SCIENTIFIC SECTION

Frictional resistance in plastic preadjusted brackets ligated with low-friction and conventional elastomeric ligatures

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Objective: To compare frictional resistance of the plastic preadjusted brackets ligated with the low-friction ligatures with those of the conventional elastomeric ligatures.

Design: In vitro study.

Setting: Department of Orthodontics, Faculty of Dentistry, Kyushu University, Fukuoka, Japan.

Materials and methods: The testing model consisted of four 0.022-inch plastic preadjusted brackets for the first premolar, the canine, the lateral incisor, and the central incisor. A superelastic nickel-titanium 0.014-inch wire and a stainless steel 0.019 × 0.025-inch wire were used for this test. The brackets were either aligned or out of line by 0.5, 1.0, 1.5 and 2.0 mm for the 0.014-inch wire and aligned for the 0.019 × 0.025-inch wire. The frictional forces in plastic preadjusted brackets with low-friction ligatures and conventional elastomeric ligatures were measured at a pulling speed of 0.1 mm/second. Welch t-tests were used to compare the mean differences of each testing measurement between the low-friction and the conventional elastomeric ligatures.

Results: In both use of the superelastic nickel-titanium 0.014-inch wire and the stainless steel 0.019 × 0.025-inch wire, the brackets with the low-friction ligatures showed significantly lower frictional forces than those of the conventional elastomeric ligatures in both aligned and all misaligned brackets ($P < 0.0001$).

Conclusion: The study found the significantly lower frictional forces for the low-friction ligatures than those of the conventional elastomeric ligatures.

Key words: Frictional resistance, esthetic bracket, low-friction ligature, elastomeric ligature

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Introduction

Aesthetic brackets are often preferred by orthodontic patients, particularly adults. A major disadvantage of ceramic brackets is that friction is significantly higher than with brackets made of stainless steel[1–3] or other aesthetic materials such as plastic or plastic brackets incorporating a metal sleeve.[4] The disadvantage of plastic brackets is that they can be deformed due to the compressive forces of ligation and it is thought that this might explain the higher frictional resistance found with plastic brackets than with stainless steel brackets.[5]

Many factors contribute to the frictional resistance between the archwire and the bracket. Edwards *et al.*[6] reported that ligation method can influence the orthodontic frictional resistance and Griffiths *et al.*[7] found that even the cross sectional shape of elastomeric ligatures will have an effect. There are several ways to reduce frictional forces. Very low friction has been clearly demonstrated by several researchers when using self-ligating brackets;[8–10] however these brackets are more expensive than most good quality conventional brackets. Another method of reducing friction is to use a ligation method which markedly reduces the amount of

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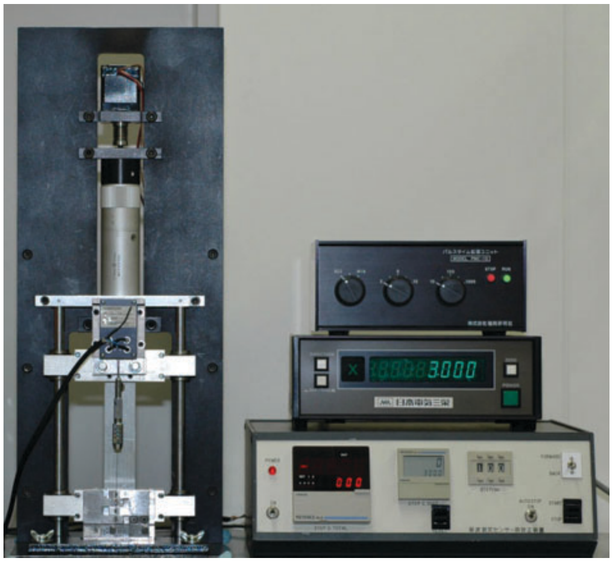

Figure 1 The instruments used for measuring frictional forces

friction between a conventional edgewise bracket and an archwire[11,12]

The aim of this study was to compare the frictional resistance between a plastic preadjusted bracket ligated with a low-friction ligature to that ligated with a conventional elastomeric ligature.

Materials and methods

The instruments used for this test consisted of a micrometer, a pulse-controller, a strain gauge and a jog consisting of stand with four bracket fixation tables (Figure 1). Four 0.022-inch plastic preadjusted brackets (Clearbracket, Dentsply-Sankin, Tokyo, Japan) for the first premolar, the canine, the lateral incisor and the central incisor were bonded to each table of the stand. The adjustable tables composed of two units; one unit to represent the central incisor and the canine and the other unit to represent the lateral incisor and the first premolar. The two units were movable in opposite directions, so that adjacent brackets could be misaligned

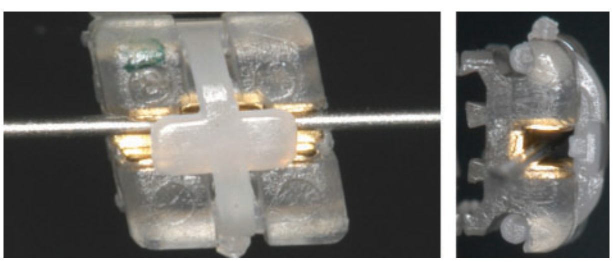

Figure 2 A plastic bracket with a low-friction ligature

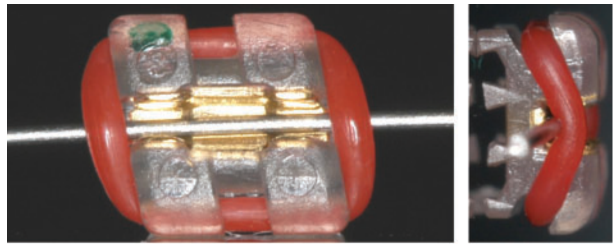

Figure 3 A plastic bracket with a conventional elastomeric ligature

by 0.5 mm in a stepped sequence. Each unit was also movable to the left or right to simulate wire deflection. The baseline deflection of 0 mm was determined by aligning all four brackets in a straight line so that a section of 0.0215×0.028-inch stainless steel wire could pass through without any tension. The interbracket distance was set at 4.5 mm.

A superelastic nickel–titanium 0.014-inch wire (Tynilloy wire, Dentsply-Sankin, Tokyo, Japan) and a stainless steel 0.019×0.025-inch wire (SUS wire, Dentsply-Sankin, Tokyo, Japan) were tested. The wire was secured in the plastic preadjusted brackets with two different types of ligatures. The first was the bracket with a low-friction ligature (Clearsnap, Dentsply-Sankin, Tokyo, Japan) (Figure 2), and the second was the same bracket with a conventional elastomeric ligature (Plastic ligatures, American Orthodontics, WI, USA) (Figure 3). The low-friction ligature was engaged so that the wire slot was covered with the plastic ligature so that the bracket became a tube. The elastomeric modules were tied with a ligature gun (Straight-Shooter, T-P Orthodontics, IN, USA). This method was used to limit possible stretching differences between the elastomeric modules. The tables were adjusted so that the brackets were either aligned or out of line by 0.5, 1.0, 1.5 and 2.0 mm for the superelastic nickel–titanium 0.014-inch wire (Figure 4). They were also adjusted so that the brackets were aligned for the stainless steel 0.019×0.025-inch wire.

The deflection values of 0.5, 1.0, 1.5, and 2.0 mm for the superelastic 0.014-inch wire were chosen to mimic clinical malalignments often seen in the initial stages of treatment. Moreover, we determined these values in order to include malocclusions with mild to moderate or severe crowding based on the reports by van Kirk and Pannel[13] and Summers.[14] The aligned brackets for the stainless steel 0.019×0.025-inch wire were chosen to represent the aligned dentition during space closure.

One end of the wire was pulled upward 3.0 mm at a speed of 0.1 mm s^{-1} by means of the micrometer (Mitutoyo, Kanagawa, Japan) driven by the

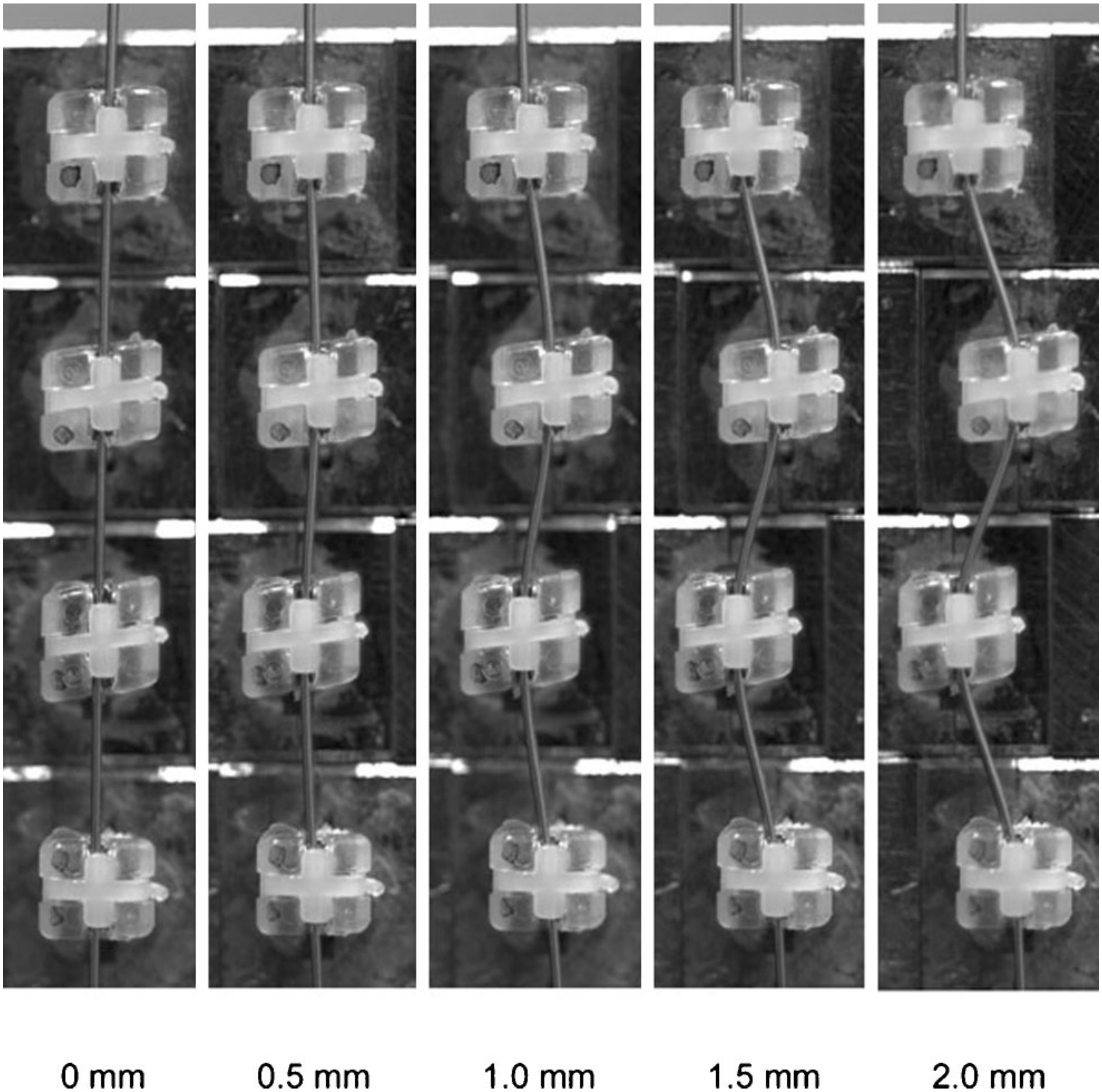

Figure 4 The different deflections produced to simulate clinical malalignment of brackets

pulse-controller (Keyence, Osaka, Japan). The forces generated by the testing unit consisting of wire, brackets, and ligatures were measured with the strain gauge (Minebea, Tokyo, Japan) and recorded graphically on an X–Y recorder (NEC San-ei, Tokyo, Japan). The frictional forces were measured at 1.0, 1.5, 2.0, and 2.5 mm of the wire displacement during the experiments and were averaged. The measurements were conducted 10 times with new wires and ligatures on each occasion. It was not possible to mask the assessor due to the differences in the appearance of the ligatures.

Statistical analysis

A sample size calculation was undertaken using nQuery Adviser software program (Version 6.01, Statistical Solutions, Cork, Ireland). According to our pilot study, it was calculated that the mean frictional force for the superelastic nickel–titanium 0.014-inch wire in the aligned brackets was 0.4 g (sd 0.1 g) for the low-friction ligatures and 182.4 g (sd 11.9 g) for the conventional elastomeric ligatures. The mean difference between them was considered to be clinically significant. Based on the

Table 1 Mean values and comparison of the frictional forces between the low-friction and the conventional elastomeric ligatures (g)

	Low-friction ligatures				Conventional elastomeric ligatures					
Deflection	*n*	Mean	SD	95% CI	*n*	Mean	SD	95% CI	95% CI for difference	*P* value
0.014-inch Superelastic wire										
0 mm	10	0.3	0.1	0.2 to 0.4	10	178.6	16.8	166.6 to 190.6	166.3 to 190.3	<0.0001
0.5 mm	10	4.5	1.8	3.2 to 5.8	10	184.2	15.5	173.2 to 195.3	168.7 to 190.9	<0.0001
1.0 mm	10	28.3	5.7	24.3 to 32.4	10	248.7	6.6	244.0 to 253.4	214.6 to 226.2	<0.0001
1.5 mm	10	81.7	7.8	76.1 to 87.3	10	259.7	9.6	252.8 to 266.5	169.7 to 186.2	<0.0001
2.0 mm	10	139.4	3.9	136.6 to 142.1	10	280.4	8.9	274.1 to 286.8	134.4 to 147.7	<0.0001
0.019 × 0.025-inch Stainless steel wire										
0 mm	10	8.6	2.3	6.9–10.2	10	350.8	51.8	313.7–387.8	305.3 to 380.2	<0.0001

CI: confidence interval.

significance level of alpha 0.01 (two-sided), the sample size calculation showed that three samples were necessary to achieve 80% power. To increase the power further it was decided to test 10 samples for each group.

The data were tested for normality by means of the Shapiro-Wilks *W*-test and were found to be normally distributed. Since some of the data did not show equal variances, a Welch *t*-test was used to compare the mean differences of each testing measurement between the low-friction and the conventional elastomeric ligatures. The minimum level of statistical significance was set at $P<0.01$ in order to adjust the alpha level to reflect the fact that multiple *t*-tests were undertaken.

Results

The mean, standard deviations, and 95% confidence intervals of the frictional forces of the two types of wires for the low-friction and the conventional ligatures are shown in Table 1. Both the superelastic nickel–titanium

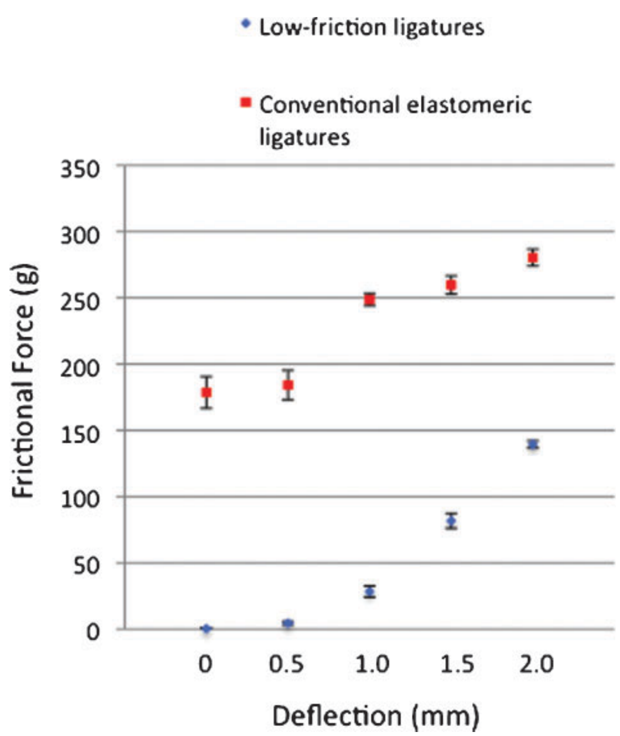

Figure 5 Mean and 95% confidence intervals of the frictional forces for the low-friction and the conventional elastomeric ligatures with the superelastic 0.014-inch wire

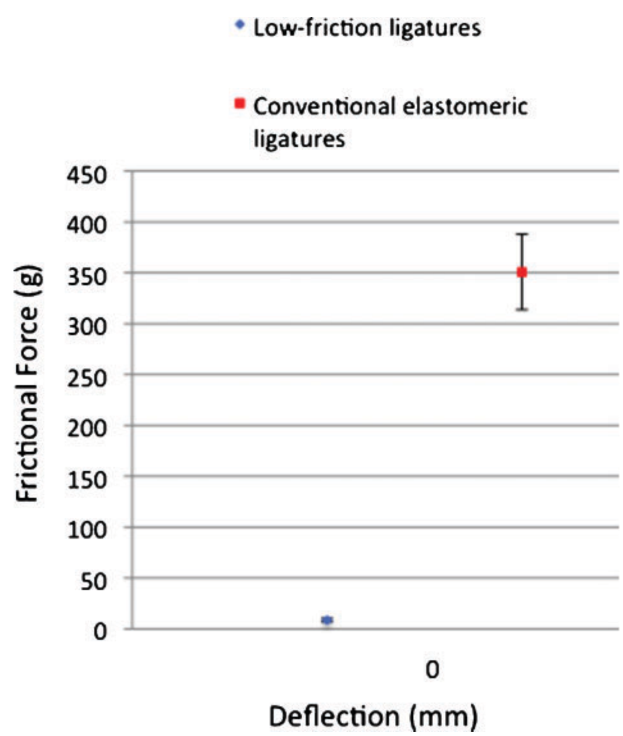

Figure 6 Mean and 95% confidence intervals of the frictional forces for the low-friction and the conventional elastomeric ligatures with the stainless steel 0.019 × 0.025-inch wire

0.014-inch wire and the stainless steel 0.019 × 0.025-inch wire showed significantly lower frictional forces with the low-friction ligatures than those of the conventional elastomeric ligatures in both aligned and misaligned brackets ($P<0.0001$) (Figures 5 and 6).

Discussion

This *in vitro* study has found that the use of low-friction ligatures with plastic brackets leads to significantly lower friction than when using conventional elastomeric ligatures with both 0.014-inch nickel–titanium aligning archwires and a 0.019 × 0.025 inch stainless steel working archwires.

Plastic brackets have been criticized because they demonstrate higher frictional forces compared with stainless steel brackets. It is thought that this is because plastic brackets can become deformed and the archwire compressed if the binding force of ligation is excessive.[5] The low-friction ligatures used in our study are designed to secure the wire without a binding force. Moreover, since this low-friction ligature is made from a thermoplastic material, it has excellent aesthetic features and might prove beneficial for efficient and comfortable tooth movement in the adult patient.

The finding that aesthetic plastic brackets with the low-friction ligatures showed significantly lower frictional forces when using a superelastic nickel–titanium 0.014-inch wire concurs with the results of a previous investigation.[15] Although we observed relatively high mean frictional forces of 139.4 g with 2.0 mm deflection in the low-friction ligatures, the value was still significantly lower that that of the conventional elastomeric ligatures (mean 280.4 g).

A similar difference in the frictional forces was observed when using the 0.019 × 0.025-inch stainless steel wire. It would therefore seem prudent to use plastic brackets with low-friction ligatures for efficient tooth movement in both the levelling and the sliding mechanics stages. Lower friction between archwire and bracket suggests that lighter forces might be used to move teeth, which is biologically is more efficient.[16,17] Moreover, Proffit[18] suggested that not only is tooth movement more efficient when areas of periodontal ligament necrosis are avoided, but pain is also lessened.

Rinchuse and Miles[19] suggest that although low friction is important for efficient tooth movement in the initial aligning and later space closure stages of treatment, high frictional forces are useful in the finishing stage, in order to fully express torque and tip. They suggest that an ideal low-friction bracket system would be a self-ligating bracket combining both a passive slide for the early stage of treatment and a spring clip for the later stage. The plastic preadjusted brackets might also provide this combination of low friction in the aligning and space closing stage by using a low-friction ligature and high friction in the finishing stage by using a conventional ligature.

Laboratory studies have the advantage of being able to control and limit the many variables that affect frictional resistance in the mouth. We were not able to mask the observer due to the different appearances of the ligature methods; however the tests were carried out using an objective methodology. We were also not able to examine the effects of saliva or masticatory forces on this bracket ligature combination. Future clinical trials will be required to determine if this method of ligation leads to reduced treatment times and improved comfort for our patients.

Conclusions

- This *in vitro* study found significantly lower frictional forces when using low-friction ligatures in a plastic bracket compared with conventional elastomeric ligatures.
- A similar result was found when using 0.014-inch superelastic nickel–titanium archwires in a laboratory jig designed to represent malaligned teeth and when using 0.019 × 0.025-inch stainless steel archwire with aligned brackets. This suggests that the low-friction ligature would be useful for both the alignment and space closure stages of treatment.

References

1. Angolkar PD, Kapila S, Duncanson MG, Jr, Nanda RS. Evaluation of friction between ceramic brackets and orthodontic wires of four alloys. *Am J Orthod Dentofacial Orthop* 1990; **98**: 499–506.
2. Ogata RH, Nanda RS, Duncanson MG, Jr, Sinha PK, Currier GF. Frictional resistance in stainless steel bracket-wire combinations with effects of vertical deflections. *Am J Orthod Dentofacial Orthop* 1996; **109**: 535–42.
3. Pratten DH, Popli K, Germane N, Gunsolley JC. Frictional resistance of ceramic and stainless steel orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1990; **98**: 398–403.
4. Bazakidou E, Nanda RS, Duncanson MG, Jr, Sinha P. Evaluation of frictional resistance in esthetic brackets. *Am J Orthod Dentofacial Orthop* 1997; **112**: 138–44.
5. Tselepis M, Brockhurst P, West VC. The dynamic frictional resistance between orthodontic brackets and arch wires. *Am J Orthod Dentofacial Orthop* 1994; **106**: 131–8.

6. Edwards GD, Davies EH, Jones SP. The ex vivo effect of ligation technique on the static frictional resistance of stainless steel brackets and archwires. *Br J Orthod* 1995; **22**: 145–53.
7. Griffiths HS, Sherriff M, Ireland AJ. Resistance to sliding with 3 types of elastomeric modules. *Am J Orthod Dentofacial Orthop* 2005; **127**: 670–5.
8. Shivapuja PK, Berger J. A comparative study of conventional ligation and self-ligation bracket systems. *Am J Orthod Dentofacial Orthop* 1994; **106**: 472–80.
9. Sims APT, Waters NE, Birnie DJ, Pethybridge RJ. A comparison of the forces required to produce tooth movement *in vitro* using two self-ligating brackets and a pre-adjusted bracket employing two types of ligation. *Eur J Orthod* 1993; **15**: 377–85.
10. Berger JL. The influence of the SPEED bracket's self-ligating design on force levels in tooth movement: a comparative *in vitro* study. *Am J Orthod Dentofacial Orthop* 1990; **97**: 219–28.
11. Fortini A, Lupoli M, Cacciafesta V. A new low-friction ligation system. *J Clin Orthod* 2005; **39**: 464–70.
12. Baccetti T, Franchi L. Friction produced by different types of elastomeric ligatures in treatment mechanics with the preadjusted appliance. *Angle Orthod* 2006; **76**: 211–6.
13. Van Kirk L, Pannel E. Assessment of malocclusion in population groups. *Am J Public Health* 1959; **49**: 1157–63.
14. Summers C. The occlusal index: a system for identifying and scoring occlusal disorders. *Am J Orthod* 1971; **59**: 552–67.
15. Camporesi M, Baccetti T, Franchi L. Forces released by esthetic preadjusted appliances with low-friction and conventional elastomeric ligatures. *Am J Orthod Dentofacial Orthop* 2007; **131**: 772–5.
16. Tuncay OC, Daphne H, Barker MK. Oxygen tension regulates osteoblast function. *Am J Orthod Dentofacial Orthop* 1994; **105**: 457–63.
17. Oppenheim A. Human tissue response to orthodontic intervention of short and long duration. *Am J Orthod Oral Surg* 1942; **28**: 263–301.
18. Proffit WR. *Contemporary Orthodontics*, 3rd Edn. St Louis, MO: Mosby, 2000, 296.
19. Rinchuse DJ, Miles P. Self-ligating brackets: present and future. *Am J Orthod Dentofacial Orthop* 2007; **132**: 216–22.