**Journal of Biomedical Engineering** MANUSCRIPT
ISSN: 1001-5515 Vol. 40 No. 3 (2023)

# A Profilometric Study To Assess The Role Of Non-Coated And Four Different Types Of Coated Toothbrushes In The Abrasion Process On Enamel Surface -An In-Vitro Study

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**Abstract:**
Background: The aim of this study was to evaluate role of noncoated and four coated toothbrushes in the abrasion process of enamel surface .
Materials and methods: Thirty freshly extracted human premolar teeth were used for this study. Teeth were sectioned horizontally at the level of CEJ to obtain the crown portion. Buccal portion of the teeth were mounted on acrylic bases and polished with pumice to clear off all the debris. The specimen were divided into 5 groups with 6 specimens in each group. Group 1 specimen were brushed with neem coated toothbrush, Group 2 with charcoal coated , Group 3 with antimicrobial coated, Group 4 with Nano mineral coated and Group 5 with non-coated nylon bristle toothbrush as control group. Customised brushing model was used to deliver uniform force. Brushing was carried out for each specimen for a duration of 2 minutes, twice a day, for 60 days, without toothpaste with standardized uniform diameter of 0.2 mm with soft bristles and in uniform movement. Profilometric analysis was carried out to measure the average surface roughness after brushing and the values were compared to assess surface abrasion. Paired t test and ANOVA was performed. Level of significance was set at $p<0.05$ .
Results: The results showed that Nano mineral-coated toothbrushes caused more abrasion than charcoal, neem and antimicrobial-coated toothbrushes The mean surface roughness in group 4 (Nano-mineral coated toothbrush) was $6.3617 \pm 0.3981$ which was found to be the maximum. The difference between all five groups was highly significant [$p < 0.01$].
Conclusion: The study concluded that coated toothbrushes cause significantly more abrasion as compared to non-coated (nylon) toothbrushes.

**Keywords:** Abrasion, profilometric analysis, coated toothbrush, Toothbrush , Toothpaste.

## 1. Introduction

A wide variety of tools can be used for the maintenance of oral hygiene and toothbrush is one of the most commonly used tools among them. An ideal toothbrush removes dental plaque efficiently and further protects the tooth structure from the harmful effects of oral microorganisms. Also it should be able to reach and clean almost all the areas of the mouth effectively1.

However, if the tooth brushing is not done cautiously, it can result in trauma to both soft and hard tissues of the oral cavity. Abrasion is one such traumas associated with faulty tooth brushing which is seen on the cervical margins of teeth2.

Abrasion is defined as the abnormal loss of tooth substance due to mechanical or frictional forces which acts between the tooth and an abrasive medium. It often appears as a "V" shaped notch on the cervical portion of the tooth3.


**DOI**: 10.105515/JBE.40.3.19

Generally, the enamel is quite hard and not easily abraded, but the dentin gets abraded 25 times faster and the cementum which is the softest of all tissues abrades 35 times faster than the enamel. This explains the high prevalence of cervical lesions as age progresses since the cementum gets exposed due to recession. In the younger age group, the most common reason for abrasion is due to improper brushing habits3.

Many factors are involved in toothbrush abrasion. These factors include the technique of brushing, the force applied during brushing, time taken for brushing, frequency of brushing, types of brush, in particular - filament material and stiffness4.

Among the various techniques used for brushing, Modified Bass method is considered safe in comparison to the horizontal scrub method which is the most commonly used brushing technique and leads to a higher prevalence of cervical abrasion. In modified bass method bristles should be placed partly on the teeth and partly on the gingiva at 45-degree angulation, then moving the bristles using vibratory back and forth and rolling motion compared to the horizontal method which involves vigorous back and forth vibratory motions4.

Duration is also an important factor in toothbrush abrasion. It has been proposed that the main reason for poor oral hygiene is the short brushing time. The major effect on plaque reduction is reached only after 45-60 seconds of brushing per quadrant. However if the brushing exceeds 120-180 seconds, chances of abrasion increase5.

Based on the diameter of the bristles, toothbrushes have been classified as soft (0.2 mm), medium (0.3 mm) and hard (0.4 mm). It is widely believed that hard bristles cause more abrasion than soft ones. However, when used with toothpaste, soft brushes caused the most abrasion when compared to hard bristles. Later, several studies concluded that filament stiffness does not influence toothpaste abrasivity6.

Some studies have found that soft brushes cause more abrasion than hard ones. This is explained by the fact that soft bristles have better flexibility; hence, they cover a larger surface area and retain more toothpaste7.

The categorization of toothbrush filament stiffness from soft to hard is based on international standards for brush designs. Today, numerous variations in toothbrush head configuration exists based on filament type and arrangement combinations8.

Filaments are available in different materials like nylon, polyester and of different designs with respect to, length, thickness, compactness, tip geometry and angulation to the head. How these various designs affect the carriage of toothpaste over the tooth surfaces and therefore abrasion of the surface has not been established8.

Nanotechnology has evolved as a promising field with new applications in dentistry9 . Among them, Silver nanoparticles are used for their antimicrobial properties10. Recently these nanoparticles have been incorporated into toothbrushes for their bactericidal property9. Charcoal-coated toothbrushes have also been on the market for some time now. But the abrasive nature of these coated toothbrushes has not been well established. The mechanism is unclear as to how abrasion varies with the use of different types of toothbrushes including coated toothbrushes10.

Abridgement of standardization and disparity in the type and method of toothbrush manufacturing has made it difficult for the shopper to choose the right toothbrush to maintain their oral health10.

Hence this study was contemplated to assess the abrasion of tooth enamel caused by coated toothbrush bristles of various commercially available toothbrushes in the market, to provide some knowledge about the quality of toothbrushes.

## 2. Materials and Methods

Thirty human-extracted premolar teeth with intact enamel surface, absence of developmental defects, cracks, hypoplasia and caries were selected for this study. The extracted teeth were cleaned of superficial debris, calculus and tissue tags. Teeth were sectioned horizontally using the diamond disc at the level of CEJ to obtain the crown portion. The crown portion was vertically sectioned into two halves as buccal and lingual [Figure 1] and the lingual half was discarded. The buccal portion of the crown was mounted on an acrylic base using self-cure acrylic resin [Figure 2]. Teeth were then polished with pumice slurry to get devoid of surface debris.

**Figure 1 : shows the buccal portion of the teeth**


**DOI**: 10.105515/JBE.40.3.19

**Figure 2: shows the mounted specimen**

The mounted acrylic specimens were divided into 5 groups with 6 specimens in each group.

- Group A – Neem-coated toothbrush [Figure 3]
- Group B – Charcoal-coated toothbrush [Figure 4]
- Group C – Antimicrobial toothbrush [Figure 5]
- Group D –Nano mineral coated toothbrush [Figure 6]

Group E- Non-coated nylon bristle toothbrush (control group) [Figure 7]

**Figure 3: shows the neem coated brush**

**Figure 4: shows the charcoal coated brush**



**DOI**: 10.105515/JBE.40.3.19

**Figure 5 : shows the antimicrobial toothbrush**

**Figure 6 : shows the nano mineral coated toothbrush**

**Figure 7 : shows the non-coated nylon bristle Toothbrush**

A customized brushing model was fabricated to deliver a uniform force of about 1.7N [Figure 8]. It was fabricated to produce unidirectional motion with 170 strokes per minute11. All these toothbrushes had a standardized uniform diameter of 0.2 mm with soft bristles. Brushing was carried out for each mounted specimen for duration of 2 minutes, twice a day, for 60 days, without toothpaste12.

The customized brushing model comprised of:

- Motor: To deliver uniform unidirectional force
- Handle: To which the toothbrush was attached
- Base: The mounted tooth specimen was placed on the base

**Figure 8 : Shows The Customized Brushing Apparatus**


**DOI**: 10.105515/JBE.40.3.19

Toothbrush procedure:
The mounted enamel specimens were firmly fixed over the base of the customized brushing apparatus. The above-mentioned predetermined time of the brushing routine was followed with a uniform amount of force in a direction perpendicular to the long axis of the tooth. Only unidirectional movement was allowed as facilitated by the design of the apparatus. No lateral movement was allowed during the brushing cycle. The same procedure was repeated for all coated toothbrushes and the control group. After all the specimens were brushed, profilometric analysis was done to assess average roughness [Ra] values post-brushing.

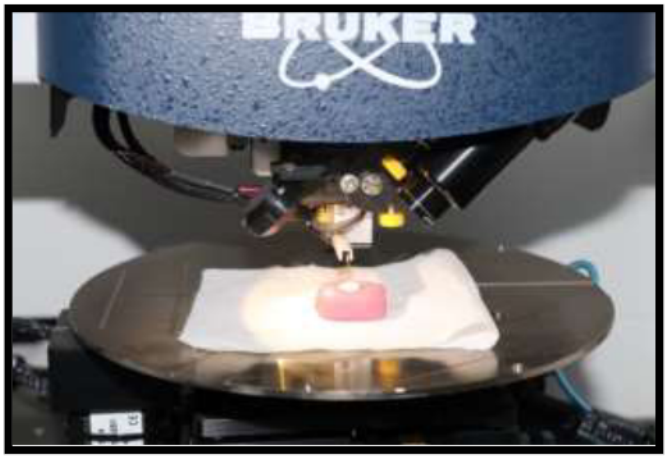
Profilometer [Figure 9] digitizes surfaces for mould texturing and provides accurate information while profiling. The device is connected to a desktop with software while conducting the scan. The device collects the sample data at a rate of micrometer per sample.

**Figure 9: Shows The Stylus Profilometer**


The surface profile of the sample was scanned using a diamond stylus with a tip radius of 2 μm in a direction opposite to the brushing direction. The force of the tip was 3 mg and the scan/profile duration was 20 seconds for a line scan of 200 microns, for 7mm.The probe of the diamond stylus was placed in an apically positioned reference mark on the mounted enamel specimen and run to an incisal positioned mark, along the long axis of the tooth. Three profiles were collected for each sample. [Figure 10]

**Figure 10: Shows The Profilometric Analysis**


**DOI**: 10.105515/JBE.40.3.19




The roughness profile's absolute values are deviated from the mean line or centre line by an amount called Ra, which is defined as the arithmetic average deviation.

The differences in profilometric readings were computed and mean values were calculated and compared. This difference in surface roughness between groups was used as a measure to assess which toothbrush causes more abrasion.

Statistical analysis

All data were entered into a Microsoft Office Excel (version 2019) spreadsheet which was prepared and validated for the data form. The data entered was checked for errors and discrepancies. Data analysis was done using Windows-based 'Med Calc Statistical Software'. Data for the surface roughness was expressed as mean, median with standard deviation (SD) and standard error of the mean (SEM) and was depicted. Inter-group comparison (2 groups) was done using a t-test. Intra group comparison (>2 groups) was done using one-way ANOVA followed by pair-wise comparison using a post hoc test. All analysis was done using one-sided ANOVA tests at alpha 5% and beta at 20%. The data was interpreted at the confidence interval of 95% and the levels of significance were as follows.

- ($p>0.05$) - Not significant
- ($p<0.05$)- Significant
- ($p<0.01$) – Highly significant

Results

This study aimed to compare the abrasiveness and surface roughness caused by five different types of toothbrushes on thirty extracted teeth. Table1, 2 and 3 gives the surface roughness (Ra) values of each sample at three vertical profiles. Table 4 shows the average roughness values of each sample in all 5 groups.

**Table 1: Surface Roughness Values (Profile 1)**

| Sample number | Group 1 Neem | Group 2 Charcoal | Group 3 Anti Microbial | Group 4 Nano mineral | Group 5 Nylon |
|---|---|---|---|---|---|
| 1 | 3.67 | 5.32 | 4.38 | 6.42 | 2.13 |
| 2 | 3.14 | 5.09 | 4.79 | 6.37 | 2.34 |
| 3 | 3.17 | 5.28 | 4.38 | 6.05 | 2.14 |
| 4 | 2.96 | 5.34 | 4.45 | 7.04 | 3.43 |
| 5 | 3.23 | 5.27 | 3.93 | 6.04 | 2.08 |
| 6 | 3.28 | 5.05 | 4.14 | 5.82 | 2.01 |


DOI: 10.105515/JBE.40.3.19

**Table 2: Surface Roughness Values (Profile 2)**

| Sample number | Group 1 Neem | Group 2 Charcoal | Group 3 Anti Microbial | Group 4 Nano mineral | Group 5 Nylon |
|---|---|---|---|---|---|
| 1 | 3.22 | 5.17 | 4.24 | 6.25 | 2.53 |
| 2 | 3.04 | 5.22 | 3.92 | 6.58 | 2.03 |
| 3 | 2.92 | 5.87 | 4.85 | 7.11 | 2.04 |
| 4 | 3.24 | 5.36 | 4.98 | 6.88 | 2.56 |
| 5 | 3.99 | 6.08 | 5.63 | 5.63 | 2.72 |
| 6 | 3.45 | 5.68 | 5.61 | 5.21 | 2.23 |

**Table 3: surface roughness values (profile 3)**

| Sample number | Group 1 Neem | Group 2 Charcoal | Group 3 Anti Microbial | Group 4 Nano mineral | Group 5 Nylon |
|---|---|---|---|---|---|
| 1 | 3.97 | 5.42 | 4.09 | 6.09 | 2.59 |
| 2 | 3.36 | 6.42 | 4.93 | 6.53 | 2.18 |
| 3 | 3.21 | 5.74 | 4.21 | 6.94 | 2.36 |
| 4 | 3.43 | 5.32 | 4.23 | 6.71 | 2.88 |
| 5 | 3.67 | 6.03 | 4.46 | 6.13 | 3.26 |
| 6 | 3.67 | 6.48 | 4.36 | 6.71 | 2.86 |

**Table 4: average surface roughness values**

| Sample number | Group 1 Neem | Group 2 Charcoal | Group 3 Anti Microbial | Group 4 Nanomineral | Group 5 Nylon |
|---|---|---|---|---|---|
| 1 | 3.62 | 5.30 | 4.24 | 6.25 | 2.42 |
| 2 | 3.18 | 5.58 | 4.55 | 6.49 | 2.18 |
| 3 | 3.10 | 5.63 | 4.48 | 6.70 | 2.18 |
| 4 | 3.21 | 5.34 | 4.55 | 6.88 | 2.96 |
| 5 | 3.63 | 5.79 | 4.67 | 5.93 | 2.69 |
| 6 | 3.47 | 5.74 | 4.70 | 5.91 | 2.37 |

Table 5 and Graph 1 indicate an intergroup comparison of the average surface roughness (Ra) values of all five groups. The mean surface roughness in group 4 (nano-mineral coated toothbrush) was 6.3617 ± 0.3981 which


**DOI**: 10.105515/JBE.40.3.19

was found to be the maximum. For Group 1 (neem-coated toothbrush) the mean surface roughness was 3.3678 ± 0.23410, Group 2 (charcoal-coated toothbrush) exhibited a mean roughness of 5.5633 ± 0.20251, Group 3 (antimicrobial coated toothbrush) exhibited mean roughness of 4.5322 ± 0.16729 and Group 5 (nylon bristle toothbrush) exhibited a mean roughness value of 2.4650 ± 0.30445. The difference between all five groups was highly significant [$p < 0.01$].

**Table 5: intergroup comparison of average surface roughness values**

| Group | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum | F value | p-value of one-way ANOVA |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | | | |
| 1 | 6 | 3.3678 | .23410 | .09557 | 3.1221 | 3.6135 | 3.10 | 3.63 | | |
| 2 | 6 | 5.5633 | .20251 | .08267 | 5.3508 | 5.7759 | 5.30 | 5.79 | | |
| 3 | 6 | 4.5322 | .16729 | .06829 | 4.3567 | 4.7078 | 4.24 | 4.70 | 200.166 | .000** |
| 4 | 6 | 6.3617 | .39831 | .16261 | 5.9437 | 6.7797 | 5.91 | 6.88 | | |
| 5 | 6 | 2.4650 | .30445 | .12429 | 2.1455 | 2.7845 | 2.18 | 2.96 | | |
| Total | 30 | 4.4580 | 1.46154 | .26684 | 3.9123 | 5.0037 | 2.18 | 6.88 | | |

**Graph 1: inter-group comparison of average surface roughness values**

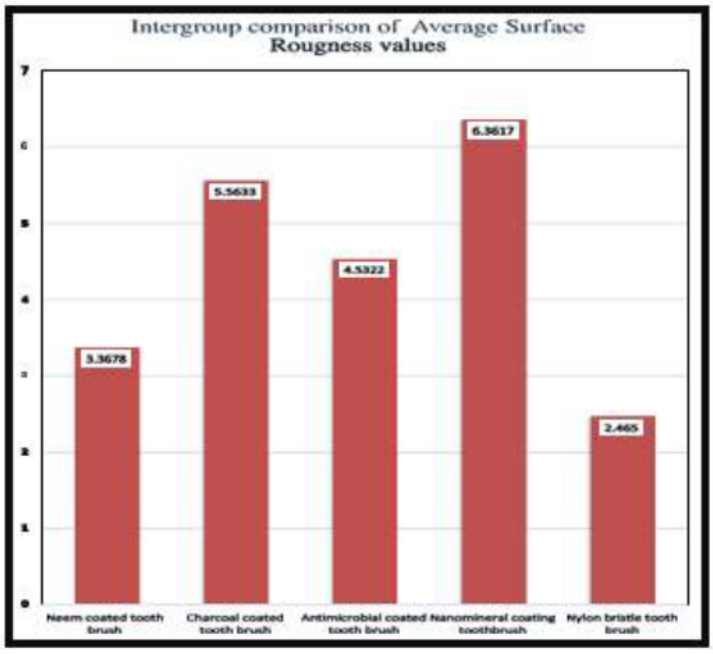



Table 6 indicates a pair-wise comparison using a Post hoc analysis this analysis revealed that there was a statistically highly significant difference seen for the values between all the pairs of groups ($p<0.01$).

**Table 6: Post Hoc Tukey Test To Analyze The Difference Within The Group**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| Group | Materials | Mean Difference | P Value |
|---|---|---|---|
| Neem | Charcoal | -1.983 | <0.01 |
| | Anti-microbial | -1.103 | <0.01 |
| | Nano mineral | -3.048 | <0.01 |
| | Control | 0.886 | <0.01 |
| Charcoal | Anti-microbial | 0.880 | <0.01 |
| | Nano mineral | -1.065 | <0.01 |
| | Control | 2.870 | <0.01 |
| Antimicrobial | Nano mineral | -1.945 | <0.01 |
| | Control | 1.990 | <0.01 |
| Nano mineral | Control | 3.935 | <0.01 |

## 3. Discussion

Toothbrush has become an inevitable part of our daily routine across many cultures around the world since 21st century. The practice of tooth cleaning continues since 1600 B.C. when the ancient Babylonians and Egyptians used tooth sticks for cleaning teeth. Over years several tools have been used for the maintenance of good oral hygiene, with toothbrushes being the most common tool among them13.

The word ‘‘toothbrush” was first coined by Dr Antony Wood. The first mass production of toothbrushes was done in England in 1780 by William Addis. Since then, toothbrushes have undergone several modifications in their design. In 1938 Nylon bristles were introduced in toothbrushes which were manufactured by DuPont. Earlier, animal hair and other organic materials were being used to create bristles. The alterations in bristle material were done to reduce the number of bacteria on the bristle of the brush14.
The American Dental Association (ADA) has described the range of dimensions of acceptable brushes; the brushing surface should be 1 to 1.25 inches (25.4 to 31.8 mm) long and 5/16 to 3/8 inch (7.9 to 9.5 mm) wide with two to four rows of bristles, and 5 to 12 tufts per row, 80-85 bristles per tuft15.

Because there are so many different designs available on the market, customers are often unsure of which toothbrush to choose, and resulting in improper tooth brushing which can wear away the enamel2. The role of different types of toothbrushes in causing abrasion is not clear, so this study was done to assess the role of different types of toothbrushes in causing abrasion.

This study involved the use of enamel specimens of the buccal surface of the premolar teeth mounted on an acrylic block, as the buccal surface of premolars, is more prone to abrasion.31 The brushing regimen was performed using an automated customized brushing device. The device helped to deliver uniform force and direction16.

Uniform force and direction gave results that can be assumed to be accurate in revealing the role of different types of toothbrushes in the abrasion process. Various studies have recommended the use of customized brushing apparatus to assess the role of toothbrushes in the abrasion process of enamel17.


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Abrasion of enamel was assessed in this study, as enamel is the first layer of the tooth exposed to brushing and needs to be protected to prevent abrasion of much softer dentin below the enamel17.
Several studies have used a Profilometer to calculate the surface roughness of the enamel18,12. From the surface topography, critical measurements like step, curvature, and flatness are calculated. In the present study, a stylus Profilometer was used for measuring the roughness values. The profilometric readings were recorded by placing the profilometric stylus at three vertical profiles of each mounted enamel specimen after tooth brushing. 4

In this study, four novel coated toothbrushes were used – neem-coated, charcoal- coated, antimicrobial-coated and nano-mineral coated toothbrushes, all with soft bristle designs. Coated toothbrushes were introduced in the market due to their antimicrobial properties19. Oral bacteria such as Streptococcus mutants and other opportunistic microorganisms, coupled with variations in toothbrush design, can create an environment where bacteria can proliferate and spread to humans20.

The spread of Streptococcus mutants, as well as other pathogenic oral bacteria such as Lactobacilli, Streptococcus mitis and other periodontal pathogens creates a potential for health risk, especially in those individuals whose health is already compromised. On comparison of toothbrush rinsing habits and residual bacteria on filaments, it was found that although rinsing and drying times affected bacterial quantity, most individuals did not rinse long enough to sufficiently remove bacteria from toothbrushes20.

Researchers have also proposed links between sore throats, flu and contaminated toothbrushes. Toothbrushes have the potential to serve as a reservoir for oral microbial flora, including pathogenic organisms, which creates a nidus for the spread of disease. Variations in toothbrush design, care, and storage, can create a potential for cross - contamination with uncovered toothbrushes. On the other hand, covering a toothbrush during storage has been found to prolong drying time thus extending the proliferation of organisms20.

Considering the evidence that suggests that oral bacteria may play a role in heart attacks, diabetes and premature births, it is prudent to consider ways to reduce or prevent organisms from establishing and proliferating on toothbrushes20. Hence various measures have been taken to prevent toothbrush contamination among which coating the toothbrushes bristles and covering the toothbrush with a protective cover are a few.

Neem has been shown to have anti-inflammatory, antipyretic, antimicrobial, antitumorigenic, antioxidant, and anti-ulcer properties. Neem is an omnipotent tree which helps in the prevention and treatment of various health ailments. Extensive research on therapeutic benefits of neem in oral and dental problems had been conducted and proven its efficacy as an excellent agent. From then, neem extracts are being incorporated into dental care products for maintaining oral hygiene and most important neem-coated toothbrushes have been introduced considering the same21.

Charcoal toothbrushes have recently been introduced to the market, which have black colour bristles with charcoal being blended into the nylon fibres, thus, possessing antimicrobial qualities which reduces the bacterial contamination of the bristles and reduces halitosis. The toothbrushes are intended to whiten teeth, freshen breath, reduce the growth of bacteria, remove bacteria by increasing the mouth pH level, and effectively clean the oral cavity22.

Charcoal has a natural porous formation. When used in the mouth, it helps in the absorption of debris and other toxic agents thereby cleaning the teeth and gums. Plaque, tannins, and the bacteria responsible for bad breath are all removed by the same carbon-absorbing properties. It does not mask or overpower the natural odour produced in the mouth but removes the bacteria that creates the odour in the first place for a more pleasant post-brushing feeling in the mouth. When compared to a traditional toothbrush, charcoal additionally absorbs and binds bacteria together at a microscopic level to decrease and remove them from the mouth22.

With the increasing demand for advances in treatment modalities, nanoparticle-coated toothbrushes were introduced. Each micro-fibre bristle of this brush can cover more area of the teeth as compared to traditional brush, and penetrate even the most intricate areas. Additionally, they possess antimicrobial and anti-inflammatory properties. Nano mineral-coated toothbrushes have been found to decrease plaque and gingivitis-associated bacteria23.

Nanosilver is the most used nanoparticle in consumer products. When used reasonably, silver does not negatively affect the human body. It also has antimicrobial properties and its use has been advocated in various


**DOI**: 10.105515/JBE.40.3.19

forms for the restoration of teeth. But the greatest risk associated with chronic exposure to colloidal silver is argyria. However, the intake of small supplements aids in wound healing, improves skin disorders, prevents or treats certain infectious diseases and even cancer24.

Nanoparticles have been incorporated into toothbrushes in an effort to take advantage of their antibacterial capabilities, which benefit both the oral cavity and the bristle's ability to self-clean. But the disadvantage is that Ag nanoparticles can be released from commercially available toothbrushes and can lead to potential consumer oral exposure and environmental exposure24.

The antimicrobial agents incorporated into the filaments of toothbrush provides antibacterial activity when released into the oral environment. As a result, using an antimicrobial toothbrush, may have an impact on pathogenic oral microorganisms. Therefore, the concept of incorporating antimicrobial agents into the bristles may reduce the number of bacteria present in the oral environment25. Since limited data is available on the abrasion-causing potential of these newly introduced toothbrushes, this study was undertaken to throw some light on the abrasion- causing property of these coated toothbrushes.

The force and duration of brushing also play an important role in the abrasion process with the average force of manual brushing ranging between 1.5 to 3N. Weigand et al found that as long as the brushing force was kept below 4.5N, there was only a very minimal chance for abrasion11.

In the present study, the brushing force was kept constant at 1.7 N by the use of automated brushing apparatus, similar to the average ideal force used during manual tooth brushing. The brushing regimen was carried out for a period of 2 mins twice daily as recommended by Mayurika et al for a period of 60 days12.

The average strokes used during manual brushing range from 150 to 300 back-and- forth motions per minute. In the present study, the brushing strokes were made constant at 170 strokes per minute for brushing the specimens12.

Post-brushing surface roughness of the specimens were measured using the profilometer and mean difference in the surface roughness between each group was calculated. In this study it was found that the nano mineral-coated toothbrushes caused more abrasion than charcoal, neem and antimicrobial-coated toothbrushes. This study also revealed that coated toothbrushes whether charcoal, neem or antimicrobial cause significantly more abrasion as compared to non-coated (nylon) toothbrushes.

The study also highlighted that the abrasion caused by the brushes used in this study from maximum to least was nano- mineral (highest) followed by charcoal-coated, antimicrobial-coated, neem-coated and nylon (least). Hence caution needs to be exercised while prescribing coated toothbrushes to patients.

Being an in-vitro study this study has certain limitations. Some of the limitations are: Oral environment (saliva) was not stimulated, since all five toothbrushes selected were commercially available toothbrushes it was not possible to standardize the bristle design, the abrasive nature of toothpaste was not considered in this study and the study was performed only for a short duration so the long-term role of a toothbrush abrasion could not be documented.

## 4. Conclusion

The difference in surface roughness was used as a measure to assess and compare abrasion caused by different types of toothbrushes. The present study revealed that nano – mineral coated toothbrushes caused most abrasion when compared to neem coated, anti microbial coated, charcoal coated and nylon toothbrushes. Any form of bristle coating produced significantly more abrasion than non- coated nylon toothbrush. Hence caution should be exercised while prescribing these coated toothbrushes to patients. However, further long-term longitudinal and clinical studies are needed to clarify the relationship between bristle-coated toothbrushes and hard tissue abrasion.

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**DOI**: 10.105515/JBE.40.3.19