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COMPARISON OF HARDNESS FOR DIFFERENT TYPES OF ORTHODONTIC WIRES

BY

RALUCA MARIA MOCANU[1*], VIOREL GOANŢĂ[2] and IRINA NICOLETA ZETU[1]

[1]"Grigore T. Popa" University of Medicine and Pharmacy, Iaşi,
Department of Orthodontics & Dentofacial Orthopedics
[2]"Gheorghe Asachi" Technical University of Iaşi,
Department of Mechanical Engineering, Mechatronics and Robotics

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Abstract. This study evaluated and compared the surface hardness of the commonly used types of orthodontic archwire (conventional and cosmetic/coated): Stainless Steel (SS) wire and Nickel-Titanium (NiTi) alloy wire. The dimension of all wires used was the same and they were tested under similar conditions, as received. In the present study, conventional SS wire had the hardest surface, followed by conventional NiTi wires and cosmetic wires. Great variances in surface microhardness were observed in regard to the manufacturers.

Key words: conventional and coated orthodontic archwires, Vickers microhardness.

1. Introduction

Orthodontic wires, which generate the biomechanical forces communicated through brackets for tooth movement, have different surface properties. These properties determine the aesthetics of orthodontic components

*Corresponding author; *e-mail*: mocanu_ralucamaria@yahoo.com

and affect the corrosion potential and biocompatibility. Tooth movement can be resisted by frictional forces between an archwire and brackets (Neumann *et al*., 2002). The surface properties, such as roughness and hardness of orthodontic archwires may affect the sliding mechanics by influencing the coefficient of friction. The surface characteristics of orthodontic archwires are important determinants of the effectiveness of archwire-guided tooth movement. Even wires of the same alloy but from different manufacturers, show a variety of characteristics with regard to chemical structure, surface roughness and microhardness (Juvvadi *et al*., 2010; Krishnan & Kumar, 2004).

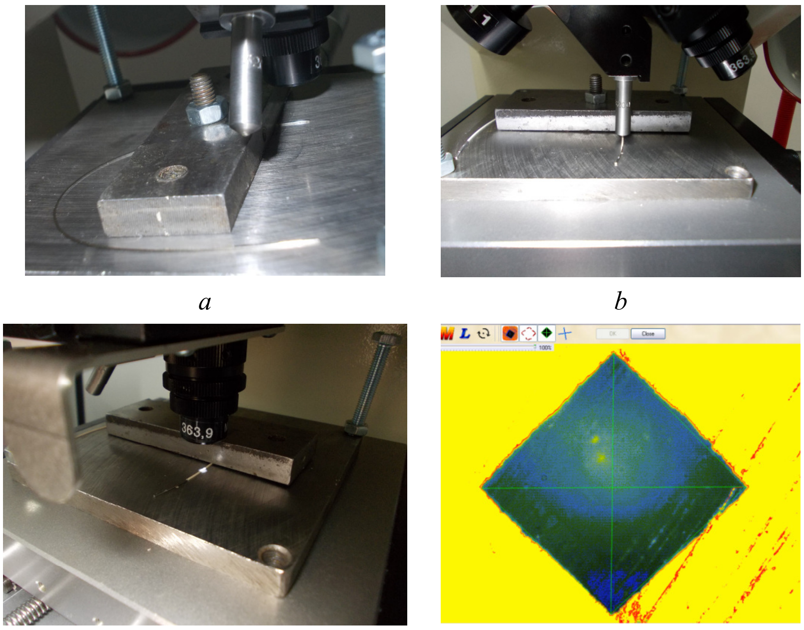
Surface hardness (the resistance to indentation) is one of most important characteristic of surface. The Vickers hardness number (HV) has been the most popular element in the investigation of the relationship between hardness and the lifetime or tensile strength of the material because of two reasons: firstly, its superior resolution as compared to spherical indenters, and secondly, the Vickers indenter is self-similar, through which the hardness is ideally independent of the indentation load and indentation depth. The degree of plastic deformation may be determined from hardness tests. The mechanical properties of a material, usually derived from the characteristic stress-strain curve obtained through uniaxial tensile, may be evaluated through indentation. Both hardness and tensile strength are indicators of metal resistance to plastic deformation. Commonly, a correlation between hardness and tensile strength is provided in literature, permitting an approximate estimation of material tensile strength from its hardness value. The hardness-tensile strength correlation is generally good (differences being usually less than ± 10%) (Pavlina & Van Tyne, 2008). The aim of this study was to evaluate and compare the surface hardness of the commonly used types of orthodontic archwire

2. Material and Method

This study evaluated and compared the surface hardness of the commonly used types of orthodontic archwire (conventional and cosmetic/coated): Stainless Steel (SS) wire (3M Unitek), Stainless Steel (Highland Metals), Cosmetic Stainless Steel (3M Unitek), Conventional Nickel-Titanium (NiTi) alloy wire (3M Unitek), Conventional Nickel-Titanium (NiTi) alloy wire (Highland Metals), Cosmetic Nickel-Titanium (NiTi) alloy wire (3M Unitek). The dimension of all wires used was the same: 0.019x0.025 in (0.48x0.64 mm) and they were tested under similar conditions. From the straight portion of every type of archwire were prepared seven specimens, 30 mm length. The microhardness of each sample was measured in eight points. All the tests were performed at the Research Laboratory of Discipline of Strength of Materials, Department of Mechanical Engineering, Mechatronics and Robotics, Faculty of Mechanical Engineering, "Gheorghe Asachi" Technical University of Iaşi.

The microhardness values were determined on an EMCOTEST M1C01A, Austria durimeter equipped with data acquisition, visualization and measurement of traces on the computer monitor. The method for determininig Vickers hardness uses a diamond intendor in the form of a square-based pyramid. Microhardness, HV is proportional to the load divided by the square of the diagonal of the indentation measured from the test. The HV number is the ratio *F/A* where *F* is the force applied to the diamond in kilograms-force and *A* is the surface area of the resulting indentation in square millimeters.

In Fig. 1 are presented the steps of determining Vickers microhardness on wires. Because the sample had a special configuration, in the first phase, the specimens were mounted on a jig that held the wire at two points using a screw, so the sample movements during the test weren't aloud. Before indenting, the focus was adjusted in order to ensure the correct distance between the diamond tip and the sample to be tested. The second phase consists in indentation under a 20 kgf load for a testing time of 15 sec. The third phase represents the visualization of the intendation track and the precise determination of the Vickers number.



a *b* *c* *d*

Fig. 1 − The steps for determining Vickers microhardness: *a* − Sample mounting; *b* − Sample indentation; *c* − Ident track visualization; *d* − Indent track measurement.

The evaluation can be made automatically if the aspect of intendation is concret and the diagonal line allow the precise measurement. In contrar the measure of the diagonals of the diamond indent (d_1 and d_2) are made manually (Fig. 2).

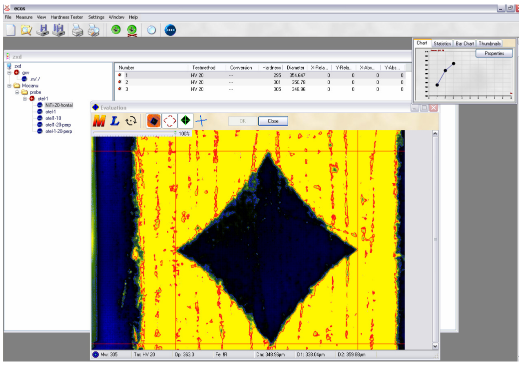


Fig. 2 − Manually determination of diagonals

In the both cases, the formula used for Vickers microhardness is:

$$HV = 1.8544\ F/d^2 \quad (1)$$

where: F is the force used to indent, [kgf]; d − the arithmetic mean of the two diagonals, [mm].

3. Experimental Results

For every type of material were prepared seven specimens and for each specimen there were performed eight measurements. A standard statistical software package (software SPSS Inc, version14 and Stat Soft, version 8) was used for data analysis. Descriptive statistics (mean and standard deviations) were calculated. The results of Vickers microhardness for the seven samples tested are listed in Table 1.

Table 1
HV Number for the Specimens Tested

Type of archwire	Stainless Steel (HM)	Stainless Steel (3M)	Stainless Steel Cosmetic (3M)	Nickel Titanium (HM)	Nickel Titanium (3M)	Nickel Titanium Cosmetic (3M)
Microhardness Vickers (determined values) [kgf/mm^2]	516	562	473	295	386	283
	527	550	512	305	400	306
	519	551	509	309	405	298
	482	541	490	299	379	318
	492	533	493	303	393	276
	498	534	474	289	384	313
	502	543	504	301	402	312
Microhardness Vickers Mean ±std dev [kgf/mm^2]	505.14 ±14.91	544.86 ±9.52	493.57 ± 14.67	300.14 ± 6.12	392.71 ±9.25	300.85 ±14.81

In the chart below (Fig. 3), it is summarized the comparison between conventional SS and NiTi wire, obtained from two different manufacturers.

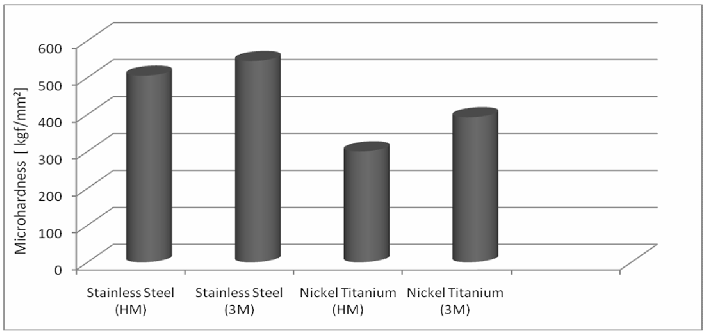


Fig. 3 – Comparison of microhardness for SS and NiTi wires from different manufacturers.

It can be observed that the NiTi wires have a lower microhardness comparing with SS and that both orthodontic wires from 3M Unitek revealed a higher microhardness. The NiTi wire (3M) had a microhardness greater by 24% when comparing to NiTi wire (HM). The highest difference- 55%- was obtained between SS (3M) and NiTi (HM).

The next chart (Fig. 4) indicates the differences regarding microhardness between conventional and coated/ cosmetic orthodontic wires. A significant difference of 30% is between conventional and cosmetic NiTi wires.

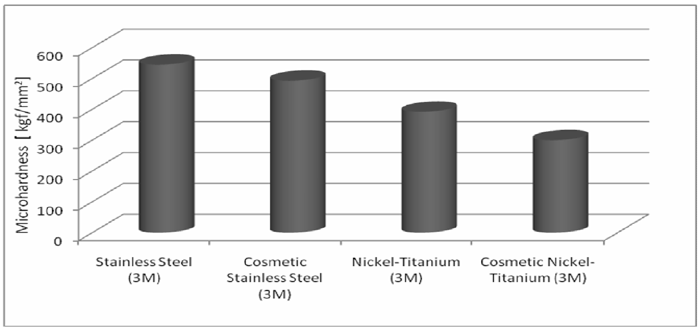


Fig. 4 − Comparison of microhardness for SS and NiTi conventional and coated wires.

4. Conclusions

1. The hardness of archwire as an essential property because the relative hardness of wire and bracket materials affects the degree of wear.

2. Even wires of the same alloy but from different manufacturers, show a variety of surface microhardness.

3. SS conventional wires had the hardest surface, but with differences regarding different manufacturers 505.14±14.91 kgf/mm^2 (Highland Metals) and 544.86±9.52 kgf/mm^2 (3M Unitek). The highest difference- 55%- was obtained between SS (3M) and NiTi (HM).

4. Conventional SS wire had the hardest surface, followed by conventional NiTi wires and cosmetic/coated wires.

5. Cosmetic SS wire (3M) had a microhardness Vickers with 30% higher than conventional NiTi wire (3M).

6. Nickel Titanium Cosmetic wire (3M) had aproximative the same hardness as conventional Nickel Titanium wire (HM).

Further studies need to take in consideration the correlation between hardness and surface topography, roughness, chemical composition and coefficient of friction.

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COMPARAŢIE PRIVIND DURITATEA DIFERITELOR TIPURI DE ARCURI ORTODONTICE

(Rezumat)

Arcurile ortodontice generează forţele biomecanice care prin intermediul bracketurilor determină deplasarea dentară. Acestea prezintă diferite caracteristici ale suprafeţei care influenţează componenta estetică, biocompatibilitatea şi coroziunea. Prezentul studiu are ca scop evaluarea şi compararea microdurităţii Vickers pentru cele mai utilizate tipuri de arcuri ortodontice: oţel inoxidabil şi aliaj nichel-titanium, în variantele convenţional şi cosmetic. Arcurile au avut aceeaşi dimensiune şi au fost testate în aceleaşi condiţii. Arcurile convenţionale din oţel inoxidabil au prezentat duritatea cea mai mare, urmate de arcurile nichel-titanium convenţionale şi de cele cosmetice. Diferenţe semnificative au fost observate între arcurile din acelaşi material obţinute de la diferiţi producători.