Original Article

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Long-term stability of dentoalveolar, skeletal, and soft tissue changes after non-extraction treatment with a self-ligating system

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Objective: To evaluate the long-term effects of self-ligating brackets (SLBs) on transverse dimensions of arches and skeletal and soft tissues and to quantitatively evaluate the treatment outcome after non-extraction treatment with SLBs. **Methods:** The sample consisted of 24 (18 female and six male) subjects, with a mean age of 14.23 ± 2.19 years, who received treatment with the Damon®3 appliances. Complete records including cephalometric radiographs and plaster models were obtained before treatment (T1), immediately after treatment (T2), six months after treatment (T3), and two years (T4) after treatment. Digital study models were generated. Twenty lateral cephalometric, six frontal cephalometric, and eight dental cast measurements were examined. The Peer Assessment Rating index was used to measure the treatment outcome. The Wilcoxon test was applied for statistical analysis of the changes. **Results:** There were significant increases in all transverse dental cast measurements with active treatment. There was some significant relapse in the long term, particularly in maxillary width ($p < 0.05$). Statistically significant increases were found in nasal ($p < 0.001$), maxillary base, upper molar, lower intercanine, and antigonial ($p < 0.05$) widths in T1-T2. Lower incisors were proclined and protruded in T1-T2. **Conclusions:** SLBs correct crowding by mechanisms involving incisor proclination and protrusion and expansion of the dental arches, without induction of clinically significant changes in hard and soft tissues of the face.
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INTRODUCTION

Non-extraction treatment of a crowded dental arch requires an increase in arch perimeter to allow achievement of arch alignment and leveling.[1] Without distal movement of arches, an increase in arch perimeter typically involves both transverse expansion and proclination.[2] However, these arch dimensional changes may adversely affect long-term stability and treatment outcomes. Particularly, expansion of the intercanine dimension and excessive proclination of the mandibular incisors are considered unstable.[3,4] Little[5] reported that the development of secondary crowding was inevitable during the post-treatment phase because of uprighting of the mandibular incisors and reduction of arch width when measured across the mandibular canine teeth. This crowding is likely to appear as long-term irregularity.

Self-ligating brackets (SLBs), first described several decades ago, have undergone a renaissance in the last 10 years.[6] Some of their advantages over conventional ligating brackets (CBs) include faster wire engagement and disengagement, shorter treatment appointments, and reduced treatment time, as well as increased patient comfort.[7-9] However, several controversial aspects regarding their mode of action and correction of malocclusions have been suggested.[10]

It has been proposed that some SLBs might induce wider arch widths.[2,11-13] These results regarding the efficiency of SLBs derive from a limited number of clinical trials. Some have shown differences in post-treatment molar widths,[2,10,14] and some have indicated no differences between CBs and SLBs.[13,15]

Because of the limited number of studies on the long-term effects on arch widths and outcomes of treatment with self-ligating systems, this retrospective study was undertaken to further clarify the long-term effects of this type of appliance.

The main purpose of this study was to evaluate the long-term effects of SLBs on transverse dimensions of maxillary and mandibular arches, skeletal structures, and soft tissues. We assessed the long-term stability of dentoalveolar, skeletal, and soft tissue changes and quantitatively evaluated the treatment outcome after non-extraction treatment with a self-ligating system.

MATERIALS AND METHODS

Ethical approval for this retrospective study was obtained from the Selcuk University Scientific Committee. The sample consisted of 24 (18 female and six male) subjects with a mean age of 14.23 ± 2.19 years. Participants were selected from a large pool of completed cases treated by the same investigator (FAB) at the Department of Orthodontics of Selcuk University according to the inclusion and exclusion criteria in Table 1.

The patients in the sample received the standard torque version of the Damon®3 0.022 inch slot appliances (Ormco, Glendora, CA, USA). The archwire sequence involved 0.014 inch CuNiTi (Ormco), 0.016 inch CuNiTi, 0.014 × 0.025 inch CuNiTi, 0.018 × 0.025 inch CuNiTi, 0.016 × 0.025 inch stainless steel (for the lower arch), and 0.019 × 0.025 inch stainless steel (for the upper arch) wires to the arches. Final lower stainless steel archwires were adapted to the initial lower dental arch forms. After completing the treatment, upper and lower lingual retainers and an upper Hawley device were applied. The Hawley appliance was worn for six months. The average active treatment time was 1.3 years.

Complete records including cephalometric radiographs with the use of the same cephalostat (Promax; Planmeca, Helsinki, Finland) by the same operator, extraoral and intraoral photographs, and plaster models prepared from alginate impressions were obtained before treatment (T1), immediately after treatment (T2), six months

Table 1. Inclusion and exclusion criteria used to select participants for this study

Inclusion criteria	Exclusion criteria
Non-extraction treatment with Damon®3 self-ligating brackets system (Ormco; Glendora, CA, USA)	Lack of data required for our research
Class I malocclusion with moderate crowding (3–6 mm or less)	Use of additional anchorage reinforcement (mini-implant, headgear, transpalatal arch, lingual arch, intermaxillary elastics, pendulum, twin block, and Nance and any removable appliances during active treatment)
Using same archwire sequences	Missing three or more appointments
Using same retention protocol	Unclear pre-treatment or post-treatment lateral cephalograms
Eruption of all mandibular and maxillary teeth	
Except all third molars; no spaces in both arches	
No adjunct therapeutic intervention involving functional removable appliances and maxillary expansion appliances	

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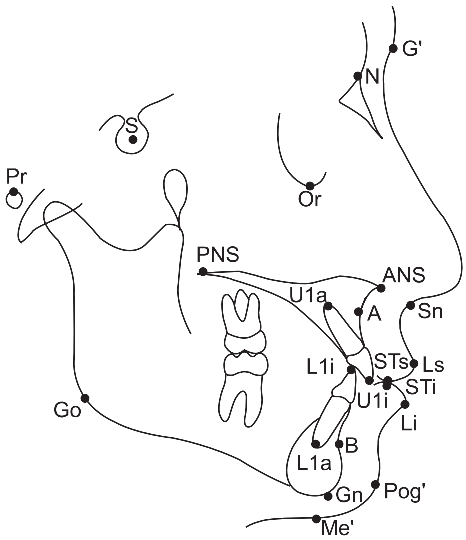

Figure 1. Lateral cephalometric landmarks used in this study. S, Sella; N, nasion; ANS, anterior nasal spine; PNS, posterior nasal spine; A, point A; B, point B; Gn, gnathion; Go, gonion; G', Glabella; Pog', soft tissue pogonion; Ls, the most anterior projection of the upper lip vermillion; Li, the most anterior projection of the lower lip vermillion; Sn, subnasale; Me', soft tissue menton; STs, upper lip stomion; STi, lower lip stomion; U1a, upper incisor apex; L1a, lower incisor apex; U1i, upper incisor incisal point; L1i, lower incisor incisal point; Pr, Porion; Or, Orbitale; SnPerp, reference line constructed by passing a line through Sn and perpendicular to the Frankfurt horizontal plane (Po-Or).

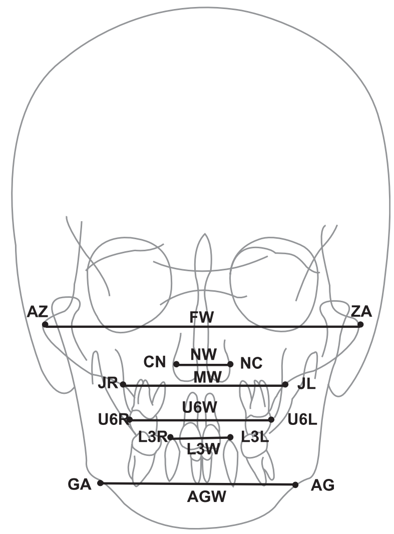

Figure 2. Frontal cephalometric landmarks and measurements used in this study. ZA and AZ, the centers of the left and the right zygomatic arches; NC and CN, the left and the right outermost points of the widest range of the nasal cavity; JL and JR, the deepest left and the right points on the jugular process; U6L and U6R, The outermost points of the buccal surfaces of the left and right first molars; L3L and L3R, the tips of the left and the right lower canines; AG and GA, the deepest left and the right points of antegonial notch; FW (facial width), the distance between ZA and AZ points; NW (Nasal width), the distance between NC and CN points; MW (maxillary width), the distance between JL and JR points; U6W (upper intermolar width), the distance between U6L and U6R points; L3W (lower intercanine width), the distance between L3L and L3R points; AGW (antegonial width), the distance between AG and GA points.

after treatment (T3), and two years after treatment (T4). Digital study models were generated (3Shape A/S, Copenhagen, Denmark). Twenty lateral cephalometric (Figure 1), six frontal cephalometric (Figure 2), and eight dental cast (Figure 3) measurements were obtained and recorded.

Linear and angular measurements performed in lateral cephalogram are shown in Table 2.

The Peer Assessment Rating (PAR) index was used to measure the treatment outcome on dental cast models. All measurements were performed by the same investigator (MA). The individual traits were weighted according to Richmond et al.[16] The difference in scores before and after treatment (reduction in PAR score) reflected the degree of improvement as a result of orthodontic intervention[16] and the change relative to the pre-treatment score, while the percentage PAR score reduction expressed the amount of correction with treatment.[17,18] This percentage was calculated using the following formula.[19]

$$PAR\ (\%) = PAR\ T2 - T1 \times 100/PAR\ T1$$

Descriptive and analytical statistical analyses were performed with SPSS for Windows software, version 15.0 (SPSS Inc., Chicago, IL, USA). The data showed a non-parametric distribution tendency; hence, we applied a Wilcoxon non-parametric test for assessing the changes statistically within periods, with the level of statistical significance set at $p < 0.05$.

Ten cephalograms as well as ten dental cast models were measured twice at an interval of two weeks to test the examiner's accuracy and consistency. The paired samples *t*-test showed no significant mean differences between the two series of records.

RESULTS

All dental cast measurements were significantly increased with active treatment ($p < 0.05$). While there was no relapse at six months after treatment for all

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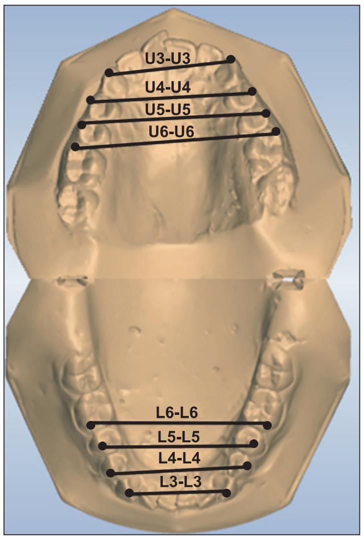

Figure 3. Transverse dental cast measurements used in this study. U3-U3, the distance between the tips of the left and right upper canines; U4-U4, the distance between the buccal cusp tips of the left and right upper first premolars; U5-U5, the distance between the buccal cusp tips of the left and right upper second premolars; U6-U6, the distance between the mesiobuccal cusp tips of the left and right upper first molars; L3-L3, the distance between the tips of the left and right lower canines; L4-L4, the distance between the buccal cusp tips of the left and right lower first premolars; L5-L5, the distance between the buccal cusp tips of the left and right lower second premolars; L6-L6, the distance between the mesiobuccal cusp tips of the left and right lower first molars.

dimensions, there was some significant relapse in the long term, particularly in maxillary width ($p < 0.05$) (Table 3).

Statistically significant increases were found in nasal ($p = 0.000$), maxillary base ($p = 0.011$), upper molar ($p = 0.024$), lower intercanine ($p = 0.045$), and antigonial ($p = 0.022$) widths in T1-T2, whereas there was no significant change in all frontal measurements ($p > 0.05$) except antigonial width in T2-T3 (Table 4).

SN-GoGn, Mx1-SN, and Mx1-Pal angles and Mx1-Na linear measurements were decreased in T2-T3 ($p < 0.05$). IMPA and Md1-NB angles and Md1-NB linear measurements were increased in T1-T2, T1-T3, and T1-T4 ($p < 0.05$). The increments in IMPA and Md1-NB (mm) were continued during T3-T4 ($p < 0.05$). While the upper lip was protruded in T1-T4, T2-T3, and T2-T4 ($p < 0.05$), the lower lip was protruded only in T2-T3 ($p < 0.01$, Table 5).

In T1-T2, G'Sn/SnMe', Sn-STs/STs-Me', and Sn-Li/Li-Me' ratios and interlabial gap measurements decreased

Table 2. Linear and angular measurements performed in lateral cephalogram

Measurements	Definition
SNA (°)	Sella-Nasion-A point angle
SNB (°)	Sella-Nasion-B point angle
ANB (°)	A point-Nasion-B point angle
SN-GoGn (°)	S-N to Go-Gn angle
Mx1-SN (°)	Upper incisor axis to S-N angle
Mx1-Pal (°)	Upper incisor axis to ANS-PNS angle
Mx1-NA (mm)	Distance from upper incisor labial surface to NA line
Mx1-NA (°)	Upper incisor axis to NA line angle
IMPA (°)	Lower incisor axis to Go-Gn angle
Md1-NB (mm)	Distance from lower incisor labial surface to NB line
Md1-NB (°)	Lower incisor axis to NB line angle
Interincisal angle (°)	Upper and lower incisor axis angle
G'-Sn/Sn-Me'	Ratio of the distance of G'-Sn and Sn-Me'
Sn-STs (mm)	Upper lip length
Sn-STs/STs-Me'	Ratio of the distance of Sn-STs and STs-Me'
Sn-Li/Li-Me'	Ratio of the distance of Sn-Li and Li-Me'
Interlabial gap (mm)	Distance of STs-STi with the lips in repose
SnPerp-Ls (mm)	Horizontal distance of Ls to the SnPerp line
SnPerp-Li (mm)	Horizontal distance of Li to the SnPerp line
SnPerp-Pog' (mm)	Horizontal distance of Pog' to the SnPerp line

NA, Nasion-A point; NB, nasion-B point; SnPerp (Subnasale Perpendicular), a line through subnasale and perpendicular to the anatomic Frankfort horizontal plane.
See Figure 1 for other abbreviations.

significantly ($p < 0.05$). In the retention periods, no significant change was found except in the Sn-Li/Li-Me' measurement in T2-T3 ($p < 0.05$, Table 6).

The mean percentage reductions in PAR values are presented in Table 7.

DISCUSSION

Years ago, a proposal of expanding the dental arches to accommodate all teeth was challenged by Tweed,[20] who claimed that teeth should be positioned over basal bone. Now, Damon's theory of dental arch expansion is

Table 3. The mean and SD for transverse dimensions (mm) measured on dental casts and comparison of the changes

	T1	T2	T3	T4	T1-T2	T1-T3	T1-T4	T2-T3	T2-T4	T3-T4
U3-U3	33.17 ± 2.43	35.33 ± 1.27	35.30 ± 1.20	35.25 ± 1.11	0.000	0.000	0.001	NS	NS	NS
U4-U4	38.67 ± 2.41	43.75 ± 1.26	43.67 ± 1.27	43.25 ± 1.57	0.000	0.000	0.000	NS	0.003	0.002
U5-U5	43.75 ± 2.64	48.25 ± 1.62	48.01 ± 1.78	47.83 ± 1.95	0.000	0.000	0.000	NS	0.002	0.002
U6-U6	49.08 ± 2.38	52.33 ± 1.88	52.16 ± 1.67	51.92 ± 2.02	0.000	0.000	0.000	NS	0.002	0.002
L3-L3	25.50 ± 1.53	26.33 ± 0.87	26.29 ± 1.01	26.25 ± 0.94	0.024	0.024	0.032	NS	NS	NS
L4-L4	32.92 ± 1.53	35.58 ± 1.14	35.45 ± 1.23	35.67 ± 1.13	0.000	0.000	0.000	NS	NS	NS
L5-L5	37.50 ± 2.62	40.83 ± 1.37	40.54 ± 1.71	40.33 ± 1.83	0.000	0.000	0.000	NS	0.010	0.010
L6-L6	43.25 ± 2.25	45.17 ± 1.37	44.88 ± 1.53	44.67 ± 1.58	0.001	0.001	0.002	NS	0.003	0.003

Values are presented as mean ± standard deviation (SD) or *p*-value.
By Wilcoxon signed rank test.
NS, Not significant; T1, before treatment; T2, immediately after treatment; T3, 6 months after treatment; T4, 2 years after treatment.
See Figure 3 for the measurements.

Table 4. The mean and SD for frontal cephalometric measurements (mm) and comparison of the changes

	T1	T2	T3	T4	T1-T2	T1-T3	T1-T4	T2-T3	T2-T4	T3-T4
FW	120.47 ± 4.31	120.44 ± 3.06	120.41 ± 3.07	120.41 ± 3.12	NS	NS	NS	NS	NS	NS
NW	30.35 ± 0.88	30.73 ± 0.99	30.65 ± 1.00	30.75 ± 1.04	0.000	0.007	0.001	NS	NS	0.005
MW	66.62 ± 3.14	67.90 ± 2.59	67.94 ± 2.65	67.95 ± 2.69	0.011	0.010	0.006	NS	NS	NS
U6W	54.57 ± 3.49	55.53 ± 2.21	55.55 ± 2.22	55.53 ± 2.24	0.024	0.012	0.012	NS	NS	NS
L3W	25.57 ± 2.05	26.13 ± 1.64	26.08 ± 1.67	26.02 ± 1.61	0.045	0.039	NS	NS	0.033	NS
AGW	87.44 ± 5.73	88.78 ± 4.87	88.62 ± 4.84	88.69 ± 4.78	0.022	0.036	0.033	0.004	NS	NS

Values are presented as mean ± standard deviation (SD) or *p*-value.
By Wilcoxon signed rank test.
NS, Not significant; T1, before treatment; T2, immediately after treatment; T3, 6 months after treatment; T4, 2 years after treatment.
See Figure 2 for the measurements.

similar to the previous proposal.[21] In addition, long-term stability of tooth alignment is an important factor in orthodontics.

Alleviation of dental crowding by orthodontic alignment and leveling of arch dimensions without extraction involves an increase in arch perimeter achieved by incisor advancement and transverse expansion. These findings have been described for CBs and SLBs.[22] However, recent studies have proposed that some SLB appliances might induce wider intermolar widths.[2,10,14] There are a limited number of studies in the literature about arch dimensional changes and long-term stability of the treatment with self-ligating systems. This study of SLBs aimed to describe the changes in transverse dimensions and hard and soft tissues, assess the long-term stability, and reveal the quality of treatment by using the PAR index. Because there are no long-term follow-up studies of SLBs, effects in long-term stability are largely unknown.

The results of this study suggest that correction of mandibular crowding after active treatment was achieved through incisor proclination and protrusion as well as expansion of the dental arches with SLBs. These results are in agreement with recent evidence.[2,10,15,22] In the present study, all transverse dimensions increased significantly. Pandis et al.[10,22] suggested that the correction of crowding with Damon®2 brackets produced a small but statistically significant expansion in the mandibular arch. They also found that the SLBs showed a statistically greater intermolar width increase than the CBs. Scott et al.,[15] using study models at various stages of treatment, found that alignment was associated with an increase in intercanine width and proclination of mandibular incisors for SLBs and CBs, but the differences were not significant.

All transverse widths obtained by active treatment re-

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Table 5. The mean and SD for skeletal and dental measurements and comparison of the changes

	T1	T2	T3	T4	T1-T2	T1-T3	T1-T4	T2-T3	T2-T4	T3-T4
SNA (°)	80.01 ± 3.02	80.40 ± 3.56	80.36 ± 3.49	80,33 ± 3,51	NS	NS	NS	NS	NS	NS
SNB (°)	77.75 ± 3.34	78.14 ± 4.04	78.05 ± 3.90	78.20 ± 4.04	NS	NS	NS	NS	NS	NS
ANB (°)	2.28 ± 1.34	2.26 ± 0.97	2.30 ± 1.04	2.13 ± 0.88	NS	NS	NS	NS	NS	0.024
SnGoGn (°)	36.55 ± 5.73	36.89 ± 6.05	36.81 ± 6.10	36.80 ± 6.02	NS	NS	NS	0.022	NS	NS
Mx1-SN (°)	101.62 ± 6.56	102.90 ± 5.52	102.76 ± 5.51	102.88 ± 5.45	NS	NS	NS	0.008	NS	0.005
Mx1-Pal (°)	109.55 ± 5.31	110.88 ± 5.15	110.56 ± 4.97	110.53 ± 4.94	NS	NS	NS	0.001	NS	NS
Mx1-NA (mm)	6.91 ± 3.26	7.42 ± 1.71	7.36 ± 1.73	7.31 ± 1.74	NS	NS	NS	0.006	NS	NS
Mx1-NA (°)	21.59 ± 6.43	22.43 ± 4.54	22.46 ± 4.58	22.50 ± 4.60	NS	NS	NS	NS	NS	NS
IMPA (°)	90.24 ± 5.98	93.48 ± 4.00	93.53 ± 4.01	93.72 ± 3.98	0.006	0.006	0.004	NS	NS	0.011
Md1-NB (mm)	6.07 ± 2.80	7.80 ± 1.95	7.80 ± 2.00	7.86 ± 2.02	0.002	0.001	0.001	NS	NS	0.022
Md1-NB (°)	24.54 ± 7.73	27.97 ± 4.83	27.81 ± 4.88	27.76 ± 4.98	0.015	0.015	0.015	0.009	NS	NS
Interincisal angle (°)	131.60 ± 13.03	127.59 ± 7.35	127.61 ± 7.43	127.93 ± 7.67	NS	NS	NS	NS	NS	NS

Values are presented as mean ± standard deviation (SD) or *p*-value.
By Wilcoxon signed rank test.
NS, Not significant; T1, before treatment; T2, immediately after treatment; T3, 6 months after treatment; T4, 2 years after treatment; Mx, maxillary; Md, mandibular.
See Table 2 for the measurements.

Table 6. The mean and SD for soft tissue measurements and comparison of the changes

	T1	T2	T3	T4	T1-T2	T1-T3	T1-T4	T2-T3	T2-T4	T3-T4
G'Sn/SnMe'	0.88 ± 0.14	0.84 ± 0.10	0.88 ± 0.20	0.84 ± 0.09	0.014	NS	0.016	NS	NS	NS
Sn-STs (mm)	23.04 ± 3.17	23.13 ± 3.03	23.13 ± 2.96	23.04 ± 2.88	NS	NS	NS	NS	NS	NS
Sn-STs/STs-Me'	0.49 ± 0.05	0.47 ± 0.03	0.46 ± 0.03	0.46 ± 0.04	0.007	0.006	0.007	NS	NS	NS
Sn-Li/Li-Me'	0.54 ± 0.10	0.52 ± 0.08	0.51 ± 0.08	0.51 ± 0.07	0.017	0.017	0.017	0.046	NS	NS
Interlabial gap (mm)	3.38 ± 3.51	2.93 ± 2.56	2.78 ± 2.30	2.54 ± 1.99	0.042	NS	NS	NS	NS	NS
SnPerp-Ls (mm)	0.38 ± 2.64	0.72 ± 1.95	0.68 ± 1.88	0.52 ± 1.63	NS	NS	NS	NS	NS	NS
SnPerp-Li (mm)	−2.88 ± 4.11	−2.13 ± 2.87	−2.03 ± 2.69	−2.15 ± 2.55	0.019	0.015	0.023	NS	NS	NS
SnPerp-Pog' (mm)	−7.54 ± 3.88	−8.00 ± 3.28	−7.95 ± 3.21	−7.92 ± 2.96	NS	NS	NS	NS	NS	NS

Values are presented as mean ± standard deviation (SD) or *p*-value.
By Wilcoxon signed rank test.
NS, Not significant; T1, before treatment; T2, immediately after treatment; T3, 6 months after treatment; T4, 2 years after treatment.
See Table 2 for the measurements.

Table 7. The mean and SD for PAR scores and PAR reduction rate (%)

	PAR score				PAR reduction rate (%)		
	T1	T2	T3	T4	T1-T2	T1-T3	T1-T4
SLBs	19.47 ± 8.74	0.61 ± 0.79	0.72 ± 0.64	0.77 ± 1.13	96.86 ± 4.14	96.30 ± 4.04	96.04 ± 5.90

Values are presented as mean ± standard deviation (SD).
SLB, Self-ligating bracket; PAR, Peer Assessment Rating index.

mained stable during the early retention period. Upper and lower second premolar and molar widths and upper first premolar width were decreased in the T3-T4 period, whereas upper and lower canine widths and lower first premolar width remained stable during all retention periods. Little[5] reported that only 10% of patients had clinically acceptable long-term results when the mandibular arch was expanded laterally. Kuijpers-Jagtman et al.[23] investigated the long-term stability for ten years after the retention phase and showed that nearly 50% of total relapse occurred within the first two years after retention. In the current study, relapse in the posterior part of the lower arch was almost 0.25 mm, which may be considered clinically insignificant. These differences between the present and previous studies may be due to retention protocol and duration.

Consistent with our active treatment findings, Tecco et al.[24] found that both fixed SLBs and traditional straight-wire appliances increased maxillary dentoalveolar widths. Yu et al.[25] compared the effect of rapid maxillary expansion (RME) and the Damon technique on the correction of dental crowding with a non-extraction approach. They reported that both RME and the Damon technique could successfully increase the arch width and correct moderate dental crowding with a non-extraction approach. They also suggested that Damon® appliances protrude the upper and lower incisors and expand the dental arch by buccal tipping of premolars and molars. However, no long-term results have been reported.

Significant increases were found in nasal, maxillary base, upper molar, lower intercanine, and antigonial widths on the frontal cephalogram with active treatment. These findings are similar to the frontal results of the RME procedure. Some previous studies that investigated the effects of RME on transverse dimensions found increases in the same width parameters, but the changes were greater by RME in those studies than by SLBs in the present study. This is an expected result. Yu et al.[25] found that the maxillary base width increased 2.1 mm in the RME group, which was significantly greater than 0.6 mm in the Damon group. Both groups showed buccal tipping of premolars and molars, with a higher extent of premolar tipping in the Damon group. However, in the current study, there was no significant change in the intermolar angle. The long-term results of the frontal cephalometric measurements showed that the changes obtained by active treatment remained stable during the retention period. Some relapses in nasal, lower intercanine, and antigonial widths were seen, but these changes may be considered clinically insignificant.

The changes in hard tissue and dental measurements determined on lateral cephalogram were clinically insignificant except for lower incisor protrusion and proclination. In soft tissue measurements, some decreases in proportional measurements were found; these were probably related to a small increase in lower facial height as well as lower lip protrusion due to lower incisor protrusion and proclination.

In this study, the PAR index was used to evaluate the results of treatment. The PAR index was developed to quantify the extent to which an individual's dentition deviates from an ideally formed dental arch and occlusion.[18] Although it is not considered the optimal tool for evaluation of treatment benefits[17] and does not take all dental variables into account, the PAR score gives a general impression of the dental arches and the occlusion.

In the current study, treatment with SLBs showed a high standard of orthodontic success according to Richmond et al.16 in all periods (96.86%, 96.30%, and 96.04% for T1-T2, T1-T3, and T1-T4, respectively). Richmond et al.[16] proposed that mean PAR reduction with treatment should exceed 70% in high-standard orthodontic treatment. The results of the PAR index reflected the long-term measurements results of this study. The mean percentage PAR reduction in active treatment was similar for both retention periods, which indicated minimal relapse. DiBiase et al.[26] evaluated both the duration of treatment and occlusal outcome with Damon®3 and CBs in extraction patients. They found 85.19% and 83.38% PAR reduction in the SLB and CB groups, respectively, and concluded that use of the Damon®3 SLB system carried no advantage over CBs in terms of occlusal outcome. The percentage PAR reduction was higher in the current study than in the study by DiBiase et al.[26] and two previous studies.[27,28] The main difference between these three studies was the extraction/non-extraction protocol. In a previous study, Ileri et al.[29] reported that, using the PAR as an index to assess treatment outcome, non-extraction treatment with CBs had a better treatment result than that with the four first premolar extraction and single lower incisor extraction protocol in Class I cases with moderate to severe mandibular anterior crowding. Machibya et al.[27] reported a mean percentage PAR reduction of 86.33% and no significant differences between SLBs and CBs.

The system used in the present study did not cause clinically significant changes in hard and soft tissues of the face. If major changes had been observed in the face with active treatment, the growth pattern of the samples should have been considered, because the samples in this study were in the growth period. However, normal growth may have supported maintenance of the transverse increments during the T1-T2 period in the long term.

This study was a retrospective study. Crowding, non-extraction treatment, archwire sequence, retention protocol, facial profile, and the individual patient's needs were considered primarily while creating the samples. Although selection bias is a significant disadvantage of a retrospective study,[30] a well-performed retrospective study can yield useful results and help clarify the study hypothesis and determine an appropriate sample size.

The limitations of this study were the lack of a control

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Table 8. Summary of clinical studies for self-ligating brackets (SLBs) and conventional ligating brackets (CBs)

First author (year)		Upper arch transverse dimension	Lower arch transverse dimension	Lower incisor inclination angle	PAR reduction rate (%)	Extraction (ET) or non-extraction (NE)
Present study	CBs group	-	-	-	-	-
	SLBs group	Significantly increased	Significantly increased	Significantly increased	96.86	NE
Pandis (2007)[22]	CBs group	-	Significantly increased		-	NE
	SLBs group	-	Significantly increased		-	NE
Scott (2008)[15]	CBs group	-	Increased	Increased	-	ET
	SLBs group	-	Increased	Increased	-	ET
Fleming (2009)[2]	CBs group	-	Increased	Increased	-	NE
	SLBs group	-	Increased	Increased	-	NE
Pandis (2010)[10]	CBs group	-	Significantly increased	Significantly increased	-	NE
	SLBs group	-	Significantly increased	Significantly increased	-	NE
DiBiase (2011)[26]	CBs group	-	-	-	83.38	ET
	SLBs group	-	-	-	85.19	ET
Pandis (2011)[13]	CBs group	-	Increased	-	-	NE
	SLBs group	-	Increased	-	-	NE
Machibya (2013)[27]	CBs group	-	-	Decreased	85.75	ET
	SLBs group	-	-	Decreased	86.33	ET

group and the evaluation of treatment time. However, the studies comparing the treatment durations of SLBs and CBs exist in the literature (Table 8). Machibya et al.[27] compared treatment time and outcome among orthodontic patients treated by SLBs and CBs. They concluded that there were significant dental and skeletal changes among adolescent orthodontic patients regardless of the bracket used and the treatment time and percentage PAR reduction were not influenced by the type of bracket.

CONCLUSION

SLBs correct crowding through mechanisms involving incisor proclination and protrusion and expansion of the dental arches, without induction of clinically significant changes in hard and soft tissues of the face. In the long term, the increases in transverse dimensions of the arches obtained with self-ligating brackets remain stable.

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