Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets

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SUMMARY The purpose of this study was to investigate the effect of treatment of mandibular crowding with self-ligating and conventional brackets on dental arch variables. Fifty-six patients were selected from a pool of subjects satisfying the following inclusion criteria: non-extraction treatment in the mandibular or maxillary arches, eruption of all mandibular teeth, no spaces and an irregularity index greater than 2 mm in the mandibular arch, and no adjunct treatment such as etxra- or intraoral appliances. The patients were assigned to two groups: one group received treatment with the self-ligating bracket and the other with a conventional edgewise appliance, both with a 0.022 inch slot. Lateral cephalometric radiographs obtained at the beginning (T1) and end (T2) of treatment were used to assess the alteration in mandibular incisor inclination, and measurements of intercanine and intermolar widths were made on dental casts to investigate changes associated with the correction. The results were analysed with bivariate and multivariate linear regression analysis in order to examine the effect of the bracket systems on arch width or lower incisor inclination, adjusting for the confounding effect of demographic and clinical characteristics.

An alignment-induced increase in the proclination of the mandibular incisors was observed for both groups; no difference was identified between self-ligating and conventional brackets with respect to this parameter. Likewise, an increase in intercanine and intermolar widths was noted for both bracket groups; the self-ligating group showed a higher intermolar width increase than the conventional group, whereas the amount of crowding and Angle classification were not significant predictors of post-treatment intermolar width.

Introduction

Self-ligating brackets, first introduced in orthodontics several decades ago, have experienced a resurgence in the last 10 years with almost all major orthodontic companies offering a self-ligating appliance (Harradine, 2003). Several advantages such as faster wire engagement and disengagement, shorter treatment appointments, longer appointment intervals (Shivapuja and Berger, 1994; Berger and Byloff, 2001; Turnbull and Birnie, 2007), reduced treatment time and increased patient comfort (Eberting *et al.*, 2001; Harradine, 2001), reduced risk of enamel decalcification, and improved periodontal indices due to elimination of elastomeric modules have been reported. Along with the tentative advantageous features of self-ligating brackets, several controversial aspects on their mode of action and correction of malocclusions have been proposed.

The currently available accumulated evidence on the topic, however, is not supportive. A clinical trial that comparatively assessed the dental changes during the initial stages of nonextraction alignment of the mandibular arch found no difference between conventional and passive self-ligating brackets. Both bracket systems achieved alignment with a combination of dental arch expansion and lower incisor proclination (Pandis *et al.*, 2008). Similar findings have been reported by other investigators who examined the dental effects of conventional and self-ligating brackets at later stages of non-extraction and extraction orthodontic treatment (Scott *et al.*, 2008a,b; Fleming *et al.*, 2009).

Nonetheless, there is a lack of evidence on the posttreatment dental arch changes associated with treatment with conventional and self-ligating appliances as all the above-cited investigations followed the treatment of patients up to the stage of crowding alleviation. It was, therefore, the purpose of this study to assess the changes in mandibular incisor inclination and intercanine and intermolar widths after the completion of orthodontic treatment with selfligating and conventional appliances.

Subjects and methods

Fifty-six patients were included in the study and they were followed until the end of orthodontic therapy. Selection of participants from a large pool of subjects was based on the following inclusion criteria: non-extraction treatment in the mandibular and maxillary arches; eruption of all mandibular teeth; no spaces in the mandibular arch; mandibular irregularity index greater than 2 mm; and no adjunct therapeutic intervention involving lip bumpers, maxillary expansion

Variable	Total n (mean ± SD or %)	Conventional n (mean \pm SD or %)	Self-ligating n (mean \pm SD or %)	P-value*
Age (years)	$54(12.9 \pm 1.5)$	$27(12.0 \pm 1.4)$	$27(12.6 \pm 1.4)$	NS
Gondor	$54(15.8 \pm 1.5)$	$27(13.9 \pm 1.4)$	$27(13.0 \pm 1.4)$	145
Male	11 (20.4) 43 (79 6)	7 (26.0) 20 (74 0)	4 (14.8) 23 (85.2)	NS
Crowding (irregularity index)	54(55+23)	27(55+25)	27(55+22)	NS
Crowding	$51(5.5 \pm 2.5)$	$27(5.5 \pm 2.5)$	$27(5.5 \pm 2.2)$	
Moderate	28 (51.8)	14 (51.8)	14 (51.8)	NS
Severe	26 (48.2)	13 (48.2)	13 (48.2)	
Angle Class				
I	32 (59.3)	18 (66.7)	14 (51.9)	NS
П	20 (37.0)	9 (33.3)	11 (40.7)	
III	2 (3.7)	0 (0.0)	2 (7.4)	

Table 1	Demographic and clinica	l characteristics of stud	y participants b	by bracket group.

NS, not significant.

*P-value for comparison of group means by t-test or differences in proportions by chi-square test.

appliances, or headgear. The demographics of the population studied are listed in Table 1. Complete records including cephalometric and panoramic radiographs radiographs with the use of the same cephalostat by the same operator; extraoral and intraoral photographs; and plaster models, prepared from alginate impressions.

The conventional edgewise group was bonded with the Roth prescription, 0.022 inch slot, (Microarch; GAC, Central Islip, New York, USA), and the self-ligating group received the low-incisor torque version of the Damon2, 0.022 inch slot appliances (Ormco, Glendora, California, USA). All first and second molars (where present) were bonded with bondable tubes. Bracket bonding, archwire insertion, as well as treatment were performed by the same clinician (NP).

The amount of crowding of the lower anterior dentition was assessed using the irregularity index (Little, 1975). Measurements were made on the initial casts by the same clinician using a fine-tip digital calliper, (Mitutoyo Digimatic NTD12-6"C; Mitutoyo Corp., Tokyo, Japan). Similarly, the irregularity index of patients was recorded and normalized in each bracket group in order to investigate the effect of bracket type at different crowding levels.

Archwire sequence was in most cases 0.016 inch CuNiTi 35°C (Ormco) ligated mainly with elastics and followed by a 0.020 inch medium Sentalloy archwire (GAC), 0.020 inch, and 0.018 × 0.025 inch stainless steel ligated with elastics for the conventional bracket group. In the self-ligating group, the archwire sequence involved a 0.014 inch CuNiTi Damon (Ormco) and 0.014 × 0.025 inch stainless steel adapted to the dental archform created by the previous archwire (0.014 × 0.025 inch).

All patients were followed on a 4–8 week basis. At the end of treatment (T2), full records were taken. Changes in the intercanine and intermolar widths were recorded from dental casts, which were taken before treatment (T1) and at the stage of alignment (T2). Measurements were made with a digital calliper (Mitutoyo) and included the distance of the tips of the canines and the central groove of the molars.

Lateral cephalograms, traced by the same person (NP), were used to assess mandibular incisor inclination using the following angular measurements: lower incisor to mandibular plane (L1 to MP) and lower incisor to N–B line.

To assess intra-examiner reliability, eight plaster models and eight cephalometric radiographs were randomly selected. The cephalometric radiographs were re-traced and measurements of cephalometric variables were repeated. The intercanine and intermolar widths were re-measured on the dental casts. The reproducibility of the measurements was investigated with a paired *t*-test for each variable. Analysis revealed no statistical significance between the first and second measurements (P > 0.05).

Statistics

Descriptive statistics on the demographics of the study sample, clinical characteristics, cast, and cephalometric data were calculated. Data analysis was performed per protocol. Bivariate analysis of the bracket systems with different characteristics was performed with the use of the *t*- or chisquare test depending on the characteristic's nature (numerical or categorical). Multivariate linear regression was used to examine the effect of the bracket system on arch width or lower incisor inclination adjusting for the confounding effect of demographic and clinical characteristics. A twotailed *P*-value of 0.05 was considered statistically significant with a 95 per cent confidence interval. To conduct the statistical analysis, the Stata program version 10.1 (StataCorp, College Station, Texas, USA) was used.

Results

Figure 1 displays the adapted CONSORT patient flow chart.

The distribution of demographic variables of the populations including age, gender, irregularity index, and Angle classification are shown in Table 1; no discrimination with respect to these factors between the two population groups was noted.

In Table 2, the initial and final values of the angles used to determine the lower incisor position at T1 and T2 are listed for the entire sample as well as per bracket group. There was an overall increase in mandibular incisor proclination at T2; however, no difference between the two bracket groups was observed.

The results of intercanine and intermolar width changes (Table 3) suggest that the correction of crowding in both cases produced a small but statistically significant expansion in the mandibular arch. When the alterations in intercanine and intermolar widths between brackets were considered, the former did not show a change, whereas intermolar width was found to increase approximately 2.4 mm in the self-ligating compared with 1 mm in the conventional bracket group (P < 0.05).

The association of intermolar width with treatment system was further investigated as clinical and demographic characteristics were all mutually adjusted through multiple regression (Table 4). Patients with self-ligating brackets displayed a significantly larger intermolar width of 1.3 mm (95 per cent confidence interval: 0.3–2.3 mm) compared with the conventional bracket, even after adjusting for the effect of crowding severity and Angle classification, which were found not to be important factors in predicting the end of treatment intermolar width.

Discussion

The results of the present study suggest that correction of mandibular crowding at T2 was achieved through similar mechanisms with conventional and self-ligating brackets. These mechanisms involve incisor proclination and expansion of the dental arches and the results are in agreement with recent evidence (Pandis *et al.*, 2008; Scott *et al.*, 2008a,b;



Figure 1 CONSORT flow chart for the study.

Measurement (°)	Total $n = 54 \text{ mean} \pm \text{SD}$	Conventional $n = 27$ mean \pm SD	Self-ligating $n = 27$ mean \pm SD	P-value*
Initial L1–MP	92.5 ± 6.9	93.2 ± 5.8	91.8 ± 7.9	NS
Final L1–MP	96.9 ± 7.6	98.8 ± 6.7	94.9 ± 8.0	NS
Initial L1–NB	25.2 ± 5.8	25.0 ± 5.5	25.4 ± 6.3	NS
Final L1–NB	30.0 ± 5.9	30.7 ± 5.5	29.3 ± 6.3	NS

 Table 2
 Mandibular incisor inclination changes by bracket group.

L1–MP, mandibular incisor to mandibular plane; L1–NB, Mandibular incisor to nasion-point B line; NS, not significant. **P*-value derived from *t*-test.

 Table 3
 Intercanine and intermolar width changes by bracket group.

Model measurement (mm)	Total $n = 54 \text{ mean} \pm \text{SD}$	Conventional $n = 27 \text{ mean} \pm \text{SD}$	Self-ligating $n = 27$ mean \pm SD	P-value*,*
Initial intercanine width	25 4 + 1 7	25.0 + 1.5	258+19	NS
Final intercanine width	27.1 ± 1.3	26.8 ± 1.2	27.4 ± 1.2	NS
Initial intermolar width	44.2 ± 2.6	44.2 ± 2.5	44.2 ± 2.6	NS
Final intermolar width	45.9 ± 1.9	45.2 ± 1.8	46.6 ± 1.7	< 0.01

NS, not significant.

*P-value derived from t-test.

*Significance denotation applies to column comparisons (conventional versus self-ligating widths). Row comparisons (initial versus final widths) indicated that, overall, statistically significant differences were present between initial and final total widths (Paired *t*-test, P < 0.001).

Table 4Multiple regression-derived intermolar width changeper indicated category of clinical predictors and corresponding 95per cent confidence intervals (95% CIs) among the 54 studyparticipants.*

Variable	Category	Parameter estimate	95% CI	P-value
Bracket	Conventional	Baseline		
	Self-ligating	1.3	0.3 to 2.3	0.01
Crowding	Moderate	Baseline		
e	Severe	0.3	-0.7 to 1.3	NS
Angle Class I		Baseline		
•	II	-0.1	-1.1 to 0.9	NS
	III	1.6	-1.1 to 4.0	NS

NS, not significant.

*Values controlled for age and gender.

Fleming *et al.*, 2009). Interestingly, Franchi *et al.* (2006) employing low friction ligatures rather than sef-ligating brackets reported a similar increase in maxillary intermolar width when compared with conventional module ligation. That study also demonstrated 4 degrees buccal tipping of the molars. This finding may imply that molar expansion observed with self-ligating brackets is related to rolling or tipping of the molars rather than bodily movement or basal maxillary expansion.

Scott *et al.* (2008b) using study models at various stages of treatment found that alignment was associated with an increase in intercanine width, reduction in arch length, and proclination of mandibular incisors for both appliances, but the differences were not significant. That investigation included extraction

cases, which may explain the associated arch length reduction and distal movement of canines into the wider section of the mandible. On the same topic, Fleming et al. (2009), employing a randomized control trial design, compared the effects of two pre-adjusted appliances on angular changes of the mandibular incisors and transverse mandibular arch changes over a minimum period of 30 weeks. The results indicated that bracket type had little effect on incisor inclination or intercanine, inter-first, and inter-second premolar dimensions. However, the self-ligating appliance produced more expansion in the molar region although this was small (0.9 mm). Such small changes in molar expansion of 1-2 mm will only result in an additional 0.27-0.58 mm increase in arch perimeter, which is also clinically insignificant (Germane et al., 1991). Torque on the mandibular incisor brackets was -1 degree for the conventional and -6 degrees for the Damon group, whereas the final wire was 0.018×0.1025 for the conventional and 0.016×0.025 for the self-ligating group. Such a small variation is not expected to result in different tooth orientation as the free play exceeds, by a factor of 2, the difference in prescription (Sebanc et al., 1984).

The actual arch space gain as a result of mandibular incisor proclination has not been unequivocally defined. Ricketts *et al.* (1982) proposed that 1 mm of incisor advancement produces 2 mm of arch length and 1 mm canine expansion produces 1 mm of arch length, whereas 1 mm of molar expansion results in an increase of 0.25 mm in arch length. Germane *et al.* (1991) developed a mathematical model and calculated the increases in arch length depending on the location of the expansion. They concluded that most arch

length is gained with a combination of incisor advancement and canine expansion compared with canine and molar expansion. They postulated that a 5 mm increase in arch length required approximately 5 mm of canine molar expansion or 4 mm of incisor advancement, or a combination of expansion and advancement. It was also shown that wide dental arches produce more arch length per millimetre of expansion compared with narrow arches and that proclination was less likely to arise where the labial segment was proclined at the outset, and expansion was unlikely to arise during levelling and alignment in wider arches. This finding has unfavourable implications for the average narrow arch shape, which in the vast majority of cases requires more expansion.

Moreover, excessive proclination may predispose to relapse and potential unfavourable periodontal sequelae in the form of loss of attachment, contributing to recession (Yared *et al.*, 2006). Even though this hypothesis has been disputed (Allais and Melsen, 2003; Ruf *et al.*, 1998), there is a possibility that proclined mandibular incisors retained with a fixed bonded appliance for long periods of time may predispose to attachment loss. Investigations, which rejected the involvement of incisor proclination in recession, did not consider the presence of a bonded appliance on the proclined teeth for long periods of time as in the case of fixed retention, which is usually advocated following correction of mandibular crowding. This factor may differentiate the effect of proclination, potentially inflicting additional changes in the periodontium.

Although overall expansion of the mandibular arch of the population treated in the study of Pandis et al. (2008) was found to be relatively small, the intermolar width in the Damon2 bracket group reached 1.5 mm above the value observed for conventional appliances. The use of preformed NiTi archwires at the initial stages of mechanotherapy precludes absolute control of the operator over the dimensions of the dental arch. It should be noted that the archwires used differed between the two bracket systems, in that the Damon 0.014×0.025 inch CuNiTi wire had a broader archform compared with the 0.020 inch Sentalloy archwire used with the conventional bracket. The difference in posterior expansion may thus be solely attributed to the differences in archwire form and cross-sectional thickness. Additionally, expansion with preformed arches in the order of 0.5-1 mm may be negligible and could be a spontaneous effect of treatment. Traditional assumptions on the intentional 'development of the arch', which are translated to substantially expanding the buccal segments, have been found to be highly unpredictable, probably depending on the axial inclination of the posterior teeth (Sandström et al., 1988).

Maxillomandibular expansion has been the focus of a great deal of research over the past 30 years. However, the vast majority of evidence is concerned with expansion with the use of appliances in the mixed dentition stage and thus no direct extrapolation can be made when treating adolescents or adults with plain expanded archwires. It is

interesting to note that McNamara *et al.* (2003) and Moussa *et al.* (1995) reported relapse with rapid maxillary expansion as high as 3 mm, whereas the use of quad-helix followed by edgewise appliances resulted in a decrease of 1.3 mm in intercanine and 1.5 mm in intermolar width.

Similarly, most changes associated with lip bumper therapy have been reported to be eliminated during fixed appliance therapy (McNamara et al., 2003); during that stage, there is little or no overall change in mandibular arch depth, and only about 33 per cent of intercanine width and 60 per cent of intermolar width increases produced during the lip bumper phase are maintained. It has been reported, in a series of studies, that treatment with maxillomandibular expansion results in mandibular intercanine width decreases of 50 per cent of the treatment effect. Mandibular arch perimeter of the group that had been out of retention was approximately 4 mm deficient at the start of treatment; it increased 1.3 mm during treatment and decreased 1.5 mm post-treatment. Mandibular arch perimeter was approximately 2 mm deficient before treatment; it increased approximately 4 mm during treatment and decreased 3 mm post-retention (Buschang et al., 2001; Ferris et al., 2005; Buschang, 2006; Vargo et al., 2007), whereas Heiser et al. (2008) showed a net mandibular intercanine width decrease in patients treated with or without extraction.

Even though expansion of the maxillary arch with the Haas type of expander has been shown to result in an increase in intercanine and intermolar width (Haas, 1980), the long-term outcome is unpredictable (Sandström et al., 1988). Moreover, the results of these studies cannot be applied to fixed appliance treatment for reasons related to the age of patients, to the mechanotherapy used, and dental tipping. Therefore, the majority of evidence is supportive of the notion that expanding indiscriminately, especially in the absence of a crossbite, to accommodate dental width in a deficient arch length, results in relapse, the extent of which depends on a number of factors potentially including the appliance and age of the patient. Partial reversal and occasional total elimination of arch length gain has been shown in certain cases. In the light of the wealth of evidence on the topic, expansion of the mandibular dentition with archwires seems to be of limited long-term use, introducing also various retention concerns.

Especially molar expansion requires long-term retention with appliances, which necessitate the cooperation of the patient and thus present an unpredictable outcome. On the other hand, 2 mm expansion in the posterior segment of the arch yields a minimum increase in arch perimeter length (less than 1 mm; Germane *et al.*, 1992), whereas an intercanine width increase provides more favourable space gain, albeit showing a higher probability of relapse compared with expansion in the molar region.

Conclusions

There was an overall increase in the proclination of the mandibular incisors associated with alleviation of crowding for both bracket groups; no difference was found between self-ligating and conventional brackets with respect to this parameter at the end of orthodontic treatment.

There was an overall increase in intercanine width at the end of treatment; however, no difference was noted between the conventional and self-ligating brackets. While intermolar width was also increased at the end of treatment for both bracket groups, nonetheless, there was a statistically significantly greater increase in the self-ligating group even after accounting for Angle classification and the variation in the amount of crowding.

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