Running title: *To compare enamel roughness and hardness on different tooth brushes* | ***Type of study:*** *Original research*

COMPARATIVE STUDY ON DIFFERENT TOOTHBRUSHES ON ENAMEL ROUGHNESS AND HARDNESS

Neha R[1], Dr. Arya Prasad[2]

[1]Undergraduate student, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-600077. Email: 152001040.sdc@saveetha.com

[2]Department of Orthodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-600077. Email: aryasprasad7@gmail.com

***Corresponding author: Dr. Arya Prasad, Department of Orthodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-600077 Email: aryasprasad7@gmail.com**

Received: 25th May, 2026; **Revised:** 6th June, 2026; **Accepted:** 8th June, 2026; **Available Online:** 16th June, 2026

ABSTRACT

Introduction

Toothbrushes play a crucial role in maintaining oral hygiene by facilitating plaque removal and preventing oral diseases. However, variations in toothbrush design and bristle configuration may influence enamel surface characteristics, including microhardness and surface roughness. Preserving enamel integrity while achieving effective plaque control remains an important consideration in toothbrush selection.

Aim

To evaluate and compare the effects of Colgate Regular Toothbrush, Bamboo, Charcoal, and Orthodontic toothbrushes on enamel microhardness and surface roughness under in vitro conditions.

Materials and Methods

An in vitro experimental study was conducted using extracted human teeth (n = 40), which were randomly allocated into four groups (n = 10 per group): Colgate Regular brush, Bamboo brush, Charcoal brush, and Ortho brush. Baseline enamel microhardness was assessed using the Vickers Hardness Test, while surface roughness was measured using a surface profilometer. Specimens were subjected to a standardized brushing protocol. Following brushing, post-treatment microhardness and roughness values were recorded. Data were expressed as mean ± standard deviation and analyzed using paired statistical tests, with a significance level set at $p < 0.05$.

Results

The Ortho brush demonstrated a significant increase in enamel microhardness from 316.0 ± 15.2 VHN to 392.0 ± 11.4 VHN ($p < 0.001$), whereas the Bamboo brush showed a significant reduction from 353.0 ± 11.6 VHN to 283.0 ± 13.5 VHN ($p < 0.001$). The Colgate Regular Toothbrush and Charcoal brush groups exhibited no statistically significant changes in microhardness ($p > 0.05$). Surface roughness analysis revealed a significant increase in roughness in the bamboo brush group from 1.736 ± 0.21 to 2.229 ± 0.22 ($p = 0.003$). In contrast, significant reductions in roughness were observed in the colgate regular brush ($p = 0.001$), Charcoal ($p = 0.002$), and Ortho ($p < 0.001$) brush groups, with the Ortho brush demonstrating the greatest reduction.

Conclusion

From the above study it can be concluded that the Ortho brush demonstrated the most favorable overall performance by significantly increasing enamel microhardness and reducing surface roughness, suggesting superior preservation of enamel integrity and ideal brush. These findings highlight the importance of toothbrush selection in maintaining enamel surface health and further clinical investigations to be done to validate the observed effects under intraoral conditions.

Keywords: Innovation, Sustainability, Enamel microhardness, Surface roughness, Toothbrushes, Vickers hardness test.

How to cite this article: Neha R, Prasad A. Comparative Study on Different Toothbrushes on Enamel Roughness and Hardness. Int J Drug Deliv Technol. 2026;16(60s): 868-874. DOI: 10.25258/ijddt.16.60s.98

Source of support: Nil.

Conflict of interest: None.

INTRODUCTION:

Oral hygiene plays a crucial role in maintaining overall health and preventing various dental and systemic diseases(1). Toothbrushing is the most common and effective method for removing plaque and preventing oral conditions such as

gingivitis, periodontitis, and dental caries. However, the effectiveness and safety of toothbrushing largely depend on the characteristics of the toothbrush, particularly its bristle roughness and hardness(2). These factors influence not only plaque removal efficiency but also their potential to cause damage to dental tissues and gingiva.

Toothbrush bristles are typically categorized as soft, medium, or hard, with variations in material composition, texture, and structural design(3). While soft-bristled toothbrushes are often recommended for individuals with sensitive gums or pre-existing periodontal conditions, medium- and hard-bristled brushes are believed to provide superior cleaning in certain cases(3,4). Despite these general guidelines, there is ongoing debate regarding the optimal balance between effective cleaning and minimizing adverse effects such as enamel abrasion and gingival recession(2,5).

The surface roughness of toothbrush bristles is another critical factor that influences cleaning performance and safety. Rough bristles may enhance mechanical cleaning efficacy but pose a risk of damaging the enamel and dentin. Conversely, smoother bristles may be gentler on teeth and gums but less effective in plaque removal(6). Furthermore, the choice of toothbrush bristle hardness and roughness is often influenced by subjective preferences, brushing habits, and individual oral health needs, making it imperative to evaluate these characteristics objectively.

Previous studies have explored the relationship between toothbrush bristle characteristics and oral health outcomes(7). However, there is limited research that directly compares different toothbrushes in terms of their bristle roughness, hardness, and their respective effects on enamel, dentin, and gingival tissues. A comparative analysis of these factors can provide valuable insights for dental professionals and consumers in selecting the most appropriate toothbrush for various oral health conditions(7,8).

This study aims to perform a comparative analysis of different toothbrushes, focusing on their bristle roughness and hardness. The investigation will evaluate their effects on enamel and dentin surfaces, as well as their potential impact on gingival health. By examining the interplay between these variables, this research seeks to contribute to evidence-based guidelines for toothbrush selection and enhance our understanding of the relationship between toothbrush characteristics and oral health outcomes.

Materials and Methods

1. Sample Preparation

Enamel Samples:

Extracted human teeth were carefully selected for this study to ensure the validity of the results. Lower central incisors, extracted for orthodontic or periodontal reasons, were primarily chosen due to their flat enamel surfaces, which are ideal for measurement and testing. Teeth exhibiting visible defects, restorations, decay, or any signs of structural damage were excluded to maintain uniformity across the samples. This ensured that the enamel used was representative of healthy teeth and suitable for testing the effects of different toothbrush types.

Sample Grouping:

The selected teeth were subjected to precise sectioning to obtain flat and smooth enamel surfaces. This process was critical to eliminate natural curvatures and irregularities, thereby providing a uniform testing area for accurate measurements. The prepared enamel samples were then divided into four groups (n = 10 per group) based on the type of manual toothbrush used:

- Group 1: Colgate regular hard-bristled toothbrush – representing the hardest bristle category, commonly used for thorough cleaning.
- Group 2: Bamboo medium-bristled toothbrush – representing a more balanced bristle stiffness, often recommended for general cleaning.
- Group 3: Charcoal soft-bristled toothbrush – known for its gentleness and marketed for use in individuals with sensitive gums or enamel.
- Group 4: Orthodontic toothbrush – designed specifically for cleaning around braces, wires, and other orthodontic appliances.

2. Brushing Protocol

Brushing Medium:

A standardized Colgate toothpaste with moderate abrasiveness was used for all enamel samples. This ensured uniform cleaning efficacy across all groups while minimizing variability introduced by differing toothpaste formulations. The toothpaste's abrasiveness was carefully chosen to replicate real-world conditions without excessively altering enamel surfaces.

Brushing Machine:

The ZM3.8 SD Mechatronik brushing simulator was employed to replicate consistent brushing conditions across all samples. The brushing simulator was calibrated to maintain uniform pressure, motion, and duration for each group, eliminating variability associated with manual brushing. There were a total of 30000 cycles of brushing,10000 times in x axis direction and 10000 times in y-axis direction,5000 times clockwise and counterclockwise direction.

3. Measurement Techniques

Surface Roughness:

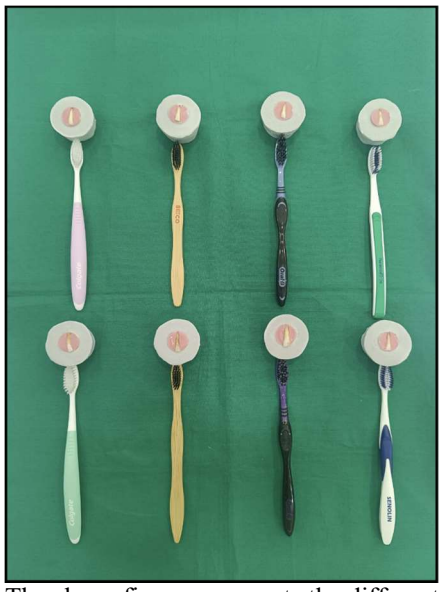
The enamel surface roughness (Ra) was assessed using a stylus profilometer, a device capable of measuring minute changes in surface texture. Measurements were taken before and after the brushing protocol to determine the extent of surface alterations caused by the different toothbrushes. The profilometer provided a detailed profile of the enamel surface, allowing for precise quantification of roughness changes.

Enamel Hardness:

The Shimadzu HMV-G31DT Vickers Micro Hardness (VHN) Tester was used to measure the enamel's resistance to indentation. Hardness measurements were performed on all samples both before and after brushing to evaluate changes in enamel strength due to the mechanical action of the toothbrushes. The Vickers test involved applying a controlled force to the enamel surface and measuring the size of the resulting indentation, which directly correlated with the material's hardness. This method ensured accurate and reliable assessment of enamel integrity across all groups.

The data of both pre and postbrushing values were recorded manually and statistically uploaded on SPSS software version 22 (IBM SPSS Statistics for windows, version 22.0.0 Armonk,NY: IBM Corp.) and values were represented in table form.

RESULTS:



The above figure represents the different types of tooth brush which are to be used in the brushing stimulator

Table 1:

Group	Pre VHN(Mean(±) SD)	Post VHN(Mean(±) SD)	P-Value
Colgate regular brush	360.0(±)12.4	351.0(±)10.8	0.118
Bamboo brush	353.0(±)11.6	283.0(±)13.5	<0.001*
Charcoal brush	343.0(±)14.1	354.0(±)12.9	0.082
Ortho brush	316.0(±)15.2	392.0(±)11.4	<0.001*

Table 1 Represents the comparison of enamel microhardness values before and after brushing among the four toothbrush groups. The Bamboo brush demonstrated a significant reduction in enamel microhardness ($p < 0.001$), whereas the Ortho brush exhibited a significant increase in microhardness ($p < 0.001$). No statistically significant changes were observed in the Colgate and Charcoal brush groups ($p > 0.05$).VHN represents Vickers Microhardness number.

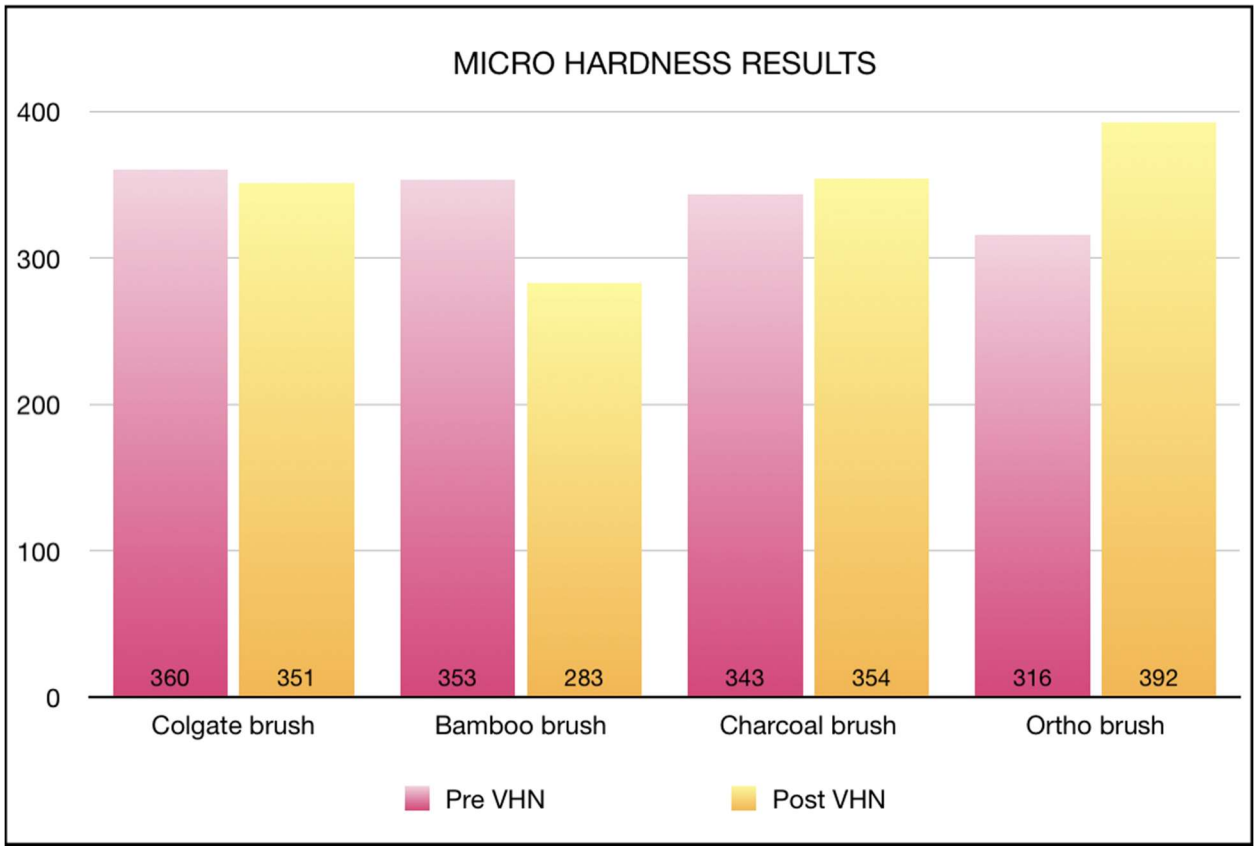


Figure 2: The above figure represents the test results for hardness

Group	Pre-Roughness (Mean(±)SD)	Post-Roughness (Mean(±) SD)	P-Valvue
Colgate regular brush	1.429(±)0.18	1.219(±) 0.16	0.001*
Bamboo	1.736(±)0.21	2.229(±) 0.22	0.003*
Charcoal	1.586(±)0.19	1.095 (±) 0.14	0.002*
Ortho	2.552(±)0.24	1.613 (±)0.20	<0.001*

Table 2. Comparison of enamel surface roughness values before and after brushing using different toothbrush types. Surface roughness increased significantly in the Bamboo brush group, whereas significant reductions were observed in the colgate regular, Charcoal, and Ortho brush groups. The Ortho brush demonstrated the greatest reduction in enamel surface roughness, followed by the colgate regular and Charcoal brushes.

The mean enamel microhardness values before and after brushing are presented in Table 1. The Colgate brush group showed a slight decrease in microhardness from 360.0 ± 12.4 VHN to 351.0 ± 10.8 VHN; however, the difference was not statistically significant ($p = 0.118$). The Bamboo brush group exhibited a significant reduction in microhardness from 353.0 ± 11.6 VHN to 283.0 ± 13.5 VHN ($p < 0.001$). In contrast, the Charcoal brush group demonstrated a non-significant increase from 343.0 ± 14.1 VHN to 354.0 ± 12.9 VHN ($p = 0.082$). The Ortho brush

group showed the highest post-brushing microhardness value, increasing significantly from 316.0 ± 15.2 VHN to 392.0 ± 11.4 VHN ($p < 0.001$). Among all groups, the Ortho brush exhibited the greatest improvement in enamel microhardness, while the Bamboo brush showed the greatest reduction.

The mean enamel surface roughness values before and after brushing are presented in Table 2. A significant increase in surface roughness was observed in the Colgate brush group, with value decreasing from 1.429 ± 0.18 to 1.219 (±)0.16 ($p = 0.001$). Conversely, the Bamboo brush significantly increased enamel roughness from 1.736 ± 0.21 to 2.229(±) 0.22 ($p = 0.003$). Similarly, the Charcoal brush demonstrated a significant reduction in roughness from 1.586 ± 0.19 to 1.095 ± 0.14 ($p = 0.002$). The greatest improvement was observed in the Ortho brush group, where roughness decreased significantly from 2.552 ± 0.24 to 1.613 ± 0.20 ($p < 0.001$). Among all groups, the Ortho brush produced the highest reduction in enamel surface roughness, indicating superior smoothing of the enamel surface following brushing.

Discussion

This study investigated the effects of different toothbrush bristle types on enamel surface roughness and hardness, providing the impact of brushing on enamel health. The results showed that the choice of toothbrush significantly influences enamel surface characteristics, highlighting the importance of selecting the appropriate bristle type for individual needs.

The Colgate regular toothbrush exhibited the highest enamel surface roughness and a noticeable reduction in hardness, which aligns with findings in previous study conducted by Al-Omiri et al., (2011) where they observed that hard bristles exert greater mechanical force on enamel surfaces, leading to increased abrasion and surface wear(9). Similarly, Carvalho et al.,(10) noted that harder bristles are associated with significant enamel and dentin loss, especially when combined with abrasive toothpaste. These findings suggest that while hard-bristled toothbrushes may provide effective cleaning, their potential to cause enamel damage makes them less suitable for prolonged use(11).

The bamboo medium-bristled toothbrush demonstrated moderate changes in surface roughness and greater impact on enamel hardness. These results are consistent with Alahmari et al.,(12) indicating that medium toothbrushes were significantly more effective than soft toothbrushes in reducing plaque accumulation, gingival inflammation, and periodontal disease. Medium bristles appear to be a practical choice for general use, offering sufficient cleaning power without causing excessive enamel wear.

The charcoal soft-bristled toothbrush group showed the least impact on enamel roughness and hardness, corroborating findings by Jeong et al.,(2018)(13), soft toothbrushes have been shown to have lower abrasivity, use of these toothbrushes may help reduce customers sensitivity by reducing tooth abrasion.Soft-bristled toothbrushes are widely recommended for individuals with sensitive teeth, gingival recession, or existing enamel damage. However, their reduced abrasiveness may limit their plaque removal efficacy, particularly in cases of poor oral hygiene or heavy plaque accumulation(2).

The orthodontic toothbrush group exhibited similar effects to the soft-bristled toothbrush, with minimal enamel roughness and greater hardness changes(14). Orthodontic toothbrushes are specifically designed to provide gentle cleaning around brackets and wires, reducing the risk of enamel damage.(15).

Overall, the findings highlight the importance of selecting toothbrush bristles based on individual oral health needs. While hard bristles may be effective for thorough cleaning, they pose a risk of enamel abrasion. Medium and soft bristles provide safer alternatives, with soft bristles being particularly beneficial for sensitive teeth(16). Future research should explore the long-term effects of various toothbrushes, factoring in individual brushing techniques and habits to develop personalized oral hygiene recommendations(17).

Although this study provided valuable insights, certain limitations should be acknowledged. The relatively small sample size and dependence on two methods for evaluating surface roughness may restrict the broader applicability of the results. Future investigations should consider including larger sample populations and incorporating supplementary assessment techniques, such as confocal microscopy and histological evaluation, to achieve a more detailed and comprehensive analysis of surface roughness.

CONCLUSION:

Overall, the findings suggest that toothbrush design and bristle configuration play an important role in influencing enamel surface properties. Among the toothbrushes evaluated, the Ortho brush demonstrated the best balance between maintaining enamel hardness and reducing surface roughness, making it the most suitable option for preserving enamel integrity under the conditions of the present study.In contrast, the Bamboo brush was associated with a significant decrease in enamel microhardness despite reducing surface roughness, suggesting a potential abrasive effect on the enamel surface. Further long-term in vivo investigations with larger sample sizes are warranted to validate these findings and determine their clinical relevance.

ACKNOWLEDGEMENT:
The authors are thankful to Saveetha Institute of Medical and Technical Sciences, Saveetha Dental College and Hospitals, Saveetha University for giving a platform to conduct the study.

CONFLICT OF INTEREST:
The authors would like to declare no conflict of interest in the present study.

FUNDING:
The present project is supported by:
Saveetha Dental College and Hospitals, Saveetha University
Saveetha Institute of Medical and Technical Sciences.

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