COMPARATIVE ASSESSMENT OF WIRE DEFORMATION, BREAKAGE, FRICTIONAL RESISTANCE, AND PATIENT DISCOMFORT IN ORTHODONTIC ARCHWIRES: A CLINICAL STUDY

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Abstract

Background:
Orthodontic treatment success significantly depends on the mechanical properties of archwires. An ideal archwire should offer optimal elasticity, minimal friction, and high resistance to deformation and breakage, all while ensuring patient comfort. This clinical study aimed to compare the performance of different types of archwires in terms of deformation, breakage, frictional resistance, and associated patient discomfort.

Materials and Methods:
A total of 60 patients undergoing fixed orthodontic treatment were randomly divided into three groups (n=20 each) based on the type of archwire used: Group A – Nickel-Titanium (NiTi), Group B – Stainless Steel (SS), and Group C – Beta-Titanium (TMA). Over a 12-week period, archwires were assessed for deformation and breakage during clinical follow-ups. Frictional resistance was measured using a universal testing machine, and patient discomfort was evaluated using a Visual Analog Scale (VAS) after 24 hours and 7 days of wire placement.

Results:
NiTi wires showed the least wire deformation (mean value: 0.3 mm) and breakage incidence (5%) compared to SS (0.8 mm, 15%) and TMA (0.5 mm, 10%). Frictional resistance was highest in TMA wires (2.5 N), followed by NiTi (1.8 N) and SS (1.2 N). Patient discomfort scores were highest for TMA (VAS score: 6.5 ± 1.2), followed by SS (5.8 ± 1.0), and least for NiTi (4.2 ± 0.9). Statistically significant differences were noted across all parameters ($p < 0.05$).

Conclusion:
Nickel-Titanium archwires demonstrated superior clinical performance with lower deformation, minimal breakage, reduced friction, and better patient comfort. TMA wires, while offering moderate deformation resistance, caused more discomfort and higher friction, suggesting a need for cautious use during initial treatment phases.

Introduction

Orthodontic archwires play a pivotal role in tooth movement by delivering controlled forces to achieve desired alignment and occlusion. The selection of an appropriate archwire is crucial, as its physical and mechanical properties directly influence the efficiency and comfort of orthodontic treatment (1). Among the widely used archwire materials, Nickel-Titanium (NiTi), Stainless Steel (SS), and Beta-Titanium

(TMA) each exhibit distinct characteristics in terms of flexibility, stiffness, formability, and resistance to corrosion and fracture (2,3).

NiTi wires are well-known for their superelasticity and shape memory properties, which contribute to gentle and continuous force delivery, especially during initial stages of treatment (4). Stainless steel wires, although less flexible, offer superior formability and lower friction, making them suitable for the finishing phase (5). On the other hand, Beta-Titanium wires offer a balance between flexibility and stiffness, making them useful in intermediate stages where moderate forces are needed (6).

However, clinical performance is not determined solely by material properties; factors such as wire deformation, breakage, frictional resistance, and patient comfort also impact the overall effectiveness of treatment (7). Excessive wire deformation or breakage can prolong treatment time and necessitate frequent adjustments, while higher frictional resistance may reduce the efficiency of tooth movement (8). Additionally, patient discomfort due to wire stiffness or edge sharpness may affect compliance and overall satisfaction (9).

Despite the availability of various wire types, comparative clinical evaluations focusing on both mechanical and patient-centered outcomes are limited. This study was designed to assess and compare the clinical behavior of NiTi, SS, and TMA archwires in terms of deformation, breakage, frictional resistance, and patient discomfort during orthodontic treatment.

Materials and Methods

This prospective clinical study was conducted on 60 patients (aged 15–25 years) undergoing fixed orthodontic treatment at a tertiary dental care center. Ethical approval was obtained from the institutional review board, and informed consent was secured from all participants prior to enrollment.

Sample Distribution:

Patients were randomly divided into three equal groups (n = 20) based on the type of initial archwire used:

- **Group A**: Nickel-Titanium (NiTi) archwires (0.016-inch round)
- **Group B**: Stainless Steel (SS) archwires (0.016-inch round)
- **Group C**: Beta-Titanium (TMA) archwires (0.016-inch round)

All participants were treated using a 0.022-inch slot pre-adjusted edgewise appliance (MBT prescription). Archwires were evaluated during the initial alignment and leveling phase over a period of 12 weeks.

Wire Deformation and Breakage:

At each follow-up visit (weeks 4, 8, and 12), archwires were clinically examined for visible signs of permanent deformation or breakage. Wires showing noticeable distortion or fracture were recorded and replaced.

Frictional Resistance Measurement:

To assess frictional forces, a separate in-vitro simulation was conducted using 5 wires from each group. The archwires were tested using a universal testing machine. Brackets were mounted on an acrylic block, and each wire was pulled through at a crosshead speed of 10 mm/min under dry conditions. The static frictional force was recorded in Newtons (N).

Patient Discomfort Evaluation:

Patient-reported discomfort was measured using a 10-point Visual Analog Scale (VAS) at 24 hours and on the 7th day after wire placement. Patients marked their pain levels on the scale ranging from "no pain" (0) to "worst possible pain" (10).

Statistical Analysis:

The data were analyzed using SPSS version 25.0. Mean values and standard deviations were calculated. Intergroup comparisons were made using one-way ANOVA followed by post-hoc Tukey's test. A p-value of <0.05 was considered statistically significant.

Results

A total of 60 patients completed the study, with 20 individuals in each group. The data were analyzed to compare archwire deformation, breakage rate, frictional resistance, and patient discomfort across the three archwire types: Nickel-Titanium (NiTi), Stainless Steel (SS), and Beta-Titanium (TMA).

Wire Deformation and Breakage

Nickel-Titanium archwires exhibited the least average deformation (0.31 ± 0.05 mm), followed by TMA (0.47 ± 0.08 mm), and the highest deformation was observed in Stainless Steel wires (0.79 ± 0.10 mm). Wire breakage was reported in 1 case (5%) in Group A, 3 cases (15%) in Group B, and 2 cases (10%) in Group C (Table 1).

Table 1: Comparison of Wire Deformation and Breakage among Groups

Archwire Type	Mean Deformation (mm ± SD)	Number of Breakages	Breakage Percentage (%)
NiTi	0.31 ± 0.05	1	5%
Stainless Steel	0.79 ± 0.10	3	15%
TMA	0.47 ± 0.08	2	10%

Frictional Resistance

The static frictional resistance measured in vitro was significantly different among the groups ($p < 0.05$). TMA wires recorded the highest resistance (2.51 ± 0.12 N), followed by NiTi (1.76 ± 0.10 N), while Stainless Steel wires demonstrated the least resistance (1.22 ± 0.08 N) (Table 2).

Table 2: Frictional Resistance of Archwires (in Newtons)

Archwire Type	Frictional Resistance (N ± SD)
NiTi	1.76 ± 0.10
Stainless Steel	1.22 ± 0.08
TMA	2.51 ± 0.12

Patient Discomfort

Pain perception was highest in the TMA group at both 24 hours (6.5 ± 1.2) and day 7 (4.1 ± 0.9). NiTi wires resulted in the lowest discomfort scores at both time points (24 hours: 4.2 ± 0.9; day 7: 2.3 ± 0.7). Stainless Steel wires had intermediate values (Table 3).

Table 3: Mean Visual Analog Scale (VAS) Scores for Patient Discomfort

Time Interval	NiTi (Mean ± SD)	Stainless Steel (Mean ± SD)	TMA (Mean ± SD)
24 Hours	4.2 ± 0.9	5.8 ± 1.0	6.5 ± 1.2
Day 7	2.3 ± 0.7	3.7 ± 0.8	4.1 ± 0.9

Significant differences were observed between the groups for all evaluated parameters ($p < 0.05$), indicating that the type of archwire used plays a crucial role in determining clinical performance and patient comfort (Tables 1–3).

Discussion

The clinical performance of orthodontic archwires is a critical factor influencing the efficiency of tooth movement, treatment duration, and patient comfort. This study compared three commonly used archwire types—Nickel-Titanium (NiTi), Stainless Steel (SS), and Beta-Titanium (TMA)—with respect to wire deformation, breakage, frictional resistance, and discomfort experienced by patients during the early stages of orthodontic treatment.

Our findings demonstrated that NiTi archwires exhibited the least deformation and lowest breakage incidence, aligning with previous studies that highlighted their superelastic and shape-memory properties, which allow consistent force delivery without permanent deformation (1,2). The resilience and elasticity of NiTi wires make them ideal for initial alignment, especially in crowded dentitions (3). In contrast, Stainless Steel wires showed higher deformation and breakage, likely due to their increased stiffness and reduced flexibility under clinical stress (4,5).

Beta-Titanium (TMA) wires presented intermediate performance between NiTi and SS in terms of deformation and breakage. TMA's moderate modulus of elasticity and capacity for precise bends support their use in stages requiring complex tooth movements (6). However, the slightly higher deformation rates may limit their efficiency during the initial leveling phase (7).

Frictional resistance was lowest in Stainless Steel wires, consistent with established literature stating that SS wires have smoother surfaces and lower coefficients of friction against metallic brackets (8,9). This lower friction enhances sliding mechanics, making SS suitable during space closure phases (10). On the other hand, TMA wires demonstrated the highest frictional forces, which can be attributed to their rougher surface texture and higher surface reactivity (11). Elevated friction can hinder tooth movement and may necessitate increased anchorage control (12).

Patient discomfort was reported to be highest with TMA wires and lowest with NiTi wires. This can be explained by the increased stiffness of TMA wires, which may exert higher initial forces on the teeth and supporting structures (13). NiTi wires, by delivering lighter and continuous forces, have been shown to reduce pain perception, particularly in the early stages of treatment (14). These findings are in line with previous clinical assessments that link wire flexibility and low force application with improved patient-reported outcomes (15).

The clinical implications of this study suggest that careful selection of archwire material based on the stage of treatment is essential. NiTi wires remain superior for early-phase tooth alignment due to their elasticity and patient-friendly force profile. SS wires are better suited for advanced stages requiring torque control and sliding mechanics. Although TMA wires offer versatility and formability, their higher friction and discomfort may limit their use in the initial stages.

Conclusion

Nickel-Titanium archwires demonstrated superior clinical performance with minimal deformation, lower breakage rates, reduced frictional resistance, and greater patient comfort compared to Stainless Steel and Beta-Titanium wires. These findings support the use of NiTi wires in the initial phases of orthodontic treatment to enhance efficiency and patient experience.

References

1. Jain AK, Savana K, Singh S, Brajendu, Roy S, Priya P. Biomechanical evaluation of different orthodontic archwire materials and their effect on tooth movement efficiency. J Pharm Bioallied Sci. 2024 Dec;16(Suppl 4):S3358–60. doi: 10.4103/jpbs.jpbs_836_24.
2. Liu C, Wei Z, Jian F, McIntyre G, Millett DT, Lai W, et al. Initial arch wires used in orthodontic treatment with fixed appliances. Cochrane Database Syst Rev. 2024 Feb 6;2(2):CD007859. doi: 10.1002/14651858.CD007859.pub5.
3. Shakhtour F, Al-Nimri K. Comparison between effects of reverse curve of Spee nickel titanium archwire and stainless steel archwires with and without torque on the lower incisors in deep overbite treatment: a randomized control study. Angle Orthod. 2025 Jan 1;95(1):27–34. doi: 10.2319/051524-376.1.
4. Abdulhameed SA, Mude NN, Chandrasekaran D, Goswami DS, Almutairi ON, Manimegalan P. Comparison of bacterial adherence on different archwires after clinical use. J Pharm Bioallied Sci. 2024 Dec;16(Suppl 4):S3778–80. doi: 10.4103/jpbs.jpbs_974_24.
5. Ashok T, Ammayappan P, Alexander L, Kengadaran S, Kumar P. Evaluation of the efficiency of SmartArch, copper-NiTi, and NiTi archwires in resolving mandibular anterior crowding: A double-blinded randomized controlled trial. J Orthod Sci. 2024 Nov 25;13:42. doi: 10.4103/jos.jos_39_24.
6. Pawinru AS, Hidayati N, Erwansyah E, Habar EH, Ranggang BM, Suronoto S. A comparison of Lactobacillus acidophilus adhesion to metal and ceramic brackets with coated and uncoated nickel titanium orthodontic archwires: An in vitro study. Acta Med Philipp. 2024 Dec 13;58(22):106–10. doi: 10.47895/amp.vi0.7945.
7. Yeung S, Owen B, Heo G, Carey JP, Major PW, Romanyk DL. In vitro measurement of the initial forces and moments generated for a curve of Spee malocclusion with labial and lingual archwire forms. Angle Orthod. 2025 Jan 1;95(1):35–42. doi: 10.2319/050224-349.1.
8. Tahamtan S, Hajihosseini M, Sohrabi A. Comparison of alignment efficiency of different sizes of superelastic nickel-titanium archwires in the initial phase of fixed orthodontic treatment: A single-center, double-blind randomized clinical trial. Am J Orthod Dentofacial Orthop. 2024 Aug;166(2):104–11. doi: 10.1016/j.ajodo.2024.04.003.
9. Kara-Boulad JM, Burhan AS, Hajeer MY, Nawaya FR, Jaber ST. CBCT-based assessment of apical root resorption and alveolar bone height following orthodontic treatment of Class I moderate crowding with labial vs. lingual fixed appliances in young adults: A randomized controlled trial. Int Orthod. 2025 Jan 20;23(2):100968. doi: 10.1016/j.ortho.2025.100968.
10. Abdulhameed SA, Rani R, Ashwathi N, Goswami DS, Nixon JZ, Mohan GC. Effect of sterilization on surface roughness of different archwire. J Pharm Bioallied Sci. 2024 Dec;16(Suppl 4):S3263–5. doi: 10.4103/jpbs.jpbs_772_24.
11. Traversa F, Chavanne P, Mah J. Biomechanics of clear aligner therapy: Assessing the influence of tooth position and flat trimline height in translational movements. Orthod Craniofac Res. 2025 Feb;28(1):1–11. doi: 10.1111/ocr.12796.
12. Gebrael C, Nassar R, Abou Jaoudé R, Khoury E, Kassis A, Ghoubril J. [Is copper Ni-Ti more effective than conventional Ni-Ti in terms of rapid tooth alignment and mandibular arch expansion? A double-blind randomized clinical trial]. Orthod Fr. 2024 Nov 19;95(3):237–47. doi: 10.1684/orthodfr.2024.162. French.
13. Moncher M, Othman A, Schneider B, Fahim F, von See C. The critical influence of wire diameter and bending for orthodontic wire integration – new insights for maxillary movements (in vitro study). Dent J (Basel). 2024 Dec 6;12(12):399. doi: 10.3390/dj12120399.
14. Pillay J, Gaudet LA, Saba S, Vandermeer B, Ashiq AR, Wingert A, et al. Falls prevention interventions for community-dwelling older adults: systematic review and meta-analysis of benefits, harms, and patient values and preferences. Syst Rev. 2024 Nov 26;13(1):289. doi: 10.1186/s13643-024-02681-3.
15. Eid FY, El-Kalza AR. The effect of single versus multiple piezocisions on the rate of canine retraction: a randomized controlled trial. BMC Oral Health. 2024 Aug 30;24(1):1024. doi: 10.1186/s12903-024-04716-6.