The use of NiTi and NiTiCu in orthodontic wires

H. Barbey[1] , F. M. Braz Fernandes[1], Rafaella Magalhães[1]

[1] *CENIMAT – Centro de Investigação de Materiais, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Campus da Caparica, 2829 - 516 Caparica, Portugal*

Introduction

Superelasticity and shape memory effect are two properties that represent an important improve in the orthodontic treatment.
Superelasticity enables the delivering of light and continuous forces to the teeth. Working with a low deactivation baseline load leads to constant and soft forces applied during the treatment. The shape memory effect is useful to install the wire : at room temperature, the presence of the martensite phase enables easy and important deformations of the wire to insert it in the bracket. At oral temperature, martensite turns into austenite and the wire tend to recover its original shape, and drag with the teeth.
Copper addition in NiTi orthodontic archwires has spread in the industry, most brands now propose copper-nickel-titanium wires in addition to classical superelastic ones. In order to compare the thermo-mechanical characteristics of these two types of wires, three test series have been performed at room temperature over 5 different kind of wires, from 3 different brands. Mechanical characterisation has been set using tensile tests on straights parts of the wires. DSC trials have been performed in order to obtain the temperature transition range of the different wires. XRD studies have also been conducted in order to obtain the structural profile of these two different alloys. The real improve due to the copper addition in the alloy is discussed in the light of a literature review. (1-3)

Materials and Methods

Material

Morelli NiTi Superelastic 0,014''
Orthometric FlexyNiTi Superelastic 0,014''
Orthometric Flexy NiTi Copper 0,014''
Ortho Technology TruFlex 0,018x0,025''
Ortho Technology TruFlex Copper 0,018x0,025''

Tests

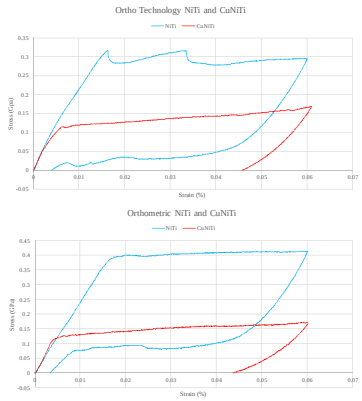
DSC thermal analysis (DSC 204 F1 Phoenix model from Netzsch)
Heating and cooling rate of 10˚C/min, Temperature range from -150°C to 150°C

Tensile testing (Shimadzu AG 50kNG)
Gauge length around 30 mm; stroke speed: 2mm/min; maximum strain 6%

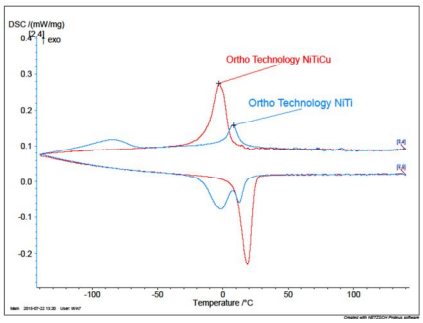
XRD tests (TTK450 chamber / Bruker rotating anode
Temperature range from -180 to 100°C

Results

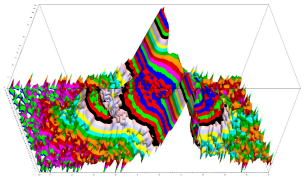
Tensile tests



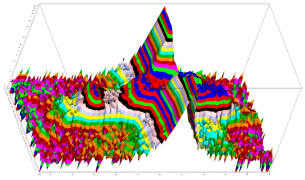
DSC Analysis



XRD



OrthoTechnology NiTiCu 0.64 x 0.46 mm



OrthoTechnology NiTi 0.64 x 0.46 mm

Conclusions

The first thing that appears during the mechanical characterisation is the non-superelastic behaviour at room temperature of the NiTiCu archwires, for all the brands studied. Contrary to the NiTi wires, no superelastic loop can be observed, and the shape recovery is really poor. This behaviour is typically the one of the martensitic phase. DSC trials confirm the main phase for the as-received samples is not the same for the two alloys at room temperature: NiTi is mainly austenitic, with a transformation peak around 0°C whether NiTiCu is still in a martensite phase, with a transformation peak around 20°C. The addition of copper appears to increase the transformation temperature range of the alloy. This means these wires can be easily deformed before being thermally activated when inserted in the mouth of the patient.
According to recent publication (1), the major interest of adding copper is to stabilize the transformation temperature of the wire to avoid significant disparities between different batches of archwires. Another study (2) shade this opinion, showing that important variability still exist between NiTiCu wires.
A study of the same wires in intra-oral conditions (37°C) is necessary to establish a better comparison between NiTi and NiTiCu.

References

(1) Y.F. Zheng, B.M. Huang, *Superelastic and Thermally Activated TiNi Alloys and their Applications in Dentistry*, Materials Science Forum, Vols. 394-395, pp. 57-60, May. 2002
(2) Wilkinson, P. D, Dysart, P. S, Hood, J. A. A, Herbison, G. P, *Load-deflection characteristics of superelastic nickel-titanium orthodontic wires*, AJO-DO May 2002; 121(5):483-95
(3) Gravina MA, Brunharo IHVP, Canavarro C, Elias CN, Quintão CCA, *Mechanical properties of NiTi and CuNiTi shape-memory wires used in orthodontic treatment. Part 1: Stress-strain tests*, Dental Press J Orthod. 2013 July-Aug,18(4): 35-42
(4) Renee C. Pompei-Reynolds and Georgios Kanavakis, *Interlot variations of transition temperature range and force delivery in copper-nickel-titanium orthodontic wires*, AJO-DO August 2014, 146(2): 215-226
(5) F. J. Gil, J. A. Planell, *Effect of Copper Addition on the Superelastic Behavior of Ni-Ti Shape Memory Alloys for Orthodontic Applications*, Biomed Mater Res (Appl Biomater) 48: 682–688, 1999

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FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA