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Comparative study of NiTi orthodontic wires

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Abstract

In this study, two superelastic NiTi orthodontic wires (0.46 x 0.64 mm^2) were analyzed. The determination of phase transformation temperatures along with the identification of the predominant phase at room and intraoral temperatures were accomplished by DSC analysis. Superelastic behavior was analyzed through tensile tests. 3-point bending tests were performed on a model design which included brackets to compare wires' behavior: lower forces corresponding to Ormco wires' reverse phase transformation plateau when compared to Dentaurum were exhibited. Wire slippage inside the brackets and friction caused by wire-bracket-ligature combinations on bending and pulling tests, respectively, are also discussed.

Keywords: orthodontic wires; NiTi; superelasticity; modified 3-point bending test; DSC

1. Introduction

Superelastic NiTi orthodontic wires enable the creation, transmission and control of light and continuous forces that allow tooth movement [1–3]. Despite characteristics like high yield strength, low elastic modulus and high resilience, the clinical interest of these wires lies in their superelastic behavior [4,5]. Due to the specificity of orthodontic fixed appliances, many authors suggest the inclusion of constraining elements on model assemblies in order to reproduce clinical reality [6–9], opposing ISO 15841:2006 methodology [10]. In this study, the approach presented for the 3-point bending test model included brackets in its setting in order to compare orthodontic wires' performances. Wire slippage inside the brackets and friction due to wire-bracket-ligature combinations on bending

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and pulling tests, respectively, are also discussed. In addition, wires' characterization was accomplished through the determination of phase transformation temperatures along with the identification of predominant phase at room and intraoral temperatures by DSC analysis while superelastic behavior was analyzed through tensile tests.

2. Materials and Methods

In this study, two superelastic NiTi orthodontic wires, *Rematitan® LITE DIMPLE* (Reference 766-076-00, Dentaurum, Ispringen, Germany) and *Niti Preformed archwires* (Reference: 210-0504, Ormco, Glendora, Calif, USA), with a 0.46 x 0.64 mm^2 rectangular cross-section, were analyzed. Brackets for incisive tooth and elastomeric ligatures were used in bending and pulling tests: bending assembly included *Equilibrium®2 Standard Edgewise 22* brackets (Reference: 722-305-11, Dentaurum, Ispringen, Germany), while pulling tests mounting included *Edgewise Prescription Standard Central* brackets (Reference 10.30.201, Morelli, Sorocaba, SP, Brazil). Both brackets had 0˚ angulation and torque with a 0.56 x 0.76 mm^2 slot dimension. Only Morelli ligatures (Reference 60.03.301, Morelli, Sorocaba, SP, Brazil) were used to constrain the wire into the Dentaurum brackets on bending tests, while both Morelli and Dentaurum (Reference 774-551-00, Dentaurum, Ispringen, Germany) elastomeric ligatures were used on pulling tests. Both ligatures' internal diameter corresponded to 1.30 mm.

The determination of phase transformation temperatures along with the identification of the predominant phase at room and intraoral temperatures were accomplished by DSC analysis; heating and cooling rate of 10˚C/min was executed.

Tensile tests were performed in order to confirm wires' superelastic behavior up to 8% strain. Knowing that ISO standards [10] do not reproduce clinical conditions, modified 3-point bending tests were executed, at room temperature, on the model shown on fig. 1 a to compare Dentaurum and Ormco wires' performances. Three loading cycles were carried out during each test for 2 and 3 mm deflection at a constant speed of 2 mm/min. Pulling tests were executed on the setting shown on Fig. 1b. These tests allowed the discussion of the friction caused by wire-bracket-ligature connection and its influence on the obtained force values.

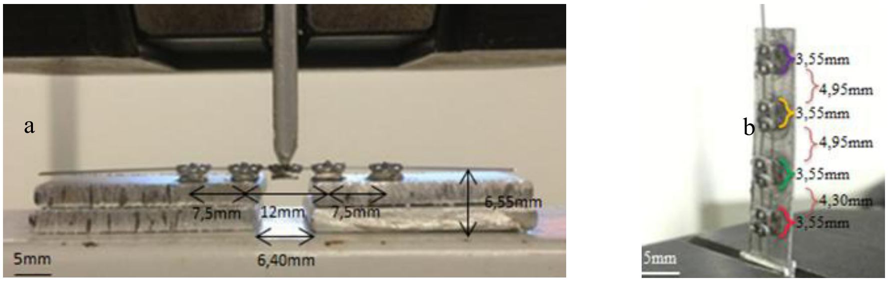

Fig. 1. (a) Modified 3-point bending test mounting included 1 row of 4 Dentaurum brackets. Load is applied on a bracket positioned at the midpoint. (b) Pulling test setting. The wire, which is attached to the top grip of the testing machine, is pulled across the 4 Morelli brackets glued to an aluminum plate attached to the bottom grip.

3. Results and Discussion

The DSC curves (Figs. 2a, b) of both wires showed a two-stage transformation during heating and cooling (heating: Martensite → R-phase → Austenite ; cooling: Austenite → R-phase → Martensite). The presence of the intermediate R-phase on these wires' transformations is consistent with previous researches [11–13]. On cooling, Dentaurum's R-phase transformation starts above room temperature while Ormco's R-phase transformation occurs below room temperature. On heating, Dentaurum's austenitic phase completion takes place at the beginning of the average intraoral temperature range, while Ormco's austenitic phase completion occurs below average intraoral temperatures.

Tensile test results showed a superelastic behaviour for both wires (Fig. 3a). Results showed higher loading plateau stress for Dentaurum wire (about 320 MPa – 350 MPa) when compared to Ormco wire's loading plateau stress (about 290MPa – 320MPa). The same happens for the unloading plateau stress (50MPa – 60MPa for Dentaurum *versus* 20 MPa – 30 MPa for Ormco). Pulling test results (Fig. 3b) showed force fluctuations due to the inconsistences on manual ligature placement or ligature dislocations [14] which leads to a variation on friction resistance [15]. Force magnitude differences emphasize the importance of wire-bracket-ligature combinations selection on the acquisition of an optimal force capable of overcoming friction [16].

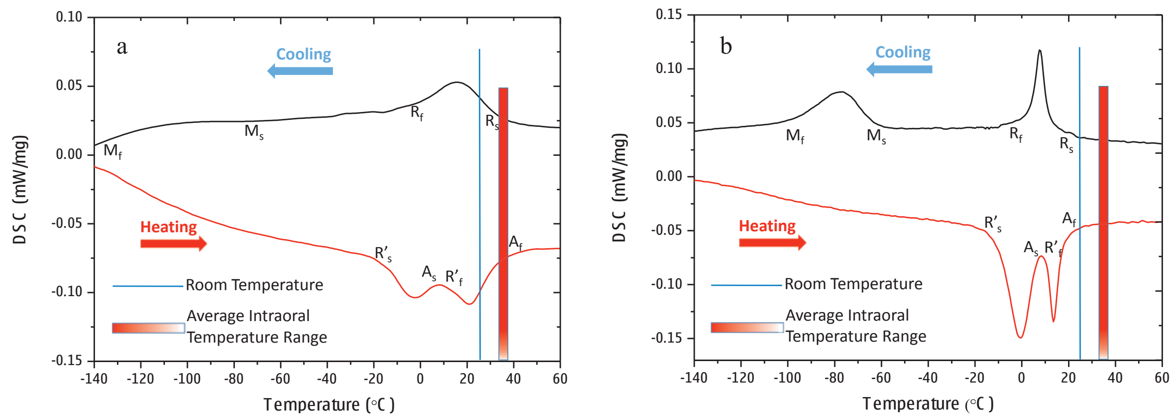

Fig. 2. (a) DSC heating and cooling curves for Dentaurum wire. (b) DSC heating and cooling curves for Ormco wire.

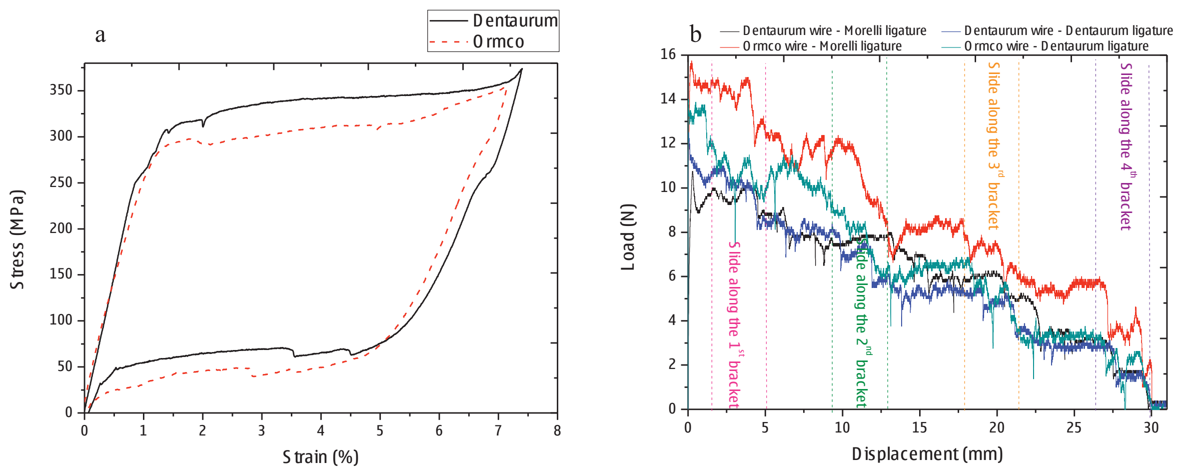

Fig. 3. (a) Tensile test results. (b) Pulling test results for the different wire-bracket-ligature combinations in study.

Reverse transformation plateaus analysis of the modified 3-point bending tests (Figs. 4a, b) showed that Ormco wire exerted lower forces than Dentaurum wire. Lower forces cause less pain and discomfort to the patient and minimize potential damage to periodontal tissues [1,4]. Bending tests with deflections up to 3 mm showed a strong slippage component associated with the excessive deflection imposed, which caused a large extent of wire passing through the brackets [17]. Loading and unloading plateaus' behaviour revealed on bending tests is consistent with tensile results.

4. Conclusion

DSC results showed that Dentaurum wire (Fig. 2a) had, at room temperature, a predominance of austenitic phase with some residual R-phase, being fully austenitic at intraoral temperature, while Ormco wire (Fig. 2b) revealed a fully austenitic phase at room and intraoral temperatures. Pulling tests exhibited force fluctuations due to the friction caused by wire-bracket-ligature connection. Both tensile and bending results showed a superelastic behavior; Ormco wires exhibited lower forces at the reverse plateau, when compared to Dentaurum wires. Bending tests up to 3 mm deflection highlight the wire slippage phenomenon inside the brackets. This work emphasizes the need to assemble settings (wire + brackets) reproducing the specificity of orthodontic fixed appliances in order to achieve reliable and realistic results that allow a better in service assessment.

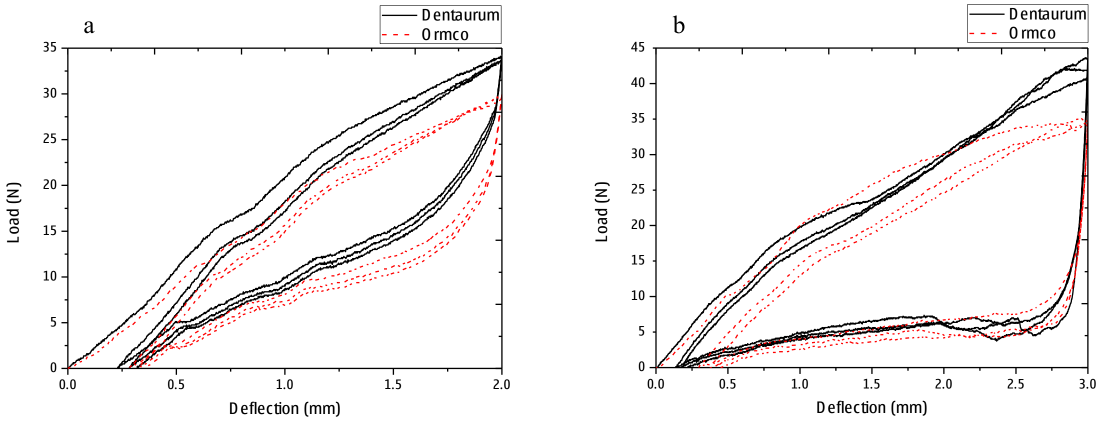

Fig. 4. (a) Load-deflection curves for 2mm deflection. (b) Load-deflection curves for 3mm deflection.

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