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Comparative Study of the Cutting Efficiency and Working Life of Carbide Burs

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Keywords
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Abstract

Purpose: The aim of this study was to establish the wear and cutting efficiency of tungsten carbide burs from different manufacturers by performing cutting tests with machinable glass ceramic.
Materials and Methods: Cutting tests were performed with 70 tungsten carbide burs from seven manufacturers: (A) Coltene/Whaledent, (B) CEI, (C) Meisinger, (D) Axis, (E) Komet, (F) Kerr, (G) Edenta. All groups were examined under scanning electron microscope (SEM) before and after the cutting efficiency test for similarities and differences. A specially designed cutting device was used. An electric handpiece was operated at 200,000 rpm with a 120 ml/min coolant water supply rate. The burs were tested under a 165 g constant load using 3 mm wide Macor ceramic as substrate. For each bur the cutting procedure involved a total of five cuts of 3 minutes on every cut, with a total cutting time for each bur of 15 minutes. Data were analyzed using one-way ANOVA at 95.0% confidence level.
Results: Significant differences ($p < 0.05$) were found in the mean cutting rates of the different groups. Groups A and B showed the highest cutting rates. Higher cutting rates were associated with a longer bur lifespan. SEM photomicrographs of the burs and substrates revealed significant changes on the surfaces after the cutting process.
Conclusions: The morphology characteristics of tungsten carbide burs are related to their effectiveness. The group that presented the worst working life also showed substantial wear on its surface according to the results of SEM.

Cutting efficiency and abrasion are the most important properties of dental rotary instruments. In 1947, rotary instruments began to be manufactured in tungsten carbide alloy. This change allowed burs to be harder than those of previous instruments, which were manufactured in steel.[1-3] Tungsten carbide is the ideal material for burs in high-speed handpieces, as such burs are able to complete the work in a short period of time, owing to their hardness and cutting efficiency.[1-4]

When choosing burs from among the several products in the market, the dentist must consider various qualitative properties, such as cutting efficiency and lifespan. An optimally designed dental bur will have a long lifespan and will remove the most material with the least patient discomfort (i.e., due to heat, vibration, and pressure).[3,4] Many operating parameters must be considered when determining the cutting efficiency of dental burs, including rotation speed, applied pressure, turbine air pressure, differences in dental hard tissues, and bur type.[3] Several studies have used milling tests performed at a fixed speed (60,000-300,000 rpm), handpiece load (50-150 g), and attack angle (90°), making individual cuts within a few seconds.[3-5]

Natural teeth cannot be easily used as substrates in cutting studies, because of their lack of uniformity. Each tooth has anatomical and morphological variables that cannot be controlled. Moreover, it is very difficult to find a substrate with identical characteristics to dental tissues. A substitute substrate must be flat, isotropic, and uniformly thick, characteristics difficult to achieve with dental enamel.[1-6] Some studies have used bovine dentin instead of human dentin, claiming that bovine teeth are similar in structure and hardness to human teeth.[9,16,24] Machinable glass ceramics are commonly used as substitutes for natural teeth. They provide a more uniform and homogeneous substrate material than natural teeth, eliminating uncontrolled variables. Moreover, their hardness, elastic moduli, and thermal properties are comparable with those of dental enamel.[4,5]

It is generally accepted that Macor machinable glass ceramic is a reliable substitute for enamel/dentin, because the material behaves similar to enamel during the machining process.[4-6] Macor is a white, nonporous, and porcelain-like ceramic composed of 55% fluorophlogopite mica and 45% borosilicate glass. Macor is frequently used as a dental substitute, because its hardness (250 KHN), elastic modulus (66.9 GPa), and thermal properties are similar to those of dental enamel (300-400 KHN hardness, 84 GPa elastic modulus).[3-7] Although cutting data reported in previous studies are varied, certain trends are evident. For example, it is known that a bur operating at 60,000 rpm removes three to five times more enamel (with a comparable rise in temperature) as a low-speed (3000 rpm) standard dental engine and handpiece. The lower force exerted on the handpiece at higher speeds reduces frictional effects, increases cutting efficiency, and reduces expedient effort.[4-9]

The aim of this study was to establish the wear and efficiency of tungsten carbide burs produced by seven manufacturers. The 1558 type of bur was used, because its morphology (shape and size) is adequate and required for the methodology of this study. Cutting tests were performed with the burs and Macor machinable glass ceramic. The null hypothesis tested was that all groups of tungsten carbide burs have equal wearing and cutting rates.

Materials and methods

Materials

The tested burs for all groups were type 1558 (1.2 mm diameter), one-piece solid carbide, round-end, and cross-cut from Coltene/Whaledent (Langenau, Germany; Group A), CEI (Bridgewater Corners, VT; Group B), Hager & Meisinger GmbH (Neuss, Germany; Group C), Axis Dental Corp. (Coppell, TX; Group D), Komet Gerb Brasseler GmbH & Co. (Lemgo, Germany; Group E), Kerr Italia (Scafati, Italy; Group F), and Edenta (Au, Switzerland; Group G). Table 1 shows the burs and lot numbers used from each group.

Scanning electron microscopy

Ten samples of burs from each of seven manufacturers (Table 1) were examined under SEM (S-360, Cambridge Instruments, Cambridge, UK) to analyze the morphology of each bur before performing cutting tests. Photomicrograms were taken by dividing the active part of each bur in four places from the point to the base.[6-9] Thirty-two images of each bur were obtained by SEM. A complete image of the bur at 17× magnification was made (Fig 1). Three pictures at 90× magnification were made of 1/3 of each bur. SEM photomicrographs at 40× magnification of the Macor block were taken before and after the cutting procedure for each group. All images were used to perform an initial qualitative analysis of the surface morphology of tungsten carbide burs and the Macor block from each manufacturer.[6-9]

Table 1 Groups investigated in the study

Groups	Manufacturer	Lot number
Group A	DIATECH Speedster S5 314 012, 1558G (Coltène) ISO 500 314 137 008 012	Lot 3034584
Group B	Nr. 1558G BARRACUDA (CEI)	Lot 2010–572351
Group C	HM 31A 012 (Meisinger) ISO 500 314 139 008 012	Lot 823692
Group D	H1558RZ FG Razor (Axis)	Lot 607451
Group E	Nr. R1558/HR31R.314.012 (Komet)	Lot 347013
Group F	No. 400020-JL5/FG1558 (Kerr)	Lot 3472347
Group G	Nr. H31R.314.012/1558 (Edenta) ISO 500 314 137 007 012	Lot W11.002

Cutting procedure

Cutting tests were performed with a cutting machine, specially designed at the university based on previous studies.[3-5] The machine was calibrated and tested with every bur of the study to assure correct performance during the cutting test. An electric motor handpiece (Bien Air, Bienne, Switzerland) was mounted on a vertical wall, and moved perpendicularly on the substrate.[3-5] The cutting substrate was mounted rigidly in a stainless steel holder attached to the base of the cutting assembly.[3-5] The electric handpiece was operated at 200,000 rpm with a 120 ml/min coolant water supply rate. The cutting force applied to/on the handpiece head was 165 g (Fig 2). [10-15]

For the cutting procedure, the active part of the bur was placed in contact with the cutting substrate (Macor). The substrate was examined by SEM at magnifications of 15× and 40× to analyze its surface morphology before and after cutting.[7,8] Fabricated 200 mm^2 substrate blocks (3 mm thick)[14-17] were marked using a pencil and a digital gauge before placing them on the cutting machine. Consecutive marks were made every 4 mm on the substrate block, to determine the correct position of the bur and the distance of each cut performed in the block. This provided a better view of the lines made by the burs once all the cuts were made. Five consecutive cuts for 3 minutes each were made on each substrate block with every bur ($n = 10$) of all groups. The depth of the cut (material removed) and cutting time were measured with a digital vernier caliper and digital chronometer, respectively (Fig 3). At the end of the total cutting time, each substrate block was measured to determine the amount of substrate lost during the cutting process (Fig 4). After cutting, SEM images at 15× and 91.1× were obtained for all burs and blocks to observe the wear and morphological state of their surfaces.

Statistical analysis

The mean cutting distance for each group was calculated and analyzed using one-way ANOVA at the 95.0% confidence level.[18,19]

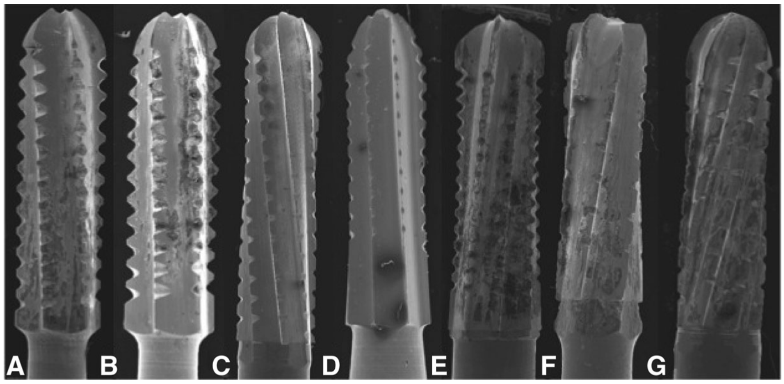

Figure 1 SEM photographs of each manufacturer's bur. (A) Coltene, (B) CEI, (C) Meisinger, (D) Axis, (E) Komet, (F) Kerr, (G) Edenta.

Figure 2 Test cutting machine.

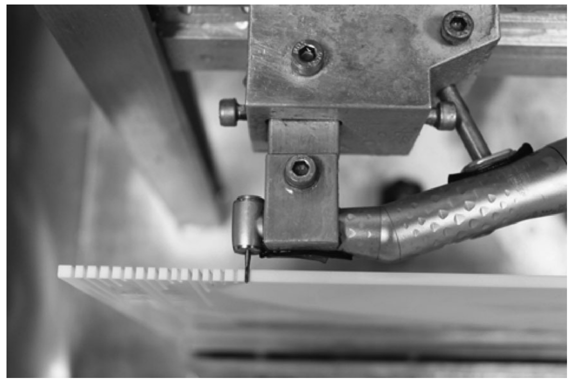

Figure 4 Cutting test performed on the machinable glass ceramic (Macor).

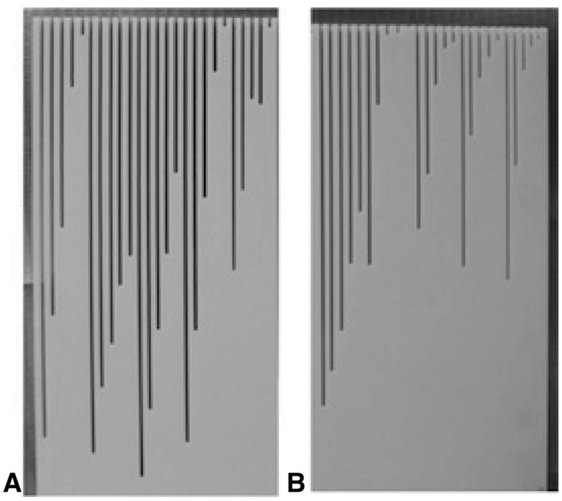

Figure 3 Representative photograph of the depths of the cuts produced by two burs: (A) Coltene, (B) CEI.

Results

Wear and cutting efficiency

ANOVA revealed significant differences in the wear and cutting efficiencies between groups (Fig 5). The mean cutting rate for distance was highest in group A (147.59 mm/min) and lowest in group G (9.15 mm/min). Group B was 80.94 mm/min, whereas groups C, D, E, and F had similar mean cutting rates (25.85, 48.61, 35.24, and 45.66 mm/min, respectively).

Figure 6 shows the cutting rate as a function of the number of cuts made in each group. The mean cutting rate was highest for the first cut in all groups (113.78 mm/min) and decreased with the number of cuts, with the lowest mean cutting rate at the fifth cut in all groups (21.90 mm/min). ANOVA revealed significant differences in the cutting distance between the total number of cuts, except for the fourth and fifth cuts (Fig 7).

Among the groups, group A showed the best cutting rates, with the least decrease in efficiency after every cut. The lowest cutting rates were found in group C, which also had the highest decrease in efficiency between the first and second cut (Fig 8).

Scanning electron microscopy of burs and substrate

Figure 9 shows SEM photomicrographs of burs before and after the cutting test. Comparison of the photographs in each group revealed wear on the cutting edges. Burs from group G showed marked deformations, which were made during the cutting test, on the bur edges. The active part of burs from group C also showed substantial wear on the 90× magnification SEM photomicrographs. SEM photomicrographs at 40× magnification

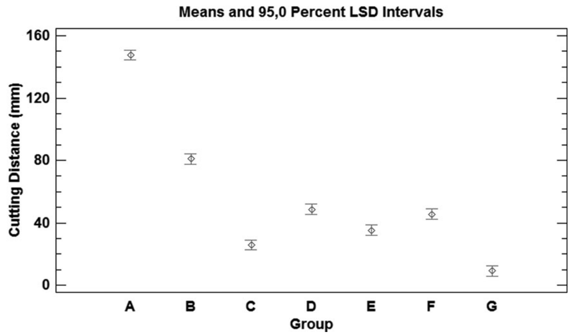

Figure 5 Cutting rates of different manufacturers.

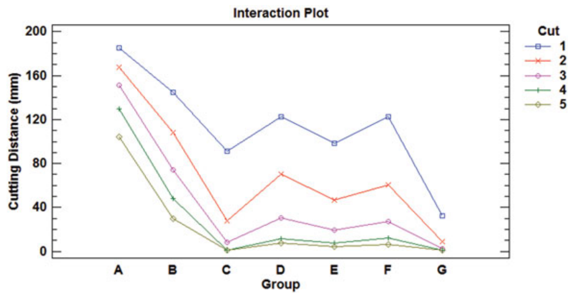

Figure 6 Relationship between manufacturers and number of cuts.

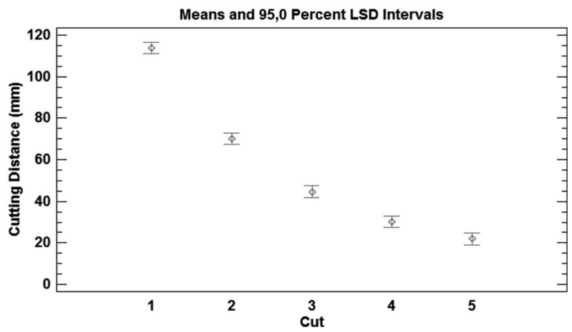

Figure 7 The mean cutting rates for the five cuts made by each group in the study.

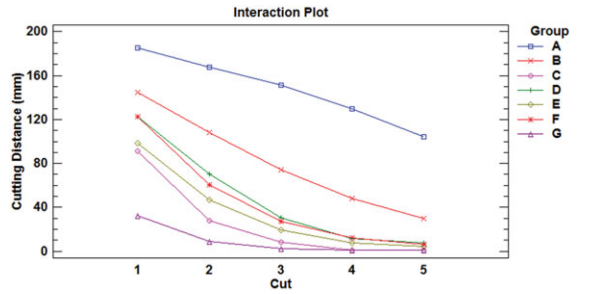

Figure 8 Comparison between the numbers of cuts made by each manufacturer.

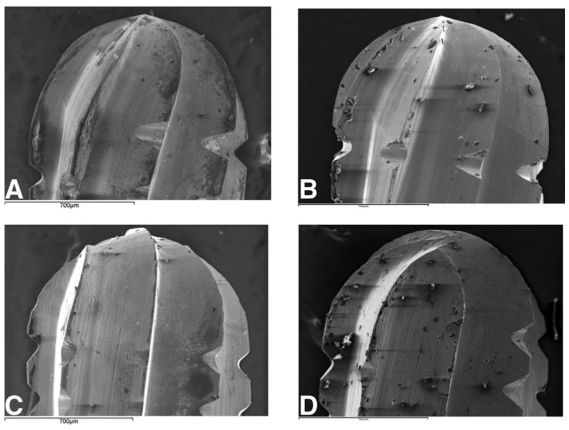

Figure 9 SEM photomicrographs of burs (90×) before and after cutting test. Bur from group G before (A) and after (B) cutting test. Note wear of the cutting edges after the test. Bur from group C bur before (C) and after (D) cutting test.

demonstrated that burs from groups C and G made cleaner and more linear cuts on the Macor block than burs from groups A and B (Fig 10).

Discussion

To ensure faster and better preparations, it is vital that restorative dentists choose appropriate materials.[19,20] The cutting efficiency of dental burs is influenced by many factors, including instrument design, operating variables, and bur properties.[21–23] In this study, burs from seven manufacturers were tested under the same operating conditions. Group A had the longest lifespan and cutting efficiency among all burs tested. As expected, all burs performed best during the first cut, with cutting efficiency decreasing from the first to the final cut. Greatest cutting efficiency was observed during the first 3 minutes of cutting. These results are consistent with those of other studies, in which the greatest efficiency for tungsten carbide burs was found in the first 2 to 2.5 minutes.[3] Carbide burs have a sharp cutting edge that wears out with every cut made. They are also brittle and susceptible to breakage.[2] These characteristics may explain the results found in this study. Differences between the groups could also be explained by the bur designs employed by each manufacturer. All the groups have similar morphological design; however, each manufacturer presented small differences in tooth geometry. These differences were also reflected in the morphological variations of the cuts made in the Macor block by the different groups. A bur with a large cutting edge could result in improved cutting efficiency and longer lifespan. The burs from groups A and B have a more pointed and sharp tooth design, and also show a deeper tooth shape angle. Group C shows teeth with flatter and smaller angles. In group D, the teeth do not extend through all the active part of the bur, and are more consecutive to each other with almost no cutting angle. Burs from group E also have pointed but smaller teeth than burs from groups A and B. Group F has almost no cutting angle, the surface of the bur is flatter, and the teeth are smaller and separated from each other. In group G, the teeth finish in a rounded shape, with more separation between each one (Fig 1). All the burs suffered cutting edge

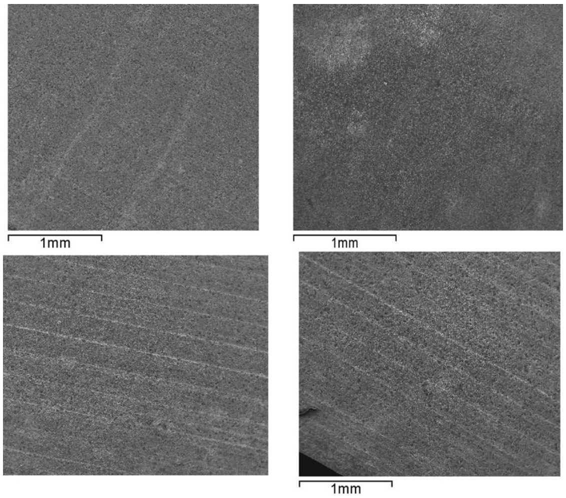

Figure 10 SEM photomicrographs of Macor block (40×) after cutting test. Blocks are shown with cuts made by bur from groups C (A), G (B), A (C), and B (D).

wear after the cutting procedures. The groups with deeper tooth angles and sharper edges (groups A and B) performed better in the cutting efficiency test among all groups. We used 200 mm^2 glass ceramic blocks (3 mm thick) as substrates. Similar previous studies have used rectangular Macor bars.[24]

In 1994, Ohmoto et al performed a cutting test with an air turbine handpiece, using a small load sensor to control the load applied by the operator.[9] Henry et al used a four-wheel carriage mounted on tracks and counterbalanced to overcome frictional forces, and a clamp to hold the substrate fixed in the center of the carriage.[1] Siegel and von Fraunhofer performed the cutting procedure with an L-shaped clear acrylic (Plexiglass) using a high-speed instrument mounted in a brass cylinder attached to a vertical wall.[2-4] In this study, a cutting machine was designed based on several previous studies.[4,5] We performed several pilot tests to calibrate the machine, as well as to determine the appropriate force to apply to the turbine head, correct water flow, angle of the bur, and important variables needed to simulate the clinical situation. In our cutting procedure, 3 minutes of continuous cutting and a total of five cuts per bur were employed. A 165 g load was applied on the handpiece head. Von Fraunhofer and Siegel[4] employed diamond burs, which made a series of ten cuts of 30-second duration each with a 147.5 g applied load. Other studies performed four cutting tests with each bur, including two tests each of 10- and 5-second duration, and measured the applied force in 5 to 10 g.[5,9] It is difficult to reproduce the clinical situation with the cutting procedure, because the clinical situation is highly dependent on the operator; therefore, it is important to control as many variables as possible in experimental studies.

The characteristics of rotary instruments are related to their effectiveness. In this study, the bur that presented the worst working life also showed substantial wear on its surface according to the results of SEM. Our results are similar to other studies that attribute the wear of the bur to its brittle nature and resulting fracture, as well as the impact produced by cutting with high-speed instruments.[22,25]

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Burs from groups A (147.59 mm/min) and B (80.94 mm/min) showed the highest cutting rate. These burs also had the largest cutting efficiency and lifespan per minute. The *p*-value (0.05) shown between brands used in the study was statistically significant.
2. The SEM photomicrographs of burs demonstrated that each bur experienced deformation on its surface edges as a result of cutting the machinable ceramics.
3. The SEM photomicrographs taken of the machinable ceramics (Macor) revealed a different cutting pattern for each bur. These patterns are related to the different morphologies of the burs in the study.

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