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® 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. [Korean J Orthod 2014;44(3):119-127] Key words: Stability, Extraction vs. nonextraction, Bracket, Stability, Bracket
INTRODUCTION

Non-extraction treatment of a crowded dental arch requires an increase in arch perimeter to allow achievement of arch alignment and leveling. Without distal movement of arches, an increase in arch perimeter typically involves both transverse expansion and proclination. 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. Little 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. 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. However, several controversial aspects regarding their mode of action and correction of malocclusions have been suggested. It has been proposed that some SLBs might induce wider arch widths. These results regarding the efficiency of SLBs derive from a limited number of clinical trials. Some have shown differences in post-treatment molar widths, and some have indicated no differences between CBs and SLBs. 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 after treatment (T3), and at the end of six months of retention (T4).

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    | Lack of data required for our research                                           |
| brackets system (Ormco; Glendora, CA, USA)             |                                                                                    |
| Class I malocclusion with moderate crowding (3–6 mm or | Use of additional anchorage reinforcement (mini-implant, headgear, transpalatal   |
| less)                                                  | 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|                                                                                    |
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.\textsuperscript{16} The difference in scores before and after treatment (reduction in PAR score) reflected the degree of improvement as a result of orthodontic intervention\textsuperscript{16} and the change relative to the pre-treatment score, while the percentage PAR score reduction expressed the amount of correction with treatment.\textsuperscript{17,18} This percentage was calculated using the following formula.\textsuperscript{19}

\[
\text{PAR} \text{ (%) } = \frac{\text{PAR T2} - \text{T1}}{\text{PAR T1}} \times 100
\]

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
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 antegonial \((p = 0.022)\) widths in T1-T2, whereas there was no significant change in all frontalis measurements \((p > 0.05)\) except antegonial 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 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, who claimed that teeth should be positioned over basal bone. Now, Damon’s theory of dental arch expansion is...
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. However, recent studies have proposed that some SLB appliances might induce wider intermolar widths. 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. In the present study, all transverse dimensions increased significantly. Pandis et al. 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., 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-

### 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    | NS    | 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    | 0.033 | NS    | 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.
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 reported that only 10% of

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      | 0.024   |
| SnGoGn (°)       | 36.55 ± 5.73 | 36.89 ± 6.05 | 36.81 ± 6.10 | 36.80 ± 6.02 | NS      | NS      | 0.022   | NS      | 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   | 0.005   |
| Mx1-Pal (°)      | 109.55 ± 5.31 | 110.88 ± 5.15 | 110.56 ± 4.97 | 110.53 ± 4.94 | NS      | NS      | NS      | NS      | NS      | NS      |
| Mx1-NA (mm)      | 6.91 ± 3.26  | 7.42 ± 1.71  | 7.36 ± 1.73  | 7.31 ± 1.74  | NS      | NS      | 0.006   | NS      | 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      | NS      |
| 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.

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 (%)

|                  | T1      | T2      | T3      | T4      | T1-T2   | T1-T3   | T1-T4   |
|------------------|---------|---------|---------|---------|---------|---------|---------|
| PAR score        |         |         |         |         |         |         |         |
| 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.
patients had clinically acceptable long-term results when the mandibular arch was expanded laterally. Kuipers-Jagtman et al.\textsuperscript{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.\textsuperscript{24} found that both fixed SLBs and traditional straightwire appliances increased maxillary dentoalveolar widths. Yu et al.\textsuperscript{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\textsuperscript{®} 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 antagonial 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.\textsuperscript{26} 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 antagonial 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.\textsuperscript{18} Although it is not considered the optimal tool for evaluation of treatment benefits\textsuperscript{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.\textsuperscript{16} in all periods (96.86%, 96.30%, and 96.04% for T1-T2, T1-T3, and T1-T4, respectively). Richmond et al.\textsuperscript{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.\textsuperscript{26} evaluated both the duration of treatment and occlusal outcome with Damon\textsuperscript{®} 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\textsuperscript{®} 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.\textsuperscript{26} and two previous studies.\textsuperscript{27,28}

The main difference between these three studies was the extraction/non-extraction protocol. In a previous study, Ileri et al.\textsuperscript{24} 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.\textsuperscript{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,\textsuperscript{20} 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
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.

**REFERENCES**

1. Weinberg M, Sadowsky C. Resolution of mandibular arch crowding in growing patients with Class I malocclusions treated nonextraction. Am J Orthod Dentofacial Orthop 1996;110:359-64.
2. Fleming PS, DiBiase AT, Sarri G, Lee RT. Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. Am J Orthod Dentofacial Orthop 2009;136:340-7.
3. Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and post-treatment. Angle Orthod 1998;68:53-60.
4. Mills JR. The long-term results of the proclination of lower incisors. Br Dent J 1966;120:355-63.
5. Little RM. Stability and relapse of mandibular anterior alignment: University of Washington studies. Semin Orthod 1999;5:191-204.
6. Harradine NW. Self-ligating brackets: where are we now? J Orthod 2003;30:262-73.
7. Eberting JJ, Straja SR, Tuncay OC. Treatment time, outcome, and patient satisfaction comparisons of Damon and conventional brackets. Clin Orthod Res 2001;4:228-34.
8. Harradine NW. Self-ligating brackets and treatment efficiency. Clin Orthod Res 2001;4:220-7.

| 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          | -                      | -                                      |
| 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                                    |
9. Kim H, Kim KY, Kang YG, Kim SH, Kook YA. Clinical considerations with self-ligating brackets. Korean J Orthod 2006;36:474-82.
10. Pandis N, Polychronopoulou A, Makou M, Eliades T. Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets. Eur J Orthod 2010;32:248-53.
11. Damon DH. The rationale, evolution and clinical application of the self-ligating bracket. Clin Orthod Res 1998;1:52-61.
12. Damon DH. The Damon low-friction bracket: a biologically compatible straight-wire system. J Clin Orthod 1998;32:670-80.
13. Pandis N, Polychronopoulou A, Katsaros C, Eliades T. Comparative assessment of conventional and self-ligating appliances on the effect of mandibular intermolar distance in adolescent nonextraction patients: a single-center randomized controlled trial. Am J Orthod Dentofacial Orthop 2011;140:e99-105.
14. Cattaneo PM, Treccani M, Carlsson K, Thorgeirsson T, Myrda A, Cevdasnes LH, et al. Transversal maxillary dento-alveolar changes in patients treated with active and passive self-ligating brackets: a randomized clinical trial using CBCT-scans and digital models. Orthod Craniofac Res 2011;14:222-33.
15. Scott P, DiBiase AT, Sherriff M, Cobourne MT. Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2008;134:470.e1-8.
16. Richmond S, Shaw WC, Roberts CT, Andrews M. The PAR Index (Peer Assessment Rating): methods to determine outcome of orthodontic treatment in terms of improvement and standards. Eur J Orthod 1992;14:180-7.
17. Birkeland K, Furevik J, Bae OE, Wisth PJ. Evaluation of treatment and post-treatment changes by the PAR Index. Eur J Orthod 1997;19:279-88.
18. Stalpers MJ, Booij JW, Bronkhorst EM, Kuijpers-Jagtman AM, Katsaros C. Extraction of maxillary first permanent molars in patients with Class II Division 1 malocclusion. Am J Orthod Dentofacial Orthop 2007;132:316-23.
19. Freitas KM, Freitas DS, Valarelli FP, Freitas MR, Janson G. PAR evaluation of treated Class I extraction patients. Angle Orthod 2008;78:270-4.
20. Tweed CH. The application of the principles of the edgewise arch in the treatment of class II, division 1, malocclusion. Angle Orthod 1936;6:198-208.
21. Peck S. So what’s new? Arch expansion, again. Angle Orthod 2008;78:574-5.
22. Pandis N, Polychronopoulou A, Eliades T. Self-ligating vs conventional brackets in the treatment of mandibular crowding: a prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofacial Orthop 2007;132:208-15.
23. Kuijpers-Jagtman AM, Al Yami EA, van’t Hof MA. Long-term stability of orthodontic treatment. Ned Tijdschr Tandheelkd 2000;107:178-81.
24. Tecco S, Tetè S, Perillo L, Chimenti C, Festa F. Maxillary arch width changes during orthodontic treatment with fixed self-ligating and traditional straight-wire appliances. World J Orthod 2009;10:290-4.
25. Yu YL, Tang GH, Gong FF, Chen LL, Qian YF. A comparison of rapid palatal expansion and Damon appliance on non-extraction correction of dental crowding. Shanghai Kou Qiang Yi Xue 2008;17:237-42.
26. DiBiase AT, Nasr IH, Scott P, Cobourne MT. Duration of treatment and occlusal outcome using Damon3 self-ligated and conventional orthodontic bracket systems in extraction patients: a prospective randomized clinical trial. Am J Orthod Dentofacial Orthop 2011;139:e111-6.
27. Machibya FM, Bao X, Zhao L, Hu M. Treatment time, outcome, and anchorage loss comparisons of self-ligating and conventional brackets. Angle Orthod 2013;83:280-5.
28. Poulton D, Vlaskalic V, Baumrind S. Treatment outcomes in 4 modes of orthodontic practice. Am J Orthod Dentofacial Orthop 2005;127:351-4.
29. Ileri Z, Basciftci FA, Malkoc S, Ramoglu Sl. Comparison of the outcomes of the lower incisor extraction, premolar extraction and non-extraction treatments. Eur J Orthod 2012;34:681-5.
30. Hess DR. Retrospective studies and chart reviews. Respir Care 2004;49:1171-4.