ORIGINAL RESEARCH

In Vitro Assessment of Different Toothbrush Designs on Enamel Surface Abrasion: A Profilometric Study

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Abstract

Aim: The purpose of this study was to evaluate the impact of three different toothbrush designs on enamel surface abrasion.

Materials and methods: Sixty intact freshly extracted maxillary central incisors were considered for the study. All of the extracted teeth's surfaces were severely trimmed, leaving only the labial surface intact. In the trial, a conventional teeth-whitening dentifrice slurry was utilized. A brushing model was created to deliver uniform force in unidirectional motion. Dontrix Gauge was used to control the tension of the spring. The force was kept constant at 180 ± 20 g. The mounted enamel samples were separated into three groups (20 samples each) at random: group A: toothbrushes have a flat trim bristle design, group B: toothbrushes have a zigzag pattern, and group C: toothbrushes have a bi-level bristle design. For 2 weeks, each sample was brushed twice daily for 2 minutes. A profilometer was used to measure the average surface roughness.

Results: After toothbrushing, the maximum mean surface roughness score was found in zigzag pattern group (2.10 ± 0.23), followed by bi-level bristle design group (2.06 ± 0.12) and the least was in the flat trim bristle design group (1.96 ± 0.09). There was a significant difference between the different toothbrush bristle pattern groups ($p < 0.001$).

Conclusion: On conclusion, the results of this study showed that, in comparison to toothbrushes with zigzag patterns and bi-level bristle designs, flat trim toothbrush bristle designs cause the least amount of surface abrasion and are relatively safe to use.

Clinical significance: Toothbrushing with toothpaste contributes significantly to dental abrasion. A variety of parameters, including toothpaste abrasivity and concentration, brushing frequency, brushing length, brushing force, and toothbrush bristle stiffness, have the potential to influence the abrasion process of dental hard tissue.

Keywords: Enamel surface abrasion, Profilometer, Toothbrushing, Toothbrush abrasion.

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Introduction

Dental plaque is a key etiological component in the development and progression of both caries and periodontal disease, effective plaque control is essential to maintaining oral health. The technique for maintaining oral hygiene that is most frequently employed is plaque removal using a manual toothbrush. Most parts of the mouth should be accessible to and effectively cleaned with a toothbrush.[1] Plaque removal is a crucial component of disease prevention, and the toothbrush is the most popular tool in use today. A wide variety of toothbrush and supplementary device designs have been produced and promoted.[2]

Abrasion is the term used to describe the wearing down of a tooth's surface brought on by friction with a foreign object. Overzealous brushing can more easily abrade the buccal surfaces of teeth. The most frequent cause of abrasion on the cervical edges of teeth is toothbrushing. Numerous studies have demonstrated that a variety of factors affect toothbrush abrasion. These factors include brushing technique, brushing force, brushing frequency and length, and brush type, particularly filament stiffness. According to numerous researches, using dentifrices on a regular basis has been identified as an etiological factor in gingival recession and tooth wear.[3]

Enamel is often relatively hard and not readily abraded, while dentin gets abraded 25 times more quickly than enamel does, and cementum, the softest of all tissues, gets abraded 35 times more

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quickly than enamel. Since the cementum becomes exposed as people age due to recession, this explains why cervical lesions are so common. In younger age groups, improper brushing habits are the main cause of abrasion.[4]

In the market, there are many different toothbrush varieties with diverse bristle designs. Brushes have been divided into three categories based on the diameter of the bristles: soft (0.2 mm), medium (0.3 mm), and hard (0.4 mm). In general, toothbrush bristles differ in length, hardness, length, design, and arrangement. The diameter, length, quantity of filaments in a tuft, and filament curvature all affect how stiff bristles are. The market offers a variety of bristle styles, some of which are popular. These include flat trim, zigzag, and bi-level bristles. Brush bristle design can have an impact on surface abrasivity.[5] The mechanism is yet unknown, as abrasion varies with the usage of different types of toothbrushes. Hence, this study was designed to evaluate the effect of three different toothbrush designs on enamel surface abrasion.

Materials and Methods

The present *in vitro* study was conducted in the Department of Periodontics, Kalinga Institute of Dental Sciences, Bhubaneswar, India, during the year of 2022. Sixty intact freshly extracted maxillary central incisors were considered for the study. Teeth that were extracted due to periodontal disease and exhibited no cavities, fractures, discolorations, or enamel abnormalities were considered for the study.

Sample's Infection Control and Preparation for Study

Following extraction, damp cotton was used to delicately remove the soft tissue that was still adhered to the tooth surface. Guidelines and recommendations from the Centres for Disease Control and Prevention (CDC) and the Occupational Safety and Health Administration (OSHA) were adhered to. Following sample collection, the samples were added to a 100 mL vial that was filled with a 5.25% sodium hypochlorite solution. After 30 minutes, the solution was discarded, and the teeth were placed in separate jars with artificial saliva (Wet Mouth, ICPA Health Products Ltd.) to simulate the oral environment with 0.1% thymol added and it acts as an antifungal agent. With the use of cotton pliers, the samples were taken out and rinsed with tap water. Before being used for the study, the samples were dried by spreading them out over paper towels and blotting for a few minutes.

Using a lathe machine (Baldor 340 Dental lathe), all surfaces of the excised teeth were grossly trimmed, leaving just the labial surface intact. After gross reduction, the net labial surface area that remained was around 9 mm^2. After that, the samples were placed on separate acrylic bases with labial surface were exposed. The acrylic was allowed to dry completely. Following that, profilometric examination was performed on all of the acrylic slabs with applied enamel samples and baseline readings were noted.

Preparation of Dentifrice Slurry

A regular teeth-whitening dentifrice (Pepsodent Whitening®) was employed in this study. Prior to teeth brushing, dentifrice slurry was made and distributed over the mounted enamel samples with a measuring scoop. An identical amount (slurry of the dentifrice was prepared by dissolving 20 gm of each toothpaste in 40 mL of water for 5 minutes and mixed with 10 mL of artificial saliva) of slurry was applied each time. It was applied to the enamel surface and carefully spread with the toothbrush bristle tips.

Table 1: Evaluation of mean surface roughness score before toothbrushing in all the three groups

Experimental groups	*n*	*Before toothbrushing—surface roughness score mean ± SD (Ra1)*	*K ANOVA value*	*p-value*
Group A: Flat trim bristle design	20	1.88 ± 0.28	26.413	5.148
Group B: Zigzag pattern	20	1.90 ± 0.14		
Group C: Bi-level bristle design	20	1.86 ± 0.17		

Construction of Brushing Model and Dontrix Gauge Adjustment

A brushing model was created to deliver uniform force in unidirectional motion. The brushing model was made out of a motor (Wexco, New Jersey, USA), a handle, and a wooden base. This device was powered by electricity. The equipment was designed with a screw-and-wedge construction that allowed for easy replacement of one type of toothbrush with another. Dontrix Gauge was used to control the tension of the spring. The force was kept constant at 180 ± 20 g.[6] The tension was adjusted on a regular basis using the Dontrix Gauge.

Brushing Process

The samples of mounted enamel were divided into three groups, each with 20 samples:

Group A: Flat trim bristle design.

Group B: Zigzag pattern.

Group C: Bi-level bristle design toothbrushes.

All three toothbrushes used were medium-sized (Oral-B). Brushing was done in a direction perpendicular to the long axis of the tooth, with a uniform force, as is natural in the oral cavity. For 2 weeks, each sample was brushed twice daily for 2 minutes. The surface roughness of all mounted samples was calculated once the brushing regimen was completed. And two investigators participated in this study.

Profilometric Analysis

With the help of a profilometer, the mean surface roughness was measured. All mounted enamel samples had their Ra values determined before and after toothbrushing, and the difference between the two values (post–pre) was used to determine how much the surface had changed in roughness or abrasion.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) Version 20 was used for all statistical analyses. The Mann–Whitney *U* test and Kruskall–Wallis tests were used to determine the significance of the intergroup differences. Statistical significance was defined as a *p*-value of 0.05 or lower.

Results

Table 1 shows the mean surface roughness score before toothbrushing in all the three groups. The mean surface roughness

Table 2: Evaluation of mean surface roughness score after toothbrushing in all the three groups

Experimental groups	*n*	*After toothbrushing—surface roughness score Mean ± SD (Ra2)*	*K ANOVA value*	*p-value*
Group A: Flat trim bristle design	20	1.96 ± 0.09	29.031	0.001
Group B: Zigzag pattern	20	2.10 ± 0.23		
Group C: Bi-level bristle design toothbrushes	20	2.06 ± 0.12		

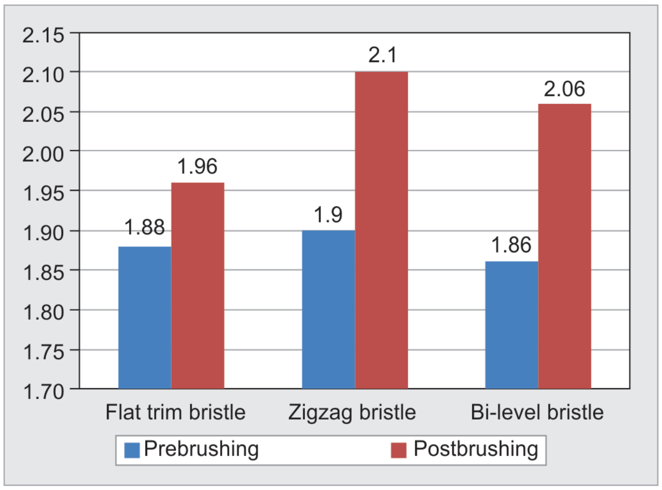

Fig. 1: Comparison of mean surface roughness score before and after toothbrushing in all the three groups

score was less in bi-level bristle design group (1.86 ± 0.17), followed by flat trim bristle design group (1.88 ± 0.28) and zigzag pattern group (1.90 ± 0.14). There was no significant difference between the different toothbrush bristle pattern groups.

Table 2 and Figure 1 reveal the mean surface roughness score after toothbrushing in all the three groups. The maximum mean surface roughness score was found in zigzag pattern group (2.10 ± 0.23), followed by bi-level bristle design group (2.06 ± 0.12) and the least was in flat trim bristle design group (1.96 ± 0.09). There was a significant difference between the different toothbrush bristle pattern groups ($p < 0.001$).

Intergroup surface roughness comparison was done using Mann–Whitney *U* test. There was a statistically significant difference found between flat trim bristle vs zigzag pattern and flat trim bristle vs bi-level bristle design groups ($p < 0.001$). Between zigzag pattern and bi-level bristle design, we did not find any statistically significant difference ($p > 0.001$) (Table 3).

Inference of this study indicates that the flat trim toothbrush bristle designs produces least surface abrasion and are relatively safe for use compared with zigzag pattern and bi-level bristle design toothbrushes.

Discussion

In the majority of countries, using a toothbrush and dentifrices to brush their teeth remains the most popular and effective oral hygiene technique. However, toothpaste and toothbrush misuse has been shown to harm dental hard and soft tissues in addition to its potential benefits of removing dental plaque biofilm and enhancing oral health. Brush abrasion is influenced by a number of variables, including brush type, particularly filament stiffness, brushing method, force, duration, and frequency.[7]

Table 3: Comparison of intergroup surface roughness score using Mann–Whitney *U* test

Intergroup comparison	*Mean rank*	*Mann–Whitney U*	*p-value*
Flat trim bristle vs zigzag pattern	22.16 – 4.12	27.46	0.001
Flat trim bristle vs bi-level bristle design	23.27 – 6.89	28.33	0.001
Zigzag pattern vs bi-level bristle design	24.58 – 7.19	30.14	0.406

A profilometer was used in the current investigation to measure the surface abrasion. Similar to Young AAdeA et al.[5] and Willems G et al.,[8] they used profilometric analysis to assess changes in surface roughness. The Ra of a sample is the arithmetic mean height of imperfections in the roughness component measured within the sampling length. The tip of the profilometer was placed in the center of each mounted specimen that was implanted in an acrylic base to capture the data.

In this study, three alternative toothbrush bristle designs' effects on the surface abrasivity produced on the mounted enamel sample were assessed. The labial surface was chosen and exposed to a toothbrushing cycle because, under normal conditions, the labial or buccal surfaces of teeth are more vulnerable to the adverse effects of forceful toothbrushing in the oral cavity. All three toothbrush designs had the same (medium) bristle diameter, which was chosen to reduce variations. In every instance, standardized dentifrice was employed to reduce the amount of surface abrasivity brought on by the usage of various dentifrices. The current study's findings demonstrated that each sample in each of the three groups that underwent a brushing cycle had surface abrasion. When compared with toothbrushes with flat trim bristles, the surface abrasion of the zigzag and bi-level bristle designs was much higher. Similar results were reported by Drisko et al.,[9] who discovered that bristles with sharp points abrade surfaces more. The results, however, were also in contrast to Sripriya and Shaik Hyder Ali's[10] research, which concluded that there is not a particular manual toothbrush design that is preferable. Although there were some little site differences in favor of the brushes, they were not statistically significant.

According to Mazumdar P et al.,[11] surface abrasion occurred in all three groups regardless of the bristle design type. In contrast to other designs, the flat trim bristle design was discovered to be relatively safe. The amount of abrasion seen is influenced by several factors, including dentifrice abrasivity, frequency of brushing, brushing pressure, and toothbrush design. However, in this study, only the bristle design was evaluated by keeping other factors constant. The present investigation had the advantage of employing mounted samples with buccal surfaces that had been abraded with an automated brushing system, in contrast to studies by Dyer et al.[2] and Teche FV et al.[12] that used dental acrylic to measure abrasion. As enamel is the outermost layer of a tooth, it is the one that is most exposed to teeth cleaning. Therefore, enamel needs to be protected. The study's results will thus more clearly show how toothpaste and a toothbrush contribute to the abrasion process. The study made use of an automated brushing apparatus that was custom-built, and great care was taken to ensure that the tension was periodically changed so that the machine supplied consistent force.

Possible contributing factors to the impact in all three trial groups include the dentifrice's abrasive type and particle size. The identical dentifrice slurry was applied to all three of the chosen toothbrush designs as a constant to prevent any differences in the outcomes. According to the manufacturer, silica particles in visible white may have contributed to the highest degree of enamel abrasion, which is in contrast to the findings of Silva et al.[13] and Ferreira et al.[14] Recent research has shown that profilometry and radioactive abrasion are more reliable methods for assessing toothpastes' abrasiveness. Among its most significant benefits are its superior precision to other technologies and its ability to measure without causing damage to the surface.[15,16]

This study has some limitations, one of which is that the simulation of continuous washing action of the saliva and its remineralizing protective effects over the worn surfaces of teeth could be of great significance in methodological resemblance of the dental abrasion *in vitro* researches to its really occurring situation inside the mouth. Since this *in vitro* study was only run for a brief period of time, its effects on long-term toothbrush and toothpaste use cannot be established. Furthermore, the study did not account for how abrasive toothpastes are. Therefore, additional research using dentifrices with different levels of abrasivity is advised to evaluate the variation in the abrasion process.

Conclusion

This study concluded that, in comparison with toothbrushes with zigzag patterns and bi-level bristle designs, flat trim toothbrush bristle designs cause the least amount of surface abrasion and are relatively safe to use. Further long-term longitudinal and clinical investigations, however, are required to clarify the impact of various toothbrush bristle patterns on dental abrasion.

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