Original Article

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Analysis of mechanical properties and forces produced by transpalatal bars made from low-nickel alloy

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Abstract

Aim: This study evaluated assess the mechanical properties and forces produced by transpalatal bars made from low-nickel alloy. **Methods**: Using a template, a single operator made all transpalatal bars from 0.032" and 0.036" wires of two different alloys, thus originating four groups, namely: A8 (0.032" conventional stainless steel), B8 (0.032" low-nickel stainless steel), A9 (0.036" conventional stainless steel), and B9 (0.036" low-nickel stainless steel). The bars were then activated and mounted onto a device developed to serve as a support for mechanical assay in a universal testing machine (Emic DL 10.000). The values of resilience and ductility were obtained using the Origin 8 software. **Results**: No statistically significant differences ($P > 0.05$) were observed between Groups A8 and B8 neither between A9 and B9 for 0.5-, 1.0-, and 5-mm deformations. However, statistically significant differences ($P < 0.05$) were found in all groups for 15-mm deformation. Groups B8 and B9 showed greater ductility and resilience compared to groups A8 and A9, respectively. **Conclusions**: Low-nickel stainless steel transpalatal bars release the same amount of force for activations less than 10 mm compared to those made from conventional stainless steel. Mechanically, the low-nickel stainless steel bars are more ductile and resilient.

Keywords: stainless steel, nickel, orthodontics.

Introduction

First described by Goshgarian in 1972[1], the transpalatal bar has been largely used by orthodontists since then for assisting the orthodontic treatment. Its inclusion in the orthodontist's arsenal was due to its varied array of clinical applications, namely correction of molar rotation, correction of molar mesiodistal inclination, molar distalization (associated with anchorage system), anchorage[2-3], control of first molar eruption, relative intrusion, upper posterior segment expansion or contraction, and torque control of molars[4-5].In addition to these clinical applications, this low-cost device is easy to make and use because it is fabricated from stainless steel segments[6-7].

Most metallic appliances used in orthodontic treatment, including the transpalatal bars[8], are fabricated from austenitic stainless steel containing 8% nickel and 18% chrome[9-10].

Nickel has often been related to allergic manifestations as this metal causes more reactions than all other metal combinations[11]. Some case reports in have

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suggest that orthodontic devices can unchain contact dermatitis in susceptible individuals[12-14]. The incidence of nickel hypersusceptibility is significant, ranging from 10% to 30% in the population[15]. Women are more often affected than men at a 5:1 ratio. It is thought that the use of certain jewelry pieces can exacerbate the susceptibility to this metal[10 11,16].

In view of this, the industry of orthodontic products has developed a series of materials to fulfill the needs of nickel-intolerant patients One of the products available in the Brazilian market is Biowire (Morelli, Sorocaba, São Paulo, Brazil), an orthodontic wire made from low-nickel stainless steel alloy.

The present study evaluated the behavior of the transpalatal bars made from conventional and low-nickel stainless steel alloys when subjected to distalization forces.

Material and methods

The transpalatal bars were fabricated by a single operator using a template (Figure 1). The specimens were distributed into four groups, namely: Group A8: bars made from 0.032-inch conventional stainless stain alloy (CrNi) (8% Ni) wire; Group B8: bars made from 0.032-inch low-nickel stainless stain alloy (CrMnMoNi) (0,2% Ni) wire; Group A9: bars made from 0.036-inch conventional stainless stain alloy (CrNi) (8% Ni) wire; Group B9: bars made from 0.036-inch low-nickel stainless stain alloy (CrMnMoNi) (0,2% Ni) wire.

In order to assess the force generated during activation of the transpalatal bars, an acrylic resin device was made and mounted onto the base of a universal testing machine (Emic DL 10,000; EMIC – Equipamentos e Sistemas de Ensaio Ltda, São José dos Pinhais, PR, Brazil) in order to provide stability during the mechanical tests. This device allowed simulating an upper semi-arch in which the one arm of the bar was attached to the molar tube and the other left free to be moved upward during the tests (Figure 2).

Prior to the tests, the bars were activated in such a way that a 15-mm distalization was achieved for the free arm. Next, a hook was adapted to the moving part of the universal testing machine to pull the free arm until becoming in parallel to the floor at a speed of 1 mm/min, thus allowing assessing the force generated according to dislocation of 15 to 0 mm. The values obtained were expressed in N and converted into gf, which facilitates the clinical application of the results. Based on these data, the ductility and resilience of the bars were calculated using the Origin 8 software (OriginLab Corporation, Northampton, MA, USA).

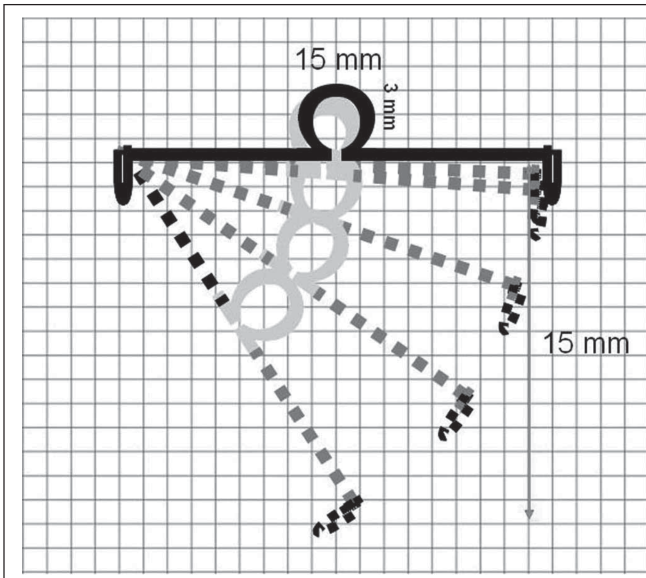

Fig. 1: Template used to fabricate and activate the transpalatal bars under study.

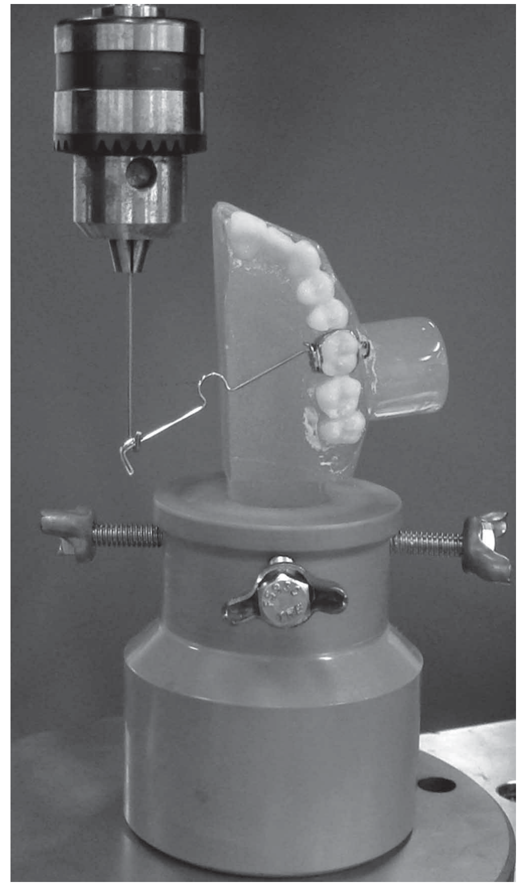
Fig. 2. Device used to attach the bars during the mechanical tests.

Statistical analysis was done using the SPSS software version 13.0 (SPSS Inc. Chicago, IL, USA). Descriptive statistical analysis was also performed for the 4 groups assessed, including means and standard deviations. Maximum deformation forces obtained in gf unit were subjected to ANOVA and Tukey's test.

Results

The forces generated during the distalization movement using different transpalatal bars are shown in Table 1.

There was no statistically significant difference between Groups A8 and B8 neither between A9 and B9 for 0.5-, 1.0-, and 5.0-mm deformations. As for 10-mm deformation, the bars made from 0.032-inch wire (Groups A8 and B8) showed no differences, but statistically significant differences were found in those bars made from 0.036-inch wire (Groups A9 and B9).

The force generated by all bars increased as a function of dislocation, and Groups A9 and B9 showed similar forces for 0.5-, 1.0-, and 5.0-mm dislocations, whereas the bars of

Table 1. Means and standard deviations of forces (gf) generated by the bars according to the deformation (mm).

Grupos	Med./DP	Est.	Med./DP	Est.	Med./DP	Est.	Med./DP	Est.	Med./DP	Est.
A8	17.59 (0)	A	17.9	A	45.75 (9.63)	A	80.95 (9.63)	A	105.5 (0)	A
B8	17.59 (0)	A	24.63 (9.63)	A	59.83 (9.63)	A	98.55 (9.64)	A	130.23 (9.63)	B
A9	52.79	B	63.35 (9.63)	B	109.08 (14.72)	B	158.35 (0)	B	211.17 (0)	C
B9	52.79	B	63.91 (7.23)	B	109.11 (14.72)	B	183.03 (15.74)	C	235.83 (9.63)	D

Mean: mean values of forces generated the bars. SD: Standard deviation. Stat: Statistics, where equal letters indicate no statistically significant difference.

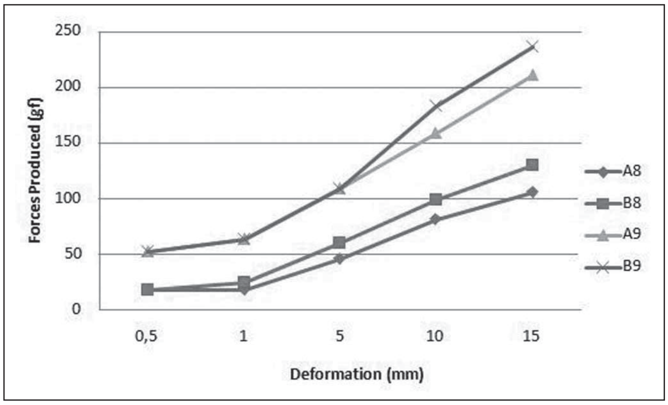

Fig. 3. Graph showing forces released by the bars for dislocations ranging from 0.5 to 15 mm.

Groups A8 and B8 showed force similarity for the 0.5-mm dislocation only (Figure 3). The relationship between applied force and bar dislocation (deflexion) is shown in Figure 3.

The results of resilience and ductility of the bars are presented in Table 2.

Table 2. Values regarding resilience and ductility of the bars.

Groups	Resilience (gf/mm)	Ductility (%)	Ration/ductility (%)
A8	919.05	6.29	B8 23.5%>A8
B8	1147.38	7.77	A9 70.59% >A8
A9	1966.27	10.73	B9 16.8% >A9
B9	2153.96	12.52	B9 61.13% > B8

Discussion

Corrosion of the metals composing orthodontic wires, such as nickel, can release metallic ions into the oral cavity and consequently allergic reactions. Allergy to nickel is a reaction of the body that manifests as contact dermatitis or even carcinogenic signs[17].

This hypersusceptibility to nickel can provoke oral manifestations and allergic contact stomatitis, which can mistakenly lead to diagnoses of gingival hyperplasia and oral ulcerations. Low-nickel stainless steel wires have been indicated to overcome this problem[17] and manufacturers of these orthodontic materials have developed metal alloys with such characteristics, among which is Biowire, a stainless steel alloy containing 0.2% nickel.

However, the use of these materials has been questioned. Do these low-nickel alloys possess the same mechanical characteristics as those of conventional materials, that is, stainless steel alloys containing 8% nickel? Based on this premise, the present study aimed at assessing the forces released by transpalatal bars made from conventional and low-nickel stainless steel alloys as well as their mechanical characteristics.

Specific methods have been developed in which a device simulating the upper semi-arch served as a support for pulling the bars, thus allowing the forces generated by different deformations to be assessed.

Two types of wires measuring 0.032" and 0.036" in diameters were used as such dimensions are largely employed by orthodontists. The 0.036-inch wire is used for control purposes because it is optimally adjusted in the tube. For standardization purposes, the bars were fabricated by the same operator using a template drawn on graph paper to serve as a model for preparing the samples.

Only the force generated for molar distalization was assessed because this would be the main function of the transpalatal bar, which requires more activation for releasing the necessary force. After 15-mm activation, the bars were inserted into molar tube and attached to it, and a hook was adapted to pull the bar upward until being in parallel to the floor. The forces generated were continuously recorded as a function of deformation.

The bars made from 0.032-inch wire generated less force compared to those made from 0.036-inch wire for all deformations observed. As for 0.5-mm deformation, both bars made from conventional and Biowire wires produced similar forces. After 1-mm activation, however, Biowire produced ever-increasing forces, but with no statistically significant differences between Groups A8 and B8 for deformations of 1.5 and 10 mm. On the other hand, statistically significant differences regarding the force released for 15-mm deformation were observed, with Biowire producing more force than other groups.

Analyzing the forces generated by the transpalatal bars evaluated in the present study, it can be observe a direct relationship to the mechanical properties (resilience and ductility) as obtained with computer software. Biowire (Groups B8 and B9) wires were found to have more resilience and ductility. These findings were also observed during the preparation of the samples, since Biowire wires were considered more difficult to bend properly. However, although low-nickel stainless steel bars (Biowire) are difficult to handle, their clinical use is facilitated by their mechanical properties, as they store more energy and consequently allow longer activation time.

In terms of clinical importance, this study shows that orthodontists treating nickel-intolerant patients may have to use low-nickel materials. Therefore, knowing the specific mechanical behavior of these materials prevents excessive activations of orthodontic devices that might generate non-physiological forces, which will cause periodontal ligament damage and delay the orthodontic treatment.

The following conclusions may be drawn from the results obtained in the present study: 0.036" transpalatal bars generated more force than 0.032" bars in all activations; low-nickel stainless steel transpalatal bars produced more force compared to those made from conventional stainless steel wire for the 5-mm deformation; and transpalatal bars made from conventional stainless steel wire had less ductility and resilience compared to those made from low-nickel material.

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