

Cutting Efficiency of Welded Diamond and Vacuum Diffusion Technology Burs and Conventional Electroplated Burs on the Surface Changes of the Teeth – An *In vitro* Study

Abstract

Context: Welded diamond and vacuum diffusion technology (WDVDT) burs in comparison to electroplated burs claim to approach the solution of dental hard tissues by increased cutting efficiency, decreasing the overheating of oral tissues and thus reducing the microcracks on the prepared tooth surface. **Aims:** This study aimed to evaluate the cutting efficiency of two different rotary diamond burs used for tooth preparation with their repeated usage on the surface changes of the prepared tooth. **Settings and Design:** This *in vitro* comparative study evaluated the cutting efficiency and surface changes of the teeth prepared with conventional electroplated burs and WDVDT burs. **Subjects and Methods:** Thirty freshly extracted, healthy, noncarious human premolars were divided into Group A and Group B with 15 each, and were further subdivided into three subgroups depending on the different usage intervals as first, fifth, and tenth (A1–A3 and B1–B3). The surface of each prepared specimen was evaluated quantitatively using a surface profilometer, and qualitative analysis was done using a scanning electron microscope. **Statistical Analysis Used:** Two-way ANOVA and Turkey's multiple *post hoc* tests were used. **Results:** The mean surface roughness of Groups A1, A2, and A3 was 1.50 ± 0.40 , 2.39 ± 0.39 , and 2.65 ± 0.65 Ra, respectively. The mean surface roughness of Groups B1, B2, and B3 was 0.76 ± 0.23 , 0.92 ± 0.10 , and 1.24 ± 0.07 Ra, respectively. The mean surface roughness of the prepared tooth surface was significantly higher in Group A and its subgroups when compared to that of Group B and its subgroups. **Conclusions:** The study results showed that surface roughness was considerably lesser and also had less wear and increased cutting efficiency of tooth preparations using burs made with WDVDT compared to the preparations using conventional electroplated burs.

Keywords: Electroplated burs, surface roughness, tooth wear, welded diamond and vacuum diffusion burs

Introduction

The ideal treatment modalities to replace missing teeth should fulfill both conservation and enhanced clinical efficiency.^[1] The removal of tooth structure and restorative materials in the process of rehabilitation should have minimal detrimental effect on the integrity of the prepared tooth.^[2] The clinical efficiency is increased with the recent rotary cutting tools, but the excessive heat generated during the tooth preparation procedure might damage the remaining tooth structure and interfere with the vitality of the pulp.^[3,4]

The rotary technology has come a long way from the first handpiece made of sharpened stones to the bow drills, clockwork drills,

pneumatic drills, belt-driven drills, and finally to today's electric handpieces equipped with an internal cooling system and air turbine power. The technological advancements in dental handpieces demanded a gradual evolution of drill bits or dental burs over the years.^[5]

The aim of an ideal dental restoration is to have a successful restoration with a prolonged prognosis, which includes the restoration and prepared tooth. This prognosis depends on many variables which include geometry of the preparation, fit of the restoration, type of the luting agent used, and periodontal condition of the abutment teeth.^[6-9] Many investigators have stated that three major factors affect wetting, namely, surface free energy,

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surface topography of the adherent, and the viscosity of the liquid, of which the influence of surface topography was the least understood.^[9,10] Evidence suggests that enhancing the surface area and wetting improves the bonding considerably.^[10] However, the surface finish can be a critical variable in the success of any restoration, but ideal roughness is required to enhance the wettability between luting agent and the prepared tooth surface. The excessive roughness is avoided in the tooth preparation to minimize the air entrapment between luting cement and dentin, which affects the longevity of the restoration.^[11]

During clinical tooth preparation for direct and indirect restorations, inlays, onlays, veneers, and crowns, a portion of enamel and dentin is removed by machining. Such preparations require safe, efficient, and rapid cutting, and the preferred rotary instruments are diamond burs.^[1]

Tooth preparation with diamond burs is often associated with indenting and scratching of enamel and dentin with sharp diamond particles. Such procedures may produce surface and subsurface damage by making cuts in the enamel and dentin, a result of fracture due to tensile stresses generated perpendicular to the surface being formed. The machining-induced damage in these materials was found to be influenced by diamond particle size and removal rate. Therefore, tooth preparation by means of dental burs containing sharp diamonds is expected to produce damage in the enamel.^[12]

It is well recognized that the grinding efficiency of conventional diamond burs deteriorates with repeated usage.^[13] These burs reveal major shortcomings such as the potential smearing of Ni₂⁺ ions from the metallic binder onto the dental substrate.^[14]

A new technology of rotary diamond burs, based on welded diamond and vacuum diffusion technology (WDVDT), is now available. According to the manufactures, this technology claims to offer a wide range of advantages over conventional electroplated technology burs, like high concentration of diamond grain of about 80%, heterogeneity in grain size, high speed of processing, high wear resistance, minimal cracks and microfractures on the tooth surface, and a claimed reduction in productivity costs in the clinical usage with sustained improvement in the efficacy with their subsequent usage.^[15] The present study intended to evaluate the cutting efficiency of WDVDT burs with conventional electroplated diamond burs and their effect on the surface roughness and surface topography of dentin during tooth preparation. We hypothesized that the type of the rotary diamond burs and their cutting efficiency with their subsequent usage will have an effect on the surface changes of prepared tooth.

Subjects and Methods

This *in vitro* study compared the cutting efficiency and surface changes of the teeth prepared with conventional

electroplated burs and WDVDT burs. The inclusion criteria were freshly extracted premolar teeth, and teeth with carious lesion, restorations, wasting diseases, or any other surface anomaly were excluded.

Specimen preparation

Thirty freshly extracted, healthy, noncarious human premolars were used in this study. All teeth were without any carious lesions and free from any surface enamel flaws. The selected teeth were cleaned, rinsed, disinfected, and subsequently placed in 10% formalin in a closed container and stored in artificial saliva. All the teeth were mounted on a cylindrical acrylic fixture of dimensions 3 cm in height and 1.5 cm in diameter. The samples were divided into two groups of 15 specimens each prepared using conventional electroplated burs (Group A) and WDVDT burs (Group B) [Figure 1]. Each group was further subdivided into three categories with five specimens each; subgroups A1, A2, and A3 were prepared using conventional electroplated burs at first, fifth, and tenth usage, respectively. Similarly, subgroups B1, B2, and B3 were prepared using WDVDT burs at the first, fifth, and tenth usage, respectively.

For all the teeth, a standardized tooth preparation was carried out to receive complete cast crowns, by using a modified milling unit. The teeth were prepared first by flattening the occlusal surface to the depth of the central groove to expose the dentin. The axial reduction was standardized by using a modified milling unit. All the tooth preparations initially were of rough cut with a torpedo diamond bur and subsequently finished. The length of the tooth preparation was controlled by the working height setting of the milling unit.

The specimens in each group and subgroups were prepared using conventional electroplated burs and WDVDT burs the rotary diamond burs used for the first, fifth and tenth usage in both the groups were documented for the study. After every subsequent use of rotary diamond burs for all the specimens, that is, first, fifth, and tenth usage,

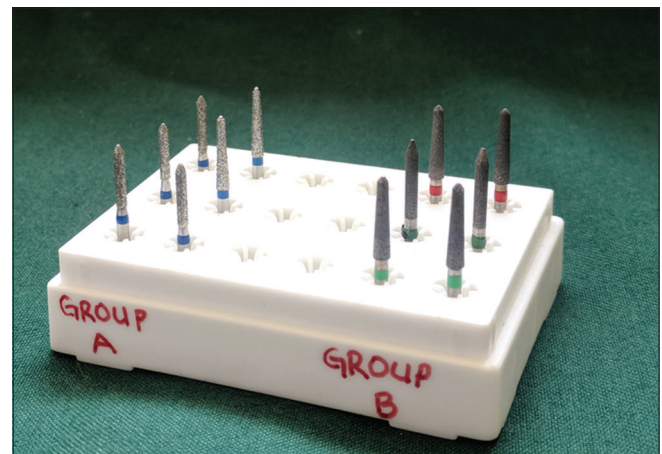


Figure 1: Group A: Conventional electroplated burs and Group B: Welded diamond and vacuum diffusion technology burs

the specimens from each subgroup were subjected for evaluation of their surface profile of the prepared tooth surface and the rotary diamond burs.

The surface of each specimen, that is, the prepared tooth surface, was evaluated quantitatively using a surface profilometer, and qualitative analysis was done using a scanning electron microscope (SEM).

All the specimens in each group and subgroup were cleaned with a steam cleaner under 0.3 Mpa pressure and were then placed in an ultrasonic cleaner for 180 s to remove any tooth debris and impurities present on the prepared tooth surface.

Surface profile analysis

For all the specimens in each subgroup, the quantitative surface roughness for the prepared tooth surface was measured using the surface profilometer [Figure 2]. Each traverse of the profilometer stylus was made to contact from the occlusal surface toward the prepared margin and was recorded parallel to the long axis of the prepared tooth. The precision of the surface analyzer was calibrated according to the American National Standard Institute for the surface roughness that will not exceed 1%. A total of five measurements were recorded for each specimen. The Ra values were recorded and tabulated for all the specimens which were prepared using different rotary diamond burs with their subsequent usage that is, the first, fifth, and tenth usage.

For the qualitative surface roughness evaluation the used rotary diamond burs according to their subsequent usage and the prepared tooth surface were subjected to scanning electron microscopic examination, the specimens were subjected to scanning electron microscopic examination. The prepared tooth in each subgroup was mounted on a clear acrylic resin block and sectioned horizontally along the long axis of the prepared surface using a hard tissue microtome to obtain the section of the prepared surface for SEM analysis [Figure 3].



Figure 2: Profilometer (quantitative surface roughness evaluation of the prepared tooth)

The resultant prepared tooth specimen in each group, subgroup, and the rotary diamond burs with their subsequent usage intervals were subjected to SEM evaluation to assess the surface profile of each specimen qualitatively [Figure 4]. The resultant findings were useful to describe the overall surface changes of the prepared tooth surface and the surface profile of each rotary diamond bur with their repeated use at each specific interval. The topographic observations of SEM of the prepared tooth surface and the rotary burs used were compared with each other as a complementary measure to the quantitative results obtained with profilometric analysis [Figures 5 and 6]. The resultant data were tabulated. The study findings were subjected to statistical analysis to draw the conclusions from the experimental data.

Results

The study evaluated the effects of different rotary diamond burs used with their subsequent usage at different intervals on the effect of surface changes of prepared tooth surface. There were two different rotary diamond burs used in the study, namely, Group A – electroplated burs and Group B – welded WDVDT burs. These groups were further subdivided into Groups A1–A3 and Groups B1–B3 depending on their subsequent usage at three different intervals.

Table 1 and Graph 1 show surface roughness in two main groups, that is, Group A and B, and their subgroups. It was found that the mean surface roughness of the prepared tooth surface was significantly higher in Group A and its subgroups when compared to that of Group B and its subgroups.

Table 2 shows the interaction between group and the usage, which was assessed by two-way repeated-measures ANOVA. Because there was no statistically significant interaction ($P = 0.0627$), the main effects (difference between the two study Groups A and B) can be interpreted as direct effects of the study group.

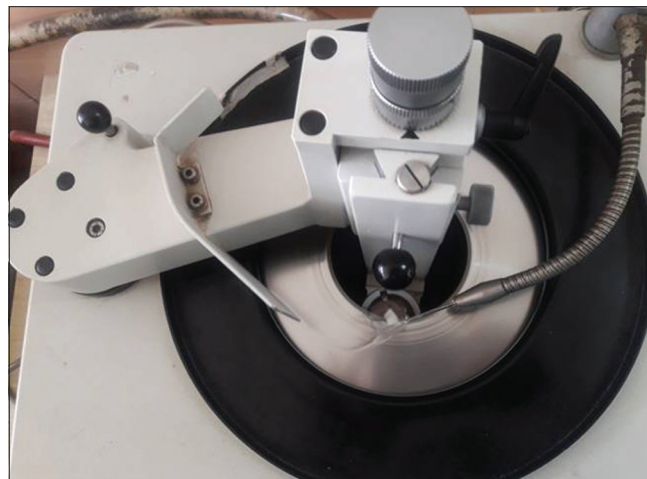


Figure 3: Hard-tissue microtome



Figure 4: Scanning electron microscope (qualitative surface evaluation of the prepared tooth and the rotary diamond burs)

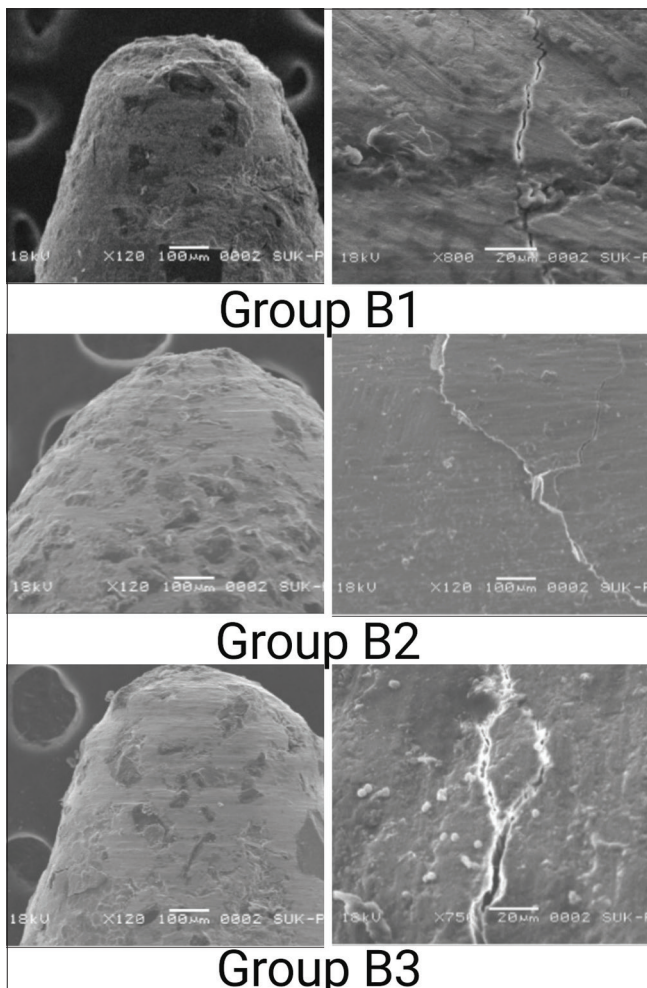


Figure 6: Scanning electron microscope images for welded diamond and vacuum diffusion technology (Group B) burs and prepared tooth surface after their first usage, fifth usage, and tenth usage

Table 3 shows pair-wise comparison of surface roughness values of Group A and Group B with respect to their subgroups using Turkey's multiple *post hoc* procedures. The mean difference in the surface roughness between Group A

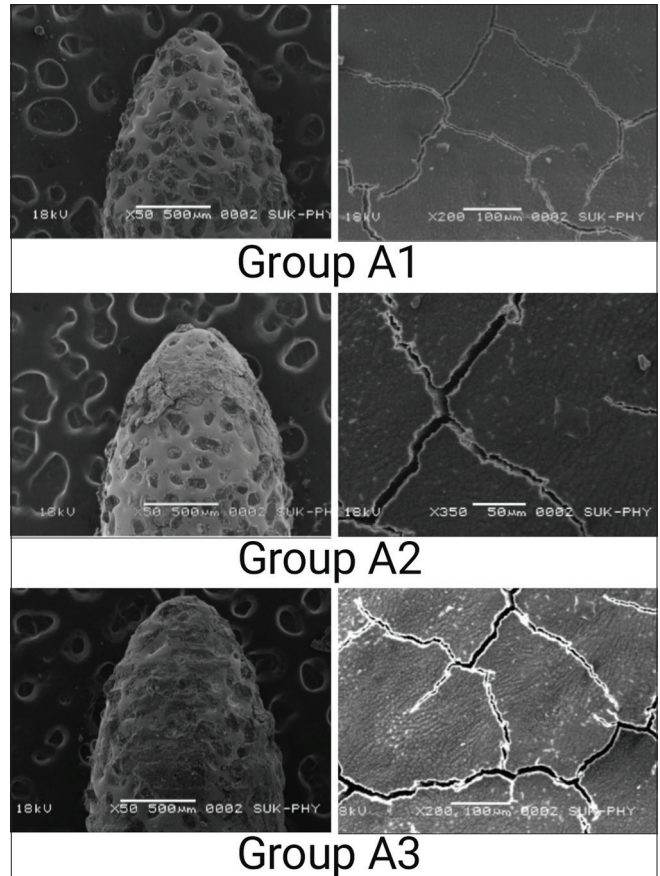
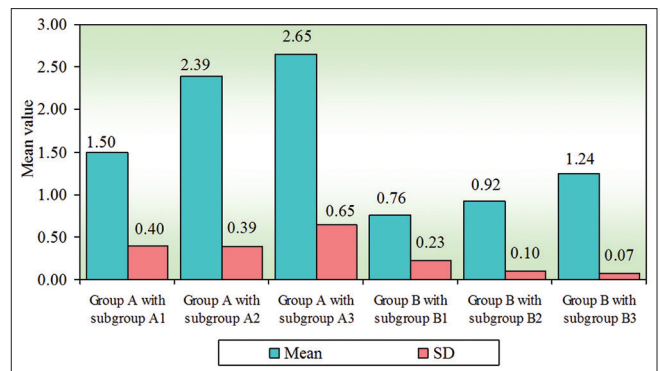


Figure 5: Scanning electron microscope images for conventional electroplated (Group A) burs and prepared tooth surface after their first usage, fifth usage, and tenth usage



Graph 1: Comparison of two main groups (Group A and Group B) and three subgroups with mean surface roughness

and Group B at the first usage (A1 vs. B1) was statistically significant ($P = 0.0433$). The mean difference in the surface roughness between Group A and Group B at the fifth usage (A2 vs. B2) was statistically significant ($P = 0.0002$). The mean difference in the surface roughness between Group A and Group B at the tenth usage (A3 vs. B3) was statistically significant ($P = 0.0002$).

The results of the present study indicated that there was a significant difference on the rotary diamond burs in Group

Table 1: Mean, standard deviation, and coefficient of variance of difference in average surface roughness R_a values (μm) of groups and subgroups of A and B

Groups with sub groups	n	Mean	SD	SE	CV
Group A with subgroup A1	5	1.50	0.40	0.18	26.69
Group A with subgroup A2	5	2.39	0.39	0.18	16.41
Group A with subgroup A3	5	2.65	0.65	0.29	24.63
Group B with subgroup B1	5	0.76	0.23	0.10	30.03
Group B with subgroup B2	5	0.92	0.10	0.04	10.74
Group B with subgroup B3	5	1.24	0.07	0.03	5.58

SE: Standard error; SD: Standard deviation; CV: Coefficient of variation

Table 2: Comparison of two main groups (A and B) and three subgroups with mean surface roughness by two-way ANOVA

Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F	P
Main effects					
Main groups	1	10.89	10.89	80.8710	0.0001*
Sub groups	2	3.44	1.72	12.7537	0.0002*
Two-way interaction effects					
Main groups × sub groups	2	0.84	0.42	3.1151	0.0627
Error	24	3.23	0.13		
Total	29	18.40			

* $P < 0.05$

A and Group B with respect to their subsequent usage studied at different intervals.

Discussion

Tooth preparation, a fundamental aspect of restorative dentistry, necessitates a safe, efficient, and speedy cutting of the tooth structure using handpiece along with dental burs and a coolant delivery system.^[16,17] The technological innovations in dental handpieces demanded a gradual evolution of drill bits or dental burs over the years.

Conventional diamond burs, using both natural and synthetic diamonds, are manufactured in multiple layers by electrodeposition, sintering, or microbrazing and provide continuous regeneration of the cutting surface as wear occurs. Studies have shown that the cutting efficiency of conventional diamond burs depends on both the diamond bur grit size and duration of the cutting procedure.^[18] Over short cutting periods, medium, coarse, and supercoarse have similar cutting rates, except on prolonged use, the latter's efficiency decreases.^[17,19]

These literatures provide few guidelines for bur selection and they suggest the recommendations for bur selection for different clinical procedures.^[20-23]

The present study evaluated the cutting efficiency of two different technology rotary diamond burs, Group A – conventional electroplated diamond burs and Group B – WDVDT burs used in fixed prosthodontics with their subsequent usage.

In this study, the R_a (surface roughness) values obtained by profilometer for both the groups were comparable with that of their SEM images. The topographic observations of the tooth surface were compared with each other as a complement to the quantitative results obtained with surface roughness assessment. Comparatively, the SEM images revealed that the specimens treated with WDVDT burs did develop cracks as those created by the conventional electroplated burs. The size of the cracks, however, increased sequentially after each (first, fifth, and tenth) use, more evidently seen in the teeth prepared by the conventional electroplated burs. These findings are contrary to the study by Prithviraj *et al.*,^[24] which evaluated the cutting efficiency and longevity of diamond burs made either with electroplated or proprietary brazing system (PBS), suggested that the cutting efficiency was limited in the former group. Ayad *et al.*^[25] compared the surface roughness of tooth preparation using tungsten carbide burs and conventional diamond burs and evaluated the outcomes using profilometer and SEM and found that the bur wear after repeated use was comparable in both the groups. Emir *et al.*^[26] conventional rotary diamond burs wear after their multiple uses and should be changed after maximum of 5 teeth preparations.

Evaluation of SEM images after cutting cycles for both Group A and B rotary diamond burs revealed two major findings. First, higher crater formations and appreciable wear of the nickel matrix of Group A (conventional electroplated burs) diamond burs. Crater formation occurs in those areas where diamond particles have been pulled out during the cutting cycle. Second, SEM also revealed that the Group A (conventional electroplated burs) coarse rotary diamond burs displayed a qualitatively greater embedding of the diamond particles, resulting in less exposed cutting surfaces than Group B (WDVDT burs) rotary diamond burs. It may be speculated that the resultant decreased availability of exposed diamond particles is the primary reason behind the lower cutting efficiency exhibited by Group A rotary diamond burs.

These findings suggest that the surface roughness indeed increased gradually in both the groups, however, its magnitude was lesser by >50% in the WDVDT group, which could translate to better cutting efficiency and last for longer periods. Pilcher *et al.*^[27] and Majd *et al.*^[28] noted that cutting rates for all diamond burs decreased with continued use and that wear and loss of diamond particles and binder material caused the decrease in

Table 3: Pair-wise comparison of two main groups (A and B) and three subgroups with mean surface roughness by Tukey's multiple *post hoc* procedures

Groups with sub groups	Group A with subgroup A1	Group A with subgroup A2	Group A with subgroup A3	Group B with subgroup B1	Group B with subgroup B2	Group B with subgroup B3
Mean	1.50	2.39	2.65	0.76	0.92	1.24
SD	0.40	0.39	0.65	0.23	0.10	0.07
Group A with subgroup A1	-					
Group A with subgroup A2 (<i>P</i>)	0.0092*	-				
Group A with subgroup A3 (<i>P</i>)	0.0007*	0.8557	-			
Group B with subgroup B1 (<i>P</i>)	0.0433*	0.0001*	0.0001*	-		
Group B with subgroup B2 (<i>P</i>)	0.1662	0.0002*	0.0001*	0.9840	-	
Group B with subgroup B3 (<i>P</i>)	0.8782	0.0007*	0.0002*	0.3389	0.7290	-

**P*<0.05. SD: Standard deviation

cutting rates. Borges *et al.*^[14] found that conventional burs lost their cutting efficiency mainly due to rapid wear on their tips compared to the rest of the bur, and such burs needed frequent replacement. Grajower *et al.*^[21] and Micci *et al.*^[29] had also previously observed considerable wear in the conventional diamond burs.

The proprietary WDVDT offers many advantages such as high concentration of diamond grain (80%), high quality of diamond grain and high-quality cut, resistance to wear and long life which is at least 10–15 times more, resistance to geometrical shape deformation, works twice faster, and cost maximization owing to minimal productivity cost in the clinical practice.^[30]

The limitation of this study is as this being an *in vitro* study, all the clinical parameters were not taken into consideration and only two different technologies of rotary diamond burs were studied; inclusion of other technologies for comparison such as Sintered, chemical vapor deposition, and PBS bonding might have attributed variable results.

The findings of this study will help the clinicians to select a rotary diamond instrument among the available wide variety considering their advantages such as high concentration of diamond grains, heterogeneous grain size, and high wear resistance with minimal detrimental effect on the surface of the prepared tooth. The type and technique of manufacturing of the diamond burs will have a significant influence on the surface roughness and cutting efficiency of tooth preparation in fixed prosthodontics.

Conclusions

The diamond burs made with the conventional electroplated burs showed the highest average surface roughness of the prepared teeth as compared to the WDVDT burs. The cutting efficiency was retained to a maximum level even after subsequent usage among the burs made of WDVDT technology. Owing to the inherent advantages of this novel technology of manufacturing burs, they have the potential to be maximizing the effectiveness of tooth preparation with minimal cost implications as compared to the standard electroplated burs that are widely used nowadays.

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Conflicts of interest

There are no conflicts of interest.

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