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Evaluation of the hardness of different orthodontic wires: A comparative study

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Abstract
Background: Patients undergoing orthodontic treatment are increasingly demanding for the better esthetic. Mechanical properties of orthodontic wires are of paramount importance as they are deeply implicated in the efficacy of orthodontic therapy. Hence; the present study was undertaken for evaluating the hardness of different orthodontic wires.
Materials & methods
Results: Mean microhardness of the specimens of the stainless steel group, nickel-titanium group and beta-titanium group was 512.36, 356.12 and 302.47 respectively. While comapring in between the three study groups, significant results were otbaiend.
Conclusion: Highest microhardness was seen among specimens of stainless steel group. However; further studies are recommended.

Keywords: stainless, steel, orthodontic

Introduction
Patients undergoing orthodontic treatment are increasingly demanding for the better esthetic. This led to the introduction of orthodontic appliances that combine the esthetics with optimal performance. In fixed orthodontic therapy, the introduction of esthetic orthodontic brackets partially solved the issue, but most of the orthodontic wire alloys are stainless steel, cobalt-chromium, beta-titanium, and nickel-titanium (NiTi) [1- 3].
Metallic archwires are coated with colored polymers or inorganic materials to fulfill the growing esthetic needs of the orthodontic patients. Materials used in esthetic coating are polymers such as synthetic fluorine-containing resin or epoxy resin or polytetrafluoroethylyene (PTFE Teflon), which simulates the tooth color [4, 5].
Mechanical properties of orthodontic wires are of paramount importance as they are deeply implicated in the efficacy of orthodontic therapy. Fundamental mechanical properties such as modulus of elasticity, yield strength, fracture strength, and others are mostly evaluated by tensile, bending, and torsion testings. Recently, the instrumented indentation testing (IIT) has been adopted by the International Organization for Standardization (ISO) as an alternative methodology for testing a vast spectrum of mechanical properties such as hardness, modulus of elasticity, creep, relaxation, and more [6-8]. Hence; the present study was undertaken for evaluating the hardness of different orthodontic wires.

Materials & methods
The present study was conducted for evaluating the hardness of different orthodontic wires. The wires used in the present study were made of stainless steel (SS) (Germany), nickel titanium (NiTi, USA), and beta-titanium (TMA, USA). In the present study, we used the edgewise bracket with a slot sixe of 0.018" for the upper left canine. Cutting of all the archwires was done into 15-mm segments. Evaluation of ten specimens from each wire brand was done. This was followed by embedding of the wires in epoxy resin. The brackets positioned in a horizontal direction. This was followed by polishing of the specimens with alumina slurry. Then, the specimens were cleaned in an ultrasonic bath. Afterwards, the hardness of the external surfaces of the brackets was measured. The micrographs of the representative Vickers indentations were obtained through an optical microscope. All the results were recorded in Microsoft excel sheet and were analysed by SPSS software.

Student t test was used for evaluation of level of significance.

Results
In the present study, mean microhardness of the specimens of the stainless steel group, nickel-titanium group and beta-titanium group was 512.36, 356.12 and 302.47 respectively. While comapring in between the three study groups, significant results were otbaiend. Highest microhardness was seen among specimens of stainless steel group while it was minimum among speccumens of beta-titanium group.

Table 1: Mean Microhardness

Wires	Microhardness (VHN)	
	Mean	SD
Stainless Steel	512.36	96.2
Nickel-titanium	356.12	35.1
Beta-titanium	302.47	39.1

Table 2: Comparison of Mean Microhardness

Group	p- value
Stainless Steel Versus Nickel-titanium	0.00*
Stainless Steel Versus Beta-titanium	0.04*
Nickel-titanium Versus Beta-titanium	0.01*

*: Significant

Discussion
In orthodontic treatment, forces are applied to teeth through activated archwires inserted into the slots of the brackets bonded to tooth enamel surfaces. Three different methods are used to manufacture metallic brackets: milling, casting, and metal injection molding (MIM). Combined brackets are manufactured by soldering with brazing alloys to connect the base and wings of the brackets or by direct laser welding the wings to the base. The MIM technique is more recent than the other three methods and was developed in the United States in the early 1980s. It is an inexpensive manufacturing process compared to other methods and is used to manufacture large quantities of complex and intricate parts [8-10]. Hence; the present study was undertaken for evaluating the hardness of different orthodontic wires and brackets.

In the present study, mean microhardness of the specimens of the stainless steel group, nickel-titanium group and beta-titanium group was 512.36, 356.12 and 302.47 respectively. While comapring in between the three study groups, significant results were otbaiend. Zinelis S *et al*. characterized of mechanical properties of representative types of orthodontic wires employing instrumented indentation testing (IIT) according to ISO 14577. Segments were cut from ten wires. The first six are made of stainless steel (SS), two are made of Ni-Ti, and the last two are made of titanium molybdenum alloys (TMA). Then, the Martens hardness (HM), the Vickers hardness (HVIT) based on indentation hardness (HIT), the indentation modulus (EIT), the ratio of elastic to total work (ηIT), and the traditional Vickers hardness (HV1) were measured by IIT. SS wires showed the highest hardness followed by TMA and Ni-Ti alloys. However, all wires showed significantly lower HVIT compared to corresponding HV1, a finding probably appended to elastic recovery around the indentation. EIT for all wires tested was determined much lower than the nominal values of the corresponding alloys due to the implication of residual stress field at the slope of unloading curve. Elastic to total work ratio was ranged from 45.8 to 64.4 % which is higher than that expected for ductile alloys (<30 %). The products tested illustrated significant differences in their mechanical properties [10].

In the present study, highest microhardness was seen among specimens of stainless steel group while it was minimum among speccumens of beta-titanium group. Inami T *et al*. Investigated the surface topography, hardness, and frictional properties of GFRPs. To investigate how fiber diameter affects surface properties, GFRP round wires with a diameter of 0.45 mm (0.018 in.) were prepared incorporating either 13 µm (GFRP-13) or 7 µm (GFRP-7) glass fibers. As controls, stainless steel (SS), cobalt-chromium-nickel alloy, β-titanium (β-Ti) alloy, and nickel-titanium (Ni-Ti) alloy were also evaluated. Frictional forces against the polymeric composite brackets of GFRP-13 and GFRP-7 were 3.45 ± 0.49 and 3.60 ± 0.38 N, respectively; frictional forces against the ceramic brackets of GFRP-13 and GFRP-7 were 3.39 ± 0.58 and 3.87 ± 0.48 N, respectively. For both bracket types, frictional forces of GFRP wires and Ni-Ti wire were nearly half as low as those of SS, Co-Cr, and β-Ti wires. There was no significant difference in surface properties between GFRP-13 and GFRP-7; presumably because both share the same polycarbonate matrix [11]. Raluca-Maria V 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 [12].

Conclusion
From the above results, the authors concluded that highest microhardness was seen among specimens of stainless steel group. However; further studies are recommended.

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