



## Original Research Article

## Effects of powered tooth brush on four different esthetically coated nickel titanium archwires -An in vitro study

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### Abstract

**Aim:** To investigate the colour, gloss, and surface roughness of Epoxy-coated, Rhodium-coated, Ceramic-coated, and Teflon-coated NiTi arch wires before and after brushing in a simulated oral environment.**Materials and Methods:** The sample group were categorized in to 4 groups based on different coatings. Group.1-Epoxy resin coated, Group.2- Rhodium coated, Group.3-Ceramic coated, Group.4-Teflon coated arch wires of 10 numbers each using sample size calculating formula for means and Baseline characteristics of arch wire i.e., gloss, colour and surface roughness were evaluated. Metallic brackets with .022" x .028" slot was bonded to the acrylic teeth portion of typhodont model and arch wires were ligated to the bracket assembly. Then the acrylic teeth portion of the typhodont along with the bracket-arch wire assembly was immersed in to the container with artificial saliva. 2 minutes of brushing was done twice daily with Colgate powered electrical toothbrush and Colgate tooth paste for 30 days and after that the arch wires were removed from the typhodont model and post brushing characteristics were evaluated. Gloss of the arch wires was measured by glossmeter. Spectrophotometer was used to determine the colour. Surface roughness was evaluated using scanning electron microscopy.**Results:** The study revealed statistically significant differences between the groups ( $p < 0.05$ ). Teflon-coated archwires exhibited the highest color stability, while Ceramic-coated archwires showed the least. Teflon-coated archwires also demonstrated the least loss of gloss, whereas Rhodium-coated archwires exhibited the highest gloss loss. In terms of surface roughness, Rhodium-coated archwires had the least roughness, with Ceramic-coated archwires displaying the highest roughness.**Conclusion:** Teflon-coated archwires performed the best in terms of color stability and gloss retention, while Rhodium-coated archwires exhibited minimal surface roughness after brushing.**Keywords:** Epoxy coated archwires, Rhodium coated archwires, Ceramic coated archwires, Teflon coated archwires, Surface roughness, Gloss, Color stability**Received:** 05-10-2024; **Accepted:** 22-09-2025; **Available Online:** 14-10-2025

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### 1. Background

Fixed orthodontic treatment is a dental procedure that utilizes brackets and wires to align the teeth. In the field, the advent of esthetic brackets has represented a noteworthy advancement in recent times.<sup>1</sup> These brackets are crafted from materials that are more inconspicuous compared to conventional metal brackets, such as Ceramic or transparent plastic.<sup>1</sup> Despite the introduction of aesthetic brackets, the majority of orthodontic wire alloys used in fixed orthodontic therapy are still stainless steel, cobalt-chromium, beta-which are essential for moving teeth into their desired positions.<sup>2</sup> While aesthetic brackets are a step towards a more discreet

orthodontic treatment, the use of these alloys is still necessary to achieve the desired outcome.<sup>2,3</sup> It is important to note that the materials used in orthodontic treatment are safe and have been extensively tested for their effectiveness and safety.<sup>4</sup>

Metallic arch-wires are coated with colored polymers or inorganic materials to meet the growing aesthetic needs of orthodontic patients.<sup>3,5</sup> To achieve this, various materials are coated with polymers that simulate the colour and translucency of natural teeth. These polymers can be synthetic fluorine-containing resin, Epoxy resin, or PTFE Teflon. Teflon coatings are usually applied in an atomizing process with purpose cleaned and comprised medium for atomized Teflon particles.<sup>5</sup> The surface coating of Rhodium-

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coated arch-wire is heterogeneous<sup>6</sup> and Epoxy is a synthetic resin and applied to an orthodontic arch-wire by electrostatic coating or E-coating.<sup>7</sup> The process of modifying a wire's surface involves a range of techniques, but two of the most commonly used methods are ion implantation and coating with polymeric resins. In ion implantation, the surface of the wire is bombarded with high-energy ions to alter its properties and improve its performance. On the other hand, coating with polymeric resins involves applying a layer of polytetrafluoroethylene (PTFE) or other similar materials on the surface of the wire to provide a protective layer and enhance its durability.<sup>5,8</sup> Coating or refining the wires surface influences the aesthetic, mechanical, and biological properties of the wires.<sup>9</sup> There has been a recent surge in interest in evaluating the aesthetic, mechanical<sup>10</sup> structural<sup>11</sup> corrosion and surface properties<sup>12</sup> of tooth-colored arch-wires. Various studies have been done to evaluate the impacts of Ph level<sup>13</sup> cigarette smoking<sup>14</sup> heat treatment and brushing<sup>5</sup> based on the colour and surface characteristics of different types of orthodontic appliances. The friction between the toothbrush and the teeth causes an abrasive effect that can lead to changes in the gloss, colour, and surface characteristics of the arch wires.<sup>15</sup> It was reported that certain types of powered toothbrushes with rotating oscillating motion produce significant reduction in plaque and gingivitis score comparing manual brushing. The powered toothbrush is employed due to its heightened efficacy in removing plaque and preventing gingivitis<sup>16</sup> In the present in vitro study, we aim to investigate whether there are any alterations in the color, gloss, and surface properties of diverse aesthetic-coated NiTi arch wires following brushing with a powered toothbrush.

## 2. Materials and Methods

The sample size was calculated using a formula for sample size determination based on means and comparisons.

$$(\text{Sample size } (n)) = \frac{(r + 1(SD)2\left(\frac{Z\alpha}{2} + z\beta\right)2}{1!} +$$

According to the calculation, 10 samples were required in each group for effective evaluation of changes. A total of 40 NiTi archwires with a .016-inch diameter were used in this study. The archwires were categorized into four groups based on the type of coating: Group 1 - Epoxy resin-coated (Rabbit Force NiTi, Liberal Traders, India), Group 2 - Rhodium-coated (OrthoOne Inc., India), Group 3 - Ceramic-coated (Koden, India), and Group 4 - Teflon-coated (D-tech Dental Technologies, India). The baseline characteristics of the archwires, including gloss, color, and surface roughness, were evaluated using a glossmeter, spectrophotometer, and atomic force microscopy, respectively. Conventional MBT brackets with .022" x .028" slots (American Orthodontics) were bonded to the typhodont teeth. The archwires were then ligated to the bracket assembly using elastic modules. The teeth portion of the typhodont, along with the bracket-

archwire assembly, was immersed in a plastic container filled with artificial saliva. Artificial saliva contains Na<sub>2</sub>HPO<sub>4</sub> (0.26%), NaCl (6.7%), NaH<sub>2</sub>PO<sub>4</sub> (0.2%), KCl (1.2%), NaHCO<sub>3</sub> (1.5%), and bovine albumin (0.1%), with a pH of 6.

Brushing was performed twice daily for two minutes as recommended by American Dental Association, using Bass technique with Colgate powered electric toothbrush (20,000 strokes/min) and Colgate toothpaste. After each brushing session, the samples were dried and placed back in the artificial saliva. Brushing was continued for 30 days. After the brushing period, the arch wires were removed from the typhodont model, and post-brushing characteristics were evaluated.

Colour was measured by spectrophotometer (KONICA MINOLTA CM-5, wavelength of 360nm to 740nm) prior to performing the measurements, the spectrophotometer was calibrated according to the manufacturer's instructions. Colour changes were characterized using the Commission Internationale de Eclairite L\*a\*b\* colour space (CIE L\*a\*b\*). Because visual colour assessment is subjective, the colour systems are quantitative systems with rectangular coordinates that allow an objective colour measurement. These systems represent adequately the visual perception of colour differences. Total colour differences are expressed by the formula  $DE^* = 5 ([DL^*]^2 + [Da^*]^2 + [Db^*]^2)^{1/2}$ , where DL\*, Da\*, and Db\* are differences in L\*, a\*, and b\* values before and after brushing.

A glossmeter (60° 3nh) was used to measure the gloss of the wire. Its primary function is to quantify the amount of specular reflection that occurs when light strikes a surface at a specific angle. The instrument typically consists of a light source, a detector, and a measurement geometry that adheres to standardized conditions. When the glossmeter's light source illuminates the surface, the detector measures the intensity of the reflected light at the designated angle, distinguishing between specular and diffuse reflection. The gloss level is then expressed in Gloss Units (GU), ranging from 0 GU (no gloss, completely matte) to 100 GU (high gloss).

To assess the surface roughness of the archwire using Atomic Force Microscopy (AFM), proper calibration of the AFM was ensured, and an appropriate sharp tip was chosen for imaging. The cantilever was calibrated for accurate force measurements, after which the sample surface was carefully approached and engaged. High-resolution topographic images were acquired using either contact or tapping mode, with adjustments made to the scan parameters as needed. The images were analyzed using AFM software, and quantitative surface roughness parameters, including area roughness and line roughness, were extracted. Arithmetic roughness (Ra), derived from line roughness, was used for comparison as it is considered the most reliable for research purposes. The process was repeated at different locations on the archwire, and the results were averaged for accuracy. The data were

interpreted in accordance with relevant standards, and both the imaging parameters and analysis settings were documented for reference.

Mean comparison among the groups was done using ANOVA one way test. Tukey's post hoc test was done for multiple comparisons between the groups.

### 3. Results

#### 3.1. Evaluation of colour

The comparison of mean Delta E values is presented in **Table 1** and **Graph 1**, showing the values calculated for the four

different groups at two points in time, T0 and T1. Upon analysis, a statistically significant difference was found in the color measurement values of the round wires at T1. The observed difference reached a significance level of  $p < 0.001$ , indicating a high probability that the difference is genuine and not due to random variation. Results from the multiple comparisons of mean differences between the groups showed that Group 4 had significantly lower Delta E values compared to the other groups. Specifically, the mean differences were statistically significant at  $p < 0.001$ ,  $p = 0.04$ , and  $p < 0.001$  when compared to Group 1, Group 2, and Group 3, respectively. This indicates that Group 4 had the lowest mean Delta E values. (**Table 2**)

**Table 1:** Comparison of mean Delta E values between 4 groups using One- way ANOVA Test

| Groups  | N  | Mean  | SD    | Min  | Max  | p-value |
|---------|----|-------|-------|------|------|---------|
| Group 1 | 10 | 5.806 | 1.151 | 4.69 | 7.90 |         |
| Group 2 | 10 | 3.107 | 0.524 | 2.45 | 4.25 | <0.001* |
| Group 3 | 10 | 7.672 | 1.179 | 5.82 | 8.89 |         |
| Group 4 | 10 | 2.006 | 0.660 | 0.84 | 2.98 |         |

**Table 2:** Multiple comparison of mean diff. in mean Delta E values b/w 4 groups using Tukey's Post hoc Test

| (I) Groups | (J) Groups | Mean Diff.(I-J) | 95% CI for the Diff |        | p-value |
|------------|------------|-----------------|---------------------|--------|---------|
|            |            |                 | Lower               | Upper  |         |
| Group 1    | Group 2    | 2.699           | 1.584               | 3.814  | <0.001* |
|            | Group 3    | -1.866          | -2.981              | -0.751 | <0.001* |
|            | Group 4    | 3.800           | 2.685               | 4.915  | <0.001* |
| Group 2    | Group 3    | -4.565          | -5.680              | -3.450 | <0.001* |
|            | Group 4    | 1.101           | -0.014              | 2.216  | 0.04*   |
| Group 3    | Group 4    | 5.666           | 4.551               | 6.781  | <0.001* |

**Table 3:** Comparison of mean loss of Gloss values in GU between 4 groups using One- way ANOVA Test

| Groups  | N  | Mean  | SD    | Min  | Max  | p-value |
|---------|----|-------|-------|------|------|---------|
| Group 1 | 10 | 0.650 | 0.341 | 0.40 | 1.40 | <0.001* |
| Group 2 | 10 | 1.840 | 0.303 | 1.30 | 2.10 |         |
| Group 3 | 10 | 0.840 | 0.280 | 0.50 | 1.50 |         |
| Group 4 | 10 | 0.300 | 0.094 | 0.10 | 0.40 |         |

**Table 4:** Multiple comparison of mean diff. in mean loss of Gloss values (in GU) b/w 4 groups using Tukey's Post hoc Test

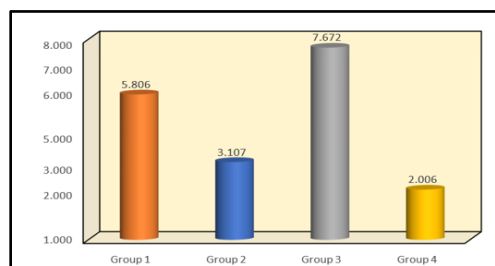
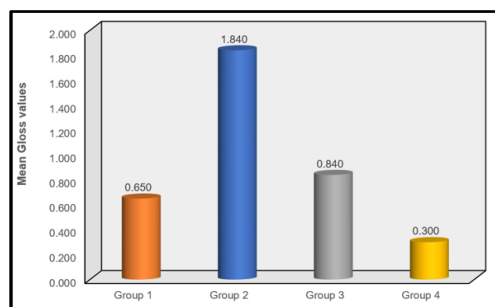
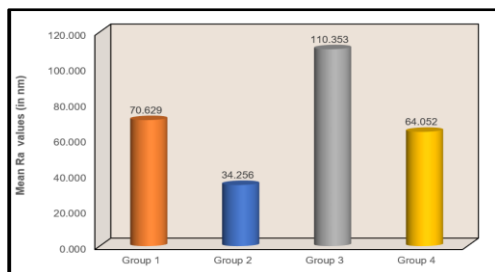
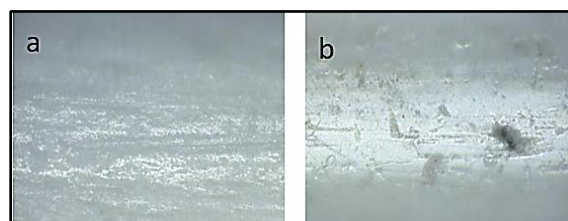
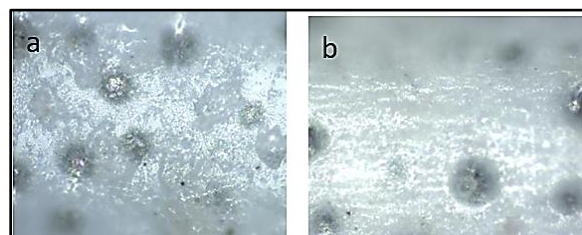
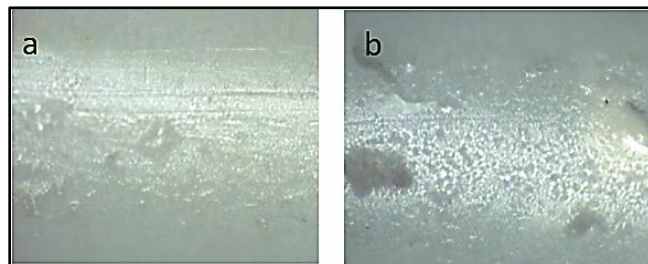
| (I) Groups | (J) Groups | Mean Diff.(I-J) | 95% CI for the Diff |        | p-value |
|------------|------------|-----------------|---------------------|--------|---------|
|            |            |                 | Lower               | Upper  |         |
| Group 1    | Group 2    | -1.190          | -1.517              | -0.863 | <0.001* |
|            | Group 3    | -0.190          | -0.517              | 0.137  | 0.41    |
|            | Group 4    | 0.350           | 0.023               | 0.677  | 0.03*   |
| Group 2    | Group 3    | 1.000           | 0.673               | 1.327  | <0.001* |
|            | Group 4    | 1.540           | 1.213               | 1.867  | <0.001* |
| Group 3    | Group 4    | 0.540           | 0.213               | 0.867  | <0.001* |

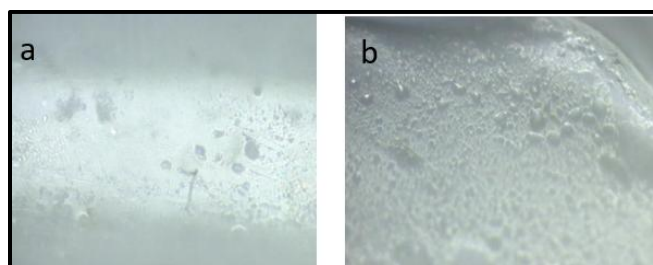
**Table 5:** Comparison of mean surface roughness (ra values in nm) values between 4 groups using one-way anova test

| Groups  | N  | Mean    | SD    | Min    | Max    | p-value |
|---------|----|---------|-------|--------|--------|---------|
| Group 1 | 10 | 70.629  | 2.333 | 65.79  | 73.80  | <0.001* |
| Group 2 | 10 | 34.256  | 0.911 | 32.97  | 35.74  |         |
| Group 3 | 10 | 110.353 | 3.453 | 103.52 | 116.05 |         |
| Group 4 | 10 | 64.052  | 1.529 | 61.69  | 65.89  |         |

**Table 6:** Multiple comparison of mean diff. in mean Surface Roughness b/w 4 groups using Tukey's Post hoc Test

| (I) Groups | (J) Groups | Mean Diff.(I-J) | 95% CI for the Diff |         | p-value |
|------------|------------|-----------------|---------------------|---------|---------|
|            |            |                 | Lower               | Upper   |         |
| Group 1    | Group 2    | 36.373          | 33.644              | 39.102  | <0.001* |
|            | Group 3    | -39.724         | -42.453             | -36.995 | <0.001* |
|            | Group 4    | 6.577           | 3.848               | 9.306   | <0.001* |
| Group 2    | Group 3    | -76.097         | -78.826             | -73.368 | <0.001* |
|            | Group 4    | -29.795         | -32.524             | -27.066 | <0.001* |
| Group 3    | Group 4    | 46.302          | 43.573              | 49.031  | <0.001* |

**Graph 1:** Mean delta e values e values between 4 groups**Graph 2:** Mean loss of gloss values b/w 4groups**Graph 3:** Mean roughness(ra values ini nm) values b/w 4 groups**Figure 1:** Group 1 AFM Images before (a) and after (b) brushing**Figure 2:** Group 2 AFM Images before (a) and after (b) brushing**Figure 3:** Group 3 AFM images before (a) and after (b) brushing



**Figure 4:** Group 4 AFM Images before (a) and after (b) brushing

#### 4. Evaluation of Gloss

**Table 3** and

**Graph 2** display the mean loss of gloss values calculated for four different groups at two time points, T0 and T1. Gloss values were measured for each group at both time points to determine differences in gloss loss. Upon analysis, a statistically significant difference was found between the four groups at T1, with a significance level of  $p < 0.001$ , strongly indicating that the observed difference is genuine and not due to random variation. Multiple comparisons of mean differences between the groups revealed interesting findings. Group 4 had significantly lower gloss loss compared to Groups 1, 2, and 3, meaning the surface of the material in Group 4 retained its glossiness much better than the other groups. The mean differences were statistically significant at  $p = 0.03$  and  $p < 0.001$ , respectively, suggesting that the results were unlikely due to chance. (**Table 4**)

##### 4.1. Evaluation of surface roughness

The comparison of mean surface roughness values is presented in **Table 5** and **Graph 3**, showing the values calculated for four different groups at two time points, T0 and T1. The analysis reveals a statistically significant difference in the surface roughness measurements of the round wires at T1. The difference is significant at a level of  $p < 0.001$ , suggesting that there may be underlying factors contributing to the observed differences in surface roughness between the groups. Multiple comparisons of mean differences between the groups revealed that Group 2 had significantly lower surface roughness values compared to Groups 1, 3, and 4. The mean differences were statistically significant at  $p < 0.001$ . This indicates that Group 2 had the lowest mean surface roughness values among all the groups. (**Table 6**)

#### 5. Discussion

Patients' growing interest in the need of esthetics during orthodontic treatments has led to the development of various esthetic orthodontic products such as Ceramic brackets, lingual orthodontics, and clear aligners<sup>1</sup> Tooth-colored arch-wires have also gained popularity in modern orthodontic practice. As a result, many researchers have evaluated the clinical performance of esthetic arch-wires in vivo and in vitro<sup>17,18</sup>. However, no studies have assessed the color, gloss, and surface roughness of Epoxy coated, Rhodium coated,

Ceramic coated and Teflon coated NiTi 0.016" inch round arch wires. Therefore, this study aimed to assess the color, gloss, and surface roughness of coated Ni-Ti wires with a thickness of 0.016" before and after brushing.

The roughness of a material plays a crucial role in determining the texture of its surface, which in turn affects the way it interacts with the environment. The quality of wire surfaces has a significant impact on several critical factors such as corrosion behavior<sup>17</sup> biocompatibility, and risk of caries and gingivitis.<sup>19</sup> Studies have shown that the surface structure of archwires is influenced by several factors, including material coating, manufacturing process, and manufacturer.<sup>19</sup> Our study observed that the Rhodium-coated arch-wires had least surface roughness and Ceramic-coated arch-wires had the highest surface roughness after usage. In this study, the surface roughness measurement of the aesthetic arch-wires demonstrated that Rhodium Coated wires had significantly lower Surface Roughness values when compared to all other groups, namely Resin Coated, Ceramic Coated, and Teflon Coated wires. Furthermore, there was a significant difference in roughness values observed among the coated arch-wires. This difference could be due to the different coating present on the arch-wires.

Most previous studies on color measurements have focused on the color stability of esthetic orthodontic appliances like brackets and ligatures<sup>20</sup>. The color of coated esthetic arch-wires should be equally matched with the color of the esthetic brackets, natural teeth, another orthodontic component. In this study, the evaluation of color demonstrated that that Teflon Coated wires had the lowest mean delta E values. This was followed by Rhodium Coated wires which showed significantly lower mean delta E values compared to Resin Coated and Ceramic Coated. Kula B et al<sup>21</sup> also observed noticeable color changes in Teflon coated arch-wires after 28 days of clinical exposure.

The gloss level in coated aesthetic arch-wires is an important factor to consider in orthodontic treatment. However, there is limited research available on the decrease in gloss of aesthetic arch-wires. It is important to note that the loss of gloss in aesthetic arch-wires can have a negative impact on the overall appearance of the orthodontic appliance. In a prior investigation, da Silva et al.<sup>12</sup> assessed the fluorescence of an aesthetic-coated arch-wire after 21 days of immersion in a staining solution and observed significant alterations. In this study, the evaluation of gloss revealed that Teflon-coated wires had significantly lower loss of gloss values compared to resin-coated, Rhodium-coated, and Ceramic-coated wires. This was in accordance with the study by Sehovic et al.<sup>22</sup> who reported that the gloss of Ceramic materials decreased significantly after aging.

#### 6. Conclusion

This study leads to the conclusion that the Teflon-coated archwires demonstrated highest colour stability and Ceramic-

coated archwires had the least colour stability. The Teflon-coated archwires demonstrated least loss of gloss and Rhodium-coated archwires had the highest loss of gloss. The Rhodium-coated archwires had least surface roughness and Ceramic-coated archwires had the highest surface roughness. Further studies are required to compare other mechanical properties and fluorescence of the wires.

## 7. Source of Funding

None.

## 8. Conflict of Interest

None.

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**Cite this article:** Shamna PK, Marish P, Kumar J, Jacob SM, Pillai AH. Effects of powered tooth brush on four different esthetically coated nickel titanium archwires -An in vitro study. *J Contemp Orthod.* 2025;9(4):548–553.