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ORIGINAL RESEARCH

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# Wire Roughness Assessment of 0.016″ × 0.022″ the Technique Lingual Orthodontics

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## ABSTRACT

**Objective:** To evaluate the difference in surface roughness of stainless steel archwires of different commercial brands used in lingual orthodontics.

**Materials and methods:** Precontoured arches measuring 0.016″ × 0.022″ were selected of the following brands: Tecnident, Adenta, G&H, Highland Metals Inc., Ormco, Incognito, and Ebraces. Quantitative evaluation of the surface roughness of archwires was performed by means of an atomic force microscope in contact mode. Three surface readouts were taken of each sample, analyzing areas of 20 × 20 μm. Each scan of the samples produced a readout of 512 lines, generating three-dimensional images of the wires. The analysis of variance statistical test was applied to prove significant variables ($p > 0.05$), with $H_0$ being rejected and $H_1$ accepted.

**Results:** The Incognito brand showed the lowest surface roughness. The archwires of brands Adenta, Tecnident, Highland, and Ormco showed similar values among them, and all close to these obtained by the Incognito brand. The archwires of the Ebraces brand showed the highest surface roughness, with values being close to those of the G&H Brand.

**Conclusion:** There was a statistical difference in surface roughness of orthodontic archwires among the brands studied.

**Clinical significance:** Companies should pay attention to the quality control of their materials, as these may directly affect the quality of orthodontic treatment.

**Keywords**: Orthodontic wires, Orthodontics, Surface roughness.

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## INTRODUCTION

The high demand for more esthetic orthodontic treatment has resulted in the lingual orthodontic technique being an excellent option for patients seeking to correct dentofacial disharmony and add value to the smile during orthodontic treatment. Consequently, an increasing number of studies have been conducted with the lingual appliance.[1-3]

An initial disadvantage of the lingual orthodontic technique is that the patient may experience difficulty with phonation, eating, and performing oral hygiene; however, all the symptoms are well tolerated and minimized after the first month of use.[4-6] With advancement in the technique, various laboratory protocols have been developed, seeking placement of lingual brackets in a more gingival position of the teeth. Thus, the differences between the morphologies of the lingual faces have been diminished, allowing the use of straight arches without bends.[7] Placement of the bracket in a more cervical position has allowed it to be closer to the center of resistance, thus maximizing control of orthodontic movement.[1]

With the aim of achieving better adaptation and improvement in the end quality of treatments, the manufacturers of brackets and archwires for lingual orthodontics have made completely customized appliances available. Some specific appliances have brackets made of gold alloy, entirely based on scanning of patients' teeth or impressions, with a high level of quality control.[4,8]

When it is necessary to perform retraction movements, there are diverse techniques and protocols with regard to the material and orthodontic archwires used; however, the main choice recommended for all of these is the use of sliding mechanics. The protocol most frequently adopted in these situations is sliding mechanics with 0.016″ × 0.022″ steel archwires quite often accompanied by a temporary esthetic facet fabricated of resin composite that masks the space created by the extraction of teeth.[9-11]

During sliding mechanics, the correct choice of brackets and archwires used is essential to obtain a better clinical result. Among the different factors to be evaluated, surface roughness of the orthodontic wire is primordial, since the increase in surface roughness may generate an increase in friction between the wire and bracket, thus leading to slower and less effective orthodontic treatment.[12,13]

Orthodontic archwires are the components that will determine the quantity of force distributed and the level of stress on the supporting structures of the teeth during the entire active stage of orthodontic therapy.[14] Due to the importance of metal archwire selection in the success and speed of orthodontic treatment, the aim of this study was to evaluate the effect of surface roughness of stainless steel lingual archwires measuring 0.016″ × 0.022″ on the lingual orthodontic technique.

## MATERIALS AND METHODS

Seven commercial brands of stainless steel lingual orthodontic archwires measuring 0.016″ × 0.022″ were evaluated, as in Table 1.

**Table 1:** Brands, lots, and models of archwires

| *Manufacturer* | *Place* | *Lot* | *Model/Material* |
|---|---|---|---|
| Tecnident | Brazil | D-2 | Prietro&Prietro |
| Adenta | Germany | 120413 | STL316X22 Size 3 |
| G&H | United States of America | 308673 | S304vm SS |
| Highland Metals Inc. | United States of America | 16066 | 0.016X0.022 Universal SS |
| Ormco | United States of America | 03H23 | Stb SST |
| Incognito | Germany | Mayra Altieri | Individualized |
| Ebraces | China | Larissa | Individualized |

The samples consisted of rectified archwire segments, measuring 5 mm from the extremity of the arches. The sample segments were immersed in absolute ethyl alcohol grade 99.5% and then taken to an ultrasound appliance for 5 minutes to dissolve and remove any impurity that may have been deposited on the surface of the archwires, capable of influencing the final results of the tests. After this, the samples were fixed to a metal plate with the aid of double-faced tape.[13]

The wire segments were analyzed by means of a piezoelectric scanner for repulsive force, in an atomic force microscope (AFM), nanoscope IIIA Bruker, belonging to the fine film laboratory of the physics faculty of the University of São Paulo. For this purpose, the thin pyramid-shaped tip of a silicon nitride cantilever rod interacts physically with the wire samples, by van der Waal's forces during scanning on the x and y axes.[14] The van der Waal's force exerted on the tip generates deflection of the rod, i.e., read by photodetectors (Fig. 1). The differences in height on the z axis, with reference to the surface topography of the wire, are mapped on the x and y axes. Thus, an AFM image is the x, y, z map reproducing three-dimensional (3D) images of the surface, determining the roughness of the material studied.[15]

Three scans of the surface were performed on each sample, analyzing an area of 20 × 20 μm, one in the center of the sample, one 2 mm to the left, and one 2 mm to the right of the first mentioned area. During each scan of the samples, readouts of 512 lines were made, generating 3D images processed by the software of the appliance itself.[14,15]

Figure 2 shows 3D images of the topography of the archwires tested, proving the existence of topographic irregularities observed in all the archwires tested.

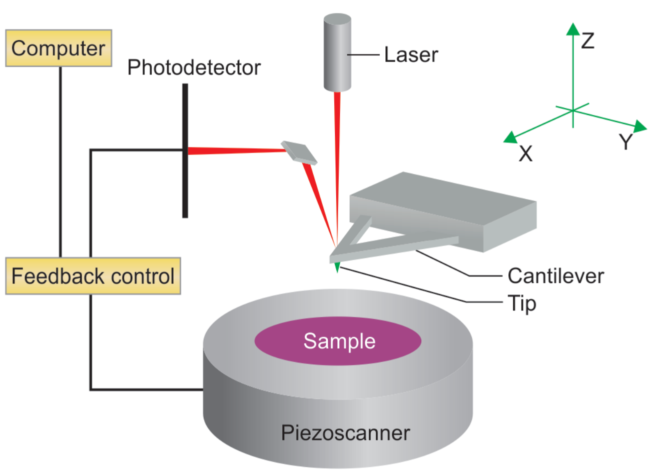



**Fig. 1:** Diagram of atomic force microscope in contact-mode. Source https://amyhallr.wordpress.com/2013/03/15/atomic-force-microscopy

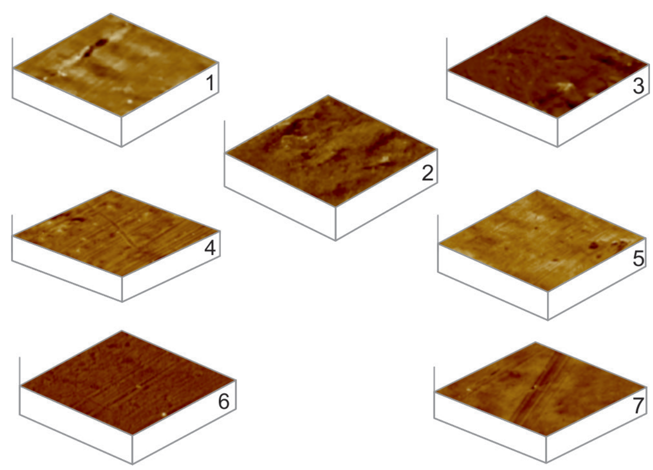
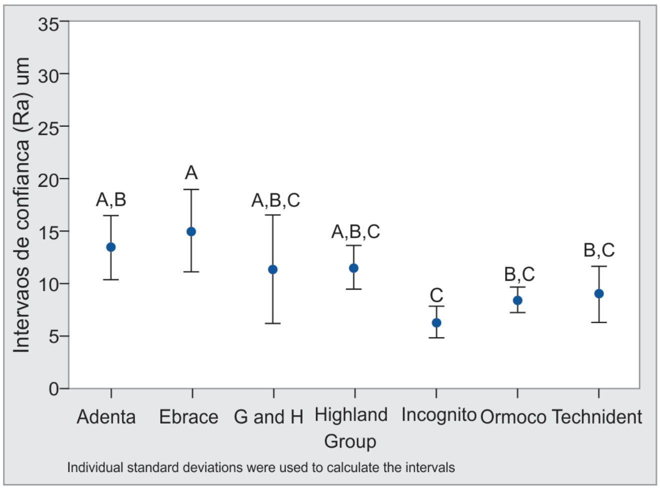
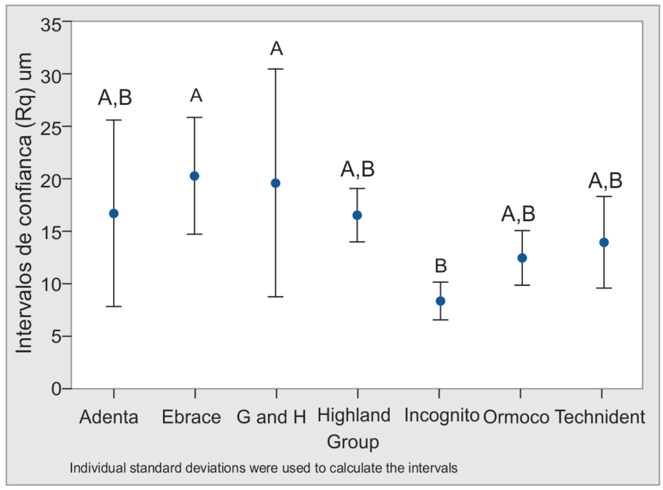



**Fig. 2:** Three-dimensional models of the archwires, (1) Adenta; (2) Ebrace; (3) G&H; (4) Highland; (5) Incognito; (6) Tecnident; and (7) Ormco




**Graph 1:** Intervals of confidence of 95% of the multiple comparisons between the commercial brands for the variable Ra




**Graph 2:** Intervals of confidence of 95% of the multiple comparisons between the commercial brands for the variable Rq

## RESULTS

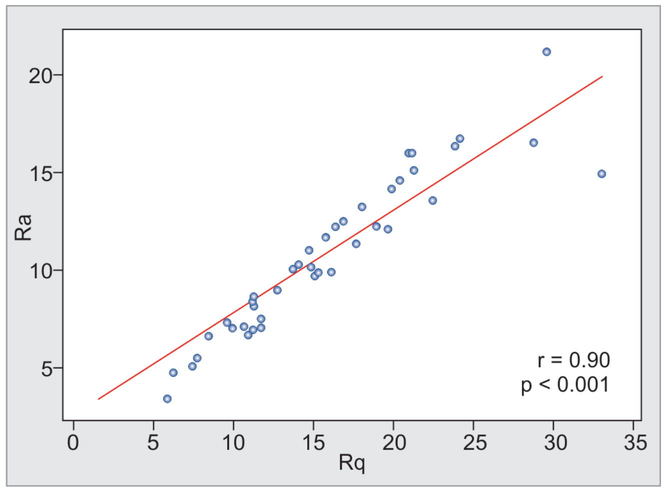
After capturing 3D images, the AFM software generated a table with the numerical data of the images, with the roughness measurements of the archwires. Roughness was measured in two ways: (a) The Ra measurement is the arithmetic mean roughness, i.e., the mean value of the entire surface studied, and may on some occasions not express the real state of the surface. (b) The measurement Rq is the mean quadratic roughness, i.e., a parameter corresponding to the Ra elevated to the square that accentuates the effects of the irregularities.[12]

In the statistical analysis, the two variables Ra and Rq were used, and a single factor of variation that was the commercial brand analyzed. The experimental design chosen was one-way analysis of variance for each variable of Ra and Rq. Both variables were shown to be significant ($p > 0.05$), thus rejecting $H_0$ and accepting $H_1$, demonstrating the influence of the Ra and Rq values on the different commercial brands.

Tukey multiple comparisons test was applied to each variable, to identify the possible differences between the commercial brands analyzed.

As presented in Graph 1, the highest Ra values observed were shown for archwires of the Ebraces brand, and the lowest for the Incognito brand. The brands Adenta, Highland, and G&H presented similar Ra values among them, and close to the values observed for the commercial brand Ebrace, whereas the roughness values of the Tecnident and Ormco archwires were similar to each other and close to the values obtained by the Incognito brand.

In the variable Rq, presented in Graph 2, the highest values observed were also for the brand Ebrace, and the lowest again for the Incognito brand, with the Adenta, Highland, Tecnident, and Ormco brands showing similar values among them, and close to those of the Incognito, and G&H brand showing similar values to those observed for the Ebraces brand.




**Graph 3:** Dispersion graph between the variables Ra and Rq. The Pearson correlation test was significant (p<0.001)

The relationship between the variables Ra and Rq was studied by the Pearson correlation test and is demonstrated in Graph 3. A strong, positive correlation was observed, with $p < 0.01$. The correlation pointed out that there is a significant association between Ra and Rq so that the increase in one involves an increase in the other.

## DISCUSSION

The correct magnitude of forces and control of friction generated at the archwire and bracket interface during sliding movements may result in a better tissue response, and consequently in swifter tooth movement. Therefore, these factors are of the utmost importance for performance of the orthodontic treatment.[15]

In the lingual technique, retraction mechanics may be performed according to different protocols, by varying the orthodontic archwire caliber and material. Anterior tooth retraction may be performed with stainless steel archwires measuring 0.018″ × 0.018″ or 0.019″ × 0.019″, depending on the slot size of the bracket used. However, the protocol most frequently used is stainless steel archwire 0.016″ × 0.022″ in slot 0.018″ × 0.025″. This allows good mechanical control because archwires of smaller caliber make it difficult to control the torque on anterior teeth, while larger caliber archwires, or those made of other metal alloys, such as nickel titanium or titanium molybdenum alloy, generating a large amount of friction in the retraction stage.[10,11,16]

Topographical study of an orthodontic archwire surface is essential, because this property may have a strong influence on orthodontic mechanics. Rougher archwires induce greater friction and, therefore, retard dental movement.[15] Furthermore, greater surface roughness may change the esthetic appearance of the orthodontic archwire, making it more opaque and may even change its biocompatibility, since a rougher surface is more prone to bacterial plaque accumulation.[17,18]

The surface roughness of an orthodontic archwire may be studied using various methods, such as scanning microscopy, rugosimeters, and the AFM.[13] The AFM is essential for studying surface roughness on nanometric scales and is superior to other methods as regards precision of the analysis.[19]

This study evaluated seven commercial brands of stainless steel lingual orthodontic archwires of 0.016″ × 0.022″, both of the customized and noncustomized type, representing some of the brands most used worldwide. By means of AFM, the authors observed that there was statistical difference for both the variables Ra and Rq among the different commercial brands analyzed in this study, in Graphs 1 and 2.

The customized archwires of the Incognito brand showed the lowest Ra and Rq values, followed by the Adenta, Highland, Tecnident, and Ormco brands, whereas the customized Ebraces archwire showed elevated Ra and Rq values. The G&H brand archwires showed values close to those of the customized Ebraces archwire. The Rq measurements showed a higher standard deviation than the values obtained by Ra because the quadratic roughness accentuates the effects of the surface irregularity of the material analyzed.

In the Pearson test, in Graph 3, a strong positive correlation was obtained between the variables Ra and Rq.

Clinically, the higher level of surface roughness, such as that observed in some types of archwires evaluated in this research, may make orthodontic treatment difficult, particularly in the movements of space closure, when sliding between the archwire and bracket is primordial for the success of this part of orthodontic mechanics.[7,20]

The higher frictional resistance caused by this increase in orthodontic archwire surface roughness would lead to the need for using higher force during space closure and may result in damage to the tissues, such as tooth resorption, bone resorption, gingival retraction, and pulp necrosis.[16]

The difference in surface roughness observed in this research may have been caused by a failure in quality control during manufacture of the orthodontic archwires. Further studies are necessary to evaluate the quality of materials used in orthodontics, since they benefit the mechanics of orthodontic treatment and minimize possible tissue damage in patients.

## CONCLUSION

The authors concluded that there is difference in the surface roughness of 0.016″ × 0.022″ orthodontic archwires among the commercial brands studied.

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