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ORIGINAL ARTICLE

Effect of sodium bicarbonate air abrasive polishing on resistance to sliding during tooth alignment and leveling: An *in vitro* study

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ABSTRACT

Objective: The aim of this *in vitro* study was to evaluate the Resistance to Sliding (RS) provided by metallic brackets and 3 types of orthodontic wires (TMA, SS and NiTi), before and after the use of sodium bicarbonate airborne particle abrasion, in an experimental model with 3 non leveled brackets. **Materials and Methods:** The bicarbonate airborne abrasion was applied perpendicularly to the bracket slots at a distance of 2 mm, for 5 seconds (T2) and 10 seconds (T3) on each bracket slot. In a universal testing machine, the wires were pulled through a set of 3 non leveled brackets at a cross head speed of 50 mm/min for a distance of 10 mm, and static and kinetic friction readings were registered at T1 (no airborne abrasion), T2 and T3. **Results:** For all tested wires, a significant RS increase between T1 and T3 (P<0.001) was seen. For SS and TMA wires, there was a statistically significant RS increase between T1 and T2 (P<0.001). Between T2 and T3, RS increase was significant for TMA (P<0.001) and NiTiwires (P<0.05). **Conclusions:** Sodium bicarbonate air abrasive polishing during orthodontic treatment is not recommended, once this procedure promoted a significant RS increase between the metallic brackets and all the three types of wires tested.

Key words
Air abrasion, friction, orthodontics

INTRODUCTION

In many situations during orthodontic treatment (closure of extraction sites, space recovery, and at the initial phase of leveling and alignment of the teeth), the sliding between the orthodontic wire and brackets is an important mechanism that can affect the efficiency of tooth movement.

The Resistance to Sliding (SR) is divided into 3 components: the first component, classical friction (FR), is the force that resists the movement between two objects as the product of the normal load (N) and the coefficient of friction (μ). FR exists as the only component of SR when the arch wire and bracket have clearance and are in a passive configuration and the angulation (θ) between the arch wire and bracket is less than the critical angulation. When the wire contacts both ends of the bracket slot, an interference fit occurs, and binding (BI) arises as a second component of RS. The third component, notching (NO), occurs when the wire's plastic deformation happens at the wire-bracket corner interface. Tooth movement stops when a notched wire catches on the bracket corner and resumes only when the notch is released.[1] It has been suggested that notching is produced due to vertical movements of the teeth or wire during mastication.[2]

During orthodontic therapy, the fixed appliances increase the number of plaque retention sites and hence, the caries likelihood. Consequently, professional tooth cleaning could be extremely important for the maintenance of oral health, especially when patient compliance is inadequate or when dexterity is poor.[3] Compared to professional tooth cleaning with rubber cup and pumice, air-polishing devices are more effective for removing dental plaque, and in addition they promote less operator fatigue due to reduced working time.[4]

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Many studies evaluated the factors that could influence the RS, such as proprieties related to bracket and wires materials,[5-10] type and force of ligation,[8,11-13] and biological variables.[14,15] However, little research has been conducted to evaluate the effect of sodium bicarbonate air abrasive polishing on RS at tooth alignment and leveling phase of orthodontic treatment. Therefore, the aim of this study was to evaluate *in vitro* the frictional resistance (static and kinetic) provided by metal brackets, using 3 types of orthodontic wires (Stainless Steel, TMA and NiTi), before and after the use of the sodium bicarbonate airborne particle abrasion, in an experimental model with 3 non leveled brackets.

MATERIALS AND METHODS

RS of 3 types of wires in association with Stainless Steel (SS) brackets was investigated, and 90 samples were divided into 3 groups ($n = 30$) as described in Table 1. The wires were manufactured by Morelli (Morelli, Sorocaba-SP, Brazil) or TP Orthodontics (TP Orthodontics Inc., La Porte, USA).

In this present study, we used an experimental model with 3 non leveled brackets to assess the frictional forces generated during the dental alignment process. To prepare the samples, 270 stainless steel standard edgewise brackets.022"(10.30.201, Morelli, Sorocaba-SP, Brazil) were employed. Stainless steel brackets were used because they have the lowest influence on frictional resistance.[16,17]

The samples were prepared by bonding 3 brackets on an acrylic block (0.5 × 6 × 3cm), which was designed to simulate a non aligned dental segment that included 2 premolars and one canine. The brackets were bonded with epoxy resin (Durepoxi; Alba, Boituva, Brazil), and the bonding procedure was standardized by using the device showed in [Figure 1]. At the base of the device, stops were welded in the stainless steel wire (0.021" × 0.025"), perfectly positioned at distal and mesial sides of the brackets. The device's 0.022-in thickness lamina remains parallel to both the long axis of the block and the test plane during the bonding procedure, so that the bracket's tipping could be avoided at any direction.

The vertical discrepancy between the brackets was set at 2 mm to simulate a non alignment situation in the segment of dental arch to be studied. The inter bracket distance was set at 11mm, according to a previous study.[8]

The brackets and wires were washed in 95% ethanol and air-dried, and then one wire segment of 6 cm was positioned on the brackets slots for each sample. Several studies have documented that a high force generated by a tight ligation will cause an increase in the measurement of frictional force.[16] To reduce the potential for such bias, all ligations were done by the same operator using a needle holder in a standardized procedure. The ligatures used in this study were elastomeric modules (Super slick clear, TP orthodontics Inc., La Porte, USA).

After the wire/brackets assembly, the samples were kept for 2 hours in a temperature-controlled environment (36.5°C) immersed into artificial saliva (0.0625% KCl, 0.0865% NaCl, 0.0056% $MgCl_2$, 0.0166% $CaCl_2$, 0.0804% Na_2HPO_4, 0.0326% KH_2PO_4, 4.274% sorbitol, 0.0004% NaF, 0.1% C6H5COONa, 2% carboxymethylcellulose, and distilled water). This procedure was performed to simulate the effect of moisture on elastomeric ligatures. Taloumis *et al.*[18] reported that moisture had a pronounced effect on force decay and permanent deformation of elastomeric ligatures.

An apparatus [Figure 2] standardized the position of

Table 1: Groups and wires tested

Group	Wire (Alloy)	Dimensions	Manufacturer
1	Stainless steel	0.016"	Morelli
2	TMA	0.016"	Morelli
3	NiTi	0.016"	TP orthodontics

Figure 1: Device used to standardize the bonding procedure

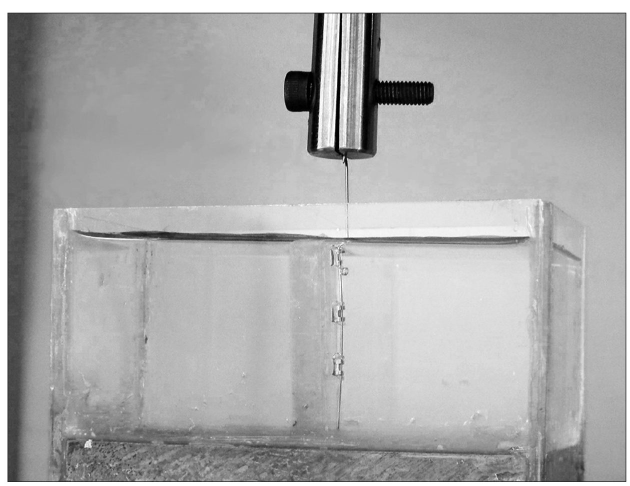

Figure 2: Device used in frictional force test

the specimens in the universal testing machine (Model DL-500; Emic Equipamento e Sistemas de Ensaio, São José dos Pinhais, Brazil) by placing the acrylic blocks into a canal that allowed the alignment of the brackets' long axis to the test course. This device included acrylic walls for artificial saliva storage (480 ml) to allow the tests conduction under saliva immersion at room temperature (25°±2°C). A grip on the upper end of the machine, attached to a 100N load cell, moved the wire through the brackets slots with a cross head speed of 50 mm/min for a distance of 10mm. One frictional force test for each sample was performed, resulting in 30 tests per group (n=30).

During the frictional force tests Static Friction (SF) and Kinetic Friction (KF) readings were performed. SF readings were obtained by determining the peak force (N) at the first 2 mm of wire displacement. KF readings were obtained by determining the average force (N) at the last 8 mm of the wire displacement. This mode of data acquisition allows differentiation between SF and KF, in situations in which these variables behave as expected (SF>KF), as well as in atypical situations (KF>SF). This atypical situation was described by Hamdanand Rock.[19]

The sodium bicarbonate airborne abrasion was performed with a deviceProfi II Ceramic (DabiAtlante, RibeirãoPreto-SP, Brazil), using sodium bicarbonate particles (DabiAtlante, RibeirãoPreto-SP, Brazil). The sodium bicarbonate powder was inserted in the device up to 90% of its reservoir total capacity, replacing the powder when it reached 75%. The airborne abrasion was applied perpendicularly to each bracket slots at a distance of 2 mm with a 2.3 bar pressure [Figure 3], on all 3 brackets of the samples. For T2, 5 seconds of airborne abrasion was applied on each bracket slot, totaling 10 seconds of application per bracket. For T3, 10 seconds of airborne abrasion was applied on each bracket slot, totaling 20 seconds of application per bracket. The frictional force tests were performed before sodium bicarbonate air abrasive polishing (T1) and after bicarbonate air abrasive polishing (T2 and T3).

Statistical analysis

By admitting the normal distribution for the dependent variable (force), according to the independent variables (wire, friction, and time), we used two-way ANOVA, with repeated measures for time, once $n \geq 30$. When ANOVA indicated statistically significant differences among factors ($P<0.05$), multiple comparisons were executed by Games-Howell parametric multiple comparison test because Levene variance homogeneity test indicated heterogeneous variances for the variable force, according to the variables wire, friction and time.

RESULTS

Figure 4 shows the comparison among the confidence intervals for the force mean values (N), according to the variable friction (SK and KF), regardless of the variables wire (TMA, SS, and NiTi) and time (T1, T2, and T3). Note that SF>KF ($P<0.001$).

Figure 5 presents the effect of sodium bicarbonate airborne abrasion on the Resistance to Sliding (RS), in Newton (N), at T1, T2, and T3, regardless of the wire type (TMA, SS, and NiTi) and of the friction type (SK and KF). Observe that RS increases in function of the airborne abrasion time, occurring statistically significant differences between T1 and T2 ($P<0.001$), T1 and T3 ($P<0.001$), and T2 and T3 ($P<0.05$).

Figure 6 demonstrates the influence of the wire's metallic alloys on RS increase at T1, T2, and T3. For all wires tested, there was a significant RS increase between T1 and T3 ($P<0.001$). In Table 2, we observe the results of Games-Howell multiple comparison tests according to the variables wire and time.

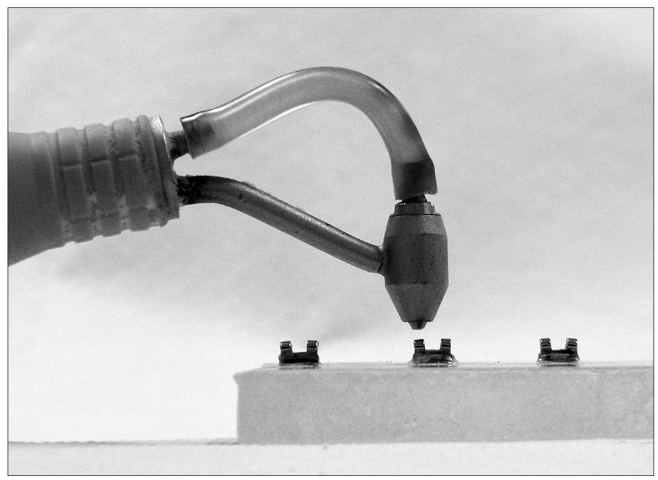

Figure 3: Standard position of the airborne abrasion device hand piece

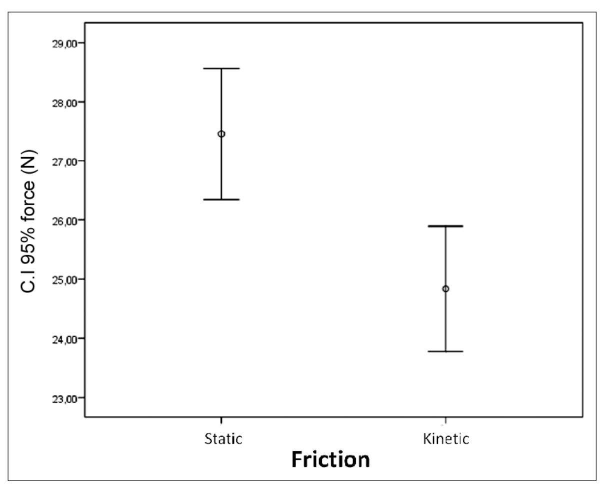

Figure 4: Comparison of the confidence intervals for the force mean values (N) according to the variable friction (SK and KF), regardless of the variables wire (TMA, SS, and NiTi) and time (T1, T2, and T3)

Figure 7 shows the confidence intervals of the force mean values (N), according to the independent variables friction, wire and time simultaneously. Table 3 exhibits Games-Howell multiple comparison test according to SF and KF. The same behavior of the variables (friction, time, and wire) observed in Figures 4-6 was repeated in Figure 7, once ANOVA indicated the existence of interaction between the variables wire and time ($P<0.001$); there was not a interaction between wire and friction, friction and time, and among the 3 variables simultaneously ($P>0.05$).

DISCUSSION

The aim of this study was to evaluate the effect of sodium bicarbonate air abrasive polishing on RS during tooth alignment and leveling phase, using an experimental model with 3 non leveled brackets. The bicarbonate airborne abrasion on orthodontic wires was not performed in this experimental model to simulate a clinical situation in which prophylaxis is only performed after the arch wire removal.

By comparing SF and KF, it was verified that regardless of the variables wire and time, KF showed smaller mean force values than SF [Figure 4] ($P<0.001$), i.e. the force required to initiate the wire sliding on the bracket's slots will always be greater than the force required to maintain it.

By analyzing the effect of the bicarbonate airborne abrasion time on RS [Figure 5], we observed that RS increases in function of the airborne abrasion time, with statistically significant differences between T1 and T2 ($P>0.001$), T2 and T3 ($P>0.05$), and T1 and T3 ($P>0.001$). This fact can be explained by the bicarbonate abrasiveness which makes the bracket slot's walls

Table 2: Games-Howell multiple comparison test for the variable force (N)

			Mean difference (I-J)	Std. error	Significant	95% confidence interval	
						Lower bound	Upper bound
TMA/T1	×	TMA/T2	−10,46667*	1.37387	0.0000	−14.8136	-6.1198
TMA/T1	×	SS/T1	−0.25000	1.49085	1.0000	−4.9617	4.4617
TMA/T1	×	NiTi/T1	1.78333	1.12277	0.8076	−1.8162	5.3828
TMA/T2	×	TMA/T3	−5,30000*	1.05623	0.0001	−8.6421	−1.9579
TMA/T2	×	SS/T2	−3.26667	1.18677	0.1413	−7.0171	0.4837
TMA/T2	×	NiTi/T2	11,81667*	0.97157	0.0000	8.7325	14.9009
TMA/T3	×	SS/T3	1.30000	0.87742	0.8619	−1.4730	4.0730
TMA/T3	×	NiTi/T3	15,45000*	0.73305	0.0000	13.1212	17.7788
SS/T1	×	SS/T2	−13,48333*	1.32043	0.0000	−17.6590	−9.3077
SS/T1	×	NiTi/T1	2.03333	1.05637	0.5994	−1.3515	5.4182
SS/T2	×	SS/T3	−0.73333	1.03086	0.9985	−3.9975	2.5308
SS/T2	×	NiTi/T2	15,08333*	0.97194	0.0000	11.9980	18.1687
SS/T3	×	NiTi/T3	14,15000*	0.69548	0.0000	11.9427	16.3573
NiTi/T1	×	NiTi/T2	−0.43333	0.56307	0.9974	−2.2215	1.3549
NiTi/T2	×	NiTi/T3	−1.66667	0.60472	0.1412	−3.5812	0.2479

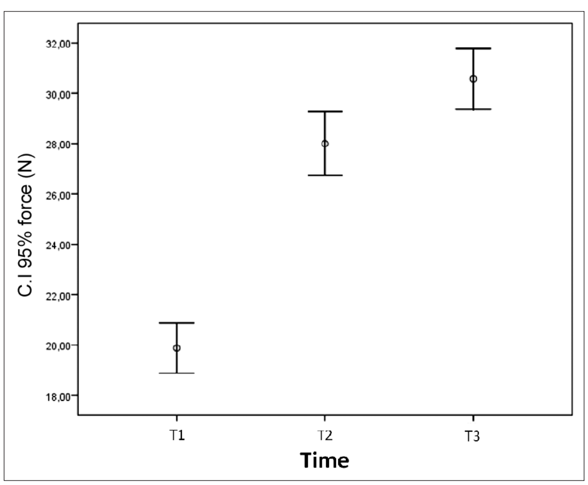

Figure 5: Comparison of the confidence intervals for the force mean values (N), according to time (T1, T2, and T3) regardless of the variables wire (TMA, SS, and NiTi) and friction (SF and KF)

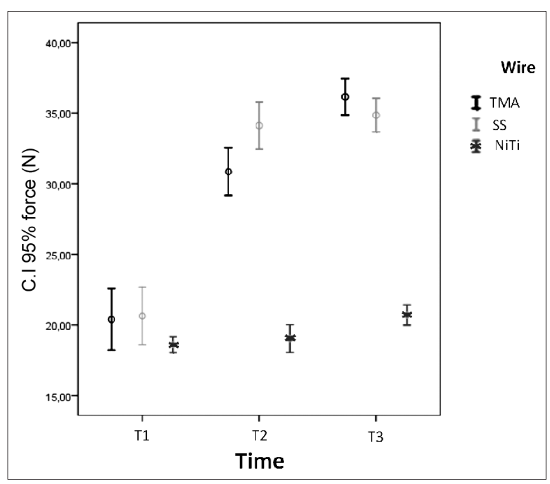

Figure 6: Comparison of the confidence intervals for the force mean values (N) at T1, T2 and T3, according to the different wires, regardless of the variable friction (SF and KF)

rougher consequently increasing RS. Parmagnani *et al.*[20] after performing sodium bicarbonate airborne abrasion on metallic and ceramic brackets observed through electron microscopy that metallic bracket abrasion modifies the slots' surface, producing visible irregularities at ×1000 magnification.

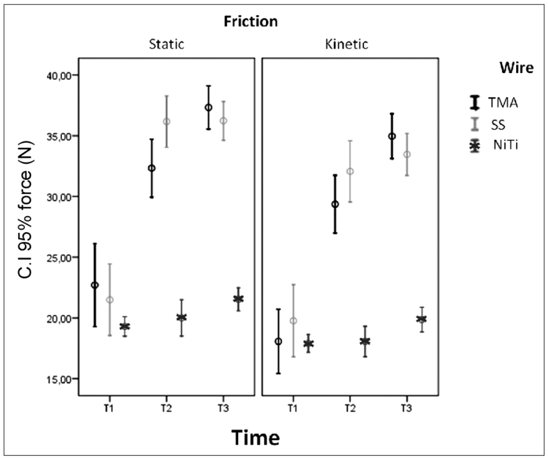

Figure 7: Confidence intervals of force mean values (N) according to friction (SF and KF), time (T1, T2, and T3) and wire (TMA, SS, and NiTi)

The influence of the wires' metallic alloys on RS increase can be observed in Figure 6. We noted that both for Stainless Steel (SS) and TMA wires, an airborne abrasion time of 5 seconds/slot was sufficient for promoting a significant RS increase because the difference between T1 and T2 for these wires was statistically significant (P<0,001). For NiTi wire, 5 second/slot airborne abrasion was not capable of significantly increasing RS, because the difference between T1 and T2 was not statistically significant (P>0.05). At T2, the greatest increase in RS levels was found for the SS wire (65.34%), followed by TMA (51.34%) and NiTi (2.32%).

However, for all the wires tested, there was a significant RS increase between T1 and T3 (P<0.001), demonstrating

Table 3: Games-Howell multiple comparison test according to SF and KF

				Mean difference (I-J)	Std. error	Significant	95% confidence Interval	
							Lower bound	Upper bound
Kinetic friction	TMA/T1	×	TMA/T2	−11,30000*	1.73829	0.00000	−17.6480	−4.9520
	TMA/T1	×	SS/T1	−1.70000	1.94382	0.99998	−8.7992	5.3992
	TMA/T1	×	NiTi/T1	0.16667	1.34017	1.00000	−4.8883	5.2216
	TMA/T2		TMA/T3	−5,60000*	1.47154	0.03362	−10.9859	−0.2141
	TMA/T2	×	SS/T2	−2.70000	1.69137	0.97668	−8.8744	3.4744
	TMA/T2	×	NiTi/T2	11,30000*	1.31430	0.00000	6.4344	16.1656
	TMA/T3	×	SS/T3	1.50000	1.23848	0.99881	−3.0213	6.0213
	TMA/T3	×	NiTi/T3	15,10000*	1.03081	0.00000	11.2895	18.9105
	SS/T1	×	SS/T2	−12,30000*	1.90198	0.00000	−19.2507	−5.3493
	SS/T1	×	NiTi/T1	1.86667	1.49408	0.99767	−3.7806	7.5139
	SS/T2	×	SS/T3	−1.40000	1.49302	0.99995	−6.8803	4.0803
	SS/T2	×	NiTi/T2	14,00000*	1.37370	0.00000	8.9048	19.0952
	SS/T3	×	NiTi/T3	13,60000*	0.98315	0.00000	9.9732	17.2268
	NiTi/T1	×	NiTi/T2	−0.16667	0.70838	1.00000	−2.7815	2.4481
	NiTi/T2	×	NiTi/T3	−1.80000	0.79027	0.69464	−4.6900	1.0900
	NiTi/T1	×	NiTi/T3	−1.96667	0.61041	0.14891	−4.2055	0.2722
Static friction	TMA/T1	×	TMA/T2	−9,63333*	2.03390	0.00206	−17.0959	−2.1708
	TMA/T1	×	SS/T1	1.20000	2.20078	1.00000	−6.8406	9.2406
	TMA/T1	×	NiTi/T1	3.40000	1.71156	0.85476	−3.0726	9.8726
	TMA/T2	×	TMA/T3	−5.00000	1.45797	0.09088	−10.3405	0.3405
	TMA/T2	×	SS/T2	−3.83333	1.55838	0.56830	−9.5252	1.8586
	TMA/T2	×	NiTi/T2	14,26667*	1.31854	0.00000	9.3847	19.1486
	TMA/T3	×	SS/T3	1.10000	1.17054	0.99996	−3.1750	5.3750
	TMA/T3	×	NiTi/T3	15,80000*	0.98968	0.00000	12.1369	19.4631
	SS/T1	×	SS/T2	−14,66667*	1.77066	0.00000	−21.1592	−8.1742
	SS/T1	×	NiTi/T1	3.60000	1.48099	0.59188	−1.9969	9.1969
	SS/T2	×	SS/T3	−0.06667	1.29346	1.00000	−4.8038	4.6705
	SS/T2	×	NiTi/T2	16,16667*	1.26590	0.00000	11.5234	20.8099
	SS/T3	×	NiTi/T3	16,36667*	0.92403	0.00000	12.9673	19.7660
	NiTi/T1	×	NiTi/T2	−0.70000	0.83066	0.99999	−3.7734	2.3734
	NiTi/T2	×	NiTi/T3	−1.53333	0.86667	0.94083	−4.7224	1.6558
	NiTi/T1	×	NiTi/T3	−2.23333*	0.60815	0.04766	−4.4558	-0.0109

KF - Kinetic friction; SF - Static friction that the cumulative effect of a total time of airborne abrasion of 15 seconds/slot is capable of significantly increasing RS for SS, TMA and NiTiwires [Figure 6]. Between T1 and T3, the greatest increase in RS levels was found for TMA wire (77.35%), followed by stainless steel (68, 90%) and NiTi (11,29%) wires.

The NiTi wires suffered the least influence on RS levels when bicarbonate airborne abrasion is performed on metallic brackets. This fact can be explained due to the low stiffness of this wire. Concerning to the SS wires, despite of their low superficial rugosity, their high stiffness induces a more intense contact between the wire and the unleveled bracket's slots. Therefore, the slots' rugosity increase promoted by the airborne abrasion produces significant RS increase for SS wires. Although TMA wires present a low stiffness when compared to SS wires, they show statistically similar RS levels at T3 ($P>0.05$). This can be explained by TMA's high superficial rugosity, opposing to the effect of this material's low stiffness on RS levels.

In Figure 7, we observed that both for stainless steel and TMA wires there was a significant KF and SF increase between T1 and T2 ($P<0.001$), and between T2 and T3 ($P<0.001$). For NiTi wires, it was noted that there was not a significant increase both for SF and KF between T1 and T2, and between T2 and T3 ($P>0.05$). However, between T1 and T3, there was a significant increase in SF values ($P<0.05$), but not for KF values ($P>0.05$), for NiTi wires [Table 3].

The results observed in this present research allowed us to conclude that sodium bicarbonate air abrasive polishing during orthodontic treatment should be contra-indicated due to RS increase caused by the aforementioned procedure. This fact may negatively affect the orthodontic mechanics, mainly at phases in which is necessary the wire sliding on the bracket. Such results are in agreement with Parmagnani and Basting,[20] who after conducting an *in vitro* study, did not recommend sodium bicarbonate air abrasive polishing on metallic and ceramic bracket's slots. These authors also observed a significant RS level increase after the airborne abrasion of metallic and ceramic bracket's slots.

However, Wilmes *et al.*[21] affirmed that bicarbonate air abrasive polishing does not cause problems related to an increase of friction during orthodontic treatment. After executing the airborne abrasion on orthodontic wire surfaces, the authors considered that the friction increasing (2.5%) observing in their study would not be clinically relevant. This contrasts to this study's results, in which we observed a RS increase of up to 77.35% (TMA/T3) after a total airborne abrasion time of 15 seconds/slot. Such differences can be explained by the differences existing between the two experimental models. While Wilmes *et al.*[21] employed an experimental model with only one bracket without angulation alterations and performed the airborne abrasion on the wire surfaces, we used an experimental model with 3 unleveled brackets and airborne abrasion on each bracket's slots. Therefore, the effect of the airborne abrasion on RS can be amplified, once the wire contact area with the slot is increased by the larger number of brackets. Additionally, the unleveled brackets also promote an increase in RS due to BI presence in RS (RS=FR+BI).

The results of present study should be interpreted with caution, because *in vivo* factors, such as oral functions (chewing, swallowing, speaking) and others biological factors (presence of dental plaqueand debris for example) are not simulated in this experimental model. Thurow[22] suggested that relatively minute movements of teeth in function provided a "walking" effect that allows a bracket to move along an arch wire more easily. On the other hand, Marques *et al.*[14] observed that the presence of debris on wire surface cause an increase in friction between the wire and bracket. Thus, further studies should be developed in order to assess the influence of sodium bicarbonate air abrasive polishing on the orthodontic mechanics *in vivo*.

CONCLUSIONS

Sodium bicarbonate air abrasive polishing is not recommended because the airborne abrasion of the brackets promoted a significant RS increase when the 3 types of wires (TMA, SS, and NiTi) were used. Concerning to SS and TMA wires, the airborne abrasion effect on RS seems to be greater due to these material's properties, once NiTi wires presented smaller RS increase after the bracket's abrasion due to, probably, its smaller stiffness.

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