

Microstructural Changes in Orthodontic Arch-wires after Alternative Bending Techniques

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Nowadays the straight-wire philosophy is the most common technique used in orthodontics. Even so, minor bends are required when it comes to the finishing phase of the case. For the finishing phase, but also for different biomechanical purposes, more types of wires can be used: NiTi, BT 3 Titan, Titanol, SS. The microstructural surface changes that occur after wire-bending can sometimes become vital to the orthodontic treatment. Mechanical characteristics, tensile strength, yield strength and elongation at break were analyzed in order to select the best arch-wire for different orthodontic purposes (alignment, stability, arch form). The tensile strength of the arch-wires was appreciated after a number of alternative bending cycles, by analyzing the microstructural changes with the use of an AM4515T8 microscope (900 x magnification). A statistical analysis was performed after testing a 0.16 NiTi wire, a BT3 BetaTi wire, Titanol Arcs, S304 SS Lingual, and a M5NiTi lingual large wire.

Key words: surface microstructural deformation, NiTi wire, tensile strength, yield strength

Only a few alloys are commonly used in orthodontics for the manufacturing of the orthodontic arch-wires. Beta titanium, stainless steel, chromium nickel titanium are only a few examples. The weldability, the low stiffness, the resistance to corrosion, the elasticity, the thermo-mechanical characteristics, like memory shape, are only some of the factors that must be taken into account when a wide range of clinical procedures are being planned [1, 3]. The martensitic phase in the NiTi wires cannot provide the plastic deformation that orthodontists need for arch bending techniques. Higher temperatures transform the martensitic phase into the austenitic one [4], so plastic deformation can occur (arch-wire bending). Generally speaking, arch-wires can be bent with the use of a three jaw plier/ two jaw plier/ Bird Beak plier. NiTi wires bends are incorporated into the arch-wire with the use of a special NiTi bender plier.

The friction between the arch-wire and the bracket slot is another variable that must not be neglected when it comes to orthodontic tooth movement. Including bends in the arch wire can increase friction and can slow down sliding mechanics [6].

The ductility, the resistance to corrosion, the memory shape characteristics and the biocompatibility makes the NiTi wires the most used wires in orthodontics, especially in the initial phases of the treatment (levelling and aligning) [6].

Our study objective was to analyze the mechanical properties of different arch-wire types. Tensile strength, yield strength and elongation at break were tested for different types of wires, after wire bending procedures. We selected a 0.16 NiTi wire for data analysis of the microstructural changes that appear at the surface, after testing the parameters mentioned above. A DinoLite microscope from the *Department of Dental Materials and Dental Prostheses Technology* was used (fig. 1). All the images were imported to a computer (through a USB). The DinoCapture software program can calibrate

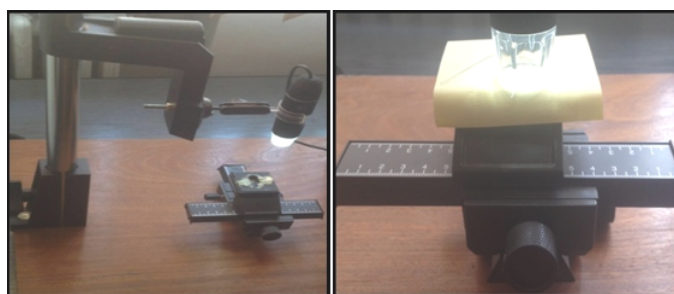


Fig. 1. The NiTi arch-wire under the DinoLite microscope

different measurements and add caption to images or video files.

Experimental part

Alternative bending was performed for multiple wires: BT3 Beta Titanium, Titanol, S304 SS Lingual Form, M5 NiTi Lingual Arch. Three different arch-wires were tested from each category (regarding tensile strength, yield strength and elongation at break). The arithmetic mean of these values was noted. The testing machine had a 1000 N testing capacity. The testing value of the wire's tension was around 10 MPa. The results were analyzed with the use of the DinoLite microscope and a statistical analysis was performed in order to compare the results.

The testing modality is similar to the SR EN ISO 7799:2003 (metallic materials). The tensile strength was appreciated after a certain number of alternative bending cycles. The experimental part took place at Politehnica University from Timisoara.

Results and discussions

The microstructural modifications that appeared in the 0.16 NiTi wire are quite high compared to the non-bended wire. The more complex the bend, the more important is the microstructural change at the material surface. (fig. 2)

Regarding the mechanical properties of different arch-wire types, the best results were obtained for the M5 NiTi Lingual Large wires, although the elongation at break was higher for BT 3 Beta Titanium wires. (table 1, fig. 3)

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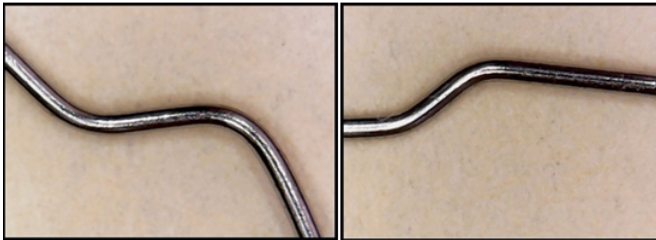


Fig. 2. Microstructural alterations observed at the surface

Table 1

THE TENSILE STRENGTH, YIELD STRENGTH AND ELONGATION AT BREAK VALUES FOR THE ANALYZED ARCH-WIRES

Arch-wire type	Tensile strength (MPa)	Yield strength	Elongation at break
BT 3 Beta Titanium	375	318.6667	55.66667
Titanol Arcs	624	568	47.33333
S304 SS Lingual Form	637.3333	351.6667	53
M5 NiTi Lingual Large	1243.333	955.333	12.33333

Arch-wire selection is very important to the clinician. Several factors must be taken into account to prevent microstructural damage that can lead to treatment failure: the residual chemical elements, the purity of the alloys, strength and thermo-mechanical properties. NiTi arch-wires are helpful in the initial phases of the treatment, while stainless steel and beta titanium arch-wires help maintain stability and arch form at the end of the treatment.

The results mentioned above are very helpful for the clinical selection of the arch-wires but offers no information regarding the thermic process that takes places when the wires are manufactured.

Several studies claim that the beta titanium arch-wires generate light orthodontic forces. Due to the higher value of the elongation at break coefficient, they are better for clinical practice than titan-molibden arch-wires [7-9].

Regarding esthetic arch-wires, even though they were not included in this study, the data from the orthodontic literature suggests that they present a high rugosity level after a 4 -week wear [10-14].

Conclusions

The mechanical properties of the arch-wires are very important in the clinical practice. The orthodontist must apply light forces through-out the wires, that must not exceed the biological limits of the periodontal tissues. The continuous research in this area had a favorable impact regarding arch-wire selection, allowing the orthodontist to choose different types of arch-wires that can satisfy any biomechanical situation.

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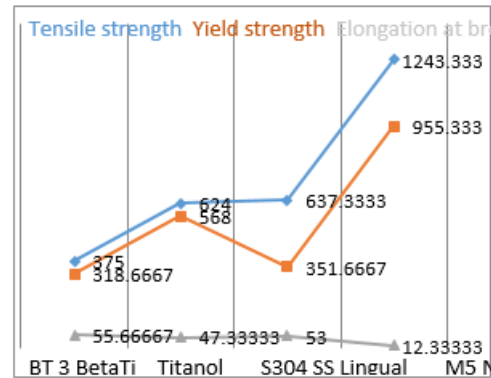


Fig. 3. Statistical analysis of the mechanical properties

References

- ES SOUNI, M., ES SOUNI, M. FISCHER B.H., On the properties of two binary NiTi shape memory alloys. Effects of surface finish on the corrosion behaviour and in vitro biocompatibility, *Biomaterials*, Vol. 23, Issues 14, July 2002, p. 2887-2894
- VERSTRYNCE A., HUMBEECK J.V., WILLEMS G. In-vitro evaluation of the material characteristics of stainless steel and beta-titanium orthodontic wires, *AJODO*, Vol. 130, Issue 4, October 2006, p. 460-470
- GHERGHESCU, I.A., JICMON, G.L., COTRUT, C., BRANZEI, M., BERBECARU, A.C., PREDESCU, A.M., CIUCA, S., *Rev. Chim. (Bucharest)*, **67**, no. 9, 2016, p. 1734
- FISCHER, H. et al, Transformation Behavior, Chemical Composition, Surface Topography and Bending Properties of Five Selected 0.016" × 0.022" NiTi Archwires, *Journal of Orofacial Orthopedics*, 2003, Vol. 64, Issue 2, p. 88-89
- WICHELHAUS, A. et al, The effect of surface treatment and clinical use on friction in NiTi orthodontic wires, *Dental Materials*, Vol. 21, Issue 10, 2005, p.938-945
- EARAR, K., MATEI, M.N., MARECI, D., TRINCA, L.C., ARITON, M.A., AROTARTEI, D., CERGHIZAN, D., BICA, C., CIUPLAN, C., *Rev. Chim. (Bucharest)*, **67**, no. 9, 2016, p. 1850
- SHUBHAKER R J,VIGNESH K,SRIDEVI P at al. Physical, mechanical, and flexural properties of 3 orthodontic wires:An in-vitro study. *Am J Orthod Dentofacial Orthop* 2010;138:623-30.
- ASTRID V, JAN V H,GUY W. In-vitro evaluation of the material characteristics of stainless steel and beta-titanium orthodontic wires. *Am J Orthod Dentofacial Orthop* 2006;130:460-70
- CACCIAFFESTA V, SFONDRINI MF, LENA A, SCRIBANTE A, VALLITTU PK, LASSILA LV. Force levels of fiber-reinforced composites and orthodontic stainless steel wires: A 3-point bending test. *Am J Orthod Dentofacial Orthop*. 2008;133:410-3
- FIRAS E, NICK S, DAVID B. Ex vivo surface and mechanical properties of coated orthodontic Archwires. *European Journal of Orthodontics* 2008;30:661-66.
- RADOI,B.P, ALEXA,E., RADULOV, I, MORVAY, A., STROE MIHALC.S., TRASCA,T.I., Total Phenolic, Cinnamic Acids and Selected Microelements in Gluten Free Pasta Fortified with Banana, *Rev.Chim.(Bucharest)*, **66**, no.8, 2015, 1162
- SZUHANEC,C.,GLAVAN, F.,JIANU,R., *Biomechanica ortodontica Ed.Orizonturi Universitare Timisoara* 2009, 211 pag 978-973-638- 435-6.
- OANCEA,R.,BRADU,A.,SINESCU,C.,NEGRU,R.M., NEGRUTIU,M.L., ANTONIAC,I., DUMA,V.F.,PODOLEANU,A.G., Assesment of the sealant/tooth interface using optical coherence tomography, *J Adhes Sci Technol*, 2015, 29(1), 49-58, DOI:10.1080/01694243.2014. 974879, ISSN 0169-4243 (Print), 1568-5616 (Online) IF 1,153/2014
- OANCEA,R.,BONT,'E, D.,PODARIU,A.C.,SAVA ROSIANU, R.,TAMPA M.,MATEI,C., Evaluation of salivary biochemical parameters in caries free and caries active children, *Rev. Chim. (Bucharest)*, **65**, no.10, 2014, p.1200

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