurring during the late teens and early 20s. In addition, other studies have shown equal physiologic changes in the mandibular incisor alignment in orthodontically treated patients compared with untreated patients. From late adolescence through early to middle adulthood, mandibular incisor irregularity increased similarly in both untreated and treated subjects.[5]

The crowding before treatment did not explain the crowding at the last examination, because LII 6 years after treatment was the only variable that explained LII 12 years after treatment. Studies have shown that relapse of dental crowding depends on initial crowding.[21,22] In our study, the explanation value for this was low.

Correction of overjet and overbite was stable over the long term. At the last examination, the amount of overjet was almost the same in all 3 groups. Eslambolchi et al[9] also pointed out that in an untreated group of children who were followed for 29.8 years, overjet and overbite remained stable.

The arch length variable, intercanine width, and intercanine perimeter distance, decreased in all 3 groups over time and in the treatment groups also because of extractions in some cases. For patients treated in this study, intercanine width did not increase during treatment, which is an important predictor of relapse.[23,24]

The cephalometric analysis revealed only a small number of significant intergroup differences. The group with a retainer had more proclined mandibular incisors after treatment, but at follow-up no differences among the groups were found.

Because the mandibular incisor inclination to ML did not change much over time in any of the groups, this was probably not a cofactor for increased mandibular incisor crowding. Thilander[25] has claimed that no relationship has been found between various cephalometric variables and post-retention changes in mandibular incisor crowding. Mandibular incisor crowding is also thought to be related to anterior rotation of the mandible. In another study, from 2016,[26] no associations were found between different cephalometric measurements, for example, mandibular incisor inclination (L1/ML) and changes in incisor irregularity, and this lack of association was found in our study as well.

As expected, untreated subjects showed normal cephalometric values at all examinations. Thordarson et al[27] have shown in an untreated group that the inclination of the mandibular incisors increased over time from 6 to 16 years of age. However, in our study, the inclination was almost the same during the entire observation period.

In our study, there were more girls in the treatment groups than in the untreated group. The reason could be that girls are more likely to request or accept orthodontic treatment compared with boys. Nevertheless, no statistically significant differences between sexes for LII in the untreated subjects was found.[9,10] However, one study has reported certain dental sex-specific differences such as girls showing more relapse than boys 10 to 15 years after treatment.[28]

Table III. Mean values for the cephalometric variables at the 4 examination time points, measured on lateral head radiographs, and the differences in mean values among the 3 groups

		Retention group (1)		*Nonretention group (2)*		*Untreated group (0)*		
Variable	*Time point*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P *value*
SNA, °	T0	81.18	3.25	81.64	3.10	82.98	4.99	NS
	T1	80.12	3.32	81.41	2.83	–	–	NS
	T2	79.70	3.42	81.95	2.50	81.96	2.66	0≠2*,1≠2†
	T3	79.95	3.62	81.55	3.37	82.49	4.00	0≠2*
SNB, °	T0	76.30	3.32	77.61	3.82	79.62	3.68	0≠2†
	T1	76.58	3.65	78.02	3.57	–	–	NS
	T2	76.22	3.99	79.10	3.31	79.98	2.82	0≠2†,1≠2†
	T3	76.74	4.45	78.77	3.76	80.46	2.90	0≠2‡
ANB, °	T0	5.23	3.47	4.03	3.57	3.36	2.74	NS
	T1	3.53	1.76	3.38	2.42	–	–	NS
	T2	3.47	2.16	2.93	2.44	1.96	2.15	NS
	T3	3.22	2.27	2.77	2.70	2.03	2.53	NS
SN/ML, °	T0	34.21	5.58	34.20	5.42	32.12	4.40	NS
	T1	33.85	6.50	33.95	4.79	–	–	NS
	T2	32.81	7.35	31.48	5.40	30.19	3.84	NS
	T3	33.28	6.88	31.40	6.10	29.65	4.97	NS
ML/NL, °	T0	27.61	5.31	27.80	6.16	27.35	3.95	NS
	T1	27.51	6.68	27.03	5.83	–	–	NS
	T2	25.48	6.84	24.91	6.43	25.72	4.91	NS
	T3	26.21	6.51	24.68	6.95	23.80	4.93	NS
SN/NL, °	T0	6.60	3.18	6.40	3.35	4.77	3.61	NS
	T1	6.31	3.08	6.91	3.00	–	–	NS
	T2	7.34	3.24	6.94	3.08	4.47	2.68	0≠1*,0≠2*
	T3	7.05	3.38	8.18	8.34	5.86	2.47	NS
U1/NL, °	T0	109.34	9.61	113.57	6.96	109.40	5.38	1≠2*
	T1	104.07	8.17	105.46	9.88	–	–	NS
	T2	107.21	7.93	107.85	7.99	104.59	5.35	NS
	T3	106.08	9.89	106.42	8.38	108.05	7.54	NS
L1/Apg, mm	T0	0.73	3.22	1.85	2.76	2.31	2.39	NS
	T1	1.51	2.43	1.28	2.09	–	–	NS
	T2	1.70	2.36	1.47	2.26	2.16	2.25	NS
	T3	1.34	2.81	1.53	2.51	2.31	2.46	NS
L1/ML, °	T0	92.97	6.87	92.11	6.93	94.98	5.66	NS
	T1	94.75	7.91	90.21	8.43	–	–	1≠2*
	T2	96.27	7.50	92.93	7.98	94.81	6.95	NS
	T3	93.66	6.44	93.02	7.56	94.39	5.68	NS
Interincisal angle, °	T0	128.12	11.90	125.39	10.95	127.96	6.72	NS
	T1	132.04	9.23	135.75	11.14	–	–	NS
	T2	130.48	8.45	133.65	9.89	131.37	10.40	NS
	T3	133.03	9.92	135.05	10.13	131.74	10.33	NS

*$P < 0.05$; †$P < 0.01$; ‡$P < 0.001$.

Consequently, the importance of sex for relapse seems to be unclear.

When studying stability after orthodontic treatment, an important question must be asked: How much of the unwanted tooth movement is relapse, and how much is due to natural physiologic changes? Relapse is caused not only by muscle function, but also, and to an even greater extent, by a tendency to rearrange the alveolar fibrous system. Although the principal fibers are rearranged after a certain retention period, histologic studies have shown that the supra-alveolar structures may remain displaced and stretched for more than 7 months after the cessation of orthodontic tooth movement.[29] So relapse occurring during this period of remodeling of periodontal structures must be distinguished from late changes during the post-retention period. Instead, the changes that occur later are more related to craniofacial growth, dental development, and muscle function.

Edman Tynelius et al[30] showed that a major part of relapse took place during the first year of retention (different methods of retention used) and that only small changes and differences occurred during the second year

of retention. This implies that the first year of retention is the most important to retain the treatment result. Furthermore, another study has shown that nearly 50% of the relapse occurred in the first 2 years after retention.[31] After that period, a certain stability is reached except for the mandibular incisors. Consequently, a retention time of about 2 years is probably sufficient, and tooth movements after those years are considered to be natural physiologic changes. Sadowsky et al[32] showed that an average period of 8.4 years with a fixed mandibular retainer was more favorable than shorter retention times in other studies. It seems that life-long retention for the mandibular anterior segment is needed. Thus, for patients who want straight teeth throughout their life, permanent retention is recommended. It is important to stress that improperly designed or inserted retainers may cause inadvertent tooth movements; therefore, retainers for long-term use require regular check-ups.[33]

In the present study, we used 2 different bonded retainers for permanent retention, which were merged into 1 group because we have shown in another study[2] that there were no differences in their capacity in keeping the mandibular incisors aligned in a long-term perspective.

It might be surprising that one group did not get a retainer after treatment even though the crowding situation was similar before treatment in both groups. On the other hand, this group made the present study possible. It is difficult to find an orthodontically treated group without retainers afterwards.

The untreated control group consisted of subjects followed because of infraocclusion of primary molars with permanent successors or the reversible type of ectopic eruption of the maxillary first permanent molars.[34,35] The growth and development of the dentition was normal in these cases. These subjects had Class I normal occlusion without any other malocclusions.

A limitation with this study was that the subjects in the untreated control group had only minor malocclusions. Ideally, the study should have included an untreated group of subjects with malocclusions similar to those of the treated groups. However, the postponement of a needed orthodontic intervention for 12 years is ethically unacceptable.

CONCLUSION

There were no differences found in LII for the mandibular incisors 12 years after treatment between the group that had a retainer and the group that had no retainer after treatment. In the untreated group, LII increased over time, but not to the same extent as in the treated groups. The crowding before treatment did not explain the crowding at the last examination.

The routine use of mandibular retainers for 2 to 3 years does not appear to prevent long-term relapse. If the patient wants to constrain the changes that come with natural development, then lifelong retention is needed.

It may be perceived as discouraging that the mandibular incisor stability was suboptimal, but as encouraging that the overjet and overbite were stable long-term.

REFERENCES

1. Al Yami EA, Kuijpers-Jagtman AM, van't Hof MA. Stability of orthodontic treatment outcome: follow-up until 10 years postretention. Am J Orthod Dentofacial Orthop 1999;115:300-4.
2. Schütz-Fransson U, Lindsten R, Bjerklin K, Bondemark L. Twelve year follow-up of mandibular incisor stability: A comparison between two different bonded lingual orthodontic retainers. Angle Orthod 2017;87:200-8.
3. Bjering R, Birkeland K, Vandevska-Radunovic V. Anterior tooth alignment: A comparison of orthodontic retention regimens 5 years posttreatment. Angle Orthod 2015;85:353-9.
4. Otuyemi OD, Jones SP. Long-term evaluation of treated class II division 1 malocclusions utilizing the PAR index. Br J Orthod 1995; 22:171-8.
5. Driscoll-Gilliland J, Buschang PH, Behrents RG. An evaluation of growth and stability in untreated and treated subjects. Am J Orthod Dentofacial Orthop 2001;120:588-97.
6. Samspon WJ. Current controversies in late incisor crowding. Ann Acad Med Singapore 1995;24:129-37.
7. Profitt WR. Retention. In: Profitt W, Fields H, Sarver D, editors. Contemporary orthodontics. 5th ed. Saint Louis: Elsevier Mosby–Year Book; 2013. p. 615-6.
8. Johnston CD, Littlewood S. Retention in orthodontics. Br Dent J 2015;218:119-22.
9. Eslambolchi S, Woodside DG, Rossouw PE. A descriptive study of mandibular incisor alignment in untreated subjects. Am J Orthod Dentofacial Orthop 2008;133:343-53.
10. Bondevik O. A longitudinal study of dental arches and oclusal changes in adults from 22 to 33, and 33 to 43 years of age. J Orofac Orthop 2015;76:79-89.
11. 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;35:230-5.
12. Little RM. Stability and relapse of mandibular anterior alignment: University of Washington studies. Semin Orthod 1999; 5:191-204.
13. Jonsson T, Magnusson TE. Crowding and spacing in the dental arches: l long- term development in treated and untreated subjects. Am J Orthod Dentofacial Orthop 2010;138:384.e1-7.
14. Freitas KM, Janson G, Tompson B, de Freitas MR, Simão TM, Valarelli FP, Cançado RH. Posttreatment and physiologic occlusal changes comparison. Angle Orthod 2013;83:239-45.
15. Little RM. The irregularity index. A quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-63.
16. Björk A. The face in profile. Svensk Tandl Tidskr 1947;40(Suppl 1).
17. Solow B. The pattern of craniofacial associations. Acta Odontol Scand 1966;24(Suppl 46).
18. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940.

19. Sinclair PM, Little RM. Maturation of untreated normal occlusions. Am J Orthod 1983;83:114-23.
20. Bushang PH, Shulman JD. Incisor crowding in untreated persons 15-50 years of age: United States, 1988-1994. Angle Orthod 2003;73:502-8.
21. Kahl-Nieke B, Fischbach H, Schwarze CW. Post-retention crowding and incisor irregularity: a long-term follow-up evaluation of stability and relapse. Br J Orthod 1995;22:249-57.
22. Bjering R, Sandvik L, Midtbø M, Vandevska-Radunovic V. Stability of anterior tooth alignment 10 years out of retention. J Orofac Orthop 2017;78:275-83.
23. Zachrisson BU. Important aspects of long-term stability. J Clin Orthod 1997;31:562-83.
24. Artun J, Garol JD, Little RM. Long-term stability of mandibular incisors following successful treatment of class II, division 1, malocclusions. Angle Orthod 1996;66:229-38.
25. Thilander B. Biological basis for orthodontic relapse. Semin Orthod 2000;6:195-205.
26. Oh H, Ma N, Feng PP, Kieu K, Boero R, Dugoni S, et al. Evaluation of posttreatment stability after orthodontic treatment in the mixed and permanent dentitions. Angle Orthod 2016;86:1010-8.
27. Thordarson A, Johannsdottir B, Magnusson TE. Craniofacial changes in Icelandic children between 6 and 16 years of age—a longitudinal study. Eur J Orthod 2006;28:152-65.
28. Zinad K, Schols AM, Schols JG. Another way of looking at treatment stability. Angle Orthod 2016;86:721-6.
29. Reitan K. Clinical and histologic observations on tooth movement during and after orthodontic treatment. Am J Orthod 1967;53:721-45.
30. 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;16:105-15.
31. Kuijpers-Jagtman AM. Repair and revision 8. Relapse of lower incisors: retreatment? Ned Tijdschr Tandheelkd 2002;109:42-6.
32. Sadowsky C, Schneider BJ, BeGole EA, Tahir E. Long-term stability after orthodontic treatment: Nonextraction with prolonged retention. Am J Orthod Dentofacial Orthop 1994;106:243-9.
33. Shaughnessy TG, Proffit WR, Samara SA. Inadvertent tooth movement with fixed lingual retainers. Am J Orthod Dentofacial Orthop 2016;149:277-86.
34. Kurol J. Infraocclusion of primary molars. An epidemiological, familial, longitudinal clinical and histological study [thesis]. Swed Dent J Suppl 1984;21:1-67.
35. Bjerklin K. Ectopic eruption of the maxillary first permanent molar. An epidemiological, familial, aetiological and longitudinal clinical study [thesis]. Swed Dent J Suppl 1994;100:1-66.