ORIGINAL RESEARCH

Evaluation of the Abrasive Effect of Different Types of Toothbrushes on Enamel Surface: An *In Vitro* Study

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Abstract

Aim: The aim of the current study was to assess the abrasive effect of three different types of toothbrushes on enamel surfaces.

Materials and methods: Sixty recently extracted mandibular premolar teeth for orthodontic reasons were randomly divided into three groups—group I: the samples brushed with a manual toothbrush, group II: the samples brushed with a multidirectional-powered toothbrush, and group III: the samples brushed with a sonic-powered toothbrush. A specially designed brushing apparatus was developed. The tension of the spring was adjusted to 90 ± 10 gm using a dontrix gauge. For 2 weeks, a single sample was brushed twice a day for 2 minutes each time. A profilometer was used to assess the mean surface loss. Roughness average (Ra) values were computed before brushing and after 2 weeks of brushing, and they were then statistically evaluated.

Results: The maximum surface roughness was found in group I (22.38 ± 1.86), followed by group III (19.04 ± 2.32), and least in group II (17.14 ± 1.20). There was a statistically significant difference found between group I vs group II and group I vs group III, with a mean difference of 5.24 and 3.34, respectively. There was no statistically significant difference between group II vs group III.

Conclusion: In conclusion, surface roughness was noticed in all toothbrushes that were utilized in the present investigation. However, when compared to the manual and sonic-powered toothbrush groups, the multidirectional-powered toothbrush group had the least amount of surface roughness.

Clinical significance: The three most common conditions affecting the oral cavity are gingivitis, periodontal disease, and dental caries. The primary cause of these dental conditions is plaque. For the preservation of dental and oral health, plaque reduction is crucial. One very common tool for controlling plaque is the toothbrush. There are numerous toothbrushes on the market that are designed to remove plaque. Toothbrushes are a major factor in the development of tooth wear because they create abrasion.

Keywords: Abrasion, Manual toothbrush, Powered toothbrush, Sonic toothbrush, Tooth wear.

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Introduction

Dental plaque has been considered the most significant and easily visible local etiological component, contributing significantly to the development and course of periodontal disease. The frequency and severity of gingival and periodontal disease are highly correlated with plaque and inadequate oral hygiene. Sufficient management of plaque promotes optimal gingival and periodontal health, averts dental caries, and maintains oral health. Brushing is the most often used and approved method of eliminating plaque, even though there are other methods, such as mechanical and chemical approaches.[1]

The bristle toothbrush originally appeared in China in 1600, while the invention of the toothbrush is believed to have begun around 1000 AD. It was legally protected in America for the first time in 1857. A powered toothbrush was developed in the 1930s as a replacement for manual toothbrushing techniques. For better cleaning, some powered toothbrushes use low-frequency acoustic energy in addition to their current oscillating and rotating actions.[2]

Initially, power-driven toothbrushes were designed for individuals wearing fixed orthodontic appliances or with weak motor abilities. Because power-driven toothbrushes require minimal hand motion and coordination skills, they are also advised for elderly patients, children who are severely retarded and dependent on caregivers, adolescents, and patients with low oral hygiene compliance. Manual toothbrushes can be replaced with powered toothbrushes. Power-driven toothbrushes function by using mechanical contact between the bristles and the teeth to remove plaque.[3] Cleaning is achieved by adding dynamic fluid movements

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with low-frequency acoustic energy generated slightly away from the bristle points. Bacterial deposits are prevented from adhering to oral surfaces by the vibrations. Hydrodynamic shear forces produced by power-driven toothbrushes break up plaque a short distance from the bristle tips, allowing for further interproximal plaque removal.[4]

One component of the complex process of tooth wear is toothbrush abrasion. It has been demonstrated that using a toothbrush poses a considerable risk for the development of erosive lesions, even though it is thought to have little effect on the abrasion of sound enamel and dentin. The abrasivity and concentration of the toothpaste, as well as the type of toothbrush and brushing force, all affect how much abrasion occurs from toothbrushing, particularly on worn enamel and dentin.[5]

Many studies have been carried out to assess the effectiveness of powered and manual toothbrushes in removing plaque, but relatively few have examined the effects of various powered toothbrush types on the surface of teeth. Hence, the current study was carried out to assess the abrasive effect of manual toothbrushes, multidirectional-powered toothbrushes, and sonic-powered toothbrushes on enamel surfaces.

Materials and Methods

Selection of Samples

The present *in vitro* study was conducted in the Department of Periodontics and Oral Implantology, Kalinga Institute of Dental Sciences, Bhubaneswar, India, during the years 2023–2024. Sixty recently extracted mandibular premolar teeth for orthodontic reasons were collected. Any teeth that had hypoplasia, fluorosis, decalcification, cracks, fractures, caries, restorations, abrasions, attritions, or erosions were excluded from the present study.

Sample Preparation

Care was taken during the tooth extraction process to prevent any damage to the coronal morphology. After extraction, the teeth were preserved in artificial saliva until needed, after which they were cleaned under running water and etched with citric acid to remove the smear layer. A total of 60 tooth samples were equally divided randomly into three groups, with 20 samples in each group.

Group I: The samples brushed with manual toothbrush (Soft bristles, Oral B, India).

Group II: The samples brushed with multidirectional-powered toothbrush—Trizone 1000 (Oral B, United States).

Group III: The samples brushed with sonic-powered toothbrush (Sonicare, Philips India Limited).

Using a lathe (Baldor 340 Dental lathe), all surfaces of the extracted teeth were coarsely trimmed so that only the labial surface remained intact. Following gross reduction, the net labial surface area left was approximately 9 mm^2. Subsequently, the samples were mounted on separate acrylic bases using Meliodent Cold. The enamel samples mounted on all acrylic slabs were then subjected to profilometric examination.

Customized Brushing Model

A specially designed brushing apparatus was developed. The tooth surface was intended to receive uniform force and uniform unidirectional motion from the brushing apparatus. The following components comprised the specially designed brushing apparatus: motor to propel the toothbrush back and forth while applying a constant force, handle as the part to which a toothbrush is attached, and base to sustain the entire device.

Brushing Procedure

To ensure there was no lateral movement during brushing, toothbrushes were securely attached and positioned on the brushing apparatus. The apparatus was designed to allow easy replacement of one type of toothbrush with another. Throughout brushing, the enamel slabs remained firmly in place. The tension of the spring was adjusted to 90 ± 10 gm using a Dontrix gauge (GAC International, Inc., Bohemia, New York, United States), as this pressure range reflects typical manual brushing forces applied by individuals. The tension was periodically adjusted during the brushing cycle. Brushing was conducted using a regular fluoridated dentifrice, consistent with oral cavity conditions. The brushing protocol involved applying uniform force in a direction perpendicular to the tooth's long axis. Each sample was brushed twice daily for 2 minutes over a duration of 2 weeks.

Profilometer Analysis

A profilometer (Taylor Hobson) was used to assess the mean surface loss. Each mounted enamel sample had its roughness average (Ra) value determined both before brushing and after 2 weeks of brushing, and the difference between the two values (pre-post) was used to determine changes in surface roughness and abrasion.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) statistical analysis software (IBM, Chicago, Illinois, United States) was used to tabulate and statistically analyze the collected data. Continuous measurements were reported as mean ± standard deviation (SD). The one-way analysis of variance (ANOVA) test was utilized to analyze differences between groups, followed by the Tukey honest significant difference (HSD) *post hoc* test for individual group comparisons. Significance was evaluated at the 5% level, with a confidence interval of 95%.

Results

Table 1 shows the abrasive effect of different toothbrushes. The mean surface roughness was 22.38 ± 1.86 in the manual toothbrush group, 17.14 ± 1.20 in the multidirectional-powered toothbrush group, and 19.04 ± 2.32 in the sonic-powered toothbrush group.

Table 2 depicts the comparative evaluation of the abrasive effect of different toothbrushes on tooth surfaces. The maximum

Table 1: Evaluation of abrasive effect of different toothbrushes

Type of toothbrushes	*Number of samples*	*Mean ± SD*
Group I: Manual toothbrush	20	22.38 ± 1.86
Group II: Multidirectional-powered toothbrush	20	17.14 ± 1.20
Group III: Sonic-powered toothbrush	20	19.04 ± 2.32

Table 2: Comparative evaluation of the abrasive effect of different toothbrushes on tooth surface

Type of toothbrushes	*Mean ± SD*	*F-value*	*p-value*
Group I: Manual toothbrush	22.38 ± 1.86	28.502	0.001
Group II: Multidirectional-powered toothbrush	17.14 ± 1.20		
Group III: Sonic-powered toothbrush	19.04 ± 2.32		

Table 3: Overall evaluation of the abrasive effect of different toothbrushes on tooth surface

Toothbrush groups	*Comparison with different toothbrush groups*	*Mean difference*	*p-value*
Group I	Group II	5.24	0.001
	Group III	3.34	0.001
Group II	Group I	–5.24	0.001
	Group III	–1.9	0.648
Group III	Group I	–3.34	0.001
	Group II	1.9	0.648

surface roughness was observed in the manual toothbrush group (22.38 ± 1.86), followed by the sonic-powered toothbrush group (19.04 ± 2.32), and least in the multidirectional-powered toothbrush group (17.14 ± 1.20). There was a statistically significant difference between the three toothbrush groups.

The overall evaluation of the abrasive effect of different toothbrushes on tooth surfaces is presented in Table 3. A statistically significant difference was found between the manual toothbrush group vs multidirectional-powered toothbrush group and manual toothbrush group vs sonic-powered toothbrush group, with mean differences of 5.24 and 3.34, respectively. There was no statistically significant difference between the multidirectional-powered toothbrush group vs sonic-powered toothbrush group.

Discussion

Tooth cleaning has been practiced since ancient times, even before a connection between plaque and gingival health was recognized. The toothbrush is the primary tool used by the general public to remove plaque, which is an essential component of disease control. Four unique technologies have emerged in the development of toothbrushes: manual, electromechanical, sonic, and ultrasonic brushes.[6]

Manual toothbrushing is relatively tedious and time-consuming for many individuals. Thus, as an alternative to manual toothbrushes, electric or mechanical toothbrushes are available. Powered toothbrushes are beneficial for youngsters and individuals with physical and mental disabilities due to their low hand motion and coordination requirements, potentially enhancing oral health. However, improper toothbrush use has been shown to harm dental hard and soft tissues, with abrasion being the most common injury. Despite this risk, powered toothbrushes offer potential benefits in terms of removing dental plaque biofilm and improving oral health.[1]

"Abrasion" is the term used to describe surface wear on teeth caused by contact with a foreign object. Too vigorous brushing increases the risk of abrasion on the buccal surfaces of teeth. The most common cause of abrasion on the cervical edges of teeth is brushing.[7] Numerous investigations have demonstrated that various factors affect toothbrush abrasion. These variables include the type of brush, specifically filament stiffness, brushing technique, brushing force, duration, and frequency. Several studies have shown that gingival recession and tooth wear may result from regular use of dentifrices during brushing.[8,9] The buccal or labial surfaces of teeth are typically more vulnerable to the damaging effects of vigorous toothbrushing in the oral cavity. Therefore, the labial surface was selected and subjected to the toothbrushing cycle. A profilometer is used to measure surface roughness. Profilometric analysis has been employed in *in vitro* experiments to quantify changes in surface roughness after brushing the specimens.[10]

According to the current study, manual toothbrushes tend to create more surface scratches compared to powered toothbrushes. This can be attributed to the varying pressures exerted by manual strokes during brushing by hand. The increased incidence of scratches or roughness with manual toothbrushes may also be influenced by the use of soft bristles in combination with toothpaste. Similarly, research by Al Shehab et al.[11] and Kumar et al.[12] has demonstrated that using a soft bristle brush with toothpaste is more abrasive than using a hard bristle brush. This could be explained by the fact that the bristles of soft toothbrushes are more flexible and make greater contact with the tooth surface.

The results of this study indicate that the enamel surface roughness of sonic-powered toothbrushes is lower than that of manual toothbrushes. The results are in accordance with Nathoo et al.[13] and Starke et al.[14] stated that brushing with a motorized toothbrush applied less pressure than manual brushing.

The multidirectional-powered toothbrush includes three separate brush zones with a total of over 2,000 bristles. It also produces 40,000 pulsations and 8,800 direction changes per minute for multidirectional movement execution. Sonic technology is defined as any frequency falling between 20 Hz and 20 kHz, corresponding to 31,000 scrubbing strokes per minute, within the range of human audibility. Studies on powered toothbrushes have been done by Biesbrock et al.,[15] Klukowska et al.,[16] and Nathoo et al.[13] to assess their superiority and plaque removal effectiveness in comparison to other toothbrushes. The surface roughness on the tooth surface induced by powered and manual brushing received little consideration.

However, this *in vitro* study had certain limitations. One critical aspect that could influence the methodological similarity of dental abrasion *in vitro* studies to its actual occurrence in the mouth is the simulation of saliva's continuous washing action and its protective effects in remineralizing worn tooth surfaces. Further long-term clinical studies should be conducted to assess the role of saliva and its function in preventing abrasions effectively.

Conclusion

In conclusion, surface roughness was observed in all toothbrushes used in the present investigation. However, compared to the manual and sonic-powered toothbrush groups, the multidirectional-powered toothbrush group exhibited the least amount of surface roughness.

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