

# Cutting Efficiency of Diamond Burs with Different Coatings on Ceramic and Resin Composite Materials after Multiple Use

## Keywords

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## ABSTRACT

*Objectives:* This study evaluated the cutting efficiency of dental burs with different surface coatings on various reconstruction materials and analyzed the microscopic changes after multiple uses. *Methods:* Thirty block specimens ( $N=35$ ,  $n=7$ ) were prepared from various materials: CAD/CAM PMMA, direct resin composite, lithium disilicate, CAD/CAM nano-hybrid composite, and zirconia ( $12 \times 4 \times 4$  mm<sup>3</sup>). The specimens were randomly assigned to cut under water cooling with one of seven bur types: Bur 1 (FG 307 CB), Bur 2 (6881.314.016), Bur 3 (FG 307 C), Bur 4 (ZR6881.314.016), Bur 5 (Prototype), Bur 6 (Prototype), and Bur 7 (Prototype). Each bur was used 10 times with a cutting depth of 3 mm. Images were taken of unused, used, and ultrasonically cleaned burs prior to data analysis ( $\alpha=0.05$ ). *Results:* Cutting efficiency varied significantly by material and bur type ( $p<0.05$ ). Bur 3 and Bur 5 were most effective for PMMA, while Burs 5, 6, and 7 excelled with direct resin composite. Bur 7 was best for CAD/CAM composite, Bur 3 for lithium disilicate, and Bur 6 for zirconia. Burs 1 and 2 consistently performed poorly. *Significance:* Bur selection is important for efficient cutting, reducing chair time, material wear, and costs while improving restoration precision and bur longevity.

## INTRODUCTION

Removing fixed dental prosthesis (FDP) may require cutting or drilling of the material to facilitate removal for the subsequent restoration. This process is time-consuming, as it depends on factors such as the hardness of the material, surface coating, and the shape of the dental bur used, which affects the chairside time.<sup>1-3</sup> Both patients and practitioners aim to reduce and optimize chairside time. Recent advancements in diamond bur coatings seek to minimize the time required for cutting restorative materials, making instruments more versatile across different materials. It also contributes to economic and ecological benefits.<sup>4</sup>

First introduced in the 1980s, Computer-aided design / Computer-aided (CAD/CAM) manufacturing technologies revolutionized the design and production of various tooth-, implant- and mucosa-borne reconstructions and appliances.<sup>5-7</sup> Since then, CAD/CAM dentistry has seen significant advances, including the introduction of new materials. Among CAD/CAM materials, zirconia has become the most widely used material for FDPs in recent years. However, other materials based on ceramics, polymers or a

combination are still utilized to mimic the structure of missing teeth.<sup>8-10</sup> With the diversity of materials used in restorative and CAD/CAM dentistry, considerations regarding surface hardness and other material properties are essential when cutting such materials.<sup>11,12</sup>

With increasing life expectancy, the need to replace missing teeth with dental reconstructions will remain prevalent.<sup>13-15</sup> Thus, it is essential to maintain and enhance the technical capabilities to modify dental reconstruction materials in a chair-side setting, especially since technical complications, such as debonding (15%) and chipping (4.1%), are frequent over a five-year period in resin-bonded FDP and in particular zirconia.<sup>16</sup>

Alterations may be necessary throughout the lifespan of dental reconstructions due to complications. The likelihood of clinical complications in fixed prosthodontics varies by reconstruction type. For example, conventional (27%) and resin-bonded FDPs (26%) are more prone to complications than single crowns (11%), posts and cores (10%), and all-ceramic crowns (8%).<sup>17</sup> Materials for dental reconstructions are selected based on their suitability for specific restoration types. Therefore, tools such as burs must be able to address the qualities of different reconstruction materials if a practitioner is to complete and modify a wide range of reconstructions using the same instrument.<sup>18</sup> Factors affecting cutting efficiency (mm/s) during the preparation of tooth structure or reconstruction materials include the load-energy and rotation per minute (rpm) applied by the operator, the design of the handpiece, the cooling system, the tool itself, and the material being cut.<sup>3</sup> Since the design of a bur directly impacts its cutting performance, various bur characteristics should be evaluated regarding their ability when cutting different materials.<sup>19</sup> Studies have shown that coarse and medium grit burs exhibit similar cutting efficiencies, although highly faceted diamond burs perform better than those with rounded diamond chips on a bur surface. It has been suggested that debris accumulation on diamond burs hinders cutting efficiency more than the loss of function due to diamond chip wear or loss over time.<sup>20</sup>

Previous studies have reported on the performance of dental instruments on specific dental reconstruction materials. Still, limited information exists on the re-usage and cross-sectional applicability of diamond-coated dental burs under reproducible conditions.<sup>3,19</sup> This study intended to identify an instrument that could be used effectively on a wide range of reconstruction materials, offering multiple clinical indications and long-lasting utility.

The objective of this study, therefore, was to evaluate the effect of different dental burs on the cutting efficiency of various CAD/CAM (polymethylmethacrylate-PMMA, nano-hybrid composite, lithium disilicate, and zirconia) and non-CAD/CAM (direct resin composite) reconstruction materials, and to assess the morphological surface characteristics of the burs microscopically before and after use. The null hypotheses tested were that neither 1) bur type nor 2) material type would affect the cutting efficiency.

## MATERIALS AND METHOD

### MATERIALS AND STUDY DESIGN

The general description of materials (brand, manufacturer, working principles of the burs, and chemical composition) used in this study are listed in Table 1. The study was conducted in a 7x5 design, considering seven types of diamond-coated dental burs: a) Bur 1: FG 307 CB – diamond coated (lot: 021716; coarse diamond grit; 1.63 mm, 016 diameter; Intensiv, Lugano, Switzerland); b) Bur 2: 6881.314.016 – diamond coated (coarse diamond grit, 1.56 mm, 016 diameter; Komet, Lemgo, Germany); c) Bur 3: FG 307 C – diamond coated (I21728, 021708; standard diamond grit; 016 diameter; Intensiv); d) Bur 4: ZR6881.314.016 – diamond coated (016 diameter; Komet, Lemgo, Germany); e) Bur 5: Prototype - diamond coated with extra metallic coating (021728); standard diamond grit; diameter 016; Intensi); f) Bur 6: Prototype - diamond coated with multilayer diamond coating (021728, 021807) with a range of different diamond-grit sizes from coarse to fine; diameter 016; Intensiv); g) Bur 7: Prototype - diamond coated with multilayer diamond coating and additional metallic coating (021728) with a range of different diamond-grit sizes from coarse to fine; diameter 016; Intensiv); and five restorative materials: CAD/CAM polymethylmethacrylate (PMMA), direct resin composite, lithium disilicate, CAD/CAM resin composite, and zirconia.

The primary response variable assessed was cutting efficiency, measured by the time that each bur takes to complete a cut at a determined working trajectory.

### SPECIMEN ALLOCATION

A total of 35 block specimens (n=7 blocks from each material) were prepared from various materials: a) artBloc Temp (Merz Dental, Lütjenburg, Germany), b) Tetric N-Ceram (Ivoclar AG, Schaan, Liechtenstein), c) Lava Ultimate (3M ESPE, St. Paul, USA), d) IPS e.max CAD (Ivoclar AG), and e) Katana Zirconia (Kuraray, Tokyo, Japan), each measuring 12x4x4 mm<sup>3</sup>. According to the description above, the specimens were randomly assigned to seven bur types.

### CUTTING PROCEDURE

The specimens were used as received and placed in the specimen holder of a custom-made drilling device (University of Zurich, Switzerland) (Figure 1). Efficiency tests were conducted using this device, which allows for controlled drilling procedures. The dental unit could be connected to both high- and slow-speed handpieces (Intramatic Lux 700KL, KaVo Dental GmbH, Brugg, Germany; KaVo ESTHETICA Comfort 1065, KaVo Dental AG). In this study, a high-speed handpiece was utilized.

The tool facilitated the horizontal and bidirectional movement of the handpiece on the specimen under a load of 750 g. The grinding tools were held parallel to the specimen surfaces throughout the drilling process, facilitating the cut vertically

**Table 1. Manufacturers and compositions/descriptions of the materials used in this study.**

Material	Manufacturer	Composition/Description (According to Manufacturer)
artBloc Temp D3	Merz Dental, Lütjenburg, Germany	PMMA-based block made of highly cross-linked Organic Modified Polymer Network (OMP-N), without inorganic fillers
Tetric N-Ceram	Ivoclar AG, Schaan, Liechtenstein	Dimethacrylates (e.g., Bis-GMA, UDMA), barium glass, ytterbium trifluoride, mixed oxides, and co-polymers
E.max CAD	Ivoclar AG	Lithium disilicate glass-ceramic (SiO <sub>2</sub> 57-80%, Li <sub>2</sub> O 11-19%, K <sub>2</sub> O, and other oxides).
LAVA Ultimate	3M ESPE, St. Paul, USA	Organic phase: Bis-GMA, Bis-EMA, TEGDMA, UDMA; Inorganic phase: silica (20 nm) and zirconia (4–11 nm) fillers, zirconia-silica clusters (0.6–10 µm); 79 wt% fillers
Katana	Kuraray, Tokyo, Japan	ZrO <sub>2</sub> + HfO <sub>2</sub> 87-92% Yttrium oxide (Y <sub>2</sub> O <sub>3</sub> ) 8-11% Other oxides 0-2%
Bur 1 (FG 307 CB)	Intensiv, Lugano, Switzerland	Diamond-coated dental bur, 016 diameter, coarse diamond grit, high-speed FG (friction grip)
Bur 2 (6881.314.016)	Komet, Lemgo, Germany	Diamond-coated dental bur, 016 diameter, coarse diamond grit, high-speed FG (friction grip)
Bur 3 (FG 307 C)	Intensiv	Diamond-coated dental bur, 016 diameter, standard diamond grit, high-speed FG (friction grip)
Bur 4 (ZR6881.314.016)	Komet	Diamond-coated dental bur, 016 diameter, high-speed FG (friction grip)
Bur 5 (Prototype)	Intensiv	Diamond-coated dental bur with extra metallic coating, 016 diameter, standard diamond grit, high-speed FG (friction grip)
Bur 6 (Prototype)	Intensiv	Stainless steel blank with a nickel layer with diamond crystals (crystal size: 106±15 µm) through electroplating. Chrome plating an extra diamond layer (3-5 µm) or a further fixation of the diamond crystals. high-speed FG (friction grip)
Bur 7 (Prototype)	Intensiv	Stainless steel blank with a nickel layer with diamond crystals (crystal size: 106±15 µm) through electroplating. Nickel plating an extra diamond layer (3-5 µm) or a further fixation of the diamond crystals. high-speed FG (friction grip)

to the surface and downward. The handpiece operated under water coolant (50 ml/l) at a rotational speed of 120,000 rpm, cutting the blocks to a depth of 3 mm. The time taken to complete each cut was measured from the start of drilling until a working trace of 3 mm was achieved. Each bur was used for 10 cycles, with time recorded for each usage across all blocks, maintaining an approximate distance of 3 mm between each drilling mark. For each bur a new CAD/CAM block was used, and each block was rotated for further cuts in 3 mm cutting intervals making 10 cuts possible per block.

Following the cutting operations, the specimens were ultrasonically cleaned (Branson Ultrasonic Cleaner 3510, Branson, Danbury, CT, USA) for 10 minutes in distilled water.

## TOPOGRAPHY ANALYSIS

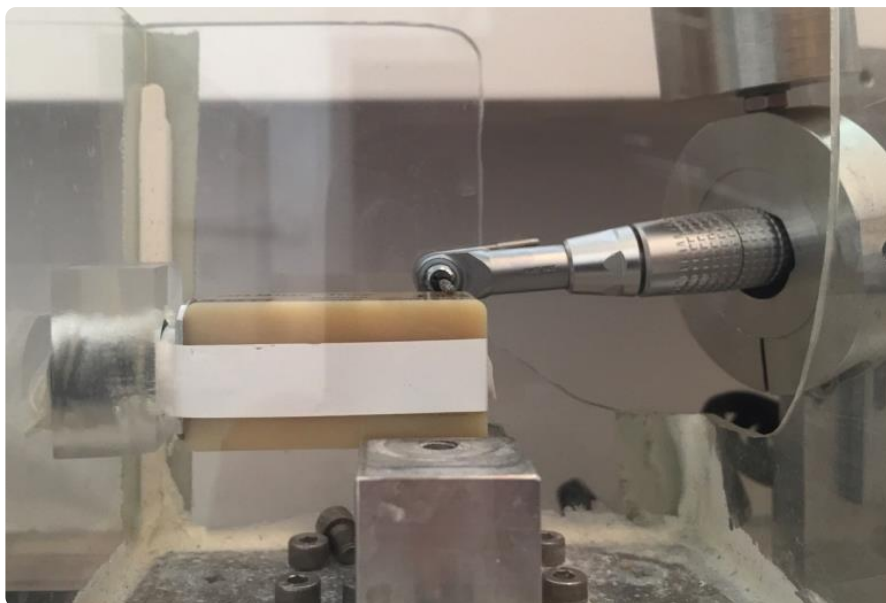
The complementary analysis included the surface topography of the burs, which was evaluated before and after use using a digital microscope (VHX-2000D; Keyence, Osaka, Japan) and following the ultrasonic cleaning procedures at a magnification of

200×. Images were captured from a predetermined reference point in the middle of each bur to visualize differences.

Additional images of new and used burs were made using scanning electron microscopy (SEM) (Zeiss Supra V50, Carl Zeiss, Oberkochen, Germany). The burs were sputter-coated with gold and palladium to a thickness of 10 nm while mounted on aluminum stubs (90 s, 45 mA; Balzers SCD 030, Balzers, Liechtenstein). SEM images were captured at a magnification of 100×, at 10 kV. Surface features of the burs (microscopy inspection) were descriptively/qualitatively analyzed.

## STATISTICAL ANALYSIS

The cutting time (seconds) data assumed a parametric and homoscedastic distribution indicated by Shapiro-Wilk and Levene tests ( $p > 0.05$ ). To test the influence of different burs and materials, two-way Analysis of Variance (ANOVA) and Tukey's *post hoc* tests ( $\alpha = 0.05$ ) were conducted (SPSS version 21, IBM Analytics, Chicago, IL, USA). A *p*-value less than 0.05 was considered statistically significant for all statistical analyses.



**Figure 1:** Experimental set-up showing position of the bur in relation to the specimen being cut.

## RESULTS

The cutting efficiency in seconds varied significantly between the different materials and bur systems ( $p < 0.05$ ). For PMMA, Bur 3 ( $19 \pm 4$ ), Bur 6 ( $22 \pm 5$ ), and Bur 5 ( $23 \pm 5$ ) exhibited the best performance, with significantly faster cutting times compared to Bur 1 ( $67 \pm 14$ ) and Bur 2 ( $72 \pm 10$ ), which were the least efficient (Table 2). Burs 4 ( $29 \pm 4$ ) and 7 ( $29 \pm 7$ ) also performed well but were slightly less efficient than Burs 3 and 5 (Figures 2a-e).

In the case of direct resin composite, Burs 5 ( $12 \pm 3$ ), 6 ( $14 \pm 2$ ), 4 ( $16 \pm 4$ ), 3 ( $18 \pm 6$ ), and 7 ( $20 \pm 2$ ) demonstrated the highest cutting efficiency, significantly outperforming Bur 1 ( $26 \pm 6$ ) and Bur 2 ( $28 \pm 4$ ) ( $p < 0.05$ ), which showed slower cutting times.

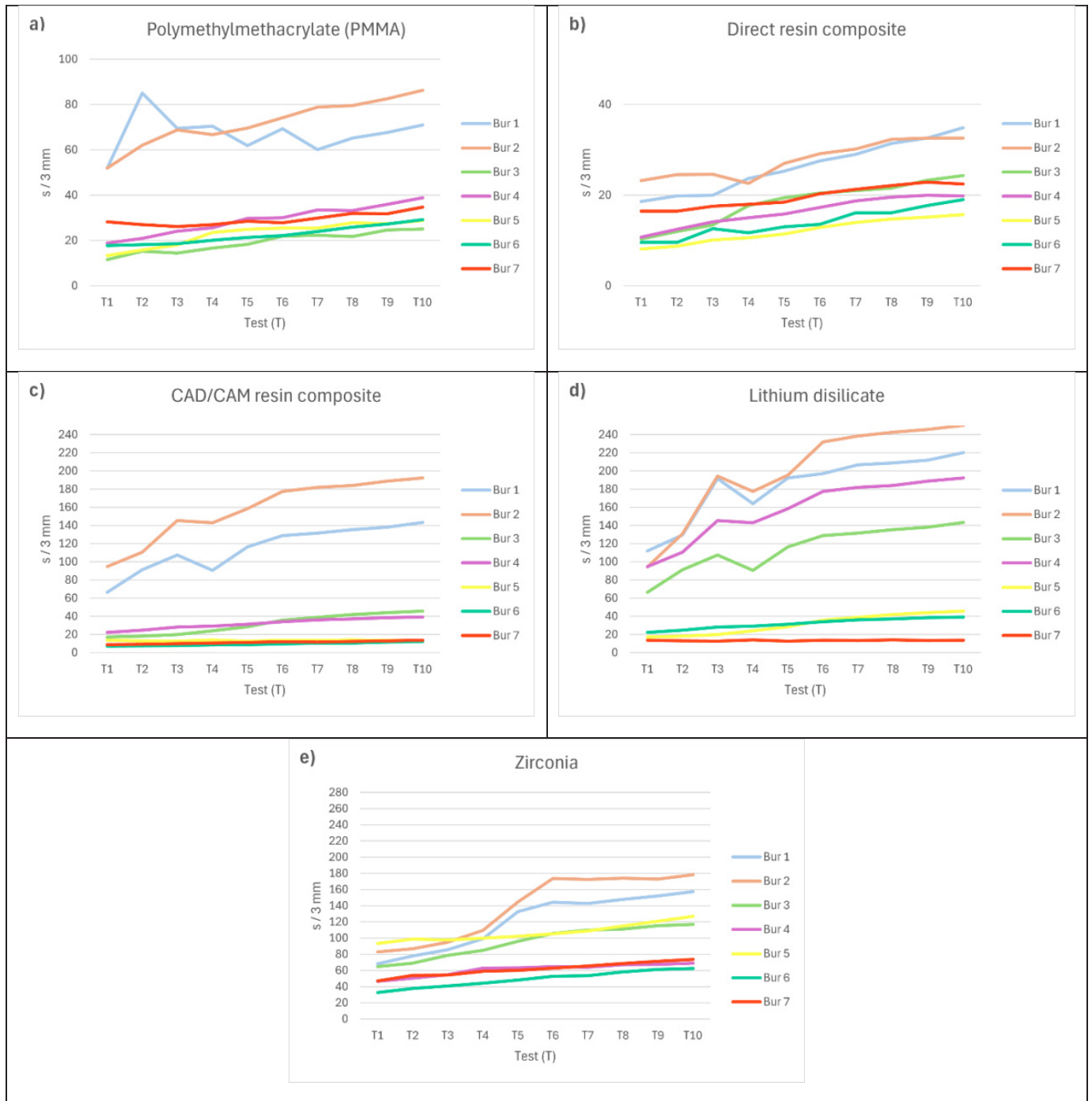
When examining CAD/CAM resin composite, Bur 7 ( $13 \pm 3$ ) provided the most efficient cutting, being significantly faster than Burs 5 ( $31 \pm 6$ ) and 6 ( $32 \pm 4$ ) ( $p < 0.05$ ). Bur 1 ( $183 \pm 74$ ), Bur 2 ( $200 \pm 44$ ), Bur 3 ( $115 \pm 32$ ), and Bur 4 ( $157 \pm 32$ ) were still less efficient, showing slower cutting times.

As for lithium disilicate, Bur 3 ( $12 \pm 3$ ) stood out as the most efficient, with significantly better performance than most of the burs, similar to Bur 5 ( $13 \pm 3$ ). Bur 5 showed cutting time similar to Bur 4 ( $22 \pm 4$ ), 6 ( $16 \pm 2$ ), and 7 ( $19 \pm 3$ ). Burs 1 ( $29 \pm 5$ ) and 2 ( $41 \pm 5$ ) also showed less efficiency, with slower cutting times than all other burs.

For zirconia, Bur 6 ( $61 \pm 5$ ) delivered the best cutting efficiency ( $p < 0.05$ ), followed by Bur 5 ( $95 \pm 15$ ) and 7 ( $107 \pm 6$ ) ( $p > 0.05$ ). These burs outperformed Burs 2 ( $120 \pm 21$ ), 3 ( $121 \pm 29$ ), and 4 ( $139 \pm 29$ ), which showed longer cutting times for zirconia. On

**Table 2. Cutting times (Mean±SD) in seconds for each bur across different materials. The table presents the cutting efficiency of seven burs (1-7) for PMMA, direct resin composite, CAD/CAM resin composite, lithium disilicate, and zirconia. \*Uppercase letters in each column represent statistical differences for the times among the groups considering each material and burs (two-way ANOVA and Tukey's post-hoc tests) ( $\alpha=0.05$ ).**

Burs	Time (seconds)				
	Mean±SD				
	PMMA	Direct resin composite	CAD/CAM resin composite	Lithium disilicate	Zirconia
1	$67 \pm 14^D$	$26 \pm 6^{FG}$	$183 \pm 74^{AB}$	$29 \pm 5^F$	$242 \pm 135^A$
2	$72 \pm 10^D$	$28 \pm 4^F$	$200 \pm 44^A$	$41 \pm 5^E$	$120 \pm 21^{BC}$
3	$19 \pm 4^G$	$18 \pm 6^G$	$115 \pm 32^{BC}$	$12 \pm 3^H$	$121 \pm 29^B$
4	$29 \pm 4^F$	$16 \pm 4^G$	$157 \pm 32^B$	$22 \pm 4^G$	$139 \pm 29^B$
5	$23 \pm 5^G$	$12 \pm 3^G$	$31 \pm 6^F$	$13 \pm 3^{GH}$	$95 \pm 15^{CD}$
6	$22 \pm 3^G$	$14 \pm 2^G$	$32 \pm 4^F$	$16 \pm 2^G$	$61 \pm 5^D$
7	$29 \pm 7^F$	$20 \pm 2^G$	$13 \pm 3^{GH}$	$19 \pm 3^G$	$107 \pm 6^C$

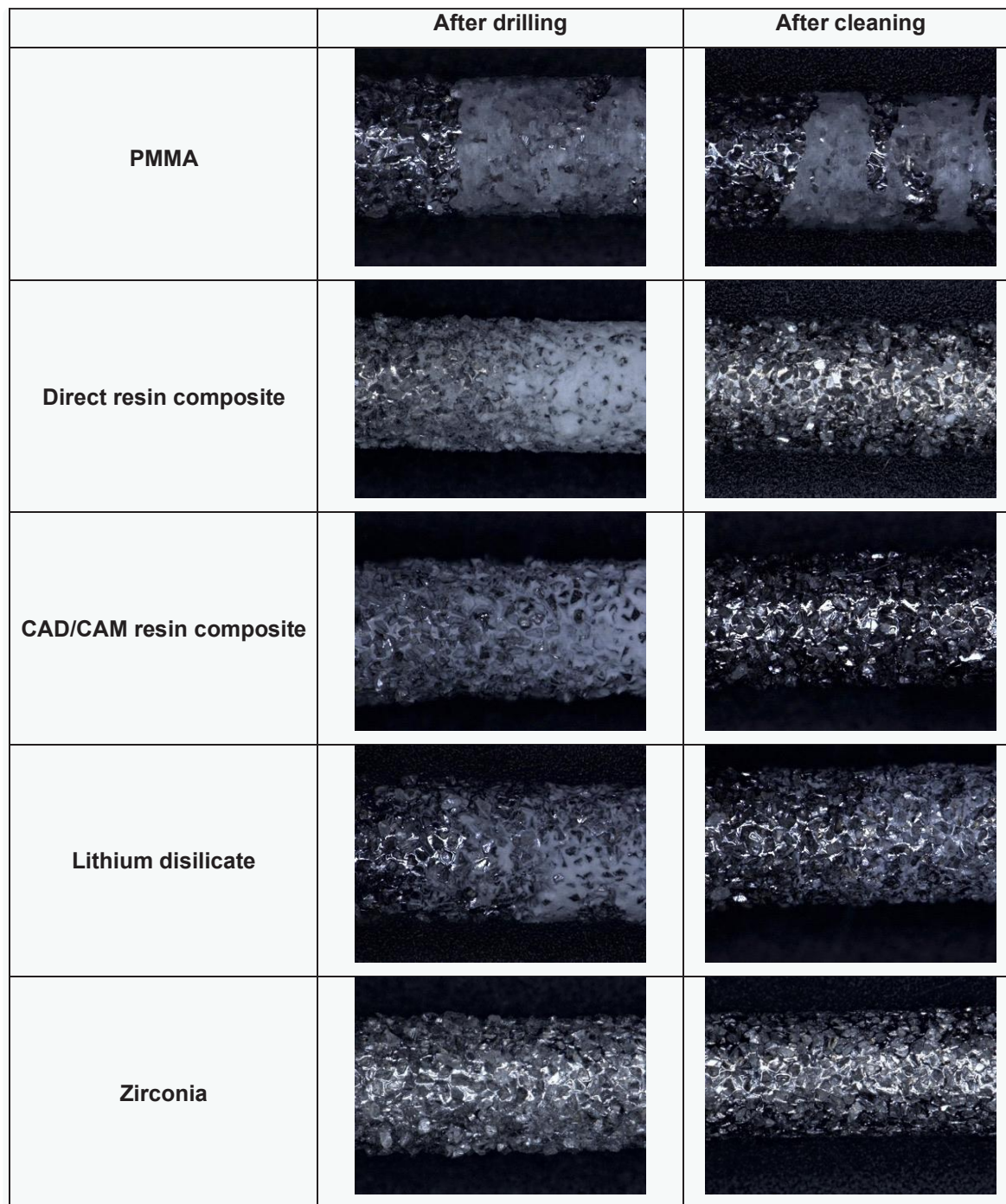


**Figure 2a-e:** Mean time (seconds) required for cutting 3 mm depth in a) Polymethylmethacrylate; b) Direct resin composite; c) CAD/CAM resin composite; d) Lithium disilicate; and e) Zirconia.

the other hand, Bur 1 ( $242 \pm 135$ ) showed the longest cutting time, being significantly longer than all groups ( $p < 0.05$ ).

Among the materials tested, zirconia and lithium disilicate required significantly more cutting time than other materials ( $p < 0.05$ ). Based on the results, Bur 7 is recommended for up to 10 times of use for PMMA, direct resin composite, and CAD/CAM resin composite, while it should be limited to 5 times of use for lithium disilicate and zirconia to maintain optimal cutting efficiency. The best-performing bur on zirconia was Bur 6, again used for cutting up to 15 mm to maintain optimal cutting efficiency.

Representative images of all burs (Figure 3) following the drilling of each material and ultrasonic cleaning revealed distinct cleaning outcomes. Ultrasonic cleaning failed to completely remove debris from the burs after drilling PMMA, with partial removal observed for direct resin composite and lithium disilicate. However, debris was eliminated from the burs after drilling CAD/CAM resin composite and zirconia. Additionally, varying levels of diamond particle loss across the different materials tested were observed in all burs (Figure 4).



**Figure 3:** Representative images of all burs after cutting each material and subsequent ultrasonic cleaning revealed varying levels of debris removal. Ultrasonic cleaning was insufficient to fully remove material debris from PMMA surfaces but it was only partially effective for direct resin composite and lithium disilicate. Note that ultrasonic cleaning successfully removed debris completely from CAD/CAM resin composite and zirconia materials.

## DISCUSSION

The main objective of this study was to assess the cutting efficiency of diamond dental burs with different coatings when drilling through various restorative materials. The findings led to the rejection of the first null hypothesis, as certain burs demonstrated significantly superior drilling performance compared to others. Notably, the study revealed that advanced coatings on burs help maintain higher cutting rates, highlighting their

potential to improve clinical efficiency. The second null hypothesis was also rejected, as the type of material being drilled significantly impacted cutting efficiency. These results are important in dental practice, where reducing treatment time and ensuring effective material removal is critical. Efficient drilling optimizes the practitioner's workflow and reduces chair time by enhancing patient comfort and satisfaction.<sup>21</sup>

Among the tested burs, bur 7 demonstrated the best performance in general, but it is important to note that the best cutting performance on zirconia was demonstrated by the prototype

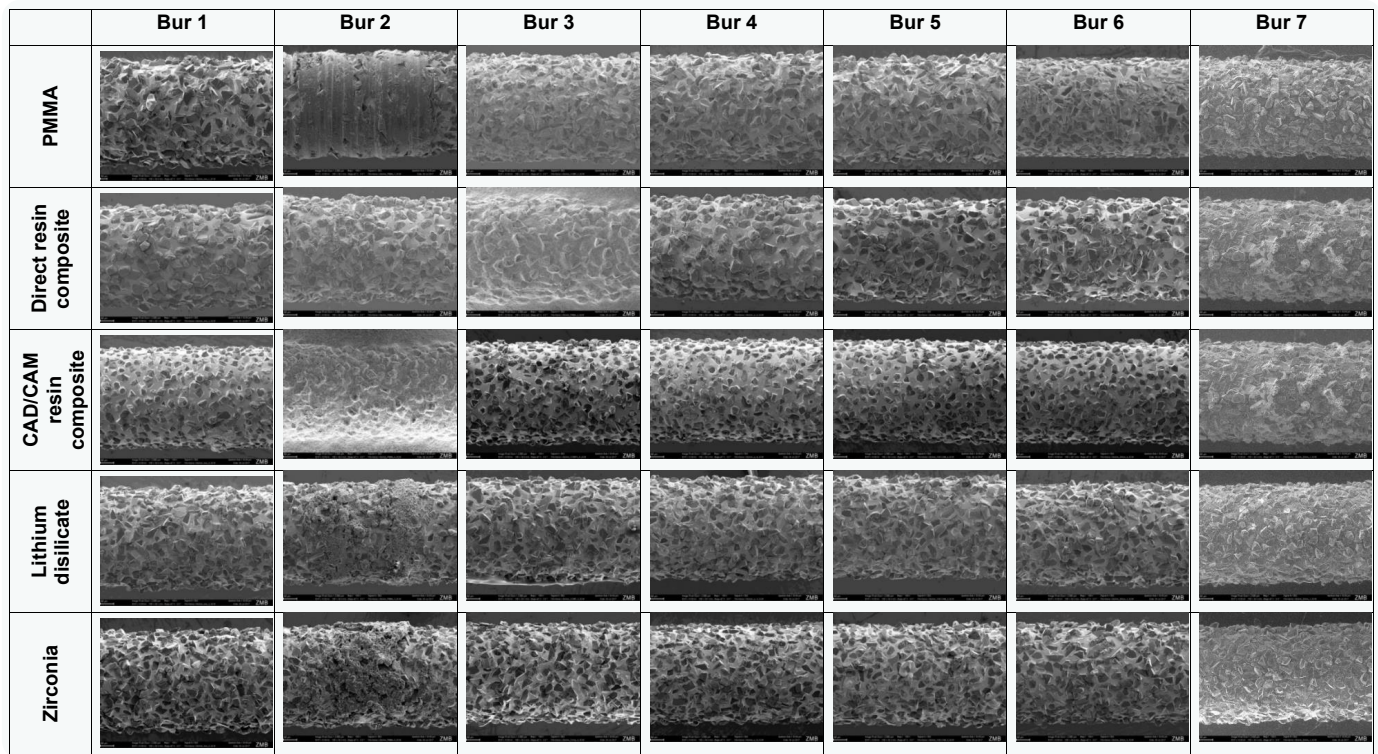


Figure 4: Varying levels of diamond particle loss across the different materials tested for each bur type.

Bur 6. This superior efficiency can be attributed to the advanced coating technology that enhances its cutting ability and overall efficiency in material removal compared to the other burs evaluated.<sup>22</sup> The unique composition and structure of the coating allowed for better dispersion of diamond particles, resulting in sharper cutting edges and reduced friction during operation. Bur 7 is composed of a stainless steel blank with a nickel layer incorporating diamond crystals. The dimension of the diamond crystals was  $106 \pm 15 \mu\text{m}$  which was achieved through incorporation of the crystals using electroplating. An additional nickel plating, and an extra diamond layer in the range of  $3\text{--}5 \mu\text{m}$  are performed for a further fixation of the diamond crystals.

This is critical in dental applications, where the precision and speed of cutting directly impact the quality of the final restoration and the health of the surrounding dental tissues.<sup>23</sup> Apparently, additional coating with nickel layer was more stable for stabilizing diamond crystals as opposed to chrome which eventually contributed to more efficacy in cutting a variety of CAD/CAM materials in this study.

Additionally, compared to existing literature, the cutting rates observed in this study reveal significant discrepancies. A previous study reported cutting rates of approximately  $0.95 \text{ mm/min}$  for lithium disilicate and  $1.46 \text{ mm/min}$  for zirconia.<sup>24</sup> In contrast, our study recorded a maximum cutting rate of  $13.45 \text{ mm/min}$  for Bur 7 on lithium disilicate and  $3.66 \text{ mm/min}$  for Bur 6 on zirconia. These results demonstrate the ability of modern bur coatings to significantly improve cutting efficiency in dental procedures applications.<sup>19,24</sup> The higher cutting rates achieved in our study are attributed to the advancements in bur technology, allowing for more efficient cutting through various materials increasingly used in restorative dentistry.<sup>1</sup>

The accumulation of debris on the burs during drilling raises critical concerns regarding heat generation, which can potentially damage the pulp tissue.<sup>25</sup> The images of the burs after use displayed significant debris accumulation, which likely contributes to increased friction and heat during the cutting process. This situation poses a risk of inflammation or heat transmission to the dental pulp, as excessive heat can lead to pulp necrosis or other complications. Therefore, it is essential to implement effective cooling strategies, such as copious water spray, to mitigate these risks.<sup>26</sup> Practitioners should also recognize the importance of regular bur maintenance and replacement to ensure optimal performance and patient safety. It is typically advised that diamond burs be replaced after about 10 to 15 uses, depending on the material being cut and the level of wear observed.<sup>21</sup> Proper disposal of worn burs is crucial, as they can pose safety hazards and should not be reused once they have lost their cutting efficiency.<sup>1</sup>

This study also compared the drilling efficiencies on various materials, including PMMA, direct resin composite, CAD/CAM composite, lithium disilicate, and zirconia.<sup>19,20</sup> The results indicated longer drilling times for zirconia and lithium disilicate, likely due to their higher physical inertness and density. Our findings recorded drilling speeds at  $22.2 \text{ mm/min}$  for direct resin composite,  $25.64 \text{ mm/min}$  for CAD/CAM nano-hybrid composite, and  $23 \text{ mm/min}$  for CAD/CAM PMMA.<sup>27</sup> These variations highlight the importance of selecting appropriate burs based on material characteristics to optimize drilling performance. Understanding the unique properties of each material will enable clinicians to choose the most effective burs, reducing wear on instruments and improving overall outcomes in restorative procedures.<sup>28</sup>

Due to the inherent features of highly controlled and standardized conditions in a laboratory setting, the results may not accurately reflect the clinical performance of the tested burs. Variations in loading, rotational speed, or cooling parameters of the handpieces may impact the performance of the burs. Furthermore, the study did not assess how cutting affects the integrity and mechanical properties of the restorative materials or account for patient-related factors, such as intraoral conditions and temperature fluctuations, which could influence the burs' performance in real-world settings.

Finally, future research should evaluate how different bur coatings affect the surface integrity and mechanical properties of dental materials and their subsequent interactions with bacteria.<sup>29</sup> Moreover, exploring the influence of various bur types on the mechanical properties and durability of the drilled materials would provide valuable insights for clinicians.<sup>20</sup> Further investigations into the coatings of burs are also warranted to understand better their impact on cutting efficiency and clinical performance, which will ultimately contribute to improved patient care in restorative dentistry and reduce the chairside time for both the patient and the clinician.

## CONCLUSIONS

From this study, the following could be concluded:

1. The cutting efficacy of the burs varied significantly in this study, with a diamond-coated dental bur with a multi-layer diamond coating and an additional metallic coating with nickel (Bur 7) achieving the overall highest efficacy.
2. The debris accumulation affects the cutting performance of the burs independently from the coating of the burs.
3. Significant differences in the cutting efficacy of the burs across materials were observed, with zirconia and lithium disilicate requiring more time to cut compared to polymethylmethacrylate and direct resin composites.

## CLINICAL RELEVANCE

Multilayer-coated diamond burs with an additional metallic coating increase the efficient cutting of ceramic and polymer-based restorative materials. Especially during the removal of monolithic zirconia reconstructions, the cutting efficacy of such burs could increase patient comfort, decrease chairside time, and contribute to sustainable dentistry.

## DISCLOSURE

The authors did not have any commercial interest in any of the materials used in this study, and no funding was received for it. The authors acknowledge the provision of prototype burs from Intensiv, Lugano, Switzerland, and other burs from Komet, Lemgo, Germany, which were used in this study. We

emphasize that these manufacturers had no role in the study design, data collection or analysis, decision to publish, or manuscript preparation.

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