

Load-deflection characteristics and force levels of coated nickel titanium orthodontic archwires

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ABSTRACT

Background: Coated archwires have been introduced to improve esthetics during orthodontic treatment. The aim of the present study was to evaluate and compare the load-deflection characteristics and force levels of six brands of coated nickel titanium orthodontic archwires using palatal and gingival deflection.

Materials and methods: Ten round wires (0.016 inch) and ten rectangular wires (0.019x0.025 inch) were obtained from each of six brands (G&H, Opal, Ortho Technology, Dany, Hubit and Astar Companies). The load-deflection properties of these archwires were evaluated by the modified bending test using a readymade dental arch model in both palatal and gingival directions at 37°C temperature using a universal material testing machine. Forces generated at maximum loading of 2mm and at unloading of 1.5mm were measured.

Results: All the wires showed hysteresis and significant differences in their load deflection curves, but these differences were more evident in round wires than in rectangular wires where G&H wires showed the widest loading-unloading deflection curves. The maximum loading force of round wires in gingival deflection were higher than by palatal deflection. The force decline during unloading (plateau gap) ranged between 18 to 34% for round wires and 17 to 37% for rectangular wires.

Conclusion: Coated epoxy wires (G&H, Opal, Astar and Ortho Technology) produced lower forces compared to polymer (Dany) and Teflon (Hubit) coated round and rectangular archwire.

Key words: Load-deflection; esthetic; orthodontic archwire. (J Bagh Coll Dentistry 2015; 27(2):154-157).

INTRODUCTION

The demand for esthetic orthodontic appliances is increasing, and the development of materials that present acceptable esthetics for the patients and an adequate clinical performance for clinicians is needed.¹ There has been continuing interest in the development and use of esthetic and effective orthodontic archwires. The evolution of wire manufacturing technology and the development of new orthodontic techniques have led to the search for better quality alloys, more biologically effective for the teeth and supporting tissues. Aesthetics has become an important and integral part of the orthodontic treatment. With the invention of revolutionary aesthetic brackets, the need for the aesthetic wires became very strong.²

Most fixed appliances components are metallic in nature. This problem was partially solved with introduction of esthetic orthodontic brackets and archwires. However conventionally used orthodontic archwires which are made up of metal such as stainless steel, nickel titanium etc. have excellent mechanical properties but are poor esthetically.³ Such archwires are replaced by aesthetic coated archwires.⁴

Materials used in coating are polymers such as synthetic fluorine-containing resin or epoxy resin composed mainly of polytetrafluoroethylene, which is used to simulate tooth color.⁵

The growing demand for invisible orthodontic treatment has led to remarkable advancements in aesthetic archwire technology, from PTFE and vapor-parylene coating to nonmetallic arches. These wires will continue to improve with regard to appearance, durability, and biomechanical control. Nonmetallic arches such as fiber-reinforced and self-reinforced polymers are likely the future of aesthetic orthodontic wires, and they may someday replace traditional nickel-titanium and stainless steel wires in patients receiving ceramic braces.⁶ Recently, coating technology for metallic biomedical materials based on ion-implantation technique has been developed.⁷

MATERIALS AND METHODS

Six brands of orthodontic archwires were investigated: ASTAR (epoxy coated, China), DANY (polymercoated, Korea), HUBIT (Teflon coated, Korea), G&H, OPAL and Ortho Technology (epoxy coated, USA) with sizes of 0.016 inch and 0.019x0.025 inch. Maxillary 0.022x0.028 inch slot self-ligating brackets were bonded to the teeth surfaces of the dental arch model except for the first molars to which molar tubes were attached. Secure attachment was achieved for the brackets and buccal molar tubes by bonding the base of them to the crown. Accurate slot alignment was achieved by using a plain 0.021x0.025 inch stainless steel archwire as a former while the bonding was light cured. The test was carried out by deflecting the wire at 15mm between the midpoints of the brackets.

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This interbracket distance was derived from typical tooth dimensions.⁸

The bending test was carried out in both palatal and gingival deflections in a water bath at temperature $37^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ with digital thermometer controlling a Universal Material

Tester. Each bending test was done 10 times, with a new piece of wire for each repetition (Fig.1). Load at maximum deflection of 2mm and unloading phase at 1.5mm deflection were registered.

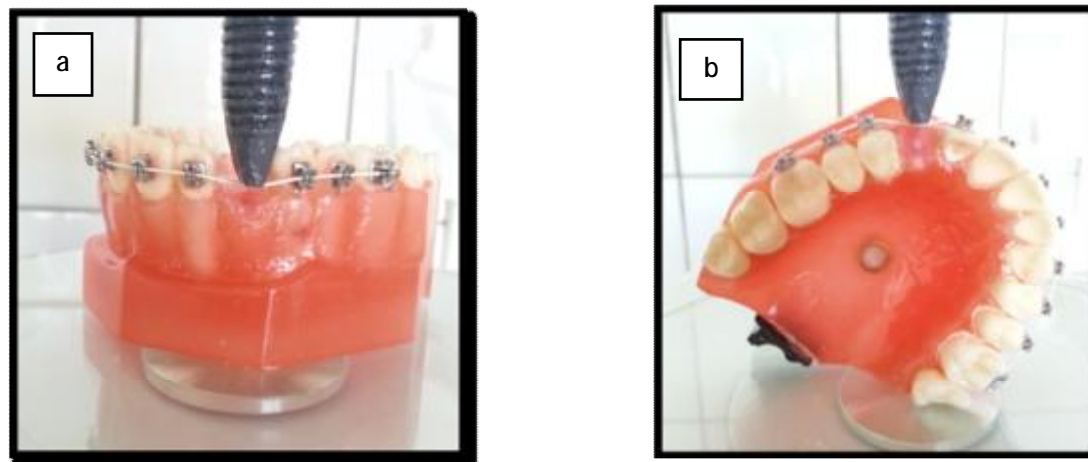


Figure 1: A modified bending test procedure was carried out on the tested archwire by the pressure of the metal blade in (a) palatally and (b) gingivally directions.

RESULTS

The load-deflection curves for the two NiTi wires from six brands using gingival and palatal deflections are shown in Fig. 2 when the wires were loaded to 2.0mm deflection and then unloaded. In each wire the hysteresis loop was observed. As the deflection reduced from the maximum 2.0mm, the load decreased then the curve showed a plateau where the deflection decreased finally and went back to zero.

The results of the ANOVA and LSD show that the forces generated by the six brands of the two NiTi wire gauges at loading and unloading showed highly significant difference at the $p < 0.001$ level.

In general, for round wire, Hubit showed high loading and unloading forces while G&H gave the lowest forces. Whereas for rectangular wire, Dany displayed high loading and unloading forces while G&H gave the lowest forces.

DISCUSSION

Many of the load - deflection curves of NiTi orthodontic wires have so far been derived from the free- end, simple three point bending tests but in the present study, the bending test was performed on a dental arch model with the wire being restrained in self ligating brackets simulating the orthodontic treatment of the malaligned upper right canine by palatal and gingival deflection.

The modified bending test produced load-deflection diagrams consisting of an upper loading curve and a lower unloading curve. The loading curve represents the force needed to engage the wire in the bracket of the displaced canine, whereas the unloading curve represents the forces delivered to the teeth during treatment stages.⁹ In this study self-ligating brackets were used because of their lower friction than that of conventional brackets with elastomeric ligatures.^{10, 11}

For 0.016 inch archwires, G&H presented with lower force while the Hubit wires presented with higher force in both loading and unloading. This could be due to the facts that the teflon (Hubit) layer adds a minimal thickness (.0008 to .001 inch) to the archwire, while the epoxy (G&H) coating adds more significant thickness (.002 inch) to the archwire,⁶ so the coating of epoxy is thicker than that of the PTFE layer and may result in a smaller NiTi inner core inside them.

For 0.019x0.025 inch wires, the highest force values were for Dany wires while the lowest were for G&H and Opal wires in both loading and unloading. This could be due to the thickness of the coating of polymer wire (Dany) is approximately 0.001 inch less than that of epoxy wire (G&H, Opal).⁴

The curves for the two NiTi wires from six brands palatally deflected at the same deflection and of the same size, demonstrated a small and narrow hysteresis loop, while gingivally deflected

wires had similar behavioural characteristics (wide hysteresis curves) with wider range of forces during the loading and unloading phases and lower working forces. This may be due to that the palatally deflected wires did not express their superelasticity due to the insufficient force for inducing the martensitic transformation during loading and the increased force for reverse transformation during unloading it means that more austenite can be transformed during the formation of SIM.^{12, 13}

The majority of the round wires at 2mm loading deflection showed higher force values during gingivally deflection test While at 1.5mm unloading, all the round wires showed higher force values during palatally deflection. This may be due to that the archwires were more constrained in the bracket slots gingivally that lead to more frictional resistance which gave higher force values to exceeds the overall increase in the frictional resistance.¹⁴

For rectangular wires in loading and unloading, the highest force values were shown during palatal deflection than gingival deflection. This may be due to the rectangular wires being thicker in palatal aspect than gingival aspect

Plateau values were measured in the present study because these are frequently used to express a measure of super elasticity and force stability of NiTi wires. The wires with small plateau gap values were the more superelastic and force

stability than the wires with large plateau gap values.

0.016 inch and 0.019x0.025 inch Hubit, 0.019x0.025 inch Dany wires showed the least super elasticity values, while 0.016 inch Opal, 0.019x0.025 inch G&H, Astar wires showed the highest super elasticity values. This indicates that although wires may have comparable plateau gradients, consideration should also be given to the load levels associated with these plateau measurements.¹⁵ Because Hubit and Dany wires provided the highest unloading values for the 1.5 mm and 1.0 mm load-deflection tests, this plateau gap represented a particularly small proportional change in force level.

Percentage of hysteresis in the round wire was smaller than in rectangular wires. This agrees with **Garrecand Jordan**¹⁶ who stated that for the same maximum deformation, the volume of SIM increases with the cross-sectional dimension. Therefore, the area of the mechanical hysteresis increases. The stored elastic energy increases with the same proportion and will facilitate the reverse transformation. In this study almost wires showed higher hysteresis in gingival deflection test than in palatal deflection test, which may be due to the increased binding and higher loading forces than in palatal deflection test. These higher loading forces induce more martensitic transformation during loading and the decreased force for reverse transformation during unloading.¹⁷

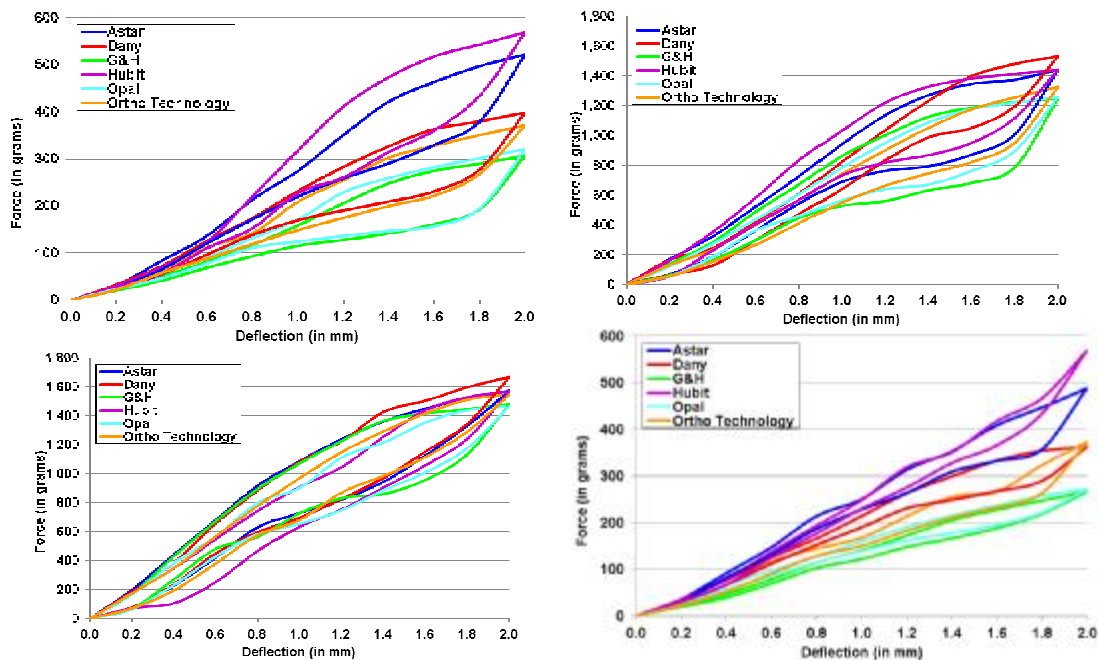


Figure 2: Load deflection curves for the two NiTi wires from six brands (a) for 0.016 inch using gingival deflection test (b) for 0.016 inch using palatal deflection test (c) for 0.019x0.025 inch using gingival deflection test (d) for 0.019x0.025 inch using palatal deflection test.

As conclusion;

1. Generally coated epoxy wires (G&H, Opal, Astar and Ortho Techonology) produced lower forces compared to polymer (Dany) and teflon (Hubit) coated round and rectangular archwire.
2. All the wires showed hysteresis in their load deflection curves where G&H wires showed the widest loading- unloading deflection curves.
3. All the wires showed significant differences in their load deflection curves, but these differences were more evident in round wires than in rectangular wires.
4. The maximum loading force of round wires in gingival deflection were higher than by palatal deflection but it gave wider hysteresis curves resulting in lower unloading forces.
5. The force decline during unloading (plateau gap) ranged between (18 to 34%) for round wires and (17 to 37%) for rectangular wires.

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