ORIGINAL ARTICLE

Investigation of Frictional Resistance Between Orthodontic Archwires and Brackets with Different Surface Coatings.

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ABSTRACT

Background

A crucial component impacting the efficacy of orthodontic therapy is the frictional resistance between orthodontic archwires and brackets. Archwires with surface coatings may greatly decrease this resistance, allowing for better tooth movement with fewer side effects. In this simulated clinical investigation, the frictional resistance of orthodontic archwires and brackets with various surface coatings is investigated.

Materials and Methods

A total of 90 orthodontic brackets and archwires were categorized into three groups (n=30 pergroup) based on the surface coatings of the archwires: Group A (uncoated stainless steel), Group B (Teflon-coated stainless steel), and Group C (nano-diamond-coated stainless steel). Testing was conducted using a universal testing machine with a simulated dry environment. Frictional resistance was measured by applying a 500 g load, and the readings were recordedin Newtons (N).

Results

The mean frictional resistance values observed were: Group A (5.4 ± N), Group B (4.2 ± 0.5 N), and Group C (3.1 ± 0.4 N). Nano-diamond-coated archwires (Group C) exhibited significantly lower frictional resistance compared to Teflon-coated(Group B) and uncoated archwires (Group A) ($p < 0.05$).

Conclusion

Surface coatings, particularly nano-diamond coatings, significantly reduce the frictional resistance between orthodontic archwires and brackets. This finding suggests that nano-diamond-coated archwires may improve the efficiency of orthodontic treatment by reducing frictional forces. Further clinical studies are warranted to confirm these results.

Keywords

Orthodontic archwires, Frictional resistance, Surface coatings, Nano-diamond coating, Tefloncoating, Orthodontic brackets

INTRODUCTION

The effectiveness of orthodontic treatment is highly dependent on the frictional resistance of the orthodontic archwires and brackets. Overly much friction can make teeth less mobile than intended, lengthen the time it takes for treatment to take effect, and raise the likelihood of problems such root resorption (1,2). Minimizing frictional resistance is essential for ensuring effective force transmission to teeth while maintaining patient comfort.

Advancements in material sciences have led to the development of various surface coatings for orthodontic archwires. These coatings aim to reduce friction at the wire- bracket interface by altering the surface properties of the archwires. Conventional uncoated stainless steel archwires

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are widely used due to their excellent mechanical properties; however, their relatively high friction levels remain a limitation (3). Surface modifications such as Teflon andnano-diamond coatings have been explored as potential solutions to overcome thisdrawback (4,5).

Nano-diamond coatings, in particular, have garnered attention due to their superior hardness, low surface roughness, and excellent biocompatibility. These properties

make them a promising choice for reducing friction in orthodontic applications (6). Similarly, Teflon coatings have demonstrated moderate success in reducing friction due to their low surface energy and lubricity, though their durability remains a concern in clinical settings (7).

The purpose of this research is to evaluate thedifference in frictional resistance betweenstainless steel archwires that have been coated with nanodiamonds, Teflon, and untreated steel. This research aims to determine the surface coating that optimises orthodontic treatment outcomes by analysing their performance under simulated clinical situations.

MATERIALS AND METHODS STUDY DESIGN

Orthodontic archwires and brackets coated with various substances were the subject of this in vitro investigation to determine their frictional resistance. The frictional resistance was measured under controlled conditions using a universal testing equipment in the investigation.

Sample Preparation

A total of 90 orthodontic brackets (stainless steel, slot size 0.022 inches) and 90 orthodontic archwires (0.019 × 0.025 inches)

were used. The archwires were divided into three groups (n=30 per group) based on theirsurface coatings:

- Group A: Uncoated stainless steelarchwires (control group).
- Group B: Teflon-coated stainlesssteel archwires.
- Group C: Nano-diamond-coatedstainless steel archwires.

The archwires were pre-treated with alcohol to ensure cleanliness, and brackets were securely bonded to a testing jig to maintain consistent alignment.

Testing Procedure

A load cell calibrated to 10 N was part of the testing setup that included a universal testing machine. Under controlled conditions, elastomeric ligatures were used to secure each archwire to its corresponding bracket. Under a static 500 g strain, the archwire was dragged through the bracket slot at a speed of

10 mm/min in order to mimic real-life clinical settings.

Every specimen had its frictional resistance measured in Newtons (N). In order to excludethe potential impact of lubrication andmoisture, all testing were conducted in a dry environment. Each group underwent three repetitions for each sample to ensure reliability and consistency in the data.

Statistical Analysis

To find statistically significant differences between the groups, we first determined their

mean frictional resistance values and thenused one-way ANOVA with post hoc Tukey's test to analyse the data. It was deemed statistically significant when the p- value was less than 0.05.

RESULTS

The frictional resistance of orthodontic archwires and brackets coated with various substances was tested in this study. The average frictional resistance (in Newtons) forevery category is shown in Table 1, which summarises the findings.

Frictional Resistance

The mean frictional resistance values for the three groups were as follows: Group A (uncoated stainless steel) recorded the highest friction (5.45 ± 0.32 N), followed by Group B (Teflon-coated archwires) with moderate friction (4.28 ± 0.25 N), and GroupC (nano-diamond-coated archwires) demonstrated the lowest friction (3.12 ± 0.20N).

Statistical Analysis

There were notable variations in frictional resistance across the three groups, as shown by statistical analysis using one-way ANOVA ($p < 0.05$). Group C demonstrated noticeably reduced friction in comparison to Groups A and B, as indicated by the post hocTukey's test ($p < 0.05$). Likewise, according to Table 1, Group B exhibited noticeably lessfriction compared to Group A ($p < 0.05$).

Summary of Findings

The results indicate that surface coatings, particularly nano-diamond coatings, effectively reduce frictional resistance between archwires and brackets, which may enhance the efficiency of orthodontictreatment.

Table 1: Frictional Resistance Values for Different Archwire Groups

Group	ArchwireType	Mean FrictionalResistance (N) ± SD
Group A	Uncoated StainlessSteel	5.45 ± 0.32
Group B	Teflon-Coated	4.28 ± 0.25
Group C	Nano- Diamond-Coated	3.12 ± 0.20

Note: Statistical significance observed between all groups ($p < 0.05$).

A critical component influencing the efficacy of tooth movement in orthodontic treatment is the frictional resistance betweenorthodontic archwires and brackets. This study demonstrated that surface coatings, particularly nano-diamond coatings, significantly reduce frictional resistance compared to uncoated and Teflon-coated archwires. These findings align with previous research that highlights the importance of surface modifications in improving orthodontic efficiency (1,2).

Uncoated stainless steel archwires, although widely used due to their excellent mechanical properties, exhibited the highest friction in this study. High frictional forces may lead to delayed tooth movement and increased anchorage requirements, which are undesirable during orthodontic treatment(3,4). These results are consistent with earlier studies that reported similar frictional behavior for uncoated stainless steel wires (5,6).

As seen in Table 1, nano-diamond-coated archwires demonstrated the lowest frictional resistance, highlighting their potential clinical advantage in reducing treatment duration and improving tooth movement efficiency.

DISCUSSION

The Teflon-coated archwires demonstrated moderate frictional resistance, which was significantly lower than uncoated wires. Teflon coatings reduce surface roughness and decrease the coefficient of friction, improving sliding mechanics. However, the durability of Teflon coatings remains a concern as repeated use in the oral environment may degrade the coating over time (7,8). Previous studies have also reported moderate friction reduction with Teflon coatings, supporting our findings (9,10).

Nano-diamond-coated archwires exhibited the lowest frictional resistance among the groups. Nano-diamond coatings offer a highly smooth surface with exceptional hardness, resulting in reduced friction and enhanced wear resistance. These properties make nano-diamond coatings a promising innovation for orthodontic applications (11,12). Similar findings have been reportedin the literature, where nano-diamond coatings demonstrated superior performancein reducing friction in orthodontic andbiomedical devices (13,14).

The clinical implications of reduced frictional resistance are significant. A shorter treatment duration and fewer adverse effects, including root resorption or loss of anchoring, are possible thanks to reduced friction, which enables efficient force transmission (15). Furthermore, improved efficiency in tooth movement enhances patient satisfaction and reduces the overall burden of treatment.

CONCLUSION

Testing how these coatings hold up over timein different intraoral environments, such as those with fluctuating temperatures, mechanical wear, and exposure to saliva, should be the focus of future studies. Additionally, clinical trials are essential to validate the in vitro findings and establish thepracticality of these coatings in routine orthodontic practice.

Conflict of Interest: None Acknowledgement: None

Authors contributions:

A.S.A.; A.S., M.A.M.E., M.K.A. conceived the research idea; A.S.A.; M.K.A. prepared the article; A.S.A.; M.K.A. collected and tabulated the information; A.S.A.; A.S., M.A.M.E., M.K.A. carried out the bibliographic search; A.S.A.; A.S., M.A.M.E., M.K.A. helped in the development of the discussion; and A.S.A., A.S., M.A.M.E., M.K.A. carried out the critical revision of the article. All authors approved the final version of the article.

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