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〔原著〕

Slot Tolerance and Frictional Resistance of New and Recycled Self−Ligating Brackets

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Key words : Recycled brackets, Frictional resistance, Slot tolerance.

Abstract

This study compared the slot tolerance and the frictional resistance between new and recycled brackets. Passive type premolar self−ligating bracket (Damon® Q™) with 0.022 × 0.028 inch slot size were selected. The new and recycled brackets (forty each) were purchased. The slot tolerance of the brackets was estimated using an optical microscope with 10× magnification (n=40). Static friction of the brackets was measured by drawing archwires (copper nickel−titanium wire with 0.018 × 0.025 inch cross−sectional dimensions and stainless steel wire with 0.019 × 0.025 inch cross−sectional dimension) though bracket slots, with 0° angulation, using a mechanical testing machine (n=20). Results were subjected to the Kruskal−Wallis and the Mann−Whitney *U* tests. The mean values of the bracket slot dimensions for the recycled bracket (slot height : 0.0225 inches, slot depth : 0.0287 inches) were significantly higher than those for the new bracket (slot height : 0.0222 inches, slot depth : 0.0285 inches). However, there was no statistically significant difference in frictional resistance between the new and recycled brackets. In conclusion, recycled brackets might have an equivalent clinical performance in orthodontic tooth movement compared to the as−received new orthodontic brackets.

Introduction

With the main purpose of decreasing the environmental impact of human activity, recycling has taken an important role in present−day society ; many companies now recycle and launch eco−friendly products. In orthodontics, recycling of appliances is controversial (Basudan & Al−Emran, 2001). The US Department of Health and Human Services has established that the reuse of materials is only allowed if the manufacturer can guarantee the technical requirement of each appliance.

Many authors have studied the characteristics of recycled orthodontic brackets, including size of slot (slot tolerance) (Buchman, 1980 ; Hixson et al., 1982), mechanical properties (Buchman, 1980 ; Eliades et al., 2003), bracket bond strength (Cacciafesta et al., 2004 ; Sfondrini et al., 2012), and corrosive properties (Reiman et al., 2012). Buchman (1980) investigated the dimensional stability and mechanical properties of recycled brackets from different recycling companies and reported that the number of brackets with a changed slot width was statistically significant, although the difference from the standard dimensions were in reality only ≤0.0015 inches. Hixson et al. (1982) also compared the slot tolerance of recycled brackets from three different companies and reported no statistically significant changes in the tolerance. The clinical bonding performance of reconditioned and recycled brackets have also been studied using bond strength (Cacciafesta et al., 2004 ; Sfondrini et al., 2012). Eliades et al. (2003) investigated the composition and microstructure of recycled brackets and reported that the composition of the wing and base of the brackets were changed by the recycling process, which was in agreement with the micro–hardness findings, although there was no alteration in the bulk composition of the recycled brackets.

The frictional force between the bracket and the archwire (resistance to sliding) during tooth movement is a primary issue in orthodontics (Kusy et al., 1992 ; Burrow, 2009 ; Muguruma et al., 2018). If the frictional force can be decreased, then the efficiency of tooth movement may be improved. The efficiency of orthodontic tooth movement may be influenced by a modification of the bracket slot and also by a change in the hardness of the surface, because they are subjected to the frictional properties between the bracket slot and the archwire in fixed appliance therapy.

The slot tolerance has a predominant role in torque expression and an adequate torque of each tooth is one of the six significant characteristics of normal occlusion described by Andrews in 1972. Therefore, a number of studies have reported the torque expression in different situations, such as slot size (Arrengiene et al, 2014), ligating system (self–ligating brackets and conventional brackets) (Al–Thomali, et al, 2017), archwire alloys and cross–sectional dimension of the archwires (Archambault, et al 2010), bracket fabrication materials (Morina et al, 2008). If the bracket slot tolerance is affected by the recycling process, the torque expression by archwire could be modified and then the achievement of ideal occlusion is influenced.

Recently, self–ligating brackets with slide or clip opening –closing system for ligature–free systems (involving the elimination of certain utilities or materials such as elastomeric modules, along with the process or tools associated with their application), such as Damon® (Ormco™) and In–Ovation® (Dentsply GAC™) have been introduced and become popular given their purported advantages, including less chair–side time, increased patient comfort, less frictional resistance, and shorter treatment time (Iijima et al., 2017). If the recycling self–ligating brackets does not affect their properties, then a new low–cost option could be available, with the additional benefits to the environment.

The purpose of the present study was to compare the slot tolerance and the frictional resistance between new and recycled self–ligating brackets using two different archwires.

Materials and Methods

Materials

Forty right second premolar passive–type self–ligating stainless steel recycled brackets (Damon Q™) with 0.022 × 0.028–inch slot size were purchased from a recycling company (Ortho–Cycle Co., Inc., Hollywood, FL, USA) and used in the present study. The used period and the method for recycling by the company are unknown. The same type of new brackets (Damon Q) were purchased from an orthodontic material company (Ormco, Glendora, CA, USA) served as a control. Two preformed arch wires [copper nickel–titanium with 0.018 × 0.025–inch cross–sectional dimensions (Ormco) and stainless steel with 0.019 × 0.025–inch cross–sectional dimensions (Ormco)] were used for the drawing–friction test. In clinical orthodontics using bucal brackets copper nickel–titanium with 0.018 × 0.025–inch cross–sectional dimensions complete leveling and aligning ; resolve remaing rotations and begin torque control. On the other hand, the stainless steel with 0.019 × 0.025–inch cross –sectional dimensions finish torque control and consolidate posterior space for the final detailing.

Bracket slot dimension measurement

All new and recycled brackets (n=40) were mounted on an optical microscope, and their dimensions were estimated with a 10× magnification (XSZ–107BN ; Zenith Lab, Pomona, CA, USA) (Fig. 1). The bracket slot depth and height

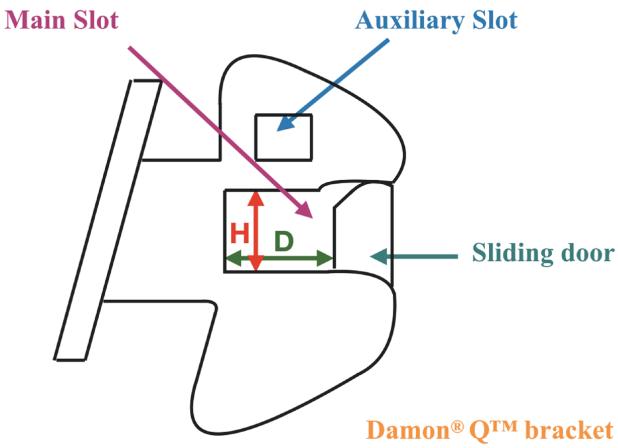

Fig. 1 : Illustration of the self–ligating brackets used in the present study. (D), The green double–headed arrow shows the bracket slot depth ; (H), The red double–headed arrow shows the bracket slot height.

were measured using the scale of a stage micrometer.

Frictional properties measured using the drawing–friction test

The static frictional forces generated with each wire/bracket combination were measured at room temperature (25° C) using a custom–fabricated drawing–friction testing device attached to a universal testing machine (AGS–X ; Shimadzu, Kyoto, Japan) (Fig. 2). Each bracket was immersed in artificial saliva for 24 hours before the friction test and then washed with distilled water to eliminate impurities. Four brackets were bonded with cyanoacrylate glue to a specimen stage using a full–size stainless steel wire (0.022 × 0.025–inch cross–sectional dimension), which allowed an accurate positioning on the stage. A segment of wire obtained from the posterior straight portion of each preformed wire was then fixed to each self–ligating bracket and tested in a closed position. The upper end of the wire was fixed with a grip that was attached to the load cell, and each wire was drawn through the bracket slot at a crosshead speed of 10 mm/min for a distance of 5 mm. The static frictional force was determined from the load–displacement curves (Burrow, 2009). The sample size for each bracket/wire combination was 20.

Statistical analysis

A statistical analysis was performed using SPSS Statistics (version 25.0 for Mac ; IBM Corp., Armonk, NY, USA). The static frictional force values were not homogenous (Levene test), and the Kruskal–Wallis test was applied to determine whether a significant difference existed between the new and the recycled brackets. The Mann–Whitney *U* test was then used for two independent bracket/wire combinations, and the Bonferroni correction was applied ($p < 0.005$).

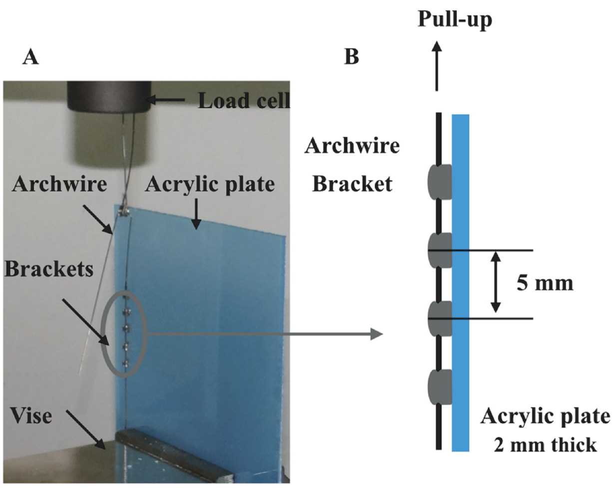

Fig. 2 : (A) Overall view of the experimental setup of custom–fabricated drawing–friction testing device attached to a universal testing machine. (B) Squematic representation of cross sectional view of the brackets/arch wire assembly in the acrylic plate.

Results

Mean values and standard deviations for the bracket slot dimensions are shown in Table 1. The mean value obtained for recycled brackets (slot height : 0.0224 inches, slot depth : 0.0287 inches) were significantly higher than those for new brackets (slot height : 0.0222 inches, slot depth : 0.0285 inches).

Figure 3 and 4 shows the frictional forces for the new and the recycled brackets combined with two different wires. The average frictional forces with the copper nickel–titanium wire with 0.018 × 0.025–inch cross–sectional dimension were 1.06 N for the new brackets and 1.06 N for the recycled brackets. The average frictional force with stainless steel wire with 0.019 × 0.025–inch cross–sectional dimension were 1.08 N for the new brackets and 0.95 N for the recycled brackets. With both wires, there were no statistically significant differences for the frictional forces between

Table 1. Mean values and standard deviation for the bracket slot dimension.

	New Mean	Recycled Mean	Kruskal–Wallis P value
Slot height, H (inches)	0.0222 ± 0.0032	0.0225 ± 0.0002	0.005
Slot depth, D (inches)	0.0285 ± 0.0002	0.0287 ± 0.0003	0.005

$p < 0.005$ Kruskal–Wallis and Mann–Whitney U test.

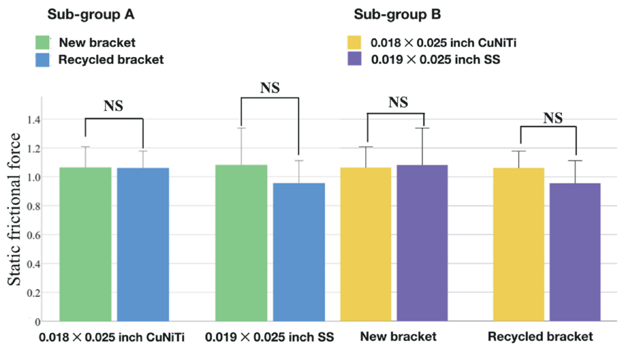

Fig. 3 : Static frictional forces for two different wires, 0.018 × 0.025–inch copper nickel–titanium (CuNiTi) wire ; 0.019 × 0.025–inch stainless steel (SS) wire, and each bracket (new and recycled). $p < 0.05$ in the Mann–Whitney *U* test ; NS stands for non-significant. Divided in two subgroups : (3A) Comparation between brackets same arch wire. (3B) Friction comparative between different arch wires same bracket type.

the new and the recycled brackets. For comparing with two different wires, there were no statistically significant difference for the frictional forces between both new and recycled bracket.

Discussion

The precise fit between the bracket slot and the archwire is of great interest in clinical orthodontics, because proper three–dimensional tooth movement using fixed appliances is dependent on the geometry of the archwire and the bracket slot. The intimate fit of the archwire into the bracket slot delivers full transmission of the bracket prescription to the tooth and its supporting tissues, which in theory, should create an individualized optimal occlusion. In clinical orthodontics there is a gap of information expressed on the tooth movement, most of it related to the tolerance of appliance components. A previous study (Lombardo et al., 2015) found that archwires are oversized and some undersized in a range between −6.47% and +5.10%. In addition, the bracket slot geometry influences the "play" between the archwire and bracket slot, which indicates how many degrees the archwire must be rotated within the bracket before its edges come into contact with the slot wall. The results of the present study showed that the bracket slot dimensions obtained for the recycled bracket (slot height : 0.0225 inches, slot depth : 0.0287 inches) were significantly higher compared to the new bracket (slot height : 0.0222 inches, slot depth : 0.0285 inches). The tolerance values for the recycled brackets in this study (0.0002 inches sloth height, 0.0003 inches slot depth) may be clinically insignificant, as reported previously by Buchman et al. (1980) (slot width : 0.0015 inches). However, further research is necessary to elucidate the effect of the tolerance values on the orthodontic tooth movement.

Frictional force between the bracket and the wire during orthodontic tooth movement is an important factor in clinical orthodontics ; if the frictional force can be decreased, the efficiency of tooth movement can be improved. Friction during clinical tooth movement depends on the size and shape of the wire (Miles et al., 2006), the bracket type (Thorstenson & Kusy, 2003), the bracket and wire materials (Kusy & Whitley, 1999), the angulation of the wire relative to the bracket (Torstenson & Kusy, 2002), and the type of ligation (Kusy et al., 1992). Although the efficiency of orthodontic treatment may be affected by any change in bracket slot size, the dimensional changes calculated for the recycled brackets in the present study did not influence the static frictional resistance for both a copper nickel–titanium wire with 0.018 × 0.025–inch cross–sectional dimensions and stainless steel wire with 0.019 × 0.025–inch cross–sectional dimensions. A previous study (Prososki et al., 1991) reported that the nickel–titanium alloy wire showed greater surface roughness and higher frictional force compared to the stainless steel wire. Therefore, it should be worthwhile to investigate the roughness change of the recycled brackets, the Otho cycle company states that their recycling process do not increase roughness.

The self–ligating appliance has acquired popularity, in part because of the elimination of certain utilities or materials, such as elastomeric modules, along with the processes or tools associated with their application (Iijima et al., 2017). The slide or clip open–close system of self–ligating brackets increases chair–side efficiency due to the elimination of the ligaturing process. One important finding of the present study was that the slides on the outside face of three recycled brackets failed after the open–close procedure during the drawing–friction test using copper nickel–titanium wire. This deterioration might be due to recycling process ; further study is necessary to verify this hypothesis.

Conclusions

Under the study conditions, the following conclusions were drawn :

The dimensional changes that occurred in the recycled slots did not affect the static friction results for neither the copper nickel–titanium nor the stainless steel wire–drawing, eventhough the slot dimensions of the recycled brackets were statistically significantly grater than that of the new brackets.

The recycled brackets might produce equivalent clinical performance in orthodontic tooth movement compared to the as–received new orthodontic brackets.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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