Evaluation of the wire flexibility used in the Mandibular Advancement Device submitted to thermal cycling

Avaliação da flexibilidade do fio utilizado no Dispositivo de Avanço Mandibular submetido ao ciclagem térmica

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ABSTRACT
This study aimed to evaluate the flexibility of wires used in the molar lock manufacture of the Mandibular Advancement Device (MAD), submitted to temperature variation. We used 64 segments of orthodontic wires (n=8), allocated as follows: G1) Dentaurum; G2) Leoni; G3) Leoni (Bio Steel); G4) Morelli; G5) Dentaurum + Thermocycling (TC); G6) Leoni + TC; G7) Leoni (Bio Steel) + TC; G8) Morelli + TC. The segments were analyzed by the three-point bending method, with the help of a Universal Testing Machine. The groups submitted to thermocycling underwent a total of 2300 thermal cycles (5°C and 55°C) corresponding to 8 months. After this period, the specimens were again immersed in distilled water at 37°C and kept in an oven for 24 hours. From this thermocycling process, the samples were submitted to a three-point bending test. The data were submitted to analysis of variance (ANOVA-two-way) followed by the Tukey test, considering the 5% significance level. There was no significant difference in flexibility between the groups with and without cycling, considering the same mark and same point ($p=0.05$). Without cycling, the Dentaurum mark presented higher average flexion at the point of 0.5mm, and Morelli presented higher flexion at the point of 1.0mm ($p<0.05$). Leoni brand showed higher values in 2 and 3 mm, and higher than Dentaurum brand in the point of 2 mm ($p<0.05$). For the groups submitted to thermocycling, at points of 0.5 mm, there was no statistical difference between the groups, except for the Leoni group, obtaining greater resistance to flexion compared to the Dentaurum brand wire ($p<0.05$). In 1, 2 and 3 mm, the Leoni branded wire showed greater flexibility compared to Dentaurum and Leoni (Bio Steel) and Morelli ($p<0.05$). The temperature variation does not influence the flexibility properties of the wires used in the making of MAD, however, there are differences between different brands when evaluated under the same conditions.

Keywords: Orthodontic wires, Thermocycling, Mandibular Advancement, Bending.

ABSTRACT
Este estudo visou avaliar a flexibilidade dos fios utilizados no fabrico da fechadura molar do Dispositivo de Avanço Mandibular (DMA), submetido a variação de temperatura. Foram utilizados 64 segmentos de fios ortodônticos (n=8), distribuídos da seguinte forma: G1) Dentaurum; G2) Leoni; G3) Leoni (Bio Steel); G4) Morelli; G5) Dentaurum + Thermocycling (TC); G6) Leoni + TC; G7) Leoni (Bio Steel) + TC; G8) Morelli + TC. Os segmentos foram analisados pelo método de flexão de três pontos, com a ajuda de uma Máquina Universal de Testes. Os grupos submetidos à termociclagem foram submetidos a um total de 2300 ciclos térmicos (5°C e 55°C) correspondentes a 8 meses. Após este período, os espécimes foram novamente imersos em água destilada a 37°C e mantidos num forno durante 24 horas. A partir deste processo de termociclagem, as amostras foram submetidas a um teste de flexão de três pontos. Os dados foram submetidos à análise de variância (ANOVA-dois vias) seguida do teste de Tukey, considerando o nível de significância de 5%. Não houve diferença significativa na flexibilidade entre os grupos com e sem ciclagem, considerando a mesma marca e o mesmo ponto ($p=0,05$). Sem ciclismo, a marca Dentaurum apresentou uma maior flexão média no ponto de 0,5mm,

e Morelli apresentou uma maior flexão no ponto de 1,0mm (p<0,05). A marca Leoni apresentou valores superiores em 2 e 3 mm, e superiores à marca Dentaurum no ponto de 2 mm (p<0,05). Para os grupos submetidos à termociclagem, nos pontos de 0,5 mm, não houve diferença estatística entre os grupos, excepto para o grupo Leoni, obtendo maior resistência à flexão em comparação com o fio da marca Dentaurum (p<0,05). Em 1, 2 e 3 mm, o fio da marca Leoni mostrou maior flexibilidade em comparação com o Dentaurum e Leoni (Bio Steel) e Morelli (p<0,05). A variação de temperatura não influencia as propriedades de flexibilidade dos fios utilizados na fabricação do MAD, no entanto, existem diferenças entre as diferentes marcas quando avaliadas sob as mesmas condições.

Palavras-chave: Fios ortodônticos, Termociclagem, Avanço Mandibular, Flexão.

1 INTRODUCTION

Class II corresponds to 42% of malocclusion cases, which is subdivided into 15% with skeletal involvement and 27% with dentoalveolar involvement with a good relationship between the bone bases [1]. Thus, this malocclusion can compromise facial aesthetics in several aspects, according to the intensity of horizontal crossbite and its relationship with soft tissues, and can affect the aesthetic appearance, self-esteem and quality of life of patients [1,2,3].

For mandibular deficiency patients, one of the treatments used is the use of fixed devices for protraction or mandibular advancement. The skeletal effects of these functional appliances, in this case Mandibular Advancement Device (MAD), are generally beneficial and have been an alternative to the intermittent use of traditional functional orthopedic appliances and are used in the treatment of Class II malocclusion with mandibular deficiency, thus indicating the use of this appliance limited only to growing patients [4,5,6,7]. Thus, this type of therapy presents a better treatment prognosis in patients with brachyfacial growth patterns, being based on Herbst's mechanical principles, becoming an alternative that allows to generate a more anterior posture of the mandible during the treatment of Class II cases. This mechanism of action maintains the mandible uninterruptedly projected anteriorly during all its functions and rest, becoming a stimulating factor in the sense of the potentiality of desired orthopedic remodeling [8,9,10,11,12,13,14].

MAD has the feature of easy installation, since its insertion is by mesial of the molar tube and easy removal during clinical care, where there is no need to remove the arches, thus generating less time in installation. In addition, it is easy to replace in case of breaks, or any other eventuality that requires its removal, easy to make, low cost, manufactured with material easily found on the market, and can be prepared before installation. It also has small dimensions, providing short time for adaptation, allowing normal opening movement and wide lateral movement [8].

This appliance also has the advantage of allowing asymmetrical or unilateral advances in cases of Class II subdivision, midline deviations and loss of anchorage of lower molars without the need for special bands or crowns [12,15]. Although there are numerous advantages within orthodontic therapy, some modifications in appliance configuration have been proposed to increase patient comfort, improve upper molar control and decrease the level of breakage of orthodontic accessories, avoiding failures and consequently longer treatment time [14,15].

Based on the difficulties related to the use of the Mandibular Advancement Device, the break in the molar lock stands out. Many studies have been conducted in order to investigate the advantages and disadvantages of MAD, however, in relation to the molar lock breakage, there is still a lack of scientific evidence. Considering the above, the objective of the present study was to evaluate the resistance to flexion of wires used in the making of the molar lock of the MAD submitted to temperature variation. The null hypotheses of the study were: 1) The different brands available on the market and used for the production of MAD do not present differences among themselves; 2) the temperature variation has no effect on the degradation of wires.

2 MATERIAL AND METHODS

2.1 EXPERIMENTAL DESIGN AND SAMPLE SELECTION

The experimental design and sample sizes were calculated in the Gpower* program, considering the 5% significance level and the effect size greater than 0.48, according to the results of the Washington et al., 2015 surveys. Thus, 10 wire segments per group, totaling 80 segments, will provide a test power of at least 0.80. In this study were used 80 segments of metal wires 1.0mm of different brands, used to make the MAD molar lock, which were allocated to the following groups, according to their brands:

Group 1- Fio 1,0 mm DENTAURUM;

Group 2- Fio 1,0 mm LEONI;

Group 3- Fio 1,0 mm LEONI (Bio Steel);

Group 4- Fio 1,0 mm MORELLI;

Group 5- Fio 1,0 mm DENTAURUM + Termociclagem (TC);

Group 6- Fio 1,0 mm LEONI + TC;

Group 7- Fio 1,0 mm LEONI (Bio Steel) + TC;

Group 8- Fio 1,0 mm MORELLI + TC.

2.2 SAMPLE PREPARATION

Metallic segments were sectioned with the aid of a pliers cutter in the distal portion coated with 55 mm of wire length and in a similar way. After cutting, two samples were obtained from each arch [16]. A working model was made and used as a support for the wire, simulating the installation of fixed orthodontic appliances and orthodontic bands.

2.3 THREE-POINT BENDING TEST

The acrylic resin base was positioned in a Instron 4411 Universal Testing Machine (Buckinghamshire, England, UK), the force applied being regulated by a 500-N load cell. A metallic blade, with a bending range of 1 mm at its end, was fixed to the load cell to flex the bows at the central point where a force required to generate a deflection of 3mm was applied, at a speed of 1 mm per minute [17,18].

The data was collected by a Dell Inspiron 15 computer (Mississippi, Arkansas, USA), connected to the measuring device, and processed using an 8.5 Bluehill (National Instruments Corporation, Austin, Texas, USA) softwer Labview. The data collected were presented in a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, Wash) and used to plot a graph for each test, showing the deflection of the test on the "x" axis and the force exerted on the "y" axis. Each curve obtained represented the initial loading phase - with no particular clinical relevance. A load/deflection curve was obtained for each sample of each type of wire tested.

2.4 THERMOCYCLING

After the specimens were made, the groups submitted to thermocycling were 2300 cycles, corresponding to 8 months. Thermocycling was performed in a thermal cycler (MSCT 3, Marnucci ME, São Carlos, SP, Brazil) for an immersion time of 30 seconds in each bath, with intervals of 10s at temperatures of 5ºC and 55ºC, corresponding to each proposed time. After this period, the specimens were again immersed in distilled water at 37º and kept in an oven for 24 hours, after which the readings were taken.

2.5 SCANNING ELECTRON MICROSCOPY AND ENERGY DISPERSIVE SPECTROSCOPY (SEM-EDS).

The wire segments were fixed in stubs with the aid of double face carbon tape (Electron Microscopy Sciences, Washington 19034 - USA) and analyzed in the Scanning Electron Microscopy

(JSM 5600 LV; JEOL, Tokyo, Japan) at a voltage acceleration of 15 kV at 35x magnifications by the same previously calibrated operator. Energy dispersive spectroscopy (EDS) was also performed, identifying qualitatively and semi-quantitatively the chemical composition of the specimens.

2.6 STATISTICAL ANALYSIS

Statistical analysis was performed through the R (R Core Team - 2018) program. R. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria). The data regarding the bending strength of each group were evaluated by the test of normality and heterogeneity. Given the normality of the data, the ANOVA (two-way) and Tukey's post-test were used. The statistical significance was defined in $p<0,05$.

3 RESULTS

The bending resistance results obtained through the 3 points method, showed that there was no significant difference in mean bending between the groups with and without cycling, for the same mark and at the same point ($p>0.05$).

The groups that were not submitted to thermocycling showed no significant difference between the marks at points of 0.5 and 1 mm ($p\geq0.05$). In the points of 2 mm and 3 mm, the wires of the Leoni brand (Bio Steel) presented values of bending significantly lower than the others, and in the point of 3 mm, the wires of the Dentaurum brand presented bending significantly lower than those of Leoni and Morelli ($p<0.05$).

For the groups that were submitted to thermocycling, there was a significant difference for the Dentaurum group in the points of 0.5; 1 and 2mm, when compared to the other groups ($p<0.05$). For the rest, at 0.5 mm, the Dentaurum mark showed significantly less bending than Leoni at points of 1 mm, 2 mm and 3 mm ($p<0.05$). Moreover, the Dentaurum group presented significantly less bending than the Morelli group at the point of 1 mm ($p<0.05$). Still with cycling, the Leoni brand (Bio Steel) showed significantly lower bending than the others at 2 mm, and significantly lower than Leoni at 3 mm ($p<0.05$).

Figure 1 shows the morphology of the wire segments, where the analysis of energy dispersive X-ray spectroscopy (EDS) was also performed, identifying qualitatively and semi-quantitatively the chemical composition of the arcs (Figure 2).

Figure 1: Wire scanning electron microscopy: A) Dentaurum; B) Leoni; C) Leoni BS; D) Morelli

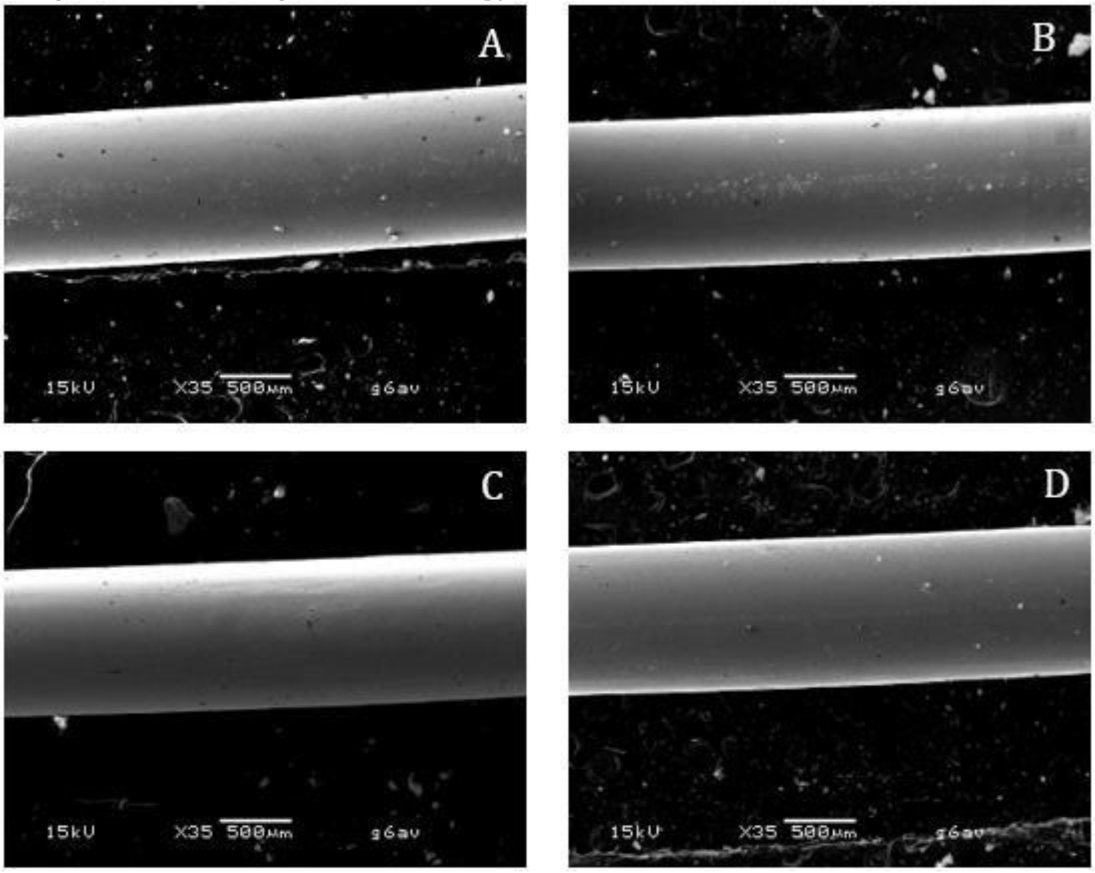

Figure 2: Energy dispersive spectroscopy of the wire: A) Dentaurum; B) Leoni; C) Leoni BS; D) Morelli.

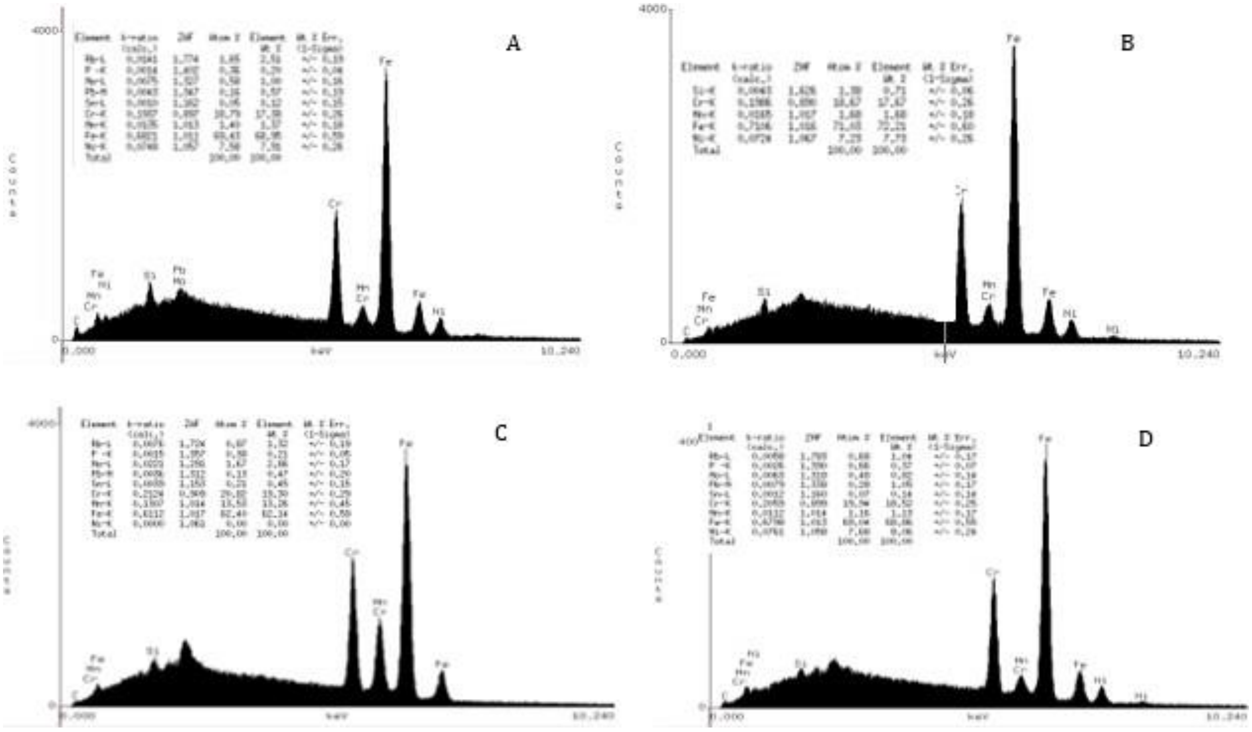

Table 1. Mean (standard deviation) (number of wires) of the Bending (MPa) as a function of the point, the mark and the thermocycling.

Thermal Cycling	**Trade Mark**	**Point**			
		0.5 mm	**1 mm**	**2 mm**	**3 mm**
Without	Dentaurum	776.48 (45.03) Da	1.442.05 (51.89) Ca	2.092.58 (28.54) Ba	2.258.26 (26.18) Ab
	Leoni	749.67 (50.91) Da	1.432.76 (91.42) Ca	2.174.25 (40.06) Ba	2.369.37 (12.94) Aa
	Leoni (Bio Steel)	733.96 (89.49) Da	1.370.72 (100.69) Ca	1.907.96 (30.19) Bb	2.052.96 (13.62) Ac
	Morelli	774.43 (57.75) Da	1.444.68 (91.10) Ca	2.125.61 (34.13) Ba	2.307.84 (20.42) Aab
With	Dentaurum	706.58 (97.41) Ca	1.383.53 (127.54) Bb	2.050.43 (85.34) Ab	2.171.88 (14.93) Ab
	Leoni	793.45 (31.47) Da	1.510.07 (63.43) Ca	2.175.71 (26.98) Ba	2.298.33 (10.72) Aa
	Leoni (Bio Steel)	802.37 (44.51) Da	1.410.10 (75.15) Cab	2.184.31 (26.88) Bc	1.998.33 (15.40) Ac
	Morelli	798.08 (48.07) Da	1.503.68 (124.33) Ca	2.127.51 (50.44) Bab	2.251.57 (19.33) Aab

Means followed by distinct letters (upper case horizontal and lower case vertical comparing the marks in the same condition of cycling) differ from each other ($p \leq 0.05$). p(group)<0.0001; p(cycling)=0.3927; p(group x cycling)=0.0848; p(point)<0.0001; p(group x point)<0.0001; p(cycling x point)<0.0001; p(group x cycling x point)=0.0597.

4 DISCUSSION

Clinical experience with mandibular protractor devices, installed together with fixed apparatus, demonstrates some types of challenges, both in installation and replacement in cases of fracture, and in all devices available on the market, fixed or removable. Within this context, the break in the molar lock stands out, which causes the patient to return to the orthodontist's office for possible repairs to the device.

The present study started with the purpose of evaluating the flexibility of wires of different commercial brands used in the making of the MAD molar lock, as well as its properties after the temperature variation. Thus, this study sought to analyze the relationship between the flexibility of the wires used and the fracture that occurred in the wire used to make the MAD molar lock, and with the use of flexible wires, the fracture will occur less frequently. The clinical relevance of this study is due to the fact that the patient who makes use of this device performs opening, closing and lateral movements in his/her daily life, which can generate fatigue and rupture of the wire that composes this type of device.

The effect of the orthodontic wire is directly dependent on its structural and mechanical properties. The type of alloy, biocompatibility, hardness, modulus of elasticity, friction and several other characteristics are important for the proper selection of each orthodontic wire[20]. Numerous factors that influence the elastic properties of orthodontic wires are: diameter, shape, archwire length, bracket bracket size, interbracket distance, loop design and alloy type, with the composition of the wire being another extremely relevant factor[20,21,22]. These wires are usually round, 1.0mm gauge and stainless steel alloy wires, being these the ones of choice for MAD[23].

The stainless steel orthodontic wires accept bending and therefore can be used in brackets without angulation and torque, where the orthodontist will introduce the necessary activations in the bending of the wires. Most bands, brackets and orthodontic wires are made of stainless steel, containing approximately 8% to 12% nickel, 17% to 22% chromium and varying proportions of manganese, titanium, iron and copper[20,24]

The Nitinol alloy presents approximately 52% nickel, 45% titanium and 3% cobalt, possessing properties of superelasticity and shape memory. The wires with shape memory are molded in arc shape during the manufacturing process at high temperatures. When cooled, they can be easily deflected inside the bracket channels. When temperatures around 35°C are reached in the patient's mouth, the wires tend to return to the arc shape given during manufacturing, generating activation, i.e., they tend to return to the original shape, through the change of temperature[25].

An important property in Nitinol alloy is the modulus of elasticity, the higher the modulus of elasticity, the higher the stiffness, i.e., the modulus of elasticity of nickel-titanium wires is much lower than that of stainless steel, and they can be quite deflected without suffering permanent deformation, which results in the application of light and continuous forces, but they do not accept bending or loops, such as stainless steel wires[20,24,25]

The amount of nickel present in the wire composition, whether steel or NiTi, is directly related to the flexibility factor, that is, the greater the amount of nickel present in the alloy, the greater the flexibility and consequently lower percentage of wire fatigue,[21] which may explain the greater average flexion without cycling found in the wire of the brand Dentaurum at the point of 0.5, and for the brand Morelli in 1mm, as well as greater values in 2mm and 3m for the brand Leoni. This way, being rejected the first hypothesis null.

Leoni Bio Steel wire was introduced to the market with the proposal of not having Ni in its composition. Nickel allergy has a prevalence of 30% among industrial products, presenting a great challenge for manufacturers. Allergic reactions are predominant adverse effects, due to the release of Ni ions through the corrosion of the device when subjected to oral environment. Based on EDS results, the wire does not have Ni, which gives it less resistance when bent in points 2 and 3mm compared to the groups, which can be inferred that the greater flexibility of the other groups is related to the percentage of Ni present in the composition.

The groups submitted to thermal cycling, the Dentaurum group presented less flexibility in flexions of 0.5, 1 and 2 mm, thus rejecting the second null hypothesis. This finding can be attributed to the distinct percentage of each metallic ion, interfering in the composition of the alloy. The composition is directly linked to the fatigue effect of the material, which may have been oxidized, and then lost Ni to the external environment, decreasing its bending property. The manufacturing process has a great effect on the organization of the ions in the metallic matrix, being one more justification for the possible loss of the Ni ion to the medium, when submitted to temperature variation.

It was concluded that the temperature variation did not alter the flexibility of the wire segments, but its composition, which demonstrated that the greater the amount of Nickel in the wire composition, the greater its flexibility.

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