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Analysis of mesiodistal angulations of preadjusted brackets

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Abstract: Manufacturers offer various prescriptions of preadjusted brackets for use in the "straight-wire" orthodontic technique. However, the need to incorporate bends in the rectangular wires during orthodontic finishing has led to concerns regarding the type of prescription chosen and the credibility of information provided by the manufacturer. The aim of this study was to compare the slot angulations of Roth prescription preadjusted metallic brackets for the maxillary left central incisor and maxillary left canine. For each tooth type, 10 brackets of three commercial brands (GAC, Forestadent and Morelli) were selected. Two individual metal matrices for brackets and tooth positioning were made for each group of teeth. Captured images were obtained by standardized ortho-radial photography with a digital camera. Images were exported and analyzed with the Image J software package. One-way ANOVA and Tukey statistical analyses were performed at the 5% significance level. For brackets of the maxillary left central incisor, differences in mean angulation were observed between the Morelli and GAC groups ($p < 0.01$) and between the Forestadent and GAC groups ($p < 0.01$). For brackets of the maxillary left canine, differences in mean angulation were found between the Morelli and GAC groups ($p < 0.01$) and between the Morelli and Forestadent groups ($p < 0.05$). In conclusion, despite their same prescription name, the different brands exhibited significantly different angulation measurements.

Keywords: Orthodontic Appliances; Orthodontic Appliance Design; Orthodontic Brackets.

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Introduction

In 1972, Lawrence Andrews[1] first developed the fully programmed, or "preadjusted", brackets that are currently used in the "straight-wire" mechanical technique of orthodontics. These brackets accounted for the six key features of normal occlusion and are still used as a reference today.[2,3,4] Andrews[1] built in first-, second-, and third-order bends into his brackets, corresponding to horizontal, vertical, and buccolingual movements, respectively. In contrast, the conventional "edgewise" mechanical technique uses nonprogrammed, or standard, brackets, in which the orthodontist must bend the wires to achieve the desired tooth movement.[5,6,7] Andrews maintained the use of a rectangular wire in a rectangular bracket slot to allow three-dimensional movement.

Several researchers have developed new techniques and prescriptions based on the original Andrews prescription.[5] One such technique was designed by Ronald Roth, who used photographic analyses of his patients to try to solve some problems observed in his daily clinical practice. He developed a single set of brackets with different levels of inclination and angulation. This "Roth prescription" of brackets was helpful to orthodontists because it expanded the original 11 prescriptions proposed by Andrews.[8] Many other researchers have individualized their brackets, resulting in, for example, the MBT Prescription proposed by Richard McLaughlin, John Bennett, and Hugo Trevisi; the Capelozza Prescription; and others.[5]

Various brands use these prescription designations (*e.g.*, Roth prescription, MBT prescription, etc.) for their preadjusted brackets. However, several authors have questioned the credibility of manufacturer-designated prescriptions, in terms of the torque built into these accessories and the slot size.[9,10,11] Using nonstandardized brackets makes it difficult to complete the orthodontic treatment, as several factors can influence tooth movement, such as: changes in the bracket position during bonding,[12,13] differences in tooth anatomy,[13,14,15] interplay between the wire and the bracket slot,[9,12,14,15,16] and variations in the manufacturing, design, or fabrication material of the orthodontic brackets or wires.[16,17,18,19,20] Few studies have evaluated the angulation of the bracket slot. As an important component of the preadjusted bracket, the slot angulation is used to obtain a dental position consistent with Andrews' six keys of normal occlusion.[4]

Orthodontists around the world have largely accepted the idea of using commercial brackets with a predetermined angulation to guide tooth movement, and prescriptions of preadjusted brackets are widely used. As evidence of this fact, a recent study by Banks *et al.*,[21] showed that most professionals in the UK use the Roth prescription of preadjusted brackets. However, the orthodontist should understand the characteristics of the brackets that he/she is using. Various manufacturers offer commercial "Roth prescriptions" of brackets, but seldom do they provide their angulation measures. Thus, the objective of this study was to examine whether three different brackets designated with the same prescription (Roth) show the same mesiodistal angulations.

Methodology

Materials

Sixty artificial teeth (Marília Dental Mannequins, Marília, Brazil), including 30 maxillary left central incisors and 30 maxillary left canines, were used in this study. Sixty Roth prescription preadjusted metallic brackets, with mesiodistal angulations of 5º and 13º for the incisors and canines, respectively, and a bracket slot size of 0.022", were used. Three manufacturers provided 10 brackets each for the maxillary left central incisor and the maxillary left canine: Morelli (Morelli Orthodontics, Sorocaba, Brazil), GAC (GAC International, Dentsply, New York, USA), and Forestadent (Forestadent, Pforzheim, Germany).

Groups and study design

Six groups were formed, three for each artificial tooth, with 10 teeth per group (Table 1).

The methodology was divided into five steps: 1, creating the metal matrix for tooth positioning; 2, positioning and bonding the brackets over the teeth; 3, inserting the rectangular wire in the bracket slots; 4, capturing images by standardized photography; and 5, obtaining measurements. The study was conducted by a single operator, who was blinded to the brands.

Table 1. Names and descriptions of the groups used in this study

Name	Description	Manufacturer	n
MOR1	Maxillary left central incisor with Morelli brackets	Morelli Orthodontics, Sorocaba, Brazil	10
GAC1	Maxillary left central incisor with GAC brackets	GAC International, Dentsply, New York, USA	10
FOR1	Maxillary left central incisor with Forestadent brackets	Forestadent, Pforzheim, Germany	10
MOR2	Maxillary left canine with Morelli brackets	Morelli Orthodontics, Sorocaba, Brazil	10
GAC2	Maxillary left canine with GAC brackets	GAC International, Dentsply, New York, USA	10
FOR2	Maxillary left canine with Forestadent brackets	Forestadent, Pforzheim, Germany	10

Creating the metal matrix for dental positioning

Two plastic matrices were fabricated with acrylic resins (JET Classic, Articles Dental Classic Ltd., São Paulo, Brazil; Duralay Reliance Dental Mfg. Co., Worth, USA), which functioned as templates for each tooth impression. The plastic matrices were cast in nickel chromium alloy in a circular form, by the conventional lost-wax technique. Each obtained matrix measured approximately 2.8 cm in diameter by 0.70 cm in height. A rectangular base (about 5.0 × 5.0 × 1.0 cm) of fused steel was constructed for these matrices. This base was used specifically for this research and for the fixation of the matrices. After the metal was casted, finished, and polished, four reference guides were prepared on the base metal, to guide the insertion of each matrix in the same position (Figures 1–3).

Figure 1. Rectangular steel base, with four reference guides

Figure 2. Matrix containing the central incisor

Figure 3. Matrix containing the canine

Bracket positioning

For each artificial tooth, a bracket was bonded in the center of the clinical crown (Figure 4). Teeth were randomly chosen for each manufactured bracket and were not removed from the matrix at any time. Bonding was performed with a photopolymerizable resin (Transbond™ XT, 3M Unitek, Monrovia, USA), according to the manufacturer's instructions and in a standardized way.

Insertion of the rectangular wire

After bonding, a rectangular stainless steel wire (0.019″ × 0.025″; Morelli Orthodontics) was placed in the bracket slot and fixed by orthodontic gray liga-

Figure 4. Bonding of the bracket to the center of the clinical crown

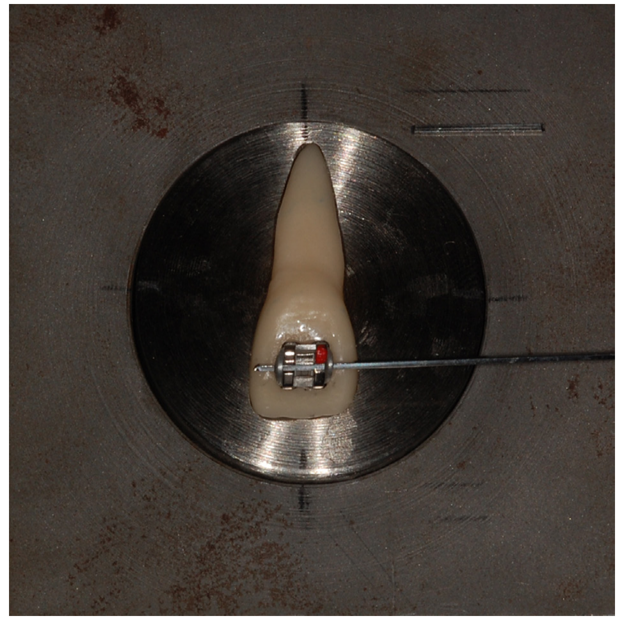

Figure 5. Fixation of the rectangular wire by an orthodontic gray ligature

ture (Morelli Orthodontics). The same wire was used for all brackets in the study to avoid material variations (Figure 5).

Image capture and analysis

Standard ortho-radial photographs were obtained with a digital camera and a Nikon macro lens (Nikon D40 Digital Camera, AF Micro Nikkor 105 mm D 1:2:8 lens, Macro Speedlight SB-29 circular flash, Nikon, Tokyo, Japan) with standard size of 6 MP. The camera was positioned in a vertical stand, so that images of the matrices would not suffer any distortion or variation. Images were exported to Image J 1.40 software (National Institute of Health, Bethesda, Maryland, USA) for analysis. For each analyzed sample, the angle between the long axis of the clinical crown and the axis of the rectangular wire positioned over the bracket was measured (Figure 6).

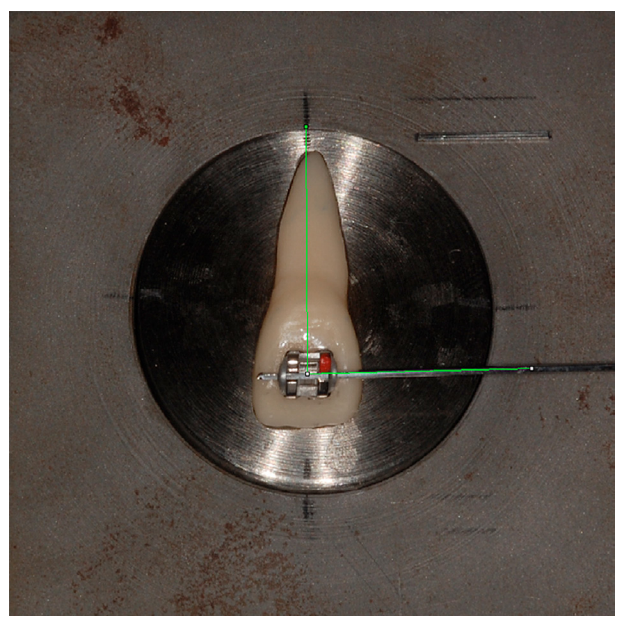

Figure 6. Angle between the long axis of the clinical crown and the axis of a 0.019" x 0.025" rectangular wire

Results

Maxillary left central incisor

Table 2 shows the descriptive statistics (mean, standard deviation [SD], and variance) of the results of the maxillary left central incisor for each group. The SDs and variances were small, indicating a normal distribution; therefore, the results were analyzed by analysis of variance (ANOVA; Table 3). There was a statistically significant difference among the group

Table 2. Descriptive statistics of mesiodistal angulation for the incisor groups

Group	Mean (°)	SD	Variance
MOR1	86.76	1.51	2.28
GAC1	88.89	0.79	0.62
FOR1	85.90	1.62	2.64

Table 3. Results of one-way ANOVA between incisor groups

Source of Variation	Degrees of freedom	Sum of squares	Mean squares
Group	2	47.431	23.716
Error	27	50.018	1.853
F-statistic	12.8019		
p-value	0.0003*		

* Statistically significant difference ($p < 0.05$).

averages ($p = 0.0003$; Table 3); thus, the Tukey test was applied at the 5% significance level. Statistically significant differences in mean angulation were obtained between the MOR1 and GAC1 groups (Table 4) and between the FOR1 and GAC1 groups (Table 5), but not between the FOR1 and MOR1 groups (Table 6).

Table 4. Comparison between mean values of the angulations for the groups MOR1 and GAC1*

Group	Mean	Difference	Q	(p)
MOR1	86.76			
		2.1320	4.9534	< 0.01**
GAC1	88.89			

* Tukey test, significance level of 5%
** Statistically significant difference.

Table 5. Comparison between mean values of the angulations for the groups GAC1 and FOR1*

Group	Mean	Difference	Q	(p)
GAC1	88.89			
		2.9910	6.9492	< 0.01**
FOR1	85.90			

* Tukey test, significance level of 5%
** Statistically significant difference.

Table 6. Comparison between mean values of the angulations for the groups MOR1 and FOR1*

Group	Mean	Difference	Q	(p)
MOR1	86.76			
		0.8590	1.9958	ns
FOR1	85.90			

* Tukey test, significance level of 5%
ns - Not statistically significant difference.

Maxillary left canine

Table 7 presents the descriptive statistics of the results for the maxillary left canine for each group. The results were analyzed by ANOVA, which revealed a statistically significant difference between the averages of the groups ($p = 0.0004$; Table 8). Therefore, the Tukey test was applied at the 5% significance level. Statistically significant differences in mean angulation were found between the MOR2 and GAC2 groups (Table 9) and between the MOR2 and FOR2 groups (Table 10), but not between the GAC2 and FOR2 groups (Table 11).

Table 7. Descriptive statistics of mesiodistal angulation for the canine groups

Group	Mean (°)	SD	Variance
MOR2	80.33	1.74	3.05
GAC2	76.43	1.71	2.92
FOR2	77.78	2.07	4.31

Table 8. One-way ANOVA results for the canine groups

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Group	2	78.813	39.407
Error	27	92.729	3.434
F-statistic	11.4741		
p-value	0.0004*		

* Statistically significant difference ($p < 0.05$).

Table 9. Comparison between mean values of the angulations for the groups MOR2 and GAC2*

Group	Mean	Difference	Q	(p)
MOR2	80.33			
		3.9090	6.6702	< 0.01**
GAC2	76.43			

* Tukey test, significance level of 5%
** Statistically significant difference.

Table 10. Comparison between mean values of the angulations for the groups MOR2 and FOR2*

Group	Mean	Difference	Q	(p)
MOR2	80.33			
		2.5560	4.3615	< 0.05**
FOR2	77.78			

* Tukey test, significance level of 5%
** Statistically significant difference.

Table 11. Comparison between mean values of the angulations for the groups GAC2 and FOR2*.

Group	Mean	Difference	Q	(p)
GAC2	76.43			
		1.3530	2.3087	ns
FOR2	77.78			

* Tukey test, significance level of 5%
ns – Not statistically significant difference.

Discussion

Based on the methodology applied, the results in this study revealed differing mesiodistal angulations among brackets of the Roth prescription supplied by three manufacturers.[5] When an orthodontist uses commercial brackets with the name "Roth," he/she does so believing that all of the bracket slots will have a standardized angulation and will lead to the same final result. However, the findings in this research contradict this notion.

In comparing the GAC1 and MOR1 incisor groups, there was a statistically significant difference of 2.13° between the mean angulations. For the canine groups, the same manufacturers (MOR2 and GAC2 groups) showed a difference in the mean angulation of 3.90°, with the GAC2 group presenting a greater mesioincisal angulation than the MOR2 group. Regardless of whether this reasoning can be extended to the narrow cross-section wires, the difference, even if statistically significant, may not be clinically important. No studies were found in the literature to verify these results. An evaluation of these results is necessary for understanding their clinical relevance. The findings indicate that, in a clinical situation, the orthodontist should not mix brackets of the MOR1 and MOR2 groups with brackets of the GAC1 and GAC2 groups in the same patient. Although they are both of the Roth prescription, these brackets have different angulations, and mixing them can cause problems when wider wires are used.

The GAC1 and FOR1 incisor groups showed a statistically significant difference of 2.99° between their mean angulations. However, when the same manufacturers were analyzed for the upper left canine (GAC2 and FOR2 groups), there was no statistically significant difference between the mean angulations. Nevertheless, the difference of 1.35° for the canine should not be ignored because clinically, a mix of brackets in the same patient will lead to different dental positions. Hence, the orthodontist will need to perform a correction with bends, which contradicts the original "straight-wire" concept. Finally, the mean angulations of the FOR1 and MOR1 groups differed by 0.85°. Although not statistically significant, this difference should not be ignored because of the possibility of adverse clinical responses. Comparison of MOR2 and FOR2 groups showed a statistically significant difference of 2.55°.

The values of the angulation differences found between the groups for the incisor and canine were small, suggesting that the difference may not be significant for all of the incisor groups. A larger sample may be required to detect these differences. Thus, some doubt remains as to whether the same prescription represents the same angulation. However, based on the methodology used, the same prescription brackets did not show the same amount of angulation.

Another factor that could interfere with the methodology is the width of the rectangular wire. Some articles have mentioned that the bracket slot should be filled completely, at least in the finishing stage. As an aside, these authors have indicated that the bracket slot should be slightly oversized and the wires slightly undersized for acceptable tolerance.[22] In the present study, a rectangular wire of 0.019″ × 0.025″ was chosen for the straight-wire treatment technique, developed based on the concept of lightforce sliding mechanics.[23] In this technique, a 0.019″ x 0.025″ rectangular wire is the final wire indicated for a 0.022″ x 0.028″ bracket slot. Regardless, evaluating the role of the bracket slot was not the aim of this study. The same bracket slot was used for all evaluated devices; thus, any methodological errors would be the same for all measurements. The same rationale can be applied regarding the use of the stainless steel ligature instead of an elastic ligature because, in the daily clinic, either device can be used.[14,22,23,24]

In 2010, Plaza *et al.*,[4] investigated variations of the manufacturer-supplied torque and angulation values among different brands of the MBT prescription, revealing statistically significant variations in angulation among the studied brands. Unfortunately, the methodology used in the study by Plaza *et al.*[4] does not allow direct comparison with the results found here. Nevertheless, it is clearly important for the orthodontist to have knowledge regarding the preadjusted brackets that he/she is using. The methodology employed in the present study also does not allow an accurate determination of whether a particular bracket type has the same angulation as the original Andrews bracket.[5] Such an investigation would also require knowledge of how the industries produce their accessories.

Although seldom studied, the mesiodistal angulation of brackets cannot be ignored because unexpected differences can lead to negative clinical effects in the treatment. Therefore, the findings in this study are of utmost importance. Although the information given by the manufacturers of different brands may be the same, the study bracket measurements are different, requiring bends to be made in the wire during orthodontic completion to move the teeth into a proper position. These results should raise awareness among orthodontists of the importance of not mixing brands of brackets because the same prescription does not guarantee that tooth movement will be equal. Further studies should be performed to assess the amount of tooth movement promoted by different brands, to serve as guidance to orthodontists.

Conclusion

Within the methodology used in this study, it can be concluded that the tested brackets had different mesiodistal angulations, even though they shared the designation of the "Roth prescription". Therefore, the mixing of different brands of brackets should be avoided.

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