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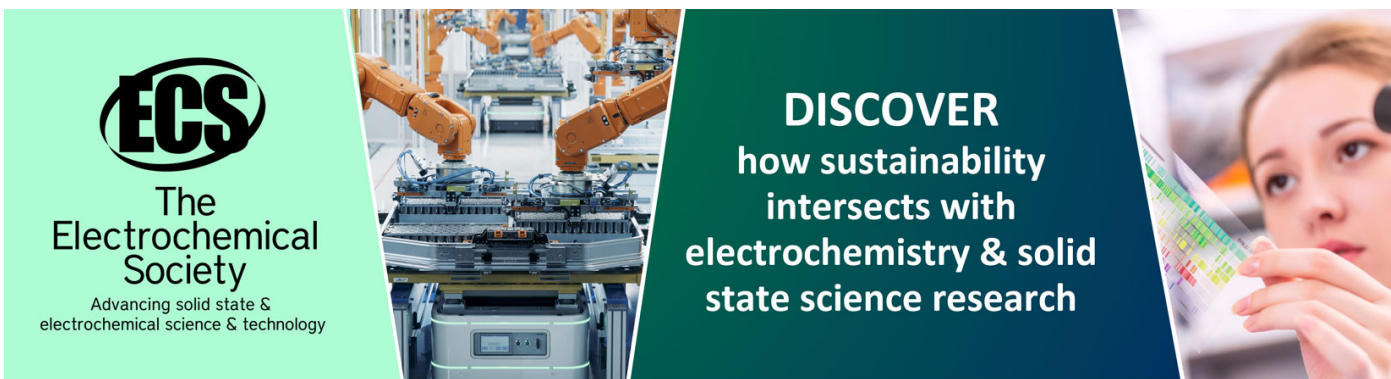
Laboratory analysis of dental sections made with commercial tungsten carbide burs coated with HFCVD diamond

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Laboratory analysis of dental sections made with commercial tungsten carbide burs coated with HFCVD diamond

F. Maass¹, Y. Aguilera² and J. Avaria³

¹ Departamento de Física, Universidad de Antofagasta, Av. Angamos 601, Antofagasta, Chile.

² Departamento de Ingeniería Industrial, Universidad de Antofagasta, Av. Angamos 601, Antofagasta, Chile.

³ Departamento de Odontología, Universidad de Antofagasta, Av. Angamos 601, Antofagasta, Chile.

E-mail: fdmaass@uantof.cl

Abstract. The objective of this study was to determine the cutting power of diamond burs obtained by the HFCVD deposition process. Diamond was deposited on the active part of each of a series of 10 commonly used Tungsten Carbide (WC) commercial burs. The quality of the section was compared with sections made by commonly used commercial burs, employing fresh human molars and a standard device [1]. Both burs and sections were analysed by using SEM and EDX techniques. The quality and tension of the deposited diamond coatings were analyzed by Raman Spectroscopy. The optimal thickness of the diamond coating which provided the best durability and finish of the sections was determined by comparative observations of results.

1. Introduction

The rotary instrument applied in dentistry always rotates on the same axis and its task is basically cutting, eroding, buring, finishing, and/or polishing [2]. The different compositions of the fundamental materials in teeth (dentine and enamel) present the main problem at the time of cutting. The dentine, which is less mineralized and of less hardness (Knoop = 68) is easier to cut than the enamel (Knoop = 343). WC burs are typically used for eroding soft tissue such as dentine and carious tissue, and diamond coated stones are used for perforation of the enamel [3]. WC work on the basis of a chiselling effect, which differs from perforations made by diamond-coated stones which function by abrasion. WC dental drills undergo premature deterioration if they are used in contact with enamel, and the diamond-coated stones quickly lose the effectiveness of the adhesive diamond grain by saturation of the intergrain spaces by residues of dentine, rapidly losing their cutting capacity [4]. Based on the preceding considerations, we decided to carry out a procedure for protecting the cutting surface of commercial WC drills with a layer of HFCVD (Hot Filament Chemical Vapour Deposition) diamond to prepare them for working well in cutting enamel while retaining the conventional chiselling properties of the WC bur. This could be accomplished due to the properties of the diamond coats which are extremely hard (Knoop hardness =10000) [5], homogeneous, and are capable of resisting wear and the corrosive effects inherent in dental practice.

2. Materials and methods

The active points of a series of 10 commercial WC (SSWhite FG-57) burs were coated with polycrystalline diamond using the HFCVD (Hot Filament Chemical Vapour Deposition) technique. The coating process was carried out in the glow discharge reactor installed at the Universidad de Antofagasta [1]. Ten discharges were effected, in each one varying the deposition time, and maintaining constant the remaining deposition parameters, including pressure (50 mbar), substrate temperature (800°C) and H and CH₄ gas flow, with 1% CH₄ in H₂. The ten burs which were coated included a range of different thicknesses from 1 µm to 20 µm. The rate of growth of the 10 coatings deposited averaged 3.4 µm/h. The burs were coated over time periods ranging from approximately 0.3 to 6.0 h.

Prior to each deposition, each bur was treated following a two-step procedure, including an ultrasonic bath, and chemical attack of the surface following the procedure described by Tsai *et al.* [6], which basically consists of cleaning the cobalt (6%) which is present on the active surface of the bur, and reducing its surface smoothness.

The various surface chemical components used in the manufacture of the burs, with and without coatings, were determined by EDX analysis [6], confirming the presence of chemical components typically present in commercial burs, and of the deposited diamond.

Scanning electron microscopy (SEM) was used to observe the structural morphology of the diamond deposition on the active portions of each bur. Raman spectroscopy was used to measure the quality of the diamond deposited and residual tension in the ten burs after being submitted to the same type of cutting using a standard device.

Standardized sections were carried out on natural samples of twenty fresh human teeth (upper third molars) with a standard device. Ten of the teeth were cut with commercial WC burs, and the other 10 with commercial burs coated with HFCVD diamond. SEM was then used to observe the roughness of the cavity surfaces, quality of the edge of the excavation[2] and the aspect of the cavity floor obtained in the cutting, comparing results obtained with both types of burs and those of different thicknesses.

3. Results

Observation of all the coated burs showed that the polycrystalline diamond was deposited in close conformity with the substrate, both on smooth surfaces, and grooved zones and blade edges, accurately maintaining the original profiles of the WC burs.

Figure 1a and 1b, shows the SEM analysis of the bur selected before and after the deposit from the series of 10, which showed the most resistance to wear and provided the best section finish. Its mean grain size was about 4 µm and coating thickness was about 15 µm.

The Raman spectroscopic analysis showed an intense peak representing the crystalline diamond (1,328.5 cm⁻¹), compared with the amorphous zone (1,538.1 cm⁻¹). The crystalline zone presented a tetrahedral *sp*³ coordination and the amorphous zone an *sp*² coordination. In general, these peaks did not shift after the CVD burs had been used in cutting, which indicated that they did not undergo tensional changes after being used in dental work.

A general SEM observation of the mesio-ocluso-distal cavities produced in teeth when using commercial WC burs, showed straight cuts with edges having some fractures of the enamel and no variations in depth. Undulations were observed on the walls of the cavity, as well as scratches on its floor, marking the traverse of the edges of the bur during the cutting (Figure 1c). SEM analysis of the mesio-ocluso-distal cavities made with WC burs coated with CVD diamond (Figure 1d), showed straight, even cuts with intact edges, smoothly polished walls, well defined angles and lines, and even floors with constant depth.

Observation of the edges of the HFCVD diamond-coated bur after its use in 60 seconds of continuous cutting on enamel, showed the diamond coating to be intact, and without detachment. Some adamantine residues were also observed. The chiselling function of the bur was not affected by enamel residues accumulating under the edges of the bur. Enamel residue was observed on bur edges

as a finely divided layer, and only in small areas. Observation also shows how the edges of an uncoated WC bur deteriorate after 60 seconds of cutting into enamel.

The profile of the EDX analysis showed the concentration curves for atoms of W, Co and C which when separately analyzed showed the different composition between the active head of the bur and the bur stem. A homogeneous concentration of Co is observed over the surfaces of the commercial WC bur before receiving the chemical pretreatment. After chemical treatment only a small amount Co remained. The analysis of a CVD diamond-coated bur showed compact, homogeneous, and continuous diamond in the substrate zone, and an abundance of W.

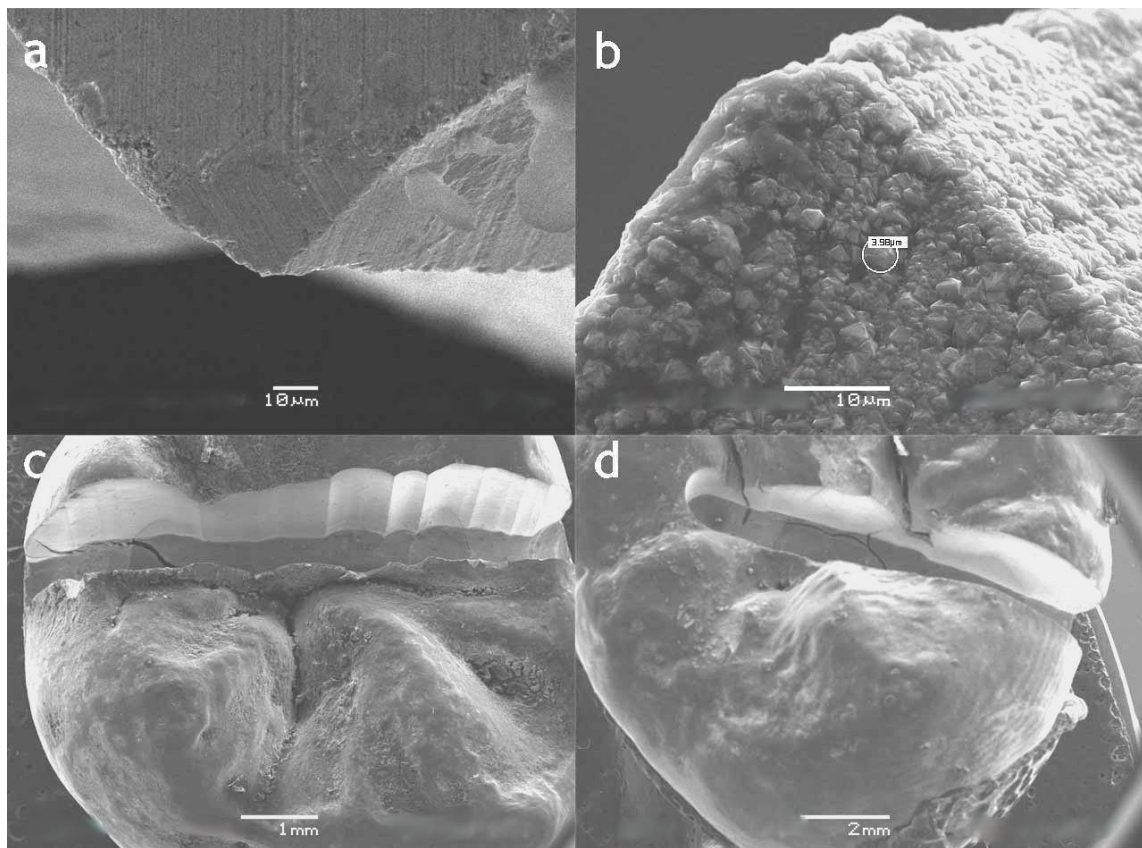


FIGURE 1. (a) SEM of a conventional WC bur without coating, (b) SEM of an HFCVD diamond coated WC bur, (c) micrograph of a human tooth with a mesial-occlusal-distal excavation made with a conventional WC bur White and d) with HFCVD diamond coated bur.

4. Discussion

The cutting efficiency of a commercial bur was not altered by CVD diamond coating, since the mass of the diamond deposited on the bur was evenly distributed and fine, retaining the chisel-cutting effects of the burs. On the other hand, conventional diamond coated stones have a lower, irregular surface density of diamond crystals which can produce vibration, irregularity of surface roughness, and accelerated loss of surface crystals, resulting in a shorter working life [7]. When the diamond crystals are very small, the bur has a reduced abrasive capacity, with the probability of generating greater heat and thus a greater need for the application of pressure during its use. In the case of commercially produced diamond-coated stones, there is insufficient retention of the diamond particles, limited cutting efficiency, minimal protection of the particles, inconsistent rotation, and obstructions.

The CVD diamond coating has the same thickness and grain size over the entire bur which does not affect its concentricity thus maintaining a balanced rotation free of vibration.

The kinetic coefficient of abrasion of CVD diamond CVD, similar to that of teflon, assisted by its high coefficient of thermal conductivity (2000 W/m/ K) which is five times higher than that of copper [6], allows heat to flow rapidly to the bur stem. Thus the surface of the cut in contact with the tooth remains at lower temperature, reducing the temperature produced when the bur is in contact with enamel, allowing cutting which is less damaging to the vitality of the pulp as well as reducing damage to the hard structure of the tooth.

5. Conclusions

The cutting quality obtained with 10 HFCVD diamond-coated WC burs was superior to that of conventional WC burs. This coating allowed making opening cuts with less wear than that experienced with conventional WC burs. The CVD diamond deposited on the active portion of the bur followed all the concavities of the substrate of the WC burs, producing a more durable WC bur, which gave better sections and lower heat generation. The thickness of the HFCVD diamond-coated bur which was optimal under the conditions tested was about 15 μm . HFCVD diamond-coated WC burs are proposed as replacement to both commercial WC burs and commercial diamond-coated stones, which could result in reduced operator time due to avoidance of switching between one tool and another, as well as decreasing instrument costs.

Acknowledgments

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