

Variability of slot inclination in conventional and self-ligating brackets

ABSTRACT

Objectives: To evaluate the accuracy of the built-in torque information by comparing the inclination of bracket's slots with the nominal values stated by the manufacturer.

Materials and Methods: In the present study, a total of 740 maxillary right central brackets manufactured by seven companies were selected. The sample comprised 0.018x0.025 inch and 0.022x0.028 inch, metal and ceramic, conventional and self-ligating brackets. Images were obtained with a digital optical microscope. Slot inclination of gingival and occlusal walls was measured using ImageJ software. Statistical analyses (Wilcoxon, sign and compliance tests) were performed.

Results: Statistical analysis showed that the slot inclination of 45% to 76% of studied brackets was significantly different from nominal values. In general, gingival inclinations tended to be superior to the nominal value, meaning that incorporated torque was lower than expected. The comparison between gingival and occlusal inclinations displayed a significant difference for 68 to 74% of the brackets. Overall, gingival inclination was superior to occlusal inclination, hence exhibiting the divergence of the slot walls. Comparison between mesial and distal sides showed that up to 45% of the brackets were significantly asymmetrical.

Conclusions: This study showed that a great proportion of measured brackets displays torque information inconsistent with the stated value. Such manufacturing inaccuracies can prevent the orthodontist from obtaining desired outcomes. We would expect the producers to improve their manufacturing precision in order to enhance the reproducibility of incorporated information.

KEY WORDS: Bracket; Slot inclination; Slot geometry; Bracket slot tolerance

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INTRODUCTION

The objective of any orthodontic treatment consists in placing the tooth in its ideal position, in accordance with the six keys of the occlusion established by Andrews¹. In order to meet those standards an effective control of tooth movement in all directions is needed and, among those, emphasis can be put on torque control. Tooth inclination has indeed been proven to be of major importance, both concerning functional and aesthetic aspects.

Functionally, it was shown that a correct buccolingual inclination of anterior teeth is a condition to obtaining proper overjet and overbite², arch length³⁻⁵ and Class I relationship⁶. In addition, correct inclination of posterior teeth enables correct cusp to pit relationships. Anterior and posterior teeth inclination will impact the face and the smile esthetic. Regarding the face, adequate buccal crown inclination will lead to satisfactory labial support, whereas undertorqued incisor will cause concave shaped profiles and thus an older appearance. Obviously, aesthetic of smile highly depends on teeth inclination as well. Proper incisor torque is necessary in order to observe an aesthetic smile line in the frontal and in the profile view⁷. It was also demonstrated that canine and premolar torque values affects perception of frontal smile when evaluated by laypersons as well as orthodontic professionals⁸.

Studies come to a consensus about the significance of teeth buccolingual inclination on the treatment outcome. Our main challenge is to determine how to control effectively the torque applied to teeth in order to achieve these goals. Multiple factors can obstruct correct results, such as bracket prescribed height⁹, tooth crown morphology^{10,11}, tooth tipping, torque values of adjacent teeth and type of appliances used during treatment. These appliance-related parameters were studied by Gioka and Eliades in a systematic review⁶, and they established five variables influencing torque expression: dimensional difference between the bracket slot and the wire, slot distortion, bracket slot and wire slot modulus, bracket-wire ligation mode and inaccuracy of actual bracket torque when compared with reported one. The purpose of this study was to focus on this last variable.

MATERIALS AND METHODS

740 upper right central incisor pre-informed brackets were selected for evaluation from seven manufacturers (Dentsply GAC, Bohemia, NY; American Orthodontics, Sheboygan, Wis; Ormco, Glendora, Calif; Rocky Mountain Orthodontics, Denver, Colo; GC Orthodontics, Breckerfeld,

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Germany; 3M Unitek, Monrovia, Calif and Dentaaurum, Ispringen, Germany). The sample comprised metal and ceramic, 0.018x0.025 inch and 0.022x0.028 inch, conventional and self-ligating brackets series. Torque prescription was ranging between 12° and 22°. Ten brackets of each series were randomly selected.

Brackets images were obtained using a digital optical microscope (Dino-Lite, AnMo Electronics Corporation, New Taipei City, Taiwan), at the magnification providing a full image of the bracket. The image comprised the base and the slot of the bracket, allowing to measure the slot inclination.

Brackets were stabilized in a customized vice, enabling to tip the bracket in such a way that the angle of acquisition was perpendicular to the slot walls. After calibration, images were measured using ImageJ software (National Institute of Medicine). Slot inclination of gingival and occlusal walls was measured at both mesial and distal sides (Figure 1). Angle measurements were round off at the first decimal. The measured values were compared to those announced by the manufacturers.

Comparison was made between mesial and distal sides to evaluate the slot symmetry, and between gingival and occlusal inclination for angle measurements to look for possible slot divergence. Statistical analyses (Wilcoxon signed-rank test, sign test and compliance test) were performed using XLStat (Addinsoft, New York, NY) and Ellistat (Pillet Consulting, Paris, France) softwares.

RESULTS Data analysis with sign and compliance tests (Supplementary Table 1 and 2) showed that 45% (occlusal measure) to 76% (gingival measure) of tested bracket series presented a significant difference between the inclination of their slot walls and the nominal value (Table 1). This difference could manifest either through an increase or a decrease of wall inclination. Maximum increase of wall inclination was shown for the Mini-V Diamond bracket serie (Ormco), exhibiting 5° of added inclination compared to the announced value. Maximum decrease of wall inclination was shown for the Fli Twin 0.018x0.025 inch bracket serie (Rocky Mountain Orthodontics), exhibiting a 4.1° reduced inclination compared to the announced value (Table 2). The reproducibility of inclination values was variable, statistical variance ranged from a minimum of 0.1 (Chic Ceramic 0.022x0.028 bracket serie, GC Orthodontics) to a maximum of 23.7 (Spirit MB, Ormco) (Table 3). In addition, results showed that up

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to 98% of bracket series presented with a gingival inclination superior to the nominal value (Supplementary Table 1 and 2).

The comparison between gingival and occlusal inclinations displayed a significant statistical difference for up to 74% of the brackets. Among the bracket series exhibiting a statistical difference, 87% (distal measure) to 96% (mesial measure) showed a gingival inclination superior to the occlusal one.

The comparison between mesial and distal sides showed that up to 45% of the brackets were significantly asymmetrical. This asymmetry reached a maximum of 7.3° (Spirit MB, Ormco) (Table 4). Self-ligating and conventional brackets were compared. Regarding the slot inclination values, we observed that 30% (occlusal measure) to 74% (gingival measure) of the self-ligating brackets evaluated showed a statistical difference with prescription value, whereas 51% (occlusal measure) to 76% (gingival measure) of the conventional brackets showed such difference. Among the self-ligating brackets, 31% to 69% of the metal brackets exhibited a statistical difference versus 29% to 86% of the ceramic brackets. Among the conventional brackets, 50% to 74% of the metal brackets exhibited a statistical difference versus 53% to 82% of the ceramic brackets.

When considering slot divergence, we noticed that 74% of self-ligating bracket slots were statistically divergent, against 65% (mesial measure) to 75% (distal measure) for the conventional

brackets. Among the self-ligating brackets, 69% to 75% of the metal brackets presented with a significant divergence, versus 71% to 86% of the ceramic brackets.

Among the conventional brackets, 71% to 79% of the metal brackets presented with a significant divergence, versus 53% to 65% of the ceramic brackets.

DISCUSSION

The use of pre-informed appliances, first developed by Andrews in 1972¹², is theoretically allowing the orthodontist to place the tooth as desired in all three dimensions of space solely by placing a straight archwire into the bracket slot. However, the outcomes can be disappointing for the clinician, as the expected placement is often only obtained after adding bends to the wire. This inability to provide an accurate result is especially noticeable in regards to torque information, to the extent that it can prevent it from distinguishing which bracket prescription was used to treat a patient.

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Indeed, Mittal and al.¹³ showed that there was no difference in clinically detectable torque values between patients treated with a Roth or a MBT bracket prescription.

Plaza and al.¹⁴ measured 200 MBT brackets from four companies: 3M Unitek, Dentaaurum, Aditek (Grabilinhos, Brazil) and Morelli (Sorocaba, Brazil) and showed differences in torque values in all the brackets evaluated when compared with expected ones.

Streva and al.¹⁵ examined 240 conventional canine brackets with 0.022x0.028 inch slot from six manufacturers (3M Unitek, American Orthodontics, Morelli (Sorocaba, Brazil), TP Orthodontics (La Porte, Ind), Abzil (São José do Rio Preto, Brazil), Ortho Organizers Inc. (Carlsbad, CA)) using an optical microscope. They concluded that for the maxillary brackets only the Morelli brand exhibited torque values different that stated whereas for the mandibular brackets both American Orthodontics and Ortho Organizers Inc. presented statistically different values.

Kim and al.¹⁶ tested four bracket brands: Daeseung Medical (Seoul, Korea), 3M Unitek, Tomy (Fukushima, Japan) and Shinye Odontology Materials (Hangzhou, China) for dimensional accuracy and concluded that Confidence (Shinye Odontology Materials) brackets showed a significant difference in manufacturing errors of torque.

Anjos and al.¹⁷ measured torque angle values of 160 canine maxillary and mandibular conventional and self-ligating Roth brackets with 0.022x0.028 inch slot provided by the following manufacturers: Abzil, Eurodonto (Curitiba, Brazil), Morelli and Ormco. They established that for maxillary brackets Abzil, Morelli and Ormco presented statistically inaccurate values, and for mandibular brackets it was Abzil, Eurodonto and Ormco who showed differences.

Alavi and al.¹⁸ evaluated the torque integrated in the slot of 64 MBT brackets marketed by American Orthodontics and Ortho Organizers and found that there was a significant difference between the American Orthodontic brackets torque information and the one reported.

In the present study, it was chosen to examine brackets provided by seven companies, and to select a wide sample of the different bracket series commercialized by each manufacturer in order to review if the variable products of the lines had comparable accuracies in terms of torque information. Results showed that, when compared with announced inclination, more than half of the tested bracket series presented with a significant difference. Among those bracket series, a great majority exhibited an increased gingival inclination when compared to the nominal value, meaning that incorporated torque was lower than expected. However, the clinician cannot prevent a torque loss simply by

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choosing extra-torqued brackets and relying on a reproducible increase of the walls inclination.

Indeed, analysis of variances proves that the intra-serie reproducibility is variable and could go up to 23.7. This findings are similar to those found by Erduran and al.¹⁹ Comparison between self-ligating and conventional brackets provided similar results, as well as between metal and ceramic brackets.

When comparing the gingival and occlusal wall inclinations, we noticed that half of the bracket series showed disparities between both values. Among those bracket series, 87% to 96% presented with a

gingival inclination superior to the occlusal one, hence exhibiting a divergence of the slot walls. Comparison between self-ligating and conventional brackets provided similar results, but discrepancy was noticed between metal and ceramic brackets. Among the self-ligating brackets, divergence was exhibited for a larger proportion of the ceramic brackets than of the metal ones. To the contrary, among the conventional brackets, divergence was exhibited for a larger proportion of the metal brackets than of the ceramic ones.

Slot walls divergence increases the play between the archwire and the slot, therefore aggravating the risk of torque loss. This lack of manufacturing accuracy is an obstacle to the predictability of the treatment outcomes. Actions should be taken in order to improve the precision of the tools provided to the orthodontist.

To check whether some corrections were needed, we advise the clinicians to be cautious with preinformed brackets, by reassessing the obtained results and comparing them with those expected. It should also be kept in mind that the variation in tooth morphology prevents from obtaining fully reproducible results¹⁰. It would thus be relevant to turn to personalized bracket systems if willing to avoid adding bends.

CONCLUSIONS

- Morphological statistical analysis of 740 commercial brackets provided by seven companies was performed.
- Torque value of 45% to 76% of the tested brackets was significantly different from expected one, mostly in favour of torque loss.
- Comparison between gingival and occlusal inclinations exhibited that up to 74% of the bracket slot walls were significantly divergent.

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- Comparison between mesial and distal sides showed that up to 45% of the brackets were significantly asymmetrical.
- Clinicians should be aware of using preadjusted appliances, as they run the risk to observe a decrease of expressed torque in the end of the treatment.

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FIGURE LEGENDS

Figure 1: Schematic bracket distal view of angles between the base and the gingival and occlusal walls

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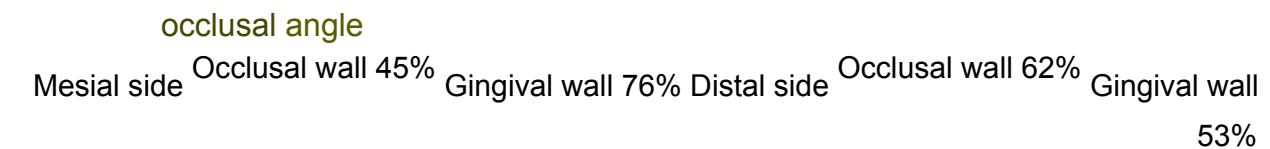


Table 1: Percentage of bracket series showing significant inclination inaccuracy with nominal value

Measured Side Wall	Maximal value	Bracket serie	Company	Torque prescription	Difference inclination
Mesial		Mini-V Diamond	18x25	Ormco	76° 79,8° 3,8°
Distal		Fli Twin	18x25 RMO	78° 73,9° 4,1°	Increase
		Fli Twin	22x28 RMO	78° 76° 82,3° 4,3°	Increase
		MB Ormco	Spirit	72,5° 3,5°	Decrease

Occlusal Increase
 Mini-V Increase
 Diamond
 Ormco 76° 81° 5° Occlusal
 18x25 Decrease InOvation
 Mini 22x28
 Dentsply GAC 78° 76,4° 1,6°
 Gingival
 Increase InOvation 18x25
 C

Dentsply GAC 78° 81,2 3,2°
 Decrease LP Low Profile AO 75° 73,3° 1,7°

Table 2: Maximal increase and decrease of observed inclinations versus nominal values Ormco (Glendora, Calif), RMO: Rocky Mountain Orthodontics (Denver, Colo), Dentsply GAC (Bohemia, NY), AO: American Orthodontics (Sheboygan, Wis)

Side Wall Variance Bracket serie Company Value
 Mesial

Occlusal Minimal Maximal Experience Metal 18x25 Fli Signature Clear 22x28 GC
 Orthodontics 0,19 RMO 4,95 Gingival Minimal Maximal Equilibrium Spirit MB Dentaurum 0,13
 Ormco 3,83

Distal

Occlusal Minimal Maximal Chic Ceramic Spirit MB 22x28 GC Orthodontics 0,08
 Ormco 23,73 Gingival Minimal Maximal Equilibrium Ti Spirit MB Dentaurum 0,20 Ormco 7,83

Table 3: Minimal and maximal statistical variance GC Orthodontics (Breckerfeld, Germany), RMO: Rocky Mountain Orthodontics (Denver, Colo), Dentaurum, Ispringen, Germany), Ormco (Glendora, Calif)

Company Bracket serie Asymmetry value Dentsply GAC InOvation C 18x25 5,1° Ormco Spirit MB 7,3° RMO Fli Signature Clear 22x28 5,8° 3M Unitek Clarity Advanced 5,3° AO LP Low Profile 4,9° GC Orthodontics Legend Mini Metal 18x25 4,8° Dentaurum Dinamique C 5°

Table 4: Maximal asymmetry values (Dentsply GAC (Bohemia, NY), AO: American Orthodontics (Sheboygan, Wis), Ormco (Glendora, Calif), RMO: Rocky Mountain Orthodontics (Denver, Colo), GC Orthodontics (Breckerfeld, Germany), 3M Unitek (Monrovia, Calif) and Dentaurum (Ispringen, Germany))

Occlusal angle Gingival angle Occlusal vs. Mesial Distal Mesial
 Gingival vs. distal

Torque | aireta
Mprescription

Mean+-Sd Mean+-Sd p Mesial Distal Mesial

Vs. torque vs. distal

prescription p Mean+-Sd Mean+-Sd p p p Mesial Distal Mesial Distal Mesial Distal Dentsply Gac

Omnirarch Plus 18x25 M +12° 79.3+-1.0 79.1+-1.1 NS ** * 80.0+-0.7 79.7+-1.5 NS *** * * Omnirarch Plus 22x28 M +12° 79.0+-1.1 78.2+-0.9 * * NS 80.1+-1.5 79.3+-0.9 NS ** * * * * Ovation C 18x25 C +12° 80.0+-1.4 77.4+-0.7 * * * * 80.4+-0.8 78.7+-0.8 ** * * * NS * Ovation C 22x28 C +12° 78.7+-0.7 77.6+-0.8 * * * NS 78.9+-0.7 77.6+-1.0 * * * NS NS NS Resolve C 18x25 C +12° 78.6+-1.0 77.3+-1.6 * NS NS 79.3+-1.1 78.8+-1.1 NS ** NS * * * Resolve C 22x28 C +12° 77.9+-1.0 76.6+-1.4 * NS * 78.9+-0.7 79.2+-0.9 NS ** * * * * MicroArch Plus 18x25 M +12° 81.1+-0.5 79.6+-1.0 * * * * * 80.9+-0.6 79.2+-0.7 * * * * * NS NS MicroArch Plus 22x28 M +12° 79.9+-1.2 78.7+-1.1 * * * * NS 80.9+-0.7 79.5+-1.3 * * * * * * Ormco Mini Diamond

Twin

18x25 M +14° 79.5+-1.4 78.8+1.3 * * * * * 78.4+-1.1 77.5+-1.2 NS * * * * *

Mini Diamond Twin

22x28 M +14° 77.8+-1.9 79.4+-1.6 NS * * * * 76.5+-1.7 76.5+-1.4 NS NS NS * * *

Mini Diamond Slim

18x25 M +14° 75.5+-1.8 75.2+-1.1 NS NS NS 79.0+-1.4 78.0+-1.2 NS * * * * * * *

Mini Diamond Orthos

18x25 M +22° 71.1+-1.8 70.9+-0.7 NS * * * * * 68.6+-1.0 68.9+-1.0 NS NS * * * * *

Mini-V Di 18x25 M +14° 79.8+-1.6 81.0+-1.1 * * * * * 77.9+-1.2 78.9+-0.9 * * * * * * * Spirit MB 18x25 C +14° 74.1+-2.1 75.6+-4.9

NS * NS 72.5+-2.0 75.8+-2.8 * * * * NS NS NS Inspire ICE 18x25 C +12° 77.6+-1.5 77.1+-1.1 NS NS * 80.7+-1.4 79.2+-1.0 * * * * * *

** Inspire ICE 22x28 C +12° 77.7+-0.8 77.3+-0.7 NS NS * 79.7+-0.6 79.4+-0.6 NS * * * * * * * Titanium Orthos

18x25 M +15° 76.5+-0.9 75.9+-0.8 NS * * * * * 78.7+-0.5 77.9+-0.9 * * * * * * *

RMO Signature III 18x25 C +12° 77.7+-0.8 77.1+-1.1 NS NS * 79.0+-1.0 78.8+-1.3 NS ** NS * *

Signature III 22x28 C +12° 79.0+-1.3 78.9+-0.5 NS * * * * 80.4+-0.9 80.5+-0.7 NS * * * * * * * Fli Twin 18x25 M +12° 73.9+-0.9

77.5+-1.3 * * * * NS 80.0+-1.2 79.7+-1.2 NS * * * * * * * Fli Twin 22x28 M +12° 74.0+-0.5 77.8+-0.7 * * * * NS 82.3+-0.8 81.0+-0.9 * * * *

* * * * * Fli signature clear

18x25 C +12° 79.1+-0.7 78.5+-0.8 NS * * * NS 79.8+-1.5 79.3+-1.8 NS ** NS NS NS

Fli signature clear

22x28 C +12° 77.9+-2.2 77.1+-2.6 NS NS NS 78.4+-1.7 78.0+-2.0 NS NS NS NS *

Integra 18x25 M +12° 77.8+-0.9 76.7+-0.6 * NS * * * 78.3+-0.6 78.4+-1.5 NS NS NS NS * Integra 22x28 M +12° 78.5+-1.1 77.2+-0.8 *

NS * 78.1+-1.0 77.4+-1.3 * NS NS NS NS Mini-Taurus 18x25 M +12° 79.0+-1.0 78.1+-1.1 NS * NS 79.52-0.9 78.3+-1.2 NS * * * NS

NS NS Mini-Taurus 22x28 M +12° 78.7+-1.1 78.2+-0.6 NS NS NS 78.8+-0.8 77.1+-2.0 * * * NS ** Synergy FSC 18x25 M +12°

77.5+-0.9 77.2+-0.7 NS NS ** 78.9+-0.6 78.3+-0.6 NS * * * NS * * Synergy FSC 22x28 M +12° 77.6+-0.9 77.1+-1.1 NS NS *

79.1+-1.1 78.7+-0.9 NS * * * * * 3M Clarity

Advanced

18x25 C +12° 77.6+-0.8 76.6+-1.3 NS NS ** 78.0+-1.0 77.0+-1.4 NS NS * NS NS

Victory Low Profile

18x25 M +12° 77.2+-1.5 76.9+1.1 NS NS * 78.0+-1.2 77.5+-1.5 NS NS NS NS NS

Victory Twin 18x25 M +14° 76.7+-0.7 75.8+-0.8 * * NS 77.6+-1.3 76.8+-0.8 NS * * NS ** AO Mini Master

Series

22x28 M +17° 73.0+-1.3 72.7+-1.0 NS NS NS 74.8+-1.1 73.6+-0.9 * * * * NS * * *

LP Low Profile 22x28 M +17° 73.6+-0.9 72.5+-1.1 * NS NS 75.8+-1.0 73.3+-1.1 * * * * NS * * * Cosmetic Radiance

22x28 C +17° 72.6+-0.7 71.8+-0.4 * * NS * * * 75.2+-1.2 75.3+-0.7 NS * * * * * * *

GC Axxess 18x25 M +12° 78.1+-0.8 77.8+-0.5 NS NS NS 78.4+-07 77.9+-0.8 NS NS NS NS NS Axxess 22x28 M +12° 78.1+-0.5

78.0+-0.8 NS NS NS 78.5+-0.6 78.3+-0.5 NS * NS NS NS Legend mini metal

18x25 M +12° 78.6+-0.9 77.2+-0.8 * * NS * * * 80.3+-1.0 78.7+-0.8 * * * * * * *

Legend mini métal

22x28 M +12° 79.0+-0.7 77.7+-0.4 * * * * NS 80.7+-0.4 78.5+-1.0 * * * * NS * * *

Legend medium metal

18x25 M +12° 79.1+-0.7 77.7+-0.6 * * * * NS 81.4+-0.8 79.8+-0.9 * * * * * * * *

Legend medium metal

22x28 M +12° 78.1+-0.5 76.8+-0.8 * * NS * * * 80.6+-0.6 78.8+-0.7 * * * * * * * *

Chic Ceramic 18x25 C +12° 79.9+-0.9 78.5+-1.2 * * * * NS 79.3+-0.7 78.2+-0.6 * * * * NS NS NS Chic Ceramic 22x28 C +12°

79.0+-0.6 78.3+-0.3 * * * * * 78.3+-0.6 77.1+-0.9 * * NS * * * * * Dentaurum Fascination 2 22x28 C +11° 80.2+-1.1 79.7+-0.7 NS * * *

82.3+-1.0 81.9+-1.2 NS * * * * * * * * * * Discovery Pearl 22x28 C +12° 79.6+-0.9 77.8+-0.9 * * * * NS 79.1+-0.7 77.7+-0.7 * * * * NS NS NS

Discovery Smart 22x28 M +12° 77.3+-1.2 76.7+-0.6 NS NS * * * 79.4+-1.4 78.9+-0.8 NS * * * * * Equilibrium Ti 22x28 M +12°

77.8+-0.5 77.1+-0.4 * NS *** 79.1+-0.4 78.0+-0.4 ** *** NS ** ** Equilibrium 2 22x28 M +12° 78.0+-0.5 77.4+-0.4 * NS *** 78.5+-0.4 78.2+-0.5 NS ** NS ** ** Discovery 22x28 M +12° 76.6+-1.0 76.7+-0.7 NS ** *** 77.9+-0.7 78.0+-1.0 NS NS NS ** ** Equilibrium mini 22x28 M +12° 76.7+-0.3 76.5+-0.3 NS ** *** 78.4+-0.6 77.7+-0.5 ** NS NS ** ** Topic 22x28 M +12° 77.8+-0.9 77.5+-0.6 NS NS * 78.1+-0.7 77.4+-0.6 NS NS ** NS NS

Supplementary table 1: Listing and characteristics of conventional brackets (M: metal, C: ceramic; NS: non significant; *: p < 0.05; **: p < 0.01; *** : p < 0.0001; Sd: standard deviation) Ormco (Glendora, Calif), RMO: Rocky Mountain Orthodontics (Denver, Colo), Dentsply GAC (Bohemia, NY), AO : American Orthodontics (Sheboygan, Wis)

Company Bracket serie Size
 I aireta
 MTorque
 prescription
 Occlusal angle Gingival angle Occlusal vs. Mesial Distal Mesial
 Gingival vs. distal
 Vs. torque prescription
 Mesial Distal Mesial
 vs. distal
 Vs. torque prescription
 Mean+-Sd Mean+-Sd p p Mean+-Sd Mean+-Sd p p p
 Mesial Distal Mesial Distal Mesial Distal Dentsply Gac
 In Ovation Mini
 18x25 M +12° 77.9+-0.5 77.0+-0.4 ** NS *** 79.7+-1.4 78.6+-1.2 ** ** NS ** **
 In Ovation Mini
 22x28 M +12° 76.8+-0.5 76.4+-0.6 NS ** *** 78.6+-0.7 77.8+-0.9 NS * NS ** **
 In Ovation C 18x25 C +12° 78.0+-0.6 76.5+-0.9 * NS *** 80.9+-1.5 81.2+-2.4 NS ** ** ** ** In Ovation C 22x28 C +12° 77.6+-0.9 76.8+-0.9 NS NS ** 80.6+-1.3 79.2+-1.2 NS ** ** ** In Ovation R 18x25 M +12° 77.3+-0.9 76.9+-0.9 NS ** ** 78.6+-0.7 78.0+-1.3 NS * NS ** * In Ovation R 22x28 M +12° 78.1+-1.0 77.7+-0.8 NS NS NS 78.8+-0.8 78.0+-1.2 NS * NS * NS Ormco Damon Q 22x28 M +15° 75.2+-1.1 75.1+-0.5 NS NS NS 75.2+-0.8 74.4+-0.8 NS NS * NS *
 Damon Clear2 22x28 C +15° 76.4+-0.9 76.1+-0.5 NS ** *** 76.5+-0.5 75.9+-1.0 NS ** * NS NS 3M Clarity SL 18x25 C +12° 77.8+-1.8 76.9+-1.4 * NS * 78.7+-1.1 78.3+-0.6 NS NS NS NS *
 Smartclip 18x25 M +12° 78.4+-1.3 77.5+-1.3 NS NS NS 77.9+-1.8 77.5+-1.1 NS NS NS NS NS Victory Series Active SL 22x28 M +12° 77.2+-0.8 77.2+-0.6 NS ** ** 79.6+-1.1 79.0+-1.3 NS ** ** **
 AO Cosmetic Empower
 22x28 C +17° 73.3+-0.9 72.2+-0.8 NS NS ** 74.4+-0.8 73.6+-1.1 * ** NS **
 Empower 2 22x28 M +17° 73.2+-0.9 73.4+-0.7 NS NS NS 75.3+-0.8 75.1+-0.8 NS ** ** ** GC Experience Metal Mini 18x25 M +12° 77.7+-0.6 76.8+-0.7 * NS ** 79.0+-1.5 78.4+-1.6 NS NS NS **
 Experience Metal Mini
 22x28 M +12° 77.9+-0.7 77.2+-0.6 * NS ** 79.2+-1.3 78.0+-0.8 NS * NS * NS
 Experience metal
 18x25 M +12° 77.7+-0.4 77.6+-0.9 NS NS NS 78.5+-0.8 78.0+-1.1 NS NS NS * NS
 Experience metal
 22x28 M +12° 77.6+-0.6 77.1+-0.6 NS NS ** 77.8+-0.7 77.5+-0.5 NS NS ** NS NS
 Experience mini metal RC
 18x25 M +12° 77.9+-0.6 77.3+-0.7 * NS ** 79.1+-1.1 78.5+-0.8 NS ** NS **
 Experience mini metal RC
 22x28 M +12° 77.1+-0.5 76.6+-0.7 NS ** *** 78.8+-1.0 78.6+-1.0 NS * NS ** **
 Experience Ceramic
 18x25 C +12° 77.5+-0.5 77.6+-0.8 NS * NS 80.0+-1.2 79.9+-0.8 NS ** ** **
 Experience Ceramic
 22x28 C +12° 78.3+-0.8 77.3+-0.7 * NS * 79.6+-1.0 79.1+-1.1 NS ** ** **
 Dentaurem Dinamique C 22x28 M +11° 80.0+-1.0 77.9+-1.1 ** * 80.5+-0.5 79.4+-1.1 ** ** NS NS ** Dinamique M 22x28 M +11° 79.4+-0.7 78.4+-0.9 * NS NS 80.1+-0.5 79.6+-0.8 NS ** ** **

Supplementary table 2: Listing and characteristics of self-ligating brackets (M: metal; C: ceramic; NS: non significant; *: p < 0.05; **: p < 0.01; *** : p < 0.0001; Sd: standard deviation) Ormco (Glendora, Calif), RMO: Rocky Mountain Orthodontics (Denver, Colo), Dentsply GAC (Bohemia, NY), AO : American Orthodontics (Sheboygan, Wis)