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ORIGINAL ARTICLE

Are polymer-based burs smart enough to remove infected dentin compared to tungsten carbide burs?

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ABSTRACT

Aim: To compare the efficiency of smart burs during cavity preparation compared to tungsten carbide burs in removing infected dentin.
Methodology: This study was experimental and survey design used. The 60 freshly extracted teeth were equally divided into the smart bur group and the tungsten carbide bur group. Each tooth cavity preparation was done at 5000rpm with a slow-speed handpiece under water irrigation. After cavity preparation, the teeth were trimmed, sectioned, and introduced on the slide with hematoxylin and eosin gram staining to identify the presence or absence of bacteria in the dentinal tubules.
Results: A statistically significant difference at a p-value of .002 was calculated between Carbide burs being more effective in infected dentin removal compared to smart burs.a majority of sections, precisely 22 sections out of the total analyzed (constituting 84.6%), exhibited discernible evidence of infected dentin, characterized by the conspicuous presence of bacterial colonies within the dentinal tubules upon microscopic examination. However, a limited number of sections, specifically 4 sections (constituting 15.4% of the sample), posed challenges for the histopathologist in providing a conclusive assessment regarding the presence or absence of organisms
Conclusion: Smart burs were unable to completely remove carious infected dentin of the prepared tooth cavities compared to carbide burs.
Keywords:Smartburs,conservative cavity preparation,infected dentin,affected dentin

INTRODUCTION

Dental caries is the most common microbial disease encountered by dentists globally. It involves demineralization of the surface layers of enamel and dentin due to acid production by the cariogenic bacteria leading to cavitation and decay. The outer carious dentin layer is termed as infected dentin which is demonstrated by bacterial invasion, irreversible denaturation of collagen matrix, and distortion of the microstructure of dentinal tubules. Whereas inner carious dentin layer, which is termed as affected dentin, has no bacterial penetration[1-5]. This affected dentin is characterized by demineralized intertubular dentin with minimal destruction of collagen matrix.

In recent times, there has been a surge in the adoption of minimal or non-invasive caries removal techniques, largely embraced as the fundamental principle of minimal intervention dentistry. These approaches emphasize the selective removal of infected dentin exclusively, aiming to diminish the bacterial load and minimize acid production within the affected tooth structure[6-8]. A well-sealed restoration is pivotal in creating an environment that promotes the re-mineralization of affected dentin and stimulates the formation of tertiary dentin, effectively averting pulpal exposure[9-10].

Early attempts at caries removal primarily relied on hand instruments, which could often cause discomfort and were not entirely efficient. This limitation prompted the evolution of rotary instruments. The conventional technique for caries removal involved utilizing burs in a high-speed handpiece to access carious lesions, followed by careful removal of caries using a low-speed handpiece. This method notably enhanced the speed of caries removal while minimizing the loss of healthy tooth structure[11-16].

However, conventional methods failed to distinguish between affected and infected dentin, resulting in the unnecessary removal of healthy tooth structure. Consequently, this drawback spurred the development of alternative selective caries removal techniques. These methods encompass fluorescence-aided excavation, laser ablation, sono-abrasion, air abrasion, chemomechanical agents, and smart burs, aiming to improve precision and minimize the loss of sound tooth structure during caries removal. Smart burs are engineered out of polymers and are designed to limit the cutting of tooth structureregardless of the pressure applied by the operator. The polymer blades of smart burs deform withoutcausing harm to healthy or affected dentin. This ensures the removal of soft, infected carious dentin only.

The objective of this inquiry was to conduct a thorough assessment of smart burs concerning their efficacy in the removal of infected dentin, juxtaposed against the conventional tungsten carbide burs. Employing a low-speed handpiece, this investigation sought to provide comprehensive insights into the comparative effectiveness of these dental instruments in clinical practice.

METHODOLOGY

This study was experimental and survey design used. approved by the Ethical Review Board of Riphah International University (IIDC/IRC.2017/12/003). A total of 60freshly extracted carious teeth,with ICDAS class 4 to 6, were taken from consenting patients and placed in saline before undergoing sterilization.The sample was divided into two equal groups: 30 teeth for each group. One group wasassigned as the ‘experimental’ or smart bur group, while the other group was assigned as the ‘control’ tungsten carbide bur group.

The dental preparations on the specimen teeth were performed by a single operator, who adhered to strict aseptic measures by wearing sterile gloves. The cavities were meticulously prepared using a low-speed handpiece equipped with smart burs (SmartPrep, SS White Burs, Inc., Lakewood, NJ, USA) and tungsten carbide burs (Mani, Japan) (as illustrated in Figure 1), set at 5000 rpm and employing copious water irrigation. The primary aim was to ensure the complete removal of soft and infected dentin. To ascertain the adequacy of dentin removal, the operator utilized both the DG16 dental explorer and a ball-ended WHO probe, assessing the texture of the dentin and identifying any residual soft dentin. Throughout the procedure, the operator diligently monitored the condition of the burs for signs of wear and tear. Blunted blades were promptly replaced with new burs, particularly if remnants of soft dentin were still observed, as depicted in Figures 2a and 2b.

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The processed teeth were initially longitudinally trimmed using a lathe-cut machine to align with the location of the prepared cavities. Subsequently, they underwent decalcification in 10% nitric acid. After the decalcification process, histological sections were meticulously prepared and subjected to staining with hematoxylin eosin, as well as gram stain techniques. The prepared histologic slides were carefully examined under a microscope at 40X magnification. An experienced histopathologist meticulously examined the slides, recording the presence or absence of bacterial organisms as shown in figure 3 and 4. Sections that did not encompass the carious area or were affected by folding, impeding a clear examination of the dentinal tubules under the microscope, were excluded from the analysis.

Figure 1: Macro photograph of a tungsten carbide bur.

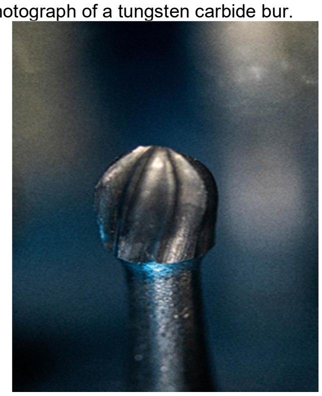


Figure 2a: Macro photograph of a New Smart bur.

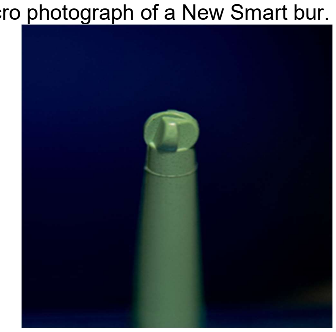
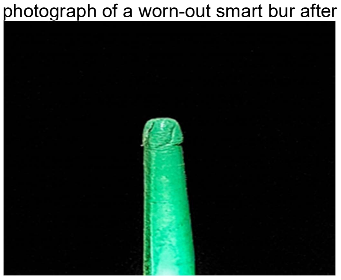


Figure 2b: Macro photograph of a worn-out smart bur after use.



RESULTS

A collective total of 26 sections were observed from both groups: the experimental group using smart burs and the control group using tungsten carbide burs. However, four sections from each group were eliminated from the analysis due to either the absence of the carious lesion or complications arising from folding during the slide preparation process. All collected data was accurately entered and subjected to analysis using SPSS version 23.0 for comprehensive statistical analysis.

In the experimental cohort, a majority of sections, precisely 22 sections out of the total analyzed (constituting 84.6%), exhibited discernible evidence of infected dentin, characterized by the conspicuous presence of bacterial colonies within the dentinal tubules upon microscopic examination. However, a limited number of sections, specifically 4 sections (constituting 15.4% of the sample), posed challenges for the histopathologist in providing a conclusive assessment regarding the presence or absence of organisms. This ambiguity stemmed from the inadequacy of staining observed in these specific sections, thereby hindering a definitive determination of the microbial presence within the dentin tubules (Table 1).

Table 1: Smart bur frequency

experimental group (Smart Bur)				
Valid	**Frequency**	**%**	**Valid%**	**Cumulative%**
Presence of bacteria in dentinal tubules	22	84.6	84.6	84.6
Cannot be determined	4	15.4	15.4	100.0
Total	26	100.0	100.0	

Within the control group, the analysis of sections revealed that a considerable majority, specifically 22 sections (accounting for 84.6% of the total samples examined), presented an absence of discernible bacterial colonies within the dentinal tubules upon histopathological examination. Conversely, a minor fraction of sections, totaling two (representing 7.7% of the samples), exhibited clear evidence of bacterial colonies upon microscopic evaluation. Additionally, two sections (7.7% of the total samples) were excluded from the assessment due to issues related to inadequate staining and tissue folding, rendering them unsuitable for precise analysis (Table 2).

Table 2: Tungsten carbide bur frequency

Control group (Tungsten Carbide burs)				
Valid	**Frequency**	**%**	**Valid%**	**Cumulative%**
Presence of bacteria in dentinal tubules	2	7.7	7.7	7.7
Absent	22	84.6	84.6	92.3
Cannot be determined	2	7.7	7.7	100.0
Total	26	100.0	100.0	

The utilization of a Chi-square test in the comparative analysis between the two groups revealed a statistically significant difference. The calculated p-value of 0.02 indicated a noteworthy contrast, demonstrating the superior efficacy of carbide burs in the removal of infected dentin when compared to smart burs. Furthermore, the derived likelihood ratio value of 8.92 suggested a moderate but discernible alteration between the experimental group (utilizing smart burs) and the control group (employing carbide burs). (Table 3)

Table 3: Chi-square statistical analysis between experimental group and control group

	Value	df	Asymptotic Sig. (2-tailed)
Pearson Chi-Square	12.03	2	.002
Likelihood Ratio	8.92	2	.012
Linear-by-Linear Association	7.39	1	.007
N of Valid Cases	26		

Figure 3: Microorganisms stained with hematoxylin eosin visible (horizontal lines) following cavity preparation in dentinal tubules after smart bur preparation

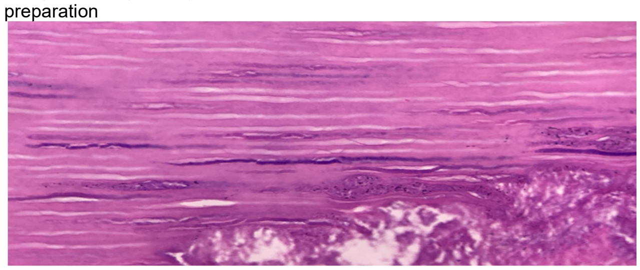
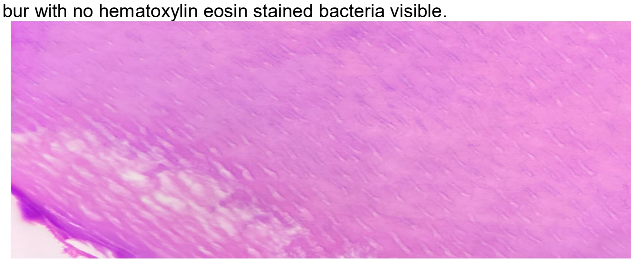


Figure 4: Infected dentin removed during preparation by tungsten carbide bur with no hematoxylin eosin stained bacteria visible.



DISCUSSION

Previous investigations exploring the efficacy of smart burs in comparison to alternative chemomechanical techniques for removing infected dentin have presented varying outcomes. While our study aligns with some prior research, showcasing that smart burs might exhibit inferior effectiveness in infected dentin removal compared to alternative methodologies, other studies have diverged in their conclusions. Certain investigations have reported findings contrary to our study, suggesting that smart burs could be equally or even more effective than other approaches in eliminating infected dentin. Thus, the available literature reveals a heterogeneous landscape of outcomes regarding the comparative efficacy of smart burs, necessitating a comprehensive assessment and synthesis of various research findings for a conclusive understanding of their performance in dentin debridement[3,12,13]. The identified discrepancies in study findings can be ascribed to several factors, including variations in tooth selection, operator proficiency, and the quality of the bur utilized.

Furthermore, our study has certain limitations that merit acknowledgment. One notable limitation pertains to the relatively restricted sample size employed, potentially impacting the generalizability of our conclusions. Additionally, the variability in cavity dimensions across the samples could have introduced inconsistencies in the assessment of dentin debridement efficacy. Another limitation involves the potential influence of smear layer preservation during the evaluation process, which might have influenced the observed outcomes. These limitations underscore the necessity for further investigations with larger sample sizes, standardized cavity dimensions, and strict control over variables to ascertain more conclusive and comprehensive findings.

The primary aim of caries excavation is to eliminate substantial portions of bacteria-infected dentin before the placement of a restoration. The outcomes derived from this investigation reveal a significant distinction between the sections prepared using smart burs and carbide burs. Sections prepared with smart burs exhibited a notable presence of residual infected dentin, consequently harboring a greater quantity of bacteria within the dentinal tubules. Conversely, carbide burs, known for their heightened abrasiveness, demonstrated minimal residual infected dentin within the prepared sections, thereby showcasing a substantially reduced presence of bacteria within the dentinal tubules.

According to a study by Kidd et al[14], small numbers of microorganisms may remain which are considered acceptable. Caries removal can be achieved using rotary burs and hand excavators[15,16]. Although it is still to be determined how the clinical excavation technique can be utilized and the risks associated with failure to remove the entire infected dentin[17]. It is reported that bacteria present in carious dentin include S mutans,Actinomyces, lactobacilli, and other gram-positive rods[18]. Lactobacilli play a role in caries progression while S mutans are acid-producing bacteria that maintain their metabolic activity even in the presence of low pH environments[17,19,20,21].

In this research, the preparation of extracted teeth with ICDAS class 4 to 6 for both groups was conducted by a singular clinician to eliminate potential biases linked to preparation skills, utilizing solely rotary burs. Hand excavators were purposefully omitted from use as the primary objective was to evaluate the residual carious dentin subsequent to the utilization of two distinct bur types (carbide and smart burs). The clinician assessed the extent of soft carious infected dentin through a clinical examination, employing tactile sensation via a WHO probe. The clinician diligently removed all areas exhibiting soft carious infected dentin, utilizing a combination of clinical visibility and tactile perception based on tooth hardness. It is crucial to note that while tactile sensation was employed, it was not solely relied upon as the exclusive method for identifying infected dentin[22,23,24].

Caries dye is an effective tool in delineating the extent of caries; however, its application was omitted in our study. This decision was made due to the tendency of the dye to stain not only areas of affected dentin but also the dentin-enamel junction, which is susceptible to demineralization caused by bacterial metabolites[25,26]. Certainly, in our study, the operator solely relied on tactile feedback during the cavity preparation process.

When using carbide bur care was required not to remove affected dentin and healthy dentin as it was difficult to control the depth of cutting due to poor tactile sensation and high cutting efficiency of these specific burs.

In contrast to carbide burs, smart burs demonstrated heightened responsiveness to tactile sensation, as observed by the clinician conducting this study. It's important to note that the extent of preparation depth can be influenced by the application of pressure during the procedure. Carbide burs have the propensity to penetrate deeper into dentin with minimal pressure, whereas smart burs tend to disintegrate under excessive pressure. It's worth mentioning that the hardness of polymer bur material is less than that of healthy dentin but higher than that of infected dentin[27]. It is this property of smart burs that its polymer edges become deformed when in contact with sound dentin[28,29].. This prevents it from cutting into the affected dentin leaving behind more dentin structure. Also, it was noted that smart burs required more time in cavity preparation compared to tungsten carbide burs. This could be due to the softer polymer blade structure of smart burs compared to the hard tungsten carbide cutting blades of the bur.

Other in-vitro studies like our study which evaluated the effectiveness of smart burs in removing carious dentin also show smart burs to be less effective at removing carious dentin than carbide burs[27,29-31]. In another study however it was shown carbide burs to remove caries similar to smart bur preparation[32]. While One study has shown smart bur to be more efficient in removing infected dentin compared to carbide burs[33].

The drawback of this study includes the evaluation of remaining bacterial presence within the dentinal tubules after the preparation and the amount of smear layer generated by these specific burs. It was noted by the operator that carbide bur was able to over-prepare the cavity and hence may have been able to remove affected dentin as well. To make results more accurate compared to carbide burs a more conservative approach to cavity preparation can be achieved by air abrasion or byultrasonic preparation[34]. Cavity preparation with air abrasion has the advantage of being pseudo-mechanical, generating less smear layer, non-rotary method of cutting and removing dental hard tissue[35]. Studies have shown cavities prepared by air abrasion to have better bonding to composite due to deeper penetration of bonding adhesive into dentinal tubules forming a greater degree of resin tags and a more uniform hybrid layer[36-38].

Air abrasion on the contrary has the limitation of being inefficient in removing soft dentin and hence is unable to prepare large cavity designs with gross caries or large restorations[34]. The lack of tactile sensation requires constant visual inspection at regular intervals to control cavity preparation depth[39]. The splatter of abrasive powder requires good isolation, high power suction, and inability to use loupes or microscope which can rebound to damage the lens surfaces. Lastly, it produces rounded cavosurface margins that are not suitable for amalgam, inlay, onlay, and margin design for crown preparation[40,41].

An alternative approach is using an ultrasonic bur handpiece, these burs help in the preservation of tooth structure[42]. They have potential advantages such as reduced noise, minimal damage to the gingival tissue, extended bur durability compared to conventional diamond burs, improved proximal cavity access, and reduced risk of hitting the adjacent tooth due to the high inclination angles of the handpiece[43-46]. Even with these various benefits of ultrasonic burs they exhibit very low cutting efficiency which is a major limitation[47]. It has been shown they require 4 times the time for the same cavity preparation when done using a high-speed conventional bur[48]. This highlights the fact that the cutting rate of ultrasonic burs, especially through the enamel, is still a crucial issue[49]. Further research on other factors like the amount of tactile pressure applied by the operator, effect of change in RPM of burs in the handpiece, access to the cavity design, illumination, presence of irrigation, use of magnification, operator skill, and knowledge can also enhance cutting efficiency and cavity preparation design[50-52].

CONCLUSION

The statistical analysis conducted in this study revealed a notable disparity between the two burs, substantiated by a p-value of .002. As a result, the findings indicate that Smart burs exhibited inefficiency in the removal of carious infected dentin, leaving a higher residual bacterial presence within the dentinal tubules of the prepared tooth cavities in comparison to carbide burs. This observation underscores the less conservative approach of carbide burs in cavity preparation, evident in their removal of not only infected dentin but also affected dentin, a distinction from the comparatively conservative approach of smart burs.

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Author contribution: SS: Concept, Drafting of work and Design of study, Methodology, Data collection, Article writing

MM: Ethical approval and Grant taken and provided with the research materials, Article review

AK: Methodology, Analysis, and data interpretation

AA: Investigation, Supervision, Review, and approval of the final draft

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