Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 18 Aug 2026
Revised 09 Sep 2026
Accepted 27 Sep 2026

Natural Resources for Human Health 2026, Vol. 6 (23s): 68–81

KEYWORDS:
Rhodium-coated archwire; Nickel–titanium archwire; Friction; Ceramic bracket; Sliding mechanics; Orthodontics.

Comparison of Frictional Forces of Two Different Brands of Rhodium-Coated Arch Wires with Ceramic Brackets – an in vitro study

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ABSTRACT: **Background**: Resistance to sliding at the bracket–archwire interface influences orthodontic tooth movement and treatment efficiency. Rhodium-coated nickel–titanium (NiTi) archwires provide improved aesthetics while maintaining the mechanical properties of conventional NiTi wires. However, evidence comparing the frictional behavior of commercially available rhodium-coated NiTi archwires remains limited. This in vitro study compared the frictional characteristics of two commercially available rhodium-coated NiTi archwires used with polycrystalline ceramic brackets.

Methods: Sixteen 0.016-inch rhodium-coated NiTi archwires were divided into two groups (n = 8): ICONIX Aesthetic Archwire and Tomy Pak White Wire. Specimens were tested with 0.022-inch MBT polycrystalline ceramic brackets using a customized Perspex jig mounted on a Universal Testing Machine. Displacement at break, force at break, tensile displacement, tensile strain, and tensile stress were recorded. Data were analyzed using an independent-samples t-test ($p < 0.05$).

Results: No significant differences were observed between the groups in displacement at break, tensile displacement, or tensile strain ($p > 0.05$). However, the Tomy Pak Wire exhibited significantly greater breaking force and tensile stress than the ICONIX Aesthetic Archwire ($p < 0.05$), indicating differences in friction-related mechanical performance between the two archwires.

1. INTRODUCTION

The demand for aesthetic orthodontic treatment has led to the development of orthodontic materials that combine pleasing appearance with optimal biomechanical performance. Among these, rhodium-coated nickel–titanium (NiTi) archwires have become increasingly popular because they provide improved aesthetics while preserving the superelastic and shape-memory properties of conventional NiTi alloys. In addition to their aesthetic advantages, rhodium coatings exhibit excellent corrosion resistance and colour stability, making them an attractive option for patients seeking less conspicuous orthodontic appliances.

Resistance to sliding at the bracket–archwire interface plays a crucial role in orthodontic tooth movement, particularly during space closure and canine retraction. Friction constitutes a major component of this resistance and directly influences the efficiency of sliding mechanics. Excessive friction results in force loss, increased anchorage requirements, and prolonged treatment duration, whereas reduced friction facilitates efficient transmission of orthodontic forces and more controlled tooth movement. The magnitude of friction is affected by several factors, including bracket material, wire alloy, wire dimensions, surface roughness, ligation method, and bracket–wire angulation. Ceramic brackets, although aesthetically superior to stainless steel brackets, generally exhibit higher frictional resistance because of their greater surface roughness and hardness.

Several studies have investigated the mechanical properties, surface characteristics, corrosion resistance, and frictional behaviour of coated orthodontic archwires. While these studies have demonstrated acceptable mechanical performance of rhodium-coated wires, conflicting results have been reported regarding their frictional characteristics. Most available investigations have compared coated and uncoated archwires, whereas direct comparisons between commercially available rhodium-coated systems remain limited. Differences in coating technology, manufacturing processes, and surface finishing among manufacturers may influence frictional performance and ultimately affect clinical efficiency.

Therefore, the present in vitro study was designed to compare the frictional characteristics of two commercially available rhodium-coated NiTi archwires used with polycrystalline ceramic brackets under standardized laboratory conditions. The study evaluated displacement at break, force at break, tensile displacement, tensile strain, and tensile stress using a Universal Testing Machine. The null hypothesis was that no significant differences would exist between the two rhodium-coated archwire systems with respect to their friction-related mechanical properties.

2. MATERIALS AND METHODS

2.1 Study Design

This in vitro comparative experimental study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Sree Mookambika Institute of Dental Sciences, Kulasekharam, to compare the frictional characteristics of two commercially available rhodium-coated nickel–titanium (NiTi) orthodontic archwires of 0.016 inch round Rhodium-Coated Nickel–Titanium Archwires ICONIX Aesthetic-AO (fig 1) and Tomy Pak White-Orthosystem (fig 2)when used with polycrystalline ceramic brackets under standardized laboratory conditions. All experimental procedures were performed under identical environmental and testing conditions to minimize variability.

2.2 Sample Size Determination

Sample size was calculated using G*Power software (Version 3.1) based on previous studies evaluating frictional characteristics of orthodontic archwires. Assuming an effect size of 1.8, a significance level (α) of 0.05, and a study power of 95%, the minimum required sample size was determined to be 16 specimens. Accordingly, sixteen rhodium-coated NiTi archwires were included and equally allocated into two experimental groups (n = 8).

2.3 Study Groups

The specimens were randomly divided into two groups:

Group A (n = 8):
ICONIX Aesthetic Rhodium-Coated Nickel–Titanium Archwire (American Orthodontics)

Group B (n = 8):
Tomy Pak White Rhodium-Coated Nickel–Titanium Archwire (Orthosystems)

Both groups consisted of 0.016-inch round superelastic rhodium-coated nickel–titanium archwires and were tested under identical laboratory conditions.

2.4 Bracket System

Polycrystalline ceramic premolar brackets with 0.022-inch MBT slot dimensions were used throughout the study. To eliminate experimental variability, brackets from the same prescription and slot size were selected for all specimens.

Each bracket was carefully inspected before testing to ensure the absence of manufacturing defects or slot irregularities.

2.4 Experimental Apparatus

A customized friction-testing assembly was fabricated to simulate orthodontic sliding mechanics.

The apparatus consisted of a rigid Perspex mounting plate onto which ceramic brackets were bonded in a straight-line configuration. (Fig 3) Adjacent brackets were positioned at 8-mm intervals, corresponding to average interbracket distances encountered clinically. A 16-mm space was maintained at the center of the assembly to accommodate the movable premolar bracket.

The movable bracket was attached to a 12-mm stainless steel power arm (fig 4), permitting controlled vertical loading during testing. The power arm was designed to reproduce the moment generated during canine retraction and to allow consistent application of experimental forces. The entire assembly was mounted onto a Universal Testing Machine (UTM) equipped with a 500-N load cell.(Fig 5)

2.5 Testing Procedure

Before testing, each rhodium-coated archwire was carefully inserted into the ceramic bracket slots without introducing permanent deformation. The archwire was secured within the bracket assembly under standardized conditions to ensure reproducibility between specimens. A 100-g vertical load was suspended from the power arm to simulate the clinical force acting through the center of resistance during sliding mechanics. The Universal Testing Machine was calibrated before each testing session according to the manufacturer's recommendations. The Perspex assembly was rigidly fixed to the lower crosshead of the testing machine, while the movable bracket assembly was connected to the upper load cell. Testing was performed using a crosshead speed of 5 mm/min, allowing controlled movement of the bracket along the stationary archwire. Each specimen was subjected to a 5-mm sliding displacement, during which frictional resistance was continuously recorded by the load cell.

All specimens were tested individually under identical conditions by the same operator to minimize operator-related variability. Fresh archwires and bracket assemblies were used for every experimental run to eliminate the influence of wear or repeated testing.



Figure 1: 0.016-inch round Rhodium-Coated Nickel–Titanium Archwires (ICONIX Aesthetic-AO)



Figure 2: 0.016-inch round Rhodium-Coated Nickel–Titanium Archwires (Tomy Pak White-Orthosystem)

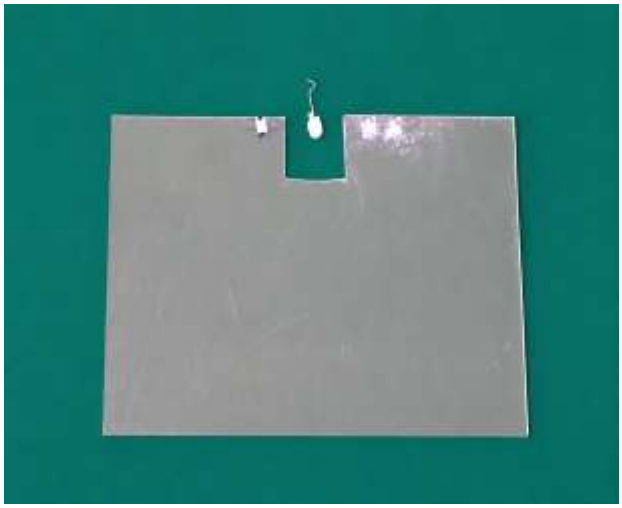


Figure 3. Customized experimental apparatus used for evaluation of frictional resistance between rhodium-coated NiTi archwires



Figure 4. polycrystalline ceramic brackets mounted on a Perspex assembly



Figure 5. Universal Testing Machine setup demonstrating the bracket–archwire assembly during tensile testing.

Outcome Measures

The following parameters were automatically recorded by the Universal Testing Machine software:

Primary outcome

Force at break (N)

Secondary outcomes

Displacement at break (mm)

Tensile displacement at break (mm)

Tensile strain at break (%)

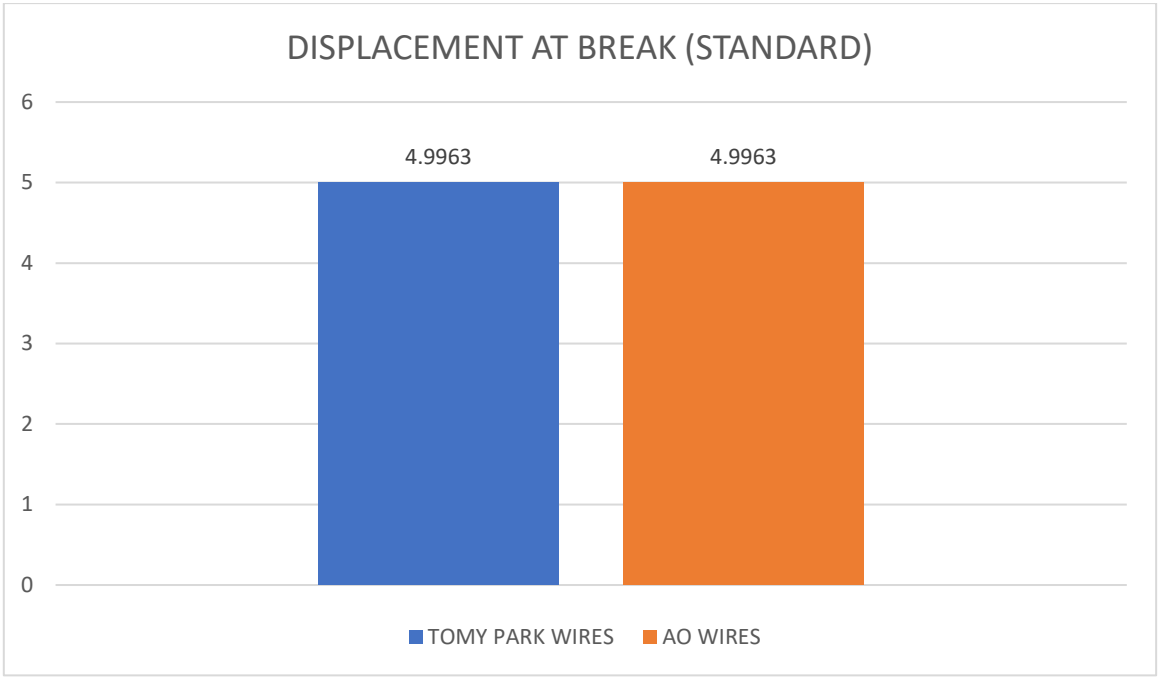
Tensile stress at break (MPa)

2.6 Statistical Analysis

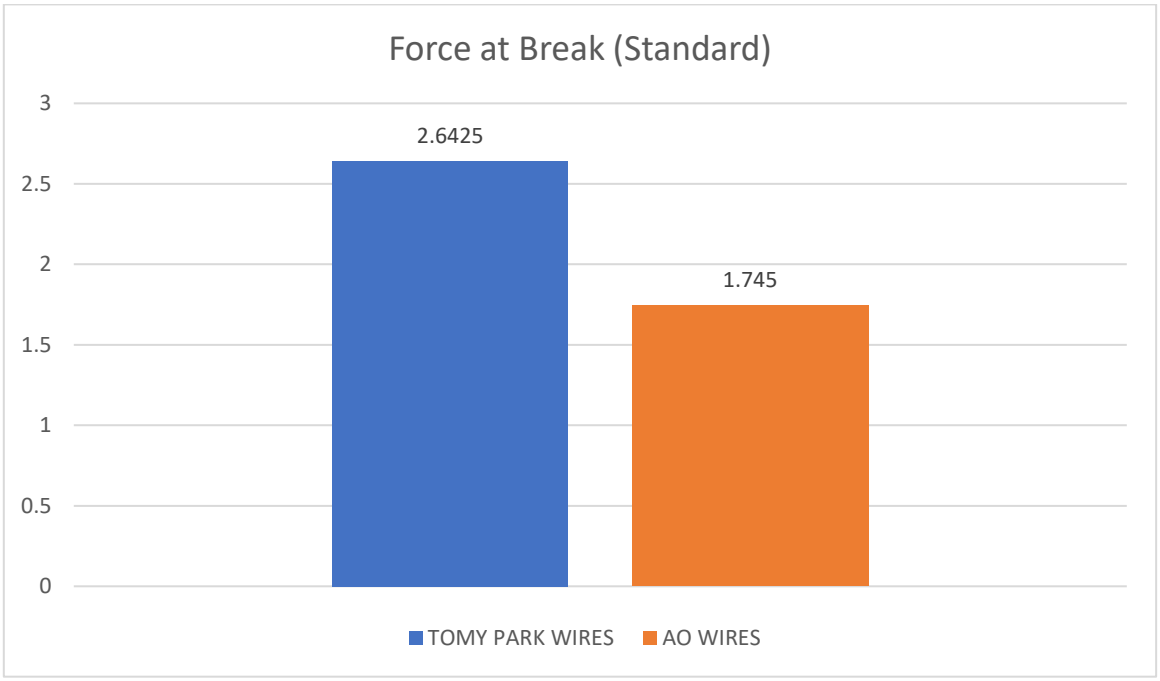
Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics Version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated and expressed as mean ± standard deviation (SD). The normality of data distribution was assessed before inferential analysis.

Intergroup comparisons were performed using the independent samples t-test. A two-tailed p-value < 0.05 was considered statistically significant. The analysis compared displacement at break, force at break, tensile displacement at break, tensile strain at break, and tensile stress at break between the two experimental groups.

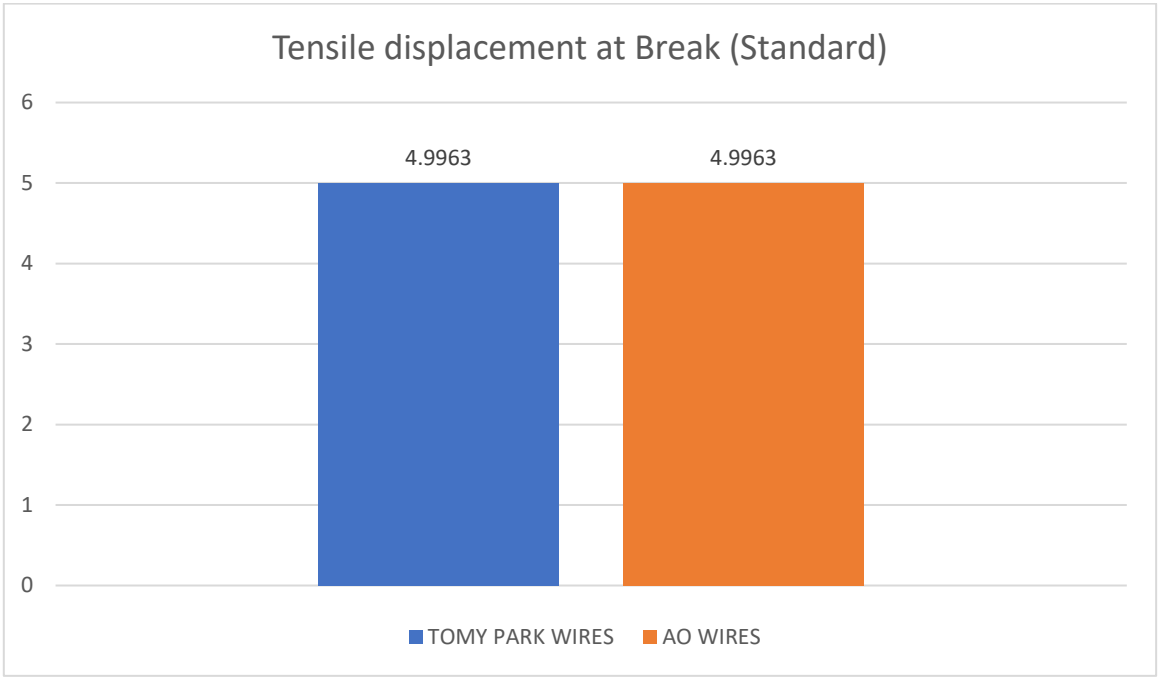
Natural Resources for Human Health
eISSN: 2583-1194



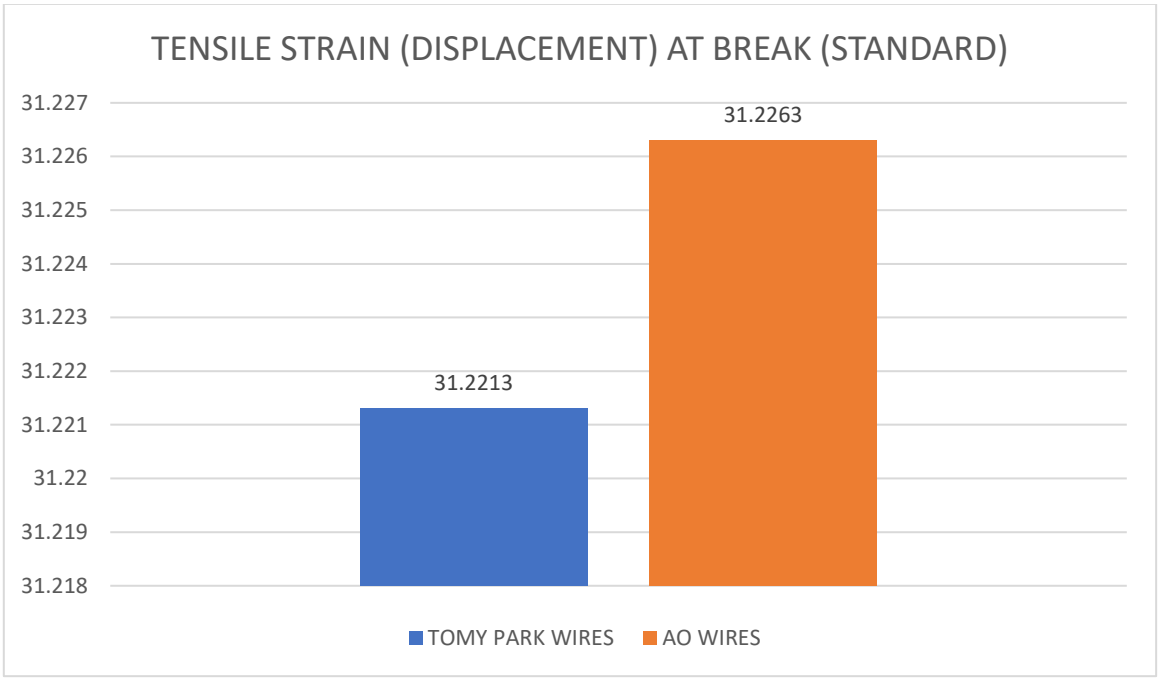
Graph 1. Comparison of displacement at break between the two rhodium-coated archwire groups.



Graph 2. Comparison of force at break between the two experimental groups.

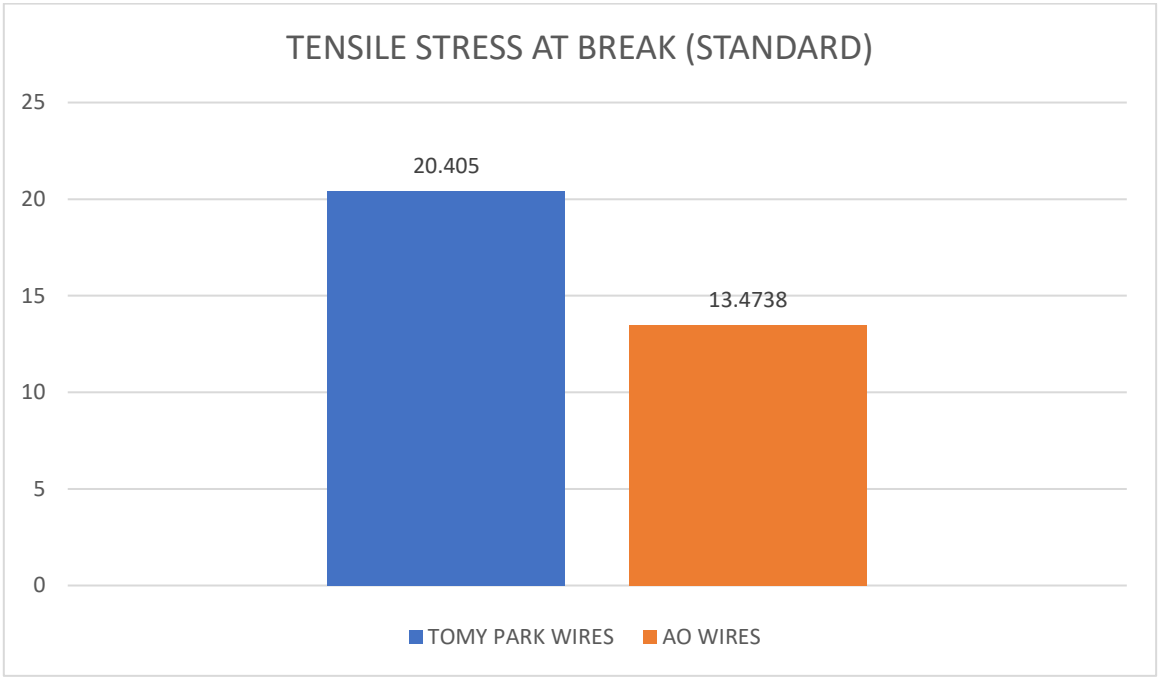


Graph 3. Comparison of tensile displacement at break.



Graph 4. Comparison of tensile strain at break.

Natural Resources for Human Health
eISSN: 2583-1194



Graph 5 . Comparison of tensile stress at break.

3. RESULTS AND DISCUSSION

A total of 16 rhodium-coated nickel–titanium archwires were evaluated, with 8 specimens in each experimental group. Group A consisted of the ICONIX Aesthetic Archwire (American Orthodontics), whereas Group B comprised the Tomy Pak White Wire (Orthosystems). The frictional characteristics of the two archwire systems were compared by evaluating displacement at break, force at break, tensile displacement, tensile strain, and tensile stress using a Universal Testing Machine.

Descriptive statistics, including the mean, standard deviation, standard error, and variance, were calculated for all outcome variables. Between-group comparisons were performed using the Independent Samples t-test, with the level of statistical significance set at $p < 0.05$.

The results are summarized in Table 1

Table 1. Comparison of mechanical properties between the two rhodium-coated NiTi archwire groups

Variable	ICONIX (Group A) Mean ± SD	Tomy Pak (Group B) Mean ± SD	t value	p value
Displacement at break (mm)	4.996 ± 0.005	4.996 ± 0.005	0.000	1.000
Force at break (N)	1.745 ± 0.428	2.643 ± 1.320	1.790	0.032*
Tensile displacement at break (mm)	4.996 ± 0.005	4.996 ± 0.005	0.000	1.000
Tensile strain at break (%)	31.226 ± 0.018	31.221 ± 0.016	0.592	0.573
Tensile stress at break (MPa)	13.474 ± 3.307	20.405 ± 10.180	1.792	0.014*

Independent Samples t-test; $p < 0.05$ indicates statistical significance.

Displacement at Break

The mean displacement at break was identical in both groups (4.996 ± 0.005 mm). No statistically significant difference was observed between the 2 groups of archwires (p = 1.000), indicating displacement characteristics before failure.

Force at Break

The Tomy Pak White Wire demonstrated a significantly greater force at break (2.643 ± 1.320 N) than the ICONIX Aesthetic Archwire (1.745 ± 0.428 N). This difference was statistically significant (p = 0.032), indicating greater resistance during sliding in the Tomy Pak group.

Tensile Displacement at Break

Both archwire systems exhibited identical tensile displacement at break (4.996 ± 0.005 mm). No statistically significant difference was observed between the groups (p = 1.000), suggesting similar elongation characteristics under tensile loading.

Tensile Strain at Break

The mean tensile strain at break was comparable between the two groups, with no statistically significant difference (p = 0.573). These findings indicate that both group archwires demonstrated similar deformation characteristics before failure.

Tensile Stress at Break

The Tomy Pak White Wire showed a significantly higher tensile stress at break (20.405 ± 10.180 MPa) than the ICONIX Aesthetic Archwire (13.474 ± 3.307 MPa). The difference was statistically significant (p = 0.014), suggesting greater resistance to tensile loading in the Tomy Pak group.

3.1 Overall Findings

Both rhodium-coated NiTi archwires have same displacement and deformation characteristics, as demonstrated by the absence of significant differences in displacement at break, tensile displacement, and tensile strain. However, statistically significant differences were observed in force at break and tensile stress, with the Tomy Pak White Wire exhibiting higher values than the ICONIX Aesthetic Archwire. The findings suggest that these differences in rhodium coating or surface characteristics might influence the mechanical performance of aesthetic archwires during sliding mechanics. ICONIX Aesthetic archwire exhibit less friction compared to Tomy Pak White Wire ,therefore it is more efficient during space closure and canine retraction .

3.2 DISCUSSION

The present in vitro study compared the friction-related mechanical characteristics of two commercially available rhodium-coated nickel–titanium (NiTi) archwires—ICONIX Aesthetic Archwire and Tomy Pak White Wire—used with polycrystalline ceramic brackets. The findings demonstrated that although both archwire systems exhibited comparable displacement at break, tensile displacement, and tensile strain, statistically significant differences were observed in force at break and tensile stress. These findings suggest that commercially available rhodium-coated archwires cannot be considered mechanically identical despite having similar alloy composition and dimensions.

Friction generated at the bracket–archwire interface is one of the principal determinants of resistance to sliding during orthodontic treatment. Increased friction reduces the effective force transmitted to the tooth, prolongs treatment duration, and increases anchorage demands. Consequently, even minor differences in the surface characteristics of orthodontic archwires may influence clinical efficiency, particularly during space closure and canine retraction. Since ceramic brackets generally exhibit greater surface roughness than stainless-steel brackets, evaluating the performance of aesthetic archwires in conjunction with ceramic brackets is of considerable clinical relevance.

In the present study, the Tomy Pak White Wire demonstrated significantly greater force at break and tensile stress than the ICONIX Aesthetic Archwire. Although both products are manufactured from superelastic NiTi alloy with a rhodium coating, differences in coating thickness, surface finish, and manufacturing processes may have contributed to the observed variation. These factors can alter the effective surface morphology of the archwire, increasing the contact area between the wire and bracket slot and thereby increasing resistance to sliding. Similar observations have been reported in previous investigations evaluating coated orthodontic archwires.

Elayyan et al2 ,reported that coated orthodontic archwires exhibited altered surface morphology and mechanical properties compared with conventional NiTi wires, indicating that the coating process itself may influence clinical performance. The authors demonstrated that coated wires possessed greater surface irregularities, which may contribute to increased frictional resistance during sliding mechanics. The present findings support these observations by demonstrating that differences may exist even between rhodium-coated archwires produced by different manufacturers.

Kim et al6, compared the frictional behaviour of aesthetic coated archwires and observed that coated wires generated greater frictional resistance than conventional uncoated NiTi archwires, particularly when used with aesthetic brackets. They attributed these findings to microscopic surface irregularities created during the coating process. Although the present investigation did not compare coated and uncoated wires, the significantly higher force at break observed in the Tomy Pak White Wire suggests that manufacturer-specific coating characteristics may similarly influence friction-related mechanical behaviour.

Similarly, da Silva et al7, demonstrated that degradation of the coating layer following simulated clinical use increased surface roughness and altered the frictional behaviour of aesthetic archwires. Although only unused archwires were evaluated in the present study, the observed differences indicate that variations in the initial coating quality alone may be sufficient to produce measurable differences in mechanical performance. These differences may become more pronounced following intraoral ageing and prolonged clinical use.

The systematic review by Nookala et al,5 concluded that the available evidence regarding the mechanical behaviour of rhodium-coated NiTi archwires remains limited and heterogeneous. The review highlighted inconsistencies among studies concerning frictional resistance and emphasized the need for standardized experimental protocols and direct comparisons between commercially available products. The present study contributes to the available evidence by comparing two commonly used rhodium-coated archwire systems under identical laboratory conditions using a standardized testing protocol.

Despite the significant differences observed in force at break and tensile stress, no statistically significant differences were found in displacement at break, tensile displacement, or tensile strain. These findings indicate that both archwire systems exhibited comparable elastic deformation characteristics. As both products are based on superelastic NiTi alloy, the similarity in deformation behaviour is expected and suggests that the observed differences are more likely related to the rhodium coating and manufacturing process than to the underlying alloy itself.

From a clinical perspective, the lower friction-related mechanical values observed with the ICONIX Aesthetic Archwire may facilitate more efficient sliding mechanics by allowing greater transmission of orthodontic forces and reducing resistance to tooth movement. Conversely, the relatively higher values observed with the Tomy Pak White Wire may provide greater resistance to sliding, which may be advantageous in selected situations requiring enhanced anchorage control. Therefore, the choice of rhodium-coated archwire should be based not only on aesthetic considerations but also on its biomechanical characteristics.

One of the strengths of the present study was the use of a standardized experimental protocol, including identical bracket systems, wire dimensions, loading conditions, and testing parameters for all specimens. These measures minimized experimental variability and improved the reliability of the comparisons between the two archwire systems. However, certain limitations should be considered. As an in vitro study, the experimental conditions could not fully reproduce the oral environment, where saliva, masticatory forces, pH fluctuations, and intraoral ageing may influence frictional behaviour. Furthermore, surface characterization techniques such as scanning electron microscopy (SEM), atomic force microscopy (AFM), or surface profilometry were not performed, preventing direct correlation between surface morphology and mechanical performance. Future investigations incorporating these techniques, together with long-term clinical studies, would further improve understanding of the behaviour of rhodium-coated archwires under clinical conditions.

4. CLINICAL IMPLICATIONS

The findings of the present study have direct clinical relevance in the selection of aesthetic orthodontic archwires during sliding mechanics. Although both rhodium-coated nickel–titanium archwires demonstrated comparable displacement and deformation characteristics, significant differences were observed in friction-related parameters. The lower frictional resistance exhibited by the ICONIX Aesthetic Archwire may facilitate more efficient tooth movement during space closure and canine retraction by allowing greater transmission of orthodontic forces to the dentition. In contrast, the higher friction generated by the Tomy Pak White Wire may be advantageous in clinical situations requiring increased resistance to sliding or enhanced anchorage control.

These observations indicate that the choice of an aesthetic archwire should be based not only on esthetic appearance but also on its biomechanical characteristics. Clinicians should recognize that commercially available rhodium-coated archwires may not exhibit identical frictional behaviour despite having similar alloy composition and dimensions.

5. STRENGTHS OF THE STUDY

The present investigation possesses several strengths that enhance the reliability of the findings.

A standardized in vitro experimental design minimized external variables that could influence frictional measurements.

All specimens were tested using identical bracket systems, wire dimensions, loading conditions, and crosshead speed.

The Universal Testing Machine provided highly accurate and reproducible measurements of mechanical properties.

Evaluation of multiple mechanical parameters allowed comprehensive assessment of the frictional behaviour of both archwire systems.

The study directly compared two commercially available rhodium-coated archwires under identical laboratory conditions, thereby providing clinically applicable information for orthodontic practice.

6. LIMITATIONS

Despite the standardized experimental protocol, certain limitations should be considered while interpreting the findings.

The present investigation was conducted under controlled laboratory conditions, which cannot completely reproduce the complex intraoral environment encountered during orthodontic treatment. Clinical factors such as saliva, masticatory forces, plaque accumulation, pH fluctuations, and long-term intraoral ageing may influence frictional behaviour differently from laboratory conditions.

Furthermore, surface characterization techniques such as scanning electron microscopy (SEM), atomic force microscopy (AFM), or surface profilometry were not performed. These techniques could have provided additional information regarding coating morphology and surface roughness, thereby allowing correlation between microscopic surface characteristics and frictional performance.

The present study evaluated only one dimension of rhodium-coated nickel–titanium archwire and one bracket type. Therefore, the findings should not be generalized to other wire dimensions, bracket systems, or orthodontic materials without further investigation.

7. FUTURE RECOMMENDATIONS

Future investigations should evaluate the long-term clinical performance of rhodium-coated archwires under conditions that more closely simulate the oral environment. Additional studies incorporating scanning electron microscopy, atomic force microscopy, and surface profilometry would provide valuable information regarding coating integrity and surface morphology.

Comparative investigations involving additional commercial brands, different wire dimensions, self-ligating bracket systems, stainless steel brackets, and monocrystalline ceramic brackets may further clarify the influence of coating characteristics on orthodontic friction.

Clinical trials evaluating treatment efficiency, colour stability, corrosion resistance, coating durability, and patient satisfaction would also provide valuable evidence for selecting aesthetic orthodontic archwires.

8. CONCLUSION

Within the limitations of this in vitro investigation, the following conclusions may be drawn:

Tomy Pak White Wire demonstrated significantly greater force at break than the ICONIX Aesthetic Archwire, indicating increased frictional resistance during sliding mechanics. Tensile stress at break was significantly higher in the Tomy Pak White Wire group, suggesting greater resistance under tensile loading. No statistically significant differences were observed in displacement at break, tensile displacement at break, or tensile strain between the two archwire systems, indicating comparable elastic and deformation characteristics. The observed differences in frictional behaviour are likely attributable to manufacturer-

dependent variations in rhodium coating characteristics rather than differences in the underlying nickel–titanium alloy. Brand-specific variations should be considered during the selection of rhodium-coated aesthetic archwires for clinical orthodontic treatment, particularly when sliding mechanics are planned.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the Department of Orthodontics and Dentofacial Orthopaedics, Sree Mookambika Institute of Dental Sciences, Kulasekharam, and white lab saveetha dental college for providing the facilities and technical support required for conducting this investigation. The authors also acknowledge the laboratory staff for their assistance during specimen preparation and mechanical testing.

AUTHOR CONTRIBUTIONS

A. **Dr.Janu.S.Nair :** Conceptualization, Investigation.
B. **Dr.Aarthi.P:** Methodology, Laboratory Analysis.
C. **Dr. Dr.Amal.S.Nair :** Data Curation, Formal Analysis.
D. **Dr.Anjana.S.Nair:** Supervision, Writing—Review & Editing.
E. **Dr. Deepika M C :** Writing—Review & Editing.
F. **Dr. Nivetha S :** Writing—Review & Editing.
G. **Dr. Jerfin Asha G :** Writing—Review & Editing.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

ETHICS STATEMENT

Ethical committee approval has been obtained

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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