Orthodontics

Forces in stainless steel, TiMolium® and TMA® intrusion arches, with different bending magnitudes

Forças em arcos de intrusão, em aço inoxidável, TiMolium® e TMA®, com diferentes magnitudes de deflexão

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Abstract: The present study compared forces in stainless steel, TiMolium® and TMA®, V-bend intrusion arches with different magnitudes of flexion. The sample consisted of rectangular-section wires, caliber .017" x .025", with ten arches of each alloy. All V-bends were made 48 mm from the midline, using the same phantom upper jaw, maintaining the same distance between the tubes fixed to the molars and the midline. Loads necessary to deflect the arches by 5, 10, 15 and 20 mm were measured by means of an Instron dynamometer with a 1 kgf load cell. Calculations for sample size confirmed the suitability of using 10 arches of each alloy. Variance tests (ANOVA) of one factor and three levels, complemented by the Tukey test for multiple comparisons, identified that TMA® intrusion arches required a smaller quantity of load in relation to conventional steel and TiMolium® at all levels of flexion. Furthermore, TiMolium® presented intermediary characteristics between steel and TMA®, and in all alloys increase in distance entailed a significant increase in force between all registered values, and that the increase in load necessary to deflect the arches at the intervals tended to decrease from first to last interval, these differences being more significant in steel, less in TiMolium® and practically non-existent in TMA®.
Descriptors: Orthodontic wires; Dental alloys; Biomechanics; Tooth movement.

Resumo: O presente estudo comparou as forças em arcos de intrusão com dobra V confeccionados em aço inoxidável, TiMolium® e TMA®, com diferentes magnitudes de deflexão. A amostra constou de fios de secção retangular e calibre 0,017" x 0,025", com dez arcos de cada liga. Todas as dobras em V foram confeccionadas a 48 mm distantes da linha média, e foi utilizado o mesmo manequim de maxila para manter a mesma distância entre os tubos fixados nos molares e a linha média. As cargas necessárias para defletir os arcos em 5, 10, 15 e 20 mm foram mensuradas por meio de dinamômetro com célula de carga de 1 kgf, da marca Instron. O cálculo para o tamanho de amostra confirmou a possibilidade de se utilizar dez arcos de cada liga. Os testes de variância (ANOVA) de um fator e três níveis, complementados com os testes de Tukey para comparações múltiplas, identificaram que os arcos de intrusão de TMA® requereram menor quantidade de carga em relação ao aço convencional e ao TiMolium® em todos os níveis de deflexão; que o TiMolium® apresentou características intermediárias entre o aço e o TMA®; que em todas as ligas o aumento das distâncias implicou em aumento significativo da força entre todos os valores registrados; e que os incrementos de carga necessários para defletir os arcos nos intervalos tenderam a decrescer do primeiro ao último intervalo, sendo essas diferenças mais significantes no aço, menores no TiMolium® e praticamente inexistentes no TMA®.
Descritores: Fios ortodônticos; Ligas dentárias; Biomecânica; Movimentação dentária.

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Introduction

Technically, several recourses are available to produce intrusion movement of anterior teeth, in cases of accentuated overbite. It is known that this movement is most susceptible to cause root resorption, and that forces beyond biological limits are involved in consequent damage to adjacent supporting tissues. Thus, proper application of intrusion mechanics is essential to achieve results with minimal side effects.[8]

Consolaro[7] (2005) affirms that the force required to move a tooth, called the optimum or ideal force, established by Schwarz[18] in 1932 as being slightly more than 20 to 26 gf per square centimeter of superficial root, is merely conceptual, as technology is not available for such measurement and calibration.

The results of studies by Chiqueto *et al.*[6] (2005) revealed a higher degree of root resorption with the use of intrusive mechanisms. Real intrusion is generally difficult to be obtained. Ng *et al.*[16] (2005) carried out a meta-analysis and identified an average intrusion of 1.46 mm for inferior incisors and 1.9 mm for superior incisors.

Intrusion arches are used in different orthodontic techniques varying in cross section and wire alloy, very much as in design. Burstone[2] (1977) cited principles which should be considered for the intrusion of incisors or canines, these being the use of optimum force magnitude and constant liberation of this force; the use of a sole contact point in the anterior region, taking care in the selection of the force application point in relation to the center of resistance of the teeth to be intruded; intrusion selection based on the geometry of anterior teeth; formation of posterior anchoring and inhibition of posterior teeth eruption.

Along with factors interfering in force magnitude transmitted to anterior teeth, quantity and size of teeth involved in the process are included, as well as the distance of the molar tube to the area where the arch will be fixed and the intensity of activation represented by the distance between arch and incisor bracket slot, when the arch is inserted in the molar tubes.

Force values suggested by Burstone *et al.*[5] (2003) for upper incisor intrusion vary from 60 - 80 gf.

The results of a study recently done by Steenbergen *et al.*[19] (2005) did not identify statistical differences between a group of patients using intrusion arches at 40 gf and those using them at 80 gf, considering the rate of incisor intrusion, alteration to axis inclination, extrusion and posterior segment narrowing.

In addition to considering magnitude, it is also necessary to control constancy of force applied, hence the reason why the use of archwires with low rate of load deflection is recommended.

The more resistant to deflection a particular wire is, the faster it will release the force acquired after activation, therefore the lower the ratio load/deflection, the higher the precision in controlling force intensity liberated by said wire.

Since the introduction of beta titanium in Orthodontics,[3,10] commercially known as TMA (titanium-molybdenum alloy), its mechanical properties have been studied by several authors.[3,4,10,12,13,20] TMA presents high springback, less stiffness than steel, high formability, ability to be welded and resistance to corrosion,[11,12,13,15] but it presents excessive friction.[14] It is considered the alloy of choice for the intermediate orthodontic treatment phases.[11]

Devanathan[9] (1999) describes the development of a new titanium alloy, called TiMolium®, affirming that it presents less friction, higher yield strength and increased compressive strength compared to TMA®.

According to Burstone[1] (2001), force magnitude can be defined by the use of tables, or directly, by means of a dynamometer. In addition, at times, clinicians tend to neglect proper force measurement and simply place a double V in the posterior region. The author adds that this could be dangerous since the arch varies in length depending on the perimeter of each patient's dental arch and there is no constant angulation for desirable activation.

The present study proposes a comparison of forces in stainless steel, TiMolium® and TMA® V-bend intrusion arches, with different magnitudes of deflection.

Material and Methods

The study outline considered the use of stainless steel wires ("A" Company, San Diego, California, USA), TiMolium® wires (TP Orthodontics, La Porte, Indiana, USA) and TMA® wires ("A" Company, San Diego, California, USA), all with rectangular section and caliber .017" x .025".

Four distances (5, 10, 15 and 20 mm) from arch to line, representative of bracket slots in the upper dental midline region, were established. In order to favor the site for fitting the hook for testing traction and preventing displacement of mentioned hook in the arch, small folds in the form of a "u" were made in the midline region.

The V-bend, also called anchor bend, for intrusion was made in the region between the first molar and second premolar.[17] Use of a template length arch ruler (TP Orthodontic, La Porte, Indiana, USA) allowed all folds to be made at a distance of 48 mm from midline.

A protractor (Desetec-Trident, Itapuí, São Paulo, Brazil) was used so that all folds had a 45° inclination. The folds thus created produced a 20 mm deflection in relation to the line representing the bracket slots.

The use of a phantom upper jaw with acrylic teeth and an enlarged gum area allowed the fixing of three rulers, one at midline and two in the cuspid region (Figure 1), facilitating bilateral control during arch execution. However, the central ruler was removed prior to testing so as to not interfere with the trial.

The use of the same phantom jaw for all arches of different alloys guaranteed standardization of possible error, since it would be of equal magnitude in the alloys studied.

The first molars had tubes fixed to them and the centre of the upper incisor crowns were marked with steel wire .016" (Morelli, Sorocaba, São Paulo, Brazil) by means of a resin (TPH, Dentsply, Petrópolis, Rio de Janeiro, Brazil) to simulate the bracket slot line. This option was adopted in the event of bracket interference during the test, impeding force measurement.

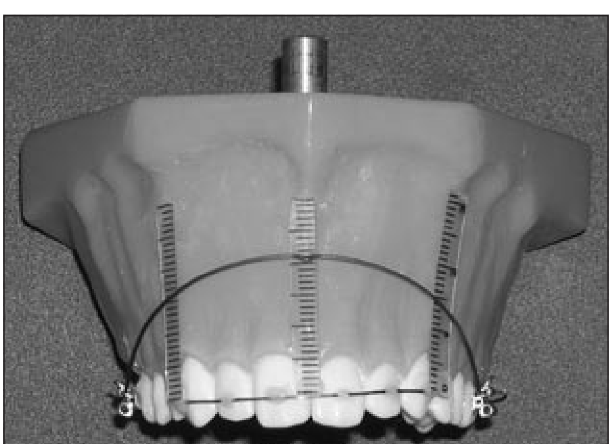

Figure 1 - Phantom upper jaw with gum area enlarged, allowing fixing of three rulers, facilitating bilateral control during arch execution.

Trials were conducted at the SENAI (National Service of Industrial Training) school laboratory ("Francisco Matarazzo" division) and a dynamometer (Instron, model 4500, Canton, MA, USA), recently calibrated by IPT (Instituto de Pesquisas Tecnológicas, São Paulo, SP, Brasil), was used with 1 kgf load cell and 0.0001 kgf resolution.

The extremities of the arches were inserted in the tube accessories of the first molars and bent in the posterior region. A hook was then fixed to the load cell and connected to the arch in the midline region to secure it (Figure 2). Trial speed was standardized at 10 mm/min. The load magnitudes and the displacements (5, 10, 15 and 20 mm) were registered by a computer coupled to the machine.

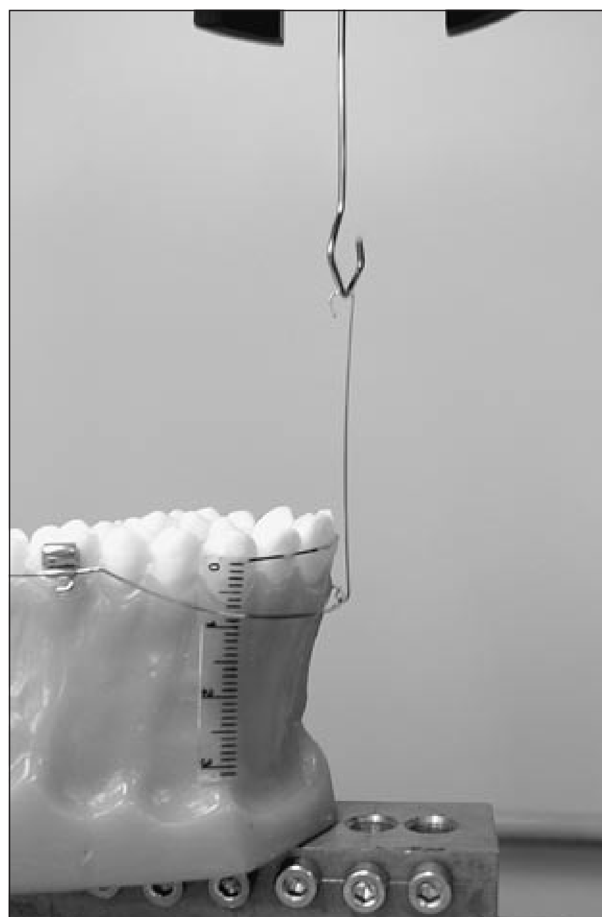

Figure 2 - Hook fixed in the load cell, and connected to the arch in the midline region to secure it fixing of arch.

Statistical method

Identification of the population distribution type was performed by means of the Kolmogorov-Smirnoff test.

The significance level adopted for all tests was 5%. Sample size was determined by sample size test and potency of test. ANOVA of one factor and three levels was used to assess force difference between alloys, and it was complemented by the Tukey test for multiple comparisons.

Results

The Kolmogorov-Smirnoff test identified a normal distribution, allowing the use of parametric statistics.

After obtaining descriptive data (mean, standard deviation, maximum and minimum values), a sample means comparison was carried out using one-way ANOVA. Sample size sufficiency was verified retrospectively setting test power = 0.80; smallest worth detection difference between means = 9.82; square root of error mean square = 6; and significance level of 5%, revealing, as a final result, the need for 9 samples.

The results of analysis of variance (ANOVA) and Tukey tests for multiple comparisons (Table 1) presented forces statistically different between all the evaluated alloys, for all of the studied distances.

When the forces registered at the distances of 5, 10, 15 and 20 mm were compared, the differences between the three alloys evaluated were all statistically significant, as shown by the figures presented in Table 2.

Comparison between the load increments necessary to deflect the arch at every 5 mm (Table 3) identified different forces between nearly all the in-

Table 1 - ANOVA and Tukey test results for multiple comparisons between alloys at different distances (arch cross section of .017" x .025").

Distances	F	p-value	Stainless steel (a)		TiMolium® (b)		TMA® (c)		Tukey		
			$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	ab	ac	bc
5 mm	43.24	0.000	38.79	9.84	23.61	2.95	13.79	2.10	s	s	s
10 mm	169.51	0.000	71.62	8.81	42.26	2.75	27.07	2.07	s	s	s
15 mm	523.86	0.000	97.48	6.88	56.89	1.70	37.72	1.75	s	s	s
20 mm	320.04	0.000	120.66	6.07	77.87	8.38	49.15	3.78	s	s	s

s = significant, ns = not significant.

Table 2 - ANOVA and Tukey test results for multiple comparisons between the distances (arch cross section of .017" x .025").

Alloys	F	p-value	5 mm (a)		10 mm (b)		15 mm (c)		20 mm (d)		Tukey					
			$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	ab	ac	ad	bc	bd	cd
SS	190.18	0.000	38.80	9.85	71.62	8.88	97.48	6.88	120.66	6.07	s	s	s	s	s	s
TiMolium®	235.42	0.000	23.61	2.95	42.26	2.75	56.88	1.70	77.87	8.38	s	s	s	s	s	s
TMA®	348.90	0.000	13.79	2.10	27.07	2.07	37.71	1.74	49.14	3.78	s	s	s	s	s	s

s = significant, ns = not significant.

Table 3 - ANOVA and Tukey test results for comparison between force increments at 5 mm intervals between all distances.

Alloys	F	p-value	5-0 mm (a)		10-5 mm (b)		15-10 mm (c)		20-15 mm (d)		Tukey					
			$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	$\overline{\chi}$ (gf)	SD	ab	ac	ad	bc	bd	cd
Stainless steel	17.57	0.000	38.79	9.84	32.82	1.19	25.86	2.21	23.17	3.13	ns	s	s	s	s	ns
TiMolium®	6.91	0.001	23.61	2.95	18.64	0.74	14.62	1.59	20.98	8.50	ns	s	ns	ns	ns	s
TMA®	3.48	0.026	13.79	2.10	13.27	1.01	10.64	0.62	11.42	4.45	ns	s	ns	ns	ns	ns

s = significant, ns = not significant.

tervals for stainless steel, and identical forces in almost all intervals for TiMolium® and TMA®.

Discussion

Method error evaluation was not done since the repeatability characteristic could not be assessed as the same arch would possibly present some change upon being newly measured, as the force measurement process could interfere with the arch.

According to Devanathan[9] (1999) and Krishnan, Kumar[13] (2004), the TiMolium® wire presented high breakage resistance, low attrition force, resistance to compression, formability, flexibility, continuous force and springback.

Furthermore, Krishnan, Kumar[13] (2004) stated that TiMolium® seemed to be an alpha-beta titanium alloy, composed of titanium (more than 85%), aluminum (6.8%) and vanadium (4.2%), the last two being stabilizing elements of the alloy.

TMA® is a stabilized titanium alloy in the beta phase composed of titanium (79%), molybdenum (11%), zirconium (6%), and tin (4%).[3,10] This alloy presents lower modulus of elasticity, springback greater than that of steel,[4] and a combination of adequate shape memory, medium stiffness, good formability, weldability and high attrition.[11,12,20]

The present study confirmed the importance of considering the choice of alloy of intrusion arches. In addition to being statistically different, the observed forces of 49.15 gf for TMA® and 77.87 gf for TiMolium® at the same distance of 20 mm, although within the range recognized by other authors[4,13] for upper incisor intrusion, could be considered clinically distinct. Furthermore, the force of 120.66 gf observed for the steel arch is considered excessive.

Even though the results of the present study were produced using a different methodology, they are concordant with those of Krishnan, Kumar[13] (2004). The TMA® wire required a lesser quantity of load than steel and TiMolium® to be deflected at 0.5 and 1 mm, and presented better springback than the others. TiMolium® presented intermediary characteristics between steel and TMA®.

Confirming the observed force difference at distances of 5, 10, 15 and 20 mm for all alloys analyzed, the need for measuring the intrusion arch force before tying it out becomes evident, as height of the buccal vestibule, crown height and arch length are extremely variable, justifying the affirmation of Burstone[1] (2001) that no V-bend angular standard exists for desirable activation.

The forces observed in the present study for the different magnitudes of deflection should not be used as the sole reference for arch installation in a clinical situation. It is imperative to measure the applied force at the moment an intrusion arch is tied, considering that the geometry of the teeth and, consequently, the distance between the point of force application and the anchoring bending site varies from patient to patient.

By comparing the load increment at each registered distance of 5 mm, it was possible to identify a higher regularity in the loads necessary to deflect the TMA® and TiMolium® arches, and a higher irregularity in the loads necessary to deflect the stainless steel arches. Moreover, it was determined that there was a decreasing tendency in load quantity from the first to the last interval.

Conclusions

Based on the analyses conducted in the present study, it was concluded that:

1. The TMA® intrusion arches required less quantity of load in relation to the conventional steel and TiMolium® arches at all levels of deflection.
2. TiMolium® presented intermediary characteristics between steel and TMA®.
3. In all alloys, increase in distance entailed a significant increase in force between all registered values.
4. The load increments necessary to deflect the arches tended to decrease from the first to the last interval, these differences being more significant in steel, less in TiMolium®, and practically non-existent in TMA®.

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