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# An Investigation on Mechanical Properties of Esthetic Orthodontic Archwires

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## Abstract

The main purpose of this study was to investigate the mechanical properties of Ni-Ti coated orthodontic archwires after surface modification. Universal test machine was used to measure the tensile strength of four groups of coated Ni-Ti wires and uncoated control group. Immersion test was applied for 21 days to discover whether the coating would peel off under friction and brushing after immersion. Student's t-test was used to explore any difference between three groups of coated wires and uncoated conventional wires in mechanical properties. The results showed no statistical difference exists between coated Ni-Ti wires and conventional uncoated wires regarding to tensile strength. The load-displacement curve of both wires looked similar. The coating has no effect on the mechanical strength of the base wire. However, after the 21-day immersion test, the epoxy resin coatings were more likely to peel off than Teflon coatings under friction and brushing ($P < 0.05$). There was no statistical difference between coated wires and conventional uncoated wires with regard to mechanical tensile strength. While orthodontists can achieve the same expected treatment result with esthetic wires, the issue of preventing coatings from peeling off needs further studies.



## Keywords

coated orthodontic archwires, stretch test, immersion test

Research Report

# An Investigation on Mechanical Properties of Esthetic Orthodontic Archwires

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## INTRODUCTION

In 1998, a Swedish study which investigated people aged 27 in average showed that 84% of respondents thought they would have been able to wear visible braces during adolescence if needed, and even in adulthood by 67% of respondents. The wearing of visible braces did not seem to be a great barrier to treatment [1]. However, esthetic issue becomes more and more important as time goes by. People want to get a perfect smile via orthodontic treatment with the preference of wearing an invisible or tooth-colored appliance. [2,3]

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Rosvall, et al. (2009) had studied the attractiveness, acceptability and value of orthodontic appliances. The results showed that standard metal braces had the lowest acceptability rate of 55%. And patients are willing to pay more money for appliances they deem more esthetic [4]. An investigation in 2012 revealed that ceramic brackets were more acceptable concerning the smile esthetics, whereas the metal brackets received the lowest scores [5]. A similar study also showed that clear aligners and sapphire brackets with esthetic archwires were considered better esthetic options [6].

Two main groups of materials used in fixed orthodontics are brackets and archwires. The plastic bracket was commercially introduced in 1963, and ceramic bracket in 1987 [7]. The orthodontic wire materials have also changed significantly [8,9,10]. Arch wires with tooth-like colors are introduced into market for cosmetic reasons at the late 20th century. Various coating techniques and materials have been used. For instance, Bandeira *et al*. [11] used a coating technology known as an electrostatic powder technique to apply epoxy paint to NiTi wires. And Teflon (PTFE, poly-tetrafluoroethylene) has been reported in the literature as one of the widest used materials to coat orthodontic appliances by ion implantation technique [12,13].

In addition, the metal-free esthetic archwire is also a research of interest for scientists. Huang [14] in 2003 proposed a new technique based on tube shrinkage for the fabrication of composite archwires. However, composite wires were more brittle than metal archwires, making them ineffective to be put into orthodontic practice. Recently, colored archwire has attracted some attention. It has been found for a long time that metals can be colorized with anodization. The anodized archwires produced a variety of colors (including purple, yellow, green, blue) resulting from optical interference [15, 16, 17].

The corrosion processes are presumed to have negative consequences on biocompatibility, aesthetic appearance and the frictional behavior between the bracket and the coated arch wires during orthodontic treatment. Kim 18 in 1999 conducted electrochemical corrosion tests and indicated that corrosion occurred readily in stainless steel, while titanium wires and epoxy-coated nickel titanium wires exhibited the least corrosive potential. Since metal ions such as nickel and chromium will release from the corroded wires and nickel is the most common metal to cause contact dermatitis in orthodontics, for patients allergic to nickel (Ni) the use of TMA wire or epoxy-coated Ni-Ti wire during orthodontic treatment is recommended [19, 20, 21].

Another investigation by Neumann [22] (2002) studied the corrosion behavior and permanent fracture resistance of eight coated wires and three uncoated arch wires of different dimensions. Surface modifications were made of teflon, polyethylene and by ion implantation. The result indicated that teflon coatings prevent the corrosion of the wires. The ß-titanium wires did not corrode either. In mechanical test, wires were bent repeatedly by mold until breaking down. The result showed that after multiple cycles of bending, the teflon coatings on wires peeled off more or less.

The orthodontic wires might be abraded and damaged to some extent in the oral environment and resulting potential mechanical, clinical, and health implications. There have been a number of studies concerning about metal wires, whereas only few studies for esthetic archwires. Therefore, the purpose of this study is to investigate the mechanical properties of the as received Ni-Ti coated archwires so as to provide reference for further clinical application.

## MATERIALS AND METHODS

In this study, two sizes of as received Ni-Ti wires were selected, i.e. 0.014 inch and 0.016 x 0.022 inch. The Ni-Ti wires were categorized into five groups as following. The control group was Ni-Ti wire without

coating; the other four groups of wire were treated with esthetic coating. The archwire produced by Dentsply Sankin had epoxy resin coating, and the rest of three groups with teflon (polytetrafluoroethylene) coating.

**A.** Uncoated wires - 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wire

**B.** Tomy Sentalloy - 0.014 inch & 0.016 x o.o22 inch Ni-Ti arch wire

**C.** SY Ivory - 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wire

**D.** Ortho Anderson - 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wire

**E.** Dentsply Sankin - 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wire

## EXPERIMENTAL METHODS

### I. Immersion test

The duration of immersion test was scheduled for three weeks. It is because the bone remodeling process lasted three to four weeks for orthodontic tooth movement.

For each group, ten pieces of arch wires (10 cm in length) was prepared. They were washed under tap water for one minute to simulate daily tooth brushing, and then were put in the petri dish containing Fusayama artificial saliva. The petri dish was preserved in the incubator at 37°C. The aforesaid procedure was repeated every 12 hours till Day 21.

All groups of wires were removed from the incubator after day 21 to observe any surface coating peeling off. Electronic caliper was used to measure the size of un-coated area on both sides of each wire, and percentage of the wire un-coated was calculated.

### II. Stretch test

Four experimental groups of esthetic Ni-Ti archwires and one control group of uncoated Ni-Ti wire (N=10) in 10 cm arch length were fixed on the universal testing machine to measure the tensile strength of archwires under stretch test.

The stretching speed of universal testing machine was set as 10 mm/min. The rupture strength (kgf), load-displacement curve, and the tensile elongation of arch-wires were recorded.

In this study, Student's t-test was applied to compare the mechanical strength among four experimental groups and the control group in which $p<0.05$ was defined as statistically significant difference.

## RESULTS

### I. Immersion test

Among the four groups of 0.014 inch esthetic as received archwires, the coatings of Dentsply Sankin archwires on Day 11 and SY ivory color arch-wire on Day 17 began to peel off. The peeled off area of Dentsply Sankin wire was about 30% while that of SY Ivory wire was 5%~10%. In addition, the surface coatings of Tomy Sentalloy and Ortho Anderson wires were intact.

For the 0.016 x 0.022 inch esthetic archwires, the coatings began to peel off on Day 9 for Dentsply Sankin, Day 18 for Tomy Sentalloy, and Day 19 for SY Ivory and Ortho Anderson. The peeled off area of Dentsply wire was about 40% while that of the other three groups were much smaller as 25~30% and locating mostly at the four corners of the rectangular wires.

### II. Mechanical property test

Table 1 and 2 showed the results of the tensile strength test. There is no statistically significant difference in mechanical strength between experimental group and control group for both 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wires ($P> 0.05$). Moreover, Ortho Anderson wires had the maximum rupture strength among five wire groups and the wire produced by Dentsply Sankin has minimum rupture strength.

***Table 1.*** *Maximum rupture strength of 0.014 inch archwire：*

| Brand name | mean (kgf) | SD |
|---|---|---|
| True Flex (uncoated) | 4.53 | 0.57 |
| SY Ivory | 4.17 | 0.71 |
| Tomy Sentalloy | 4.31 | 0.53 |
| Ortho Anderson | 4.67 | 0.69 |
| Dentply Sankin | 4.08 | 0.43 |

***Table 2.*** *Maximum rupture strength of 0.016 x 0.022 inch archwire：*

| Brand name | mean (kgf) | SD |
|---|---|---|
| True Flex (uncoated) | 7.76 | 0.91 |
| SY Ivory | 7.61 | 1.03 |
| Tomy Sentalloy | 7.32 | 0.99 |
| Ortho Anderson | 7.91 | 1.13 |
| Dentply Sankin | 7.09 | 0.81 |

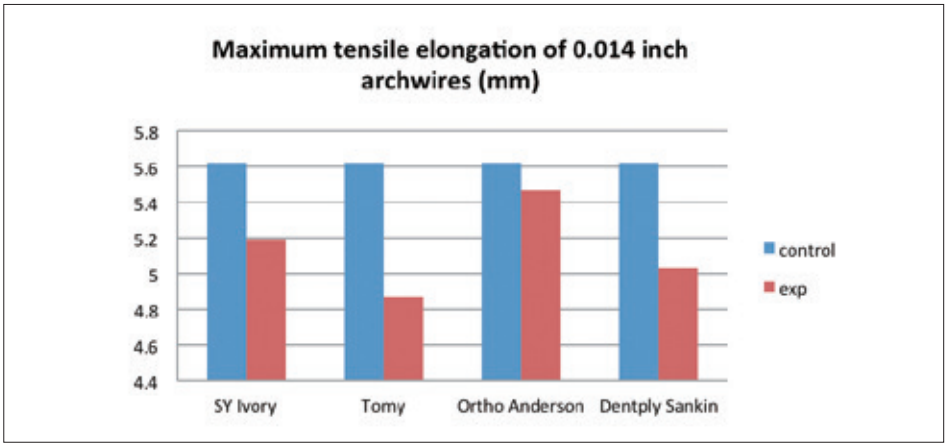


***Figure 1***. *Maximum tensile elongation of 0.014 inch archwire*

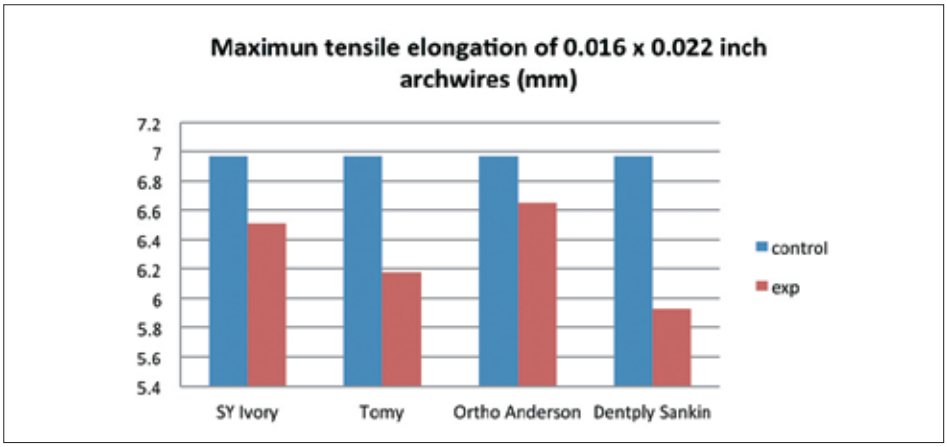


***Figure 2***. *Maximum tensile elongation of 0.016 x 0.022 inch archwire*

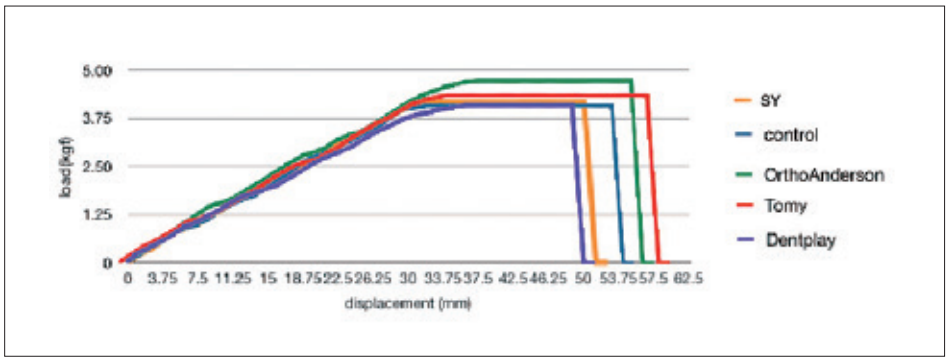


***Figure 3***. *Load-displacement curve of 0.014 inch archwire*

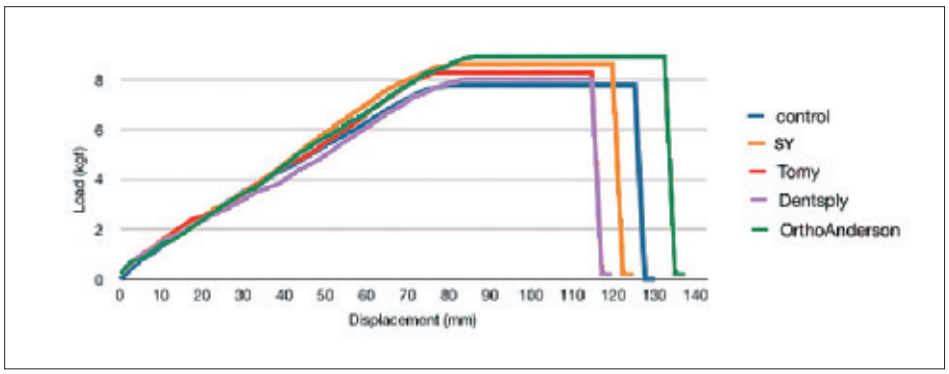


***Figure 4***. *Load-displacement curve of 0.016x0.022 inch archwire*

Figure 1 & 2 showed the maximum tensile elongation of the archwires. It was observed in figure 1 that the 0.014 inch control group has the maximum stretch length (5.62mm) while Tomy Sentalloy group has the minimum (5.17mm).

As for the 0.016 x 0.022 inch group, figure 2 shows that the uncoated control group has the maximum tensile elongation (6.97mm) while Dentsply Sankin has the minimum (5.93mm). However, for both 0.014 inch & 0.016 x 0.022 inch Ni-Ti arch wires, there is no significant difference in stretched length (tensile elongation ) between the experimental group and the control group; and no significant difference among four experimental groups ($p > 0.05$).

The diagram of load- displacement curve was drawn based on the result of stretch test by the universal testing machine. It is observed that the curves of four groups of esthetic Ni-Ti wires are similar to the uncoated control group. As for the experimental group, there is no significant difference among the four different brands of archwires and their overall curves are approximately similar (figure 3 & 4).

## DISCUSSION

The result of tensile test showed that the wire product of Dentsply Sankin has the minimal rupture strength when comparing with other esthetic archwires in both sizes (0.014 inch & 0.016 x 0.022 inch). However, according to the stretch test result of universal testing machine, there is no statistically significant difference in maximal rupture strength between experimental group and control group

of Ni-Ti wires for both size (0.014 inch & 0.016 x 0.022 inch). That is, although the base metal archwires had different surface treatments (teflon or epoxy resin coating), their mechanical strength did not change significantly. Therefore, orthodontists can achieve the same expected treatment result with the esthetic archwires.

In 2002, Neumann[18] used a mold to generate repeated bending of archwires in order to simulate masticatory movement in human. The result showed that there was little difference in mechanical properties between the material of the coating, the base wire and the permanent fracture and corrosion resistance. The archwire with polytetrafluoroethylene (Teflon) coating was most unlikely to have its coating peeled off. These findings were similar with the experimental results of this study.

Although there was no significant difference in mechanical strength among four brands of esthetic archwires, it was found that during the tensile test at the rupture moment most of the epoxy coating of Dentsply Sankin wire peeled off (7/10 samples of Sankin had 60-70% of coating peeled off, 3/10 samples had about 50% of coating lost). In addition, some ivory color (SY) wire samples also had surface coating peeled off. Such outcomes can influence clinical application and possibly prevent the wires from achieving esthetic appearance.

Imai et al.[23] (1999) had investigated the effects of water immersion on mechanical properties of an esthetic fiber-reinforced plastic orthodontic wire (FRP wire). The results showed that the mechanical properties of fiber-reinforced plastic orthodontic wires are reduced by water immersion in the initial stage. The result of the present immersion test showed a similar finding that surface coating of archwires peeled off after brushing and artificial saliva immersion (especially on rectangular wires). It is inferred that in clinical application, the peeling of the coating can be more severe than that in laboratory. A clinical significance may appear concerning about the esthetic demand of the orthodontic patients.

There are many biological and mechanical factors affecting a successful orthodontic treatment, one of them is friction. Guiding a tooth along an arch wire would result in a counteracting frictional force. The frictional forces between orthodontic brackets with different combinations such as metal bracket with metal archwire, metal bracket with esthetic archwire, ceramic orthodontic brackets with metal archwire, and ceramic orthodontic brackets with esthetic archwire had been investigated. The results showed that ceramic brackets free of metal slot with esthetic archwire had the maximum friction force. On the other hand, the metal bracket with metal archwire had the minimum friction force[24, 25]. The result is quite ironic since the combination of metal brackets with metal archwire was considered least esthetic regardless of its better and faster treatment effect. And the patients should be informed about the gains and losses while choosing the esthetic appliances.

The price difference between esthetic wires and conventional archwires is about 1.5~2 times. Besides clinical considerations, the expense of orthodontic appliances should be taken into consideration whether the esthetic archwire meets the cost-effectiveness of the dental practice.

## CONCLUSION

1). According to the experimental results, the mechanical properties of the coated esthetic wire including tensile strength and load-displacement curve are insignificantly different from the wire without surface treatment. Therefore, the coated orthodontic wire will not influence the orthodontic treatment effect.

2). The epoxy coating is more likely to peel off in daily tooth brushing and under orthodontic force, whereas the wire with polytetrafluoroethylene (Teflon) coating meets the requirement for esthetic appearance better.

3). Although orthodontists can achieve the same expected

treatment result with esthetic wires, the issue of preventing coatings from peeling off needs further investigation.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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# 美觀矯正線機械性質的研究－研究論文

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隨著時代潮流演進，人們越來越重視外表容貌，民眾對於矯正器材的美觀要求也越來越高。本篇研究的目的，在於探討經表面處理之後的鎳鈦美觀矯正線材料，其機械性質是否有所改變。

在本篇研究中我們利用萬用試驗機作拉伸試驗，比較經過表面塗層的鎳鈦矯正線跟傳統沒有塗層的鎳鈦矯正線的機械強度。另外利用浸泡試驗，模仿線材在患者口中的情形，查看經過21天的人工唾液浸泡，加上刷牙的磨耗之後，矯正線表面的塗層脫落的情況。

拉伸試驗的測量結果顯示，表面塗層並不會影響線材本身的機械強度，有塗層的鎳鈦矯正線與沒有塗層的鎳鈦矯正線並無顯著差異。而在荷重-位移曲線圖中，有塗層的鎳鈦矯正線線與沒有塗層的鎳鈦矯正線極相似。可是在浸泡試驗中，環氧樹脂塗層的矯正線，會因為刷牙的磨耗產生塗層脫落，鐵氟龍塗層的矯正線相對比較不易產生塗層脫落。矯正醫師使用有塗層的矯正線，不會影響矯正治療效果；但為達成患者美觀的要求，則需進一步研發不會脫落的塗層材料。 ***(J. Taiwan Assoc. Orthod. 26(3): 162-170, 2015)***

**關鍵詞：美觀矯正線、拉伸試驗、浸泡試驗**

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