The Use of CVD Diamond Burs for Ultraconservative Cavity Preparations: A Report of Two Cases

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ABSTRACT

During the past decades, scientific developments in cutting instruments have changed the conventional techniques used to remove caries lesions. Ultrasound emerged as an alternative for caries removal since the 1950s. However, the conventional technology for diamond powder aggregation with nickel metallic binders could not withstand ultrasonic power. Around 5 years ago, an alternative approach using chemical vapor deposition (CVD) resulted in synthetic diamond technology. CVD diamond burs are obtained with high adherence of the diamond as a unique stone on the metallic surface with excellent abrading performance. This technology allows for diamond deposition with coalescent granulation in different formats of substrates. When connected to an ultrasonic handpiece, CVD diamond burs become an option for cavity preparation, maximizing preservation of tooth structure. Potential advantages such as reduced noise, minimal damage to the gingival tissue, extended bur durability, improved proximal cavity access, reduced risk of hitting the adjacent tooth resulting from the high inclination angles, and minimal patient's risk of metal contamination. These innovative instruments also potentially eliminate some problems regarding decreased cutting efficiency of conventional diamond burs.

CLINICAL SIGNIFICANCE

This clinical report presents the benefits of using CVD diamond burs coupled with an ultrasonic handpiece in the treatment of incipient caries. CVD diamond burs coupled with an ultrasonic device offer a promising alternative for removal of carious lesions when ultraconservative cavity preparations are required. Additionally, this system provides a less-painful technique for caries removal, with minimal noise.

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INTRODUCTION

Processed diamonds are one of the most technologically advanced materials available today. They have a unique combination of excellent physical and chemical properties. Therefore, diamonds of this type are promising materials for numerous applications. For example, diamond films are of interest for many biological applications because of their high hardness, low friction coefficient, high wear resistance, chemical inertness, and biological compatibility.[1,2]

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The ability to prevent the occurrence of dental caries and to restore carious teeth through remineralization should relegate tooth restorations involving the cutting of teeth as the last option in the quest to preserve healthy dentition. When the cutting of a tooth to remove carious lesions is necessary, there is growing evidence that tooth preparation should be just large enough to allow caries removal for long-term preservation of the tooth restoration unit.[3–7]

Conventional diamond burs, dating from the 1950s, have some inherent limitations resulting from the manner in which they are made; by plating diamond particles on stainless steel shanks using a galvanic process. One of the main problems associated with diamond burs is their short lifetime resulting from their repeated sterilization. This causes a decrease in their cutting effectiveness by affecting the matrix that binds diamond particles to the shank.[8,9]

Additionally, the use of diamond burs coupled with conventional handpieces represents an unpleasant and painful procedure for the patient. Noise and mechanical vibrations in such cases cause great discomfort for patients.

Furthermore, it is hard to solely remove small proximal caries lesions because of the reduced inclination angles of rotary instruments, which results in cavities larger than necessary. This limitation is contrary to the good of minimal intervention during caries removal.[3,5–7] Hence, new durable instruments are being developed in an attempt to achieve painless techniques to remove carious lesions, with minimal removal of tooth structure.

In light of the current trend toward minimally invasive dentistry, many cavity preparation techniques have been introduced as alternatives to common bur instrumentation.[4,10–16] Some advances, such as the use of laser, sonic devices, and air abrasion, have occurred.[4,10–16] Nevertheless, experiences with lasers and air abrasion have shown that these alternatives impose difficulties in preparing well-defined cavities.[13]

To date, two potential alternatives for caries removal obtained from diamond powder aggregated on a metal surface are available. The first is the sonic system, which comprises an aggregated diamond powder oscillating instrument used for cutting and finishing proximal microcavities.[14–16] The second is the Two Striper brand (Premier Products Co., Philadelphia, PA, USA) of dental instruments, in which diamond powder crystals are permanently bonded to a hardened stainless steel shank. According to the manufacturer, this patented process yields long-lasting instruments with a more precise cut than other diamond instruments.

Around 20 years ago, chemical vapor deposition (CVD) of diamonds became a reality. In 1996, the CVD diamond burs (CVDentus, Clorovale Diamantes Ind. e Com. Ltda, São José dos Campos, São Paulo, Brazil) coupled with an ultrasonic handpiece were introduced in dentistry to eliminate some problems related to traditional diamond burs.[1]

The CVD technology is a process for obtaining coalescent diamond films in grinding layers. This method contributes to a very high adherence between the diamond film and the metal surface, induced by a chemical bond instead of a physically bonded diamond powder. Because of the inherent roughness of the sharp-edged and polycrystalline diamond layers, these tools are well suited for tooth grinding.[1]

The new CVD diamond burs were obtained by a CVD of a diamond film over a molybdenum substrate. Diamond films were synthesized inside an enhanced hot-filament-assisted reactor. This manufacturing process, and the adaptation to an ultrasonic handpiece, provide some potential advantages: minimal noise, no damage to the gingival tissue, extended bur durability, and the preservation of the healthy tooth structure.[1,2,17] However, further laboratory and clinical studies are required to support these potential advantages.

It is worth mentioning that the CVD diamond burs present unidirectional oscillating movement with maximal displacement ranging from 50 to 60 µm, at oscillating frequencies ranging from 25,000 to 32,000 Hz. Therefore, while CVD diamond burs coupled with ultrasound require only a slight touch to promote tooth grinding, conventional rotating technique promotes greater tooth grinding.

The aim of this paper was to present two cases of caries removal using the CVD diamond burs technique.

CASE REPORTS

Case #1

A 32-year-old Caucasian male presented to the Clinic of Operative Dentistry at the Bauru School of Dentistry, University of São Paulo, Brazil, for routine treatment. He complained of pain resulting from the presence of a proximal caries lesion in the right maxillary central incisor (Figure 1). A treatment plan for caries removal and tooth restoration was established after clinical and radiographic evaluations.

After prophylaxis and protection of the adjacent tooth with a metal band, a water/air spray was applied toward the lesion. The decayed tooth was then separated from the adjacent tooth by using an "Elliot" separator device (Figure 2). CVD diamond burs coupled with an ultrasonic handpiece were used to remove the carious lesion (Figures 3 and 4). Minimal noise, as compared with the conventional technique, was encountered during caries removal.

The enamel and dentin were etched with Vitremer primer (3M-ESPE, St. Paul, MN, USA) and no rinse was performed (Figure 5). The adequate control of humidity after primer etching is extremely important, thus total desiccation of dentin should be avoided.

The resin-modified glass ionomer cement was indicated because the

Figure 1. Presence of a proximal caries lesion in the maxillary right central incisor. The minimal invasive technique was indicated.

Figure 2. Aspect of the stabilized rubber dam. The field was adequate to the restoration placement. The separation from the adjacent tooth was performed with the "Elliot" separator device.

patient was a high caries-active individual. In addition, the properties of this restorative material make it useful for the restoration of carious lesions in low-stress areas such as smooth surfaces and small anterior proximal cavities.[18,19]

Glass ionomer cement was injected with a Centrix syringe (Centrix Inc., Shelton, CT, USA) (Figure 6). After being placed, the glass ionomer cement was covered with a single celluloid strip, and held over, compressed with the aid of a spatula (Figure 7). Finally, the material was photocured (Figure 8).

One week later, the excess material was trimmed with flexible discs and sandpaper strips (Figure 9). It is extremely important to protect the

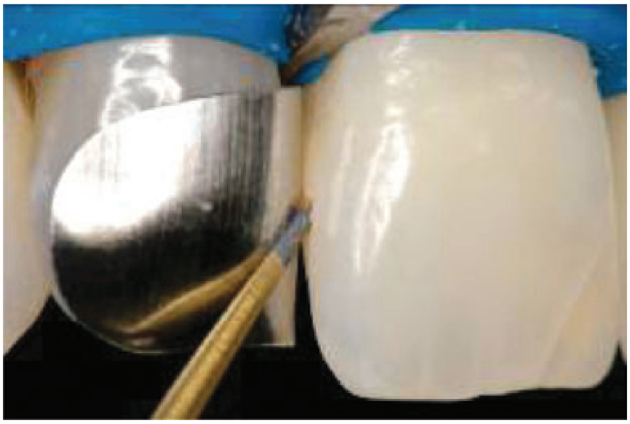

Figure 3. After prophylaxis and protection of the adjacent tooth with a metal band, the preparation was performed under a water/air spray. This procedure was performed without local anesthetic infiltration.

Figure 4. After the complete removal of the decayed tissue, the cavity's aspect could be observed. Note the quality and the precision of the borders. Such cutting precision was achieved because of the adequate control of the power to activate the ultrasound.

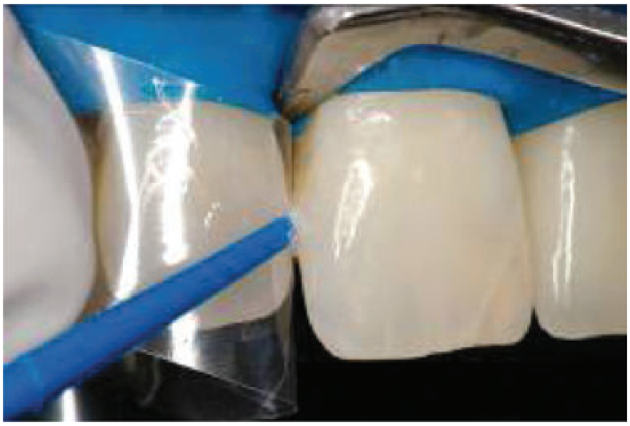

Figure 5. After protection of the adjacent tooth with a celluloid strip, the primer was applied for 30 seconds and then photocured.

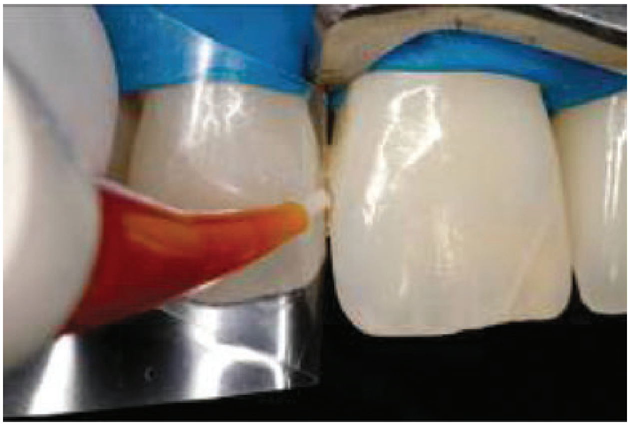

Figure 6. The cavity was filled with a glass ionomer cement type II (Vitremer, 3M-ESPE, St. Paul, MN, USA) using a Centrix syringe (Centrix Inc., Shelton, CT, USA).

Figure 7. After placement of the glass ionomer cement, it was covered with a celluloid strip and subsequently held over, compressed with the aid of a spatula.

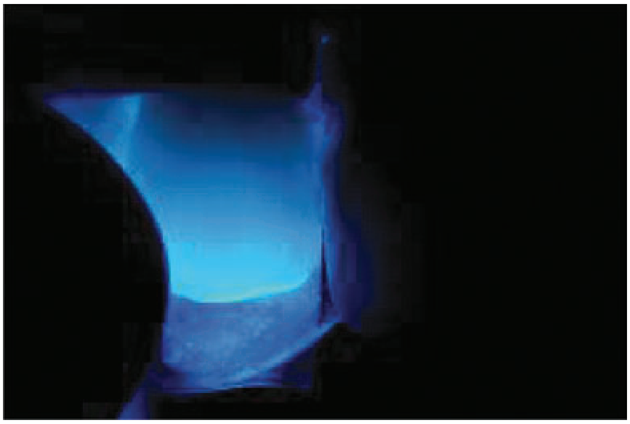

Figure 8. The restorative material was photocured for 45 seconds.

surface with a layer of petroleum jelly to prevent the loss or gain of water. Additional varnish to protect the restoration was applied (Figure 10). Despite its opacity, the glass ionomer cement provided an excellent esthetic outcome (Figure 11).

Case #2

A 20-year-old Caucasian male presented to the Clinic of Operative Dentistry at the Bauru School of Dentistry, University of São Paulo, Brazil, for routine treatment. The patient reported pain when drinking cold liquids. This symptom ceased with the end of the stimulus. Clinical and radiographic examination showed incipient caries on the occlusal surface of the right mandibular first molar (Figure 12).

The treatment was carried out without local anesthesia. The operating field was isolated with a rubber dam, and prophylaxis was performed.

Carious tissue was removed using a CVD diamond bur coupled with an ultrasonic device, which is usually found in dental offices and used for calculus removal (Figure 13).

Access to the carious tissue also was facilitated owing to the shape of the bur. Water/air spray was systematically used. An ultraconservative cavity preparation with well-defined borders was obtained (Figure 14).

The enamel and dentin were etched with 37% phosphoric acid and rinsed with water for 15 seconds. The adhesive system (Single-Bond, 3M-ESPE) was applied in two layers with a microbrush. A resin composite (Z 250, shade A2, 3M-ESPE) was inserted in two small oblique increments, which were light-cured for 40 seconds each (Figure 15). The rubber dam was then removed. When the occlusion was checked, little excess needed to be trimmed. The final restoration presented a satisfactory appearance (Figure 16).

DISCUSSION

CVD technology has two main potential advantages: it allows more precise cavity preparations and it reduces the patient's discomfort normally generated from mechanical vibrations produced by conventional drilling during tooth preparation.

Preservation of tooth structures during caries removal requires the development of skills to allow the preparation of minimally invasive cavity designs.[5] The CVD diamond burs promote more precise cavity preparations, resulting in more

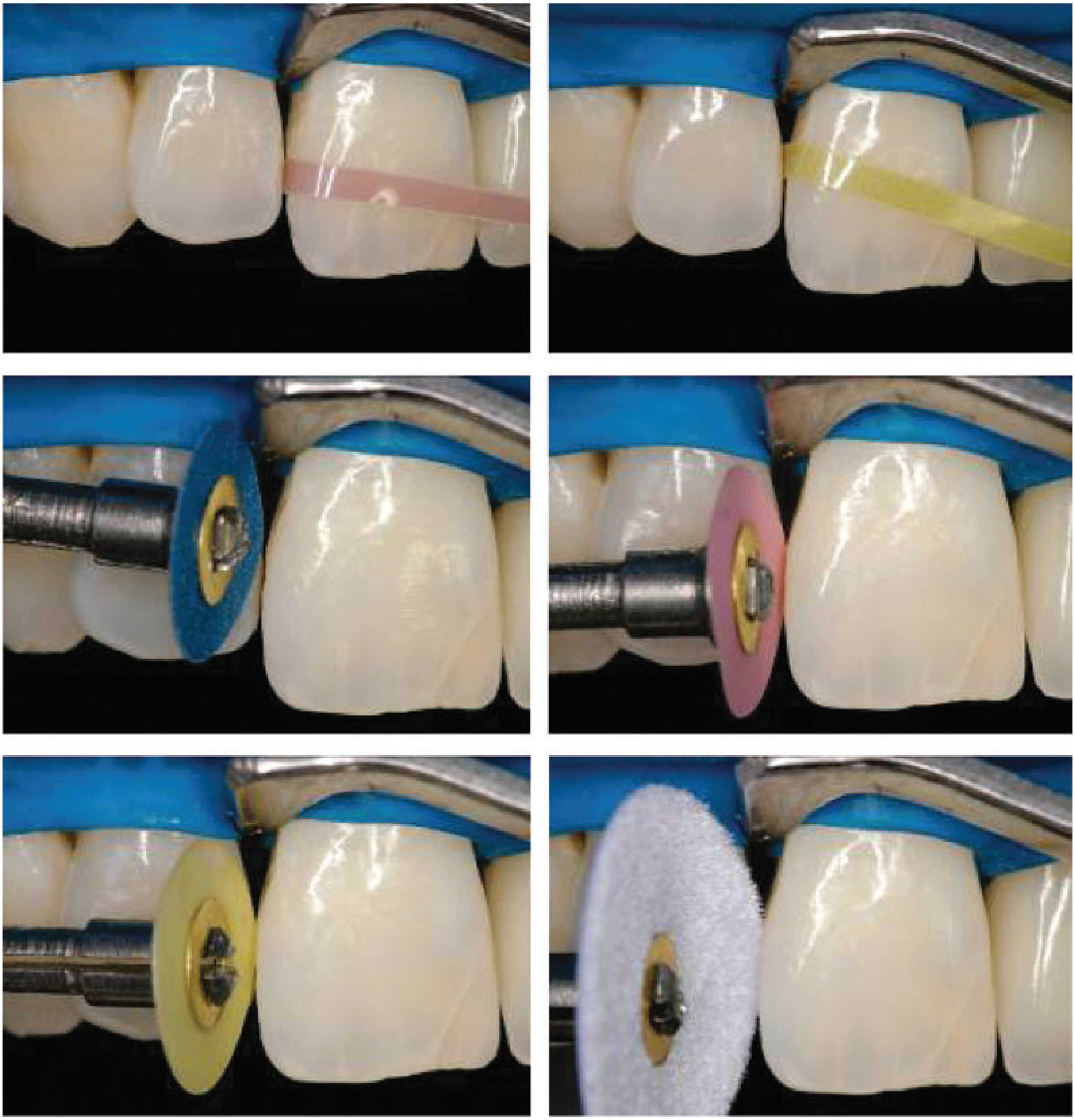

Figure 9. The polishing procedure was performed with diamond strips and disks, following the order of the grit scale.

Figure 10. The restoration was protected with varnish in order to prevent early gain and loss of water.

Figure 11. Frontal view of the final aspect of the restoration after rubber dam removal.

Figure 12. Preoperative view of the right mandibular first molar with occlusal caries lesion.

Figure 13. The cavity preparation was performed under a water/air spray using a CVD diamond bur coupled with an ultrasonic device.

Figure 14. The finished aspect of the cavity preparation.

Figure 15. The final esthetic aspect of the restoration.

Figure 16. Postoperative occlusal view of the final restoration after rubber dam removal.

conservation of sound tooth structure. This technology has already proven itself in the manufacture of ultraprecision instruments, microsystem technology, and optic lenses.[2,20] The preservation of healthy tooth structure using minimally invasive cavity designs is now one of the primary goals of modern operative dentistry.[3–7]

Cavity preparation with CVD diamond burs coupled with the ultrasound device differs from that obtained with the conventional technique using diamond burs. The use of CVD diamond burs requires a thorough knowledge of the instrument. It must be handled with light hand pressure, just enough to guide the instrument. If too much load pressure is applied, the cutting effectiveness is reduced and pain, noise, and heat will be generated. In addition, the power required for the ultrasound device is different for each type of CVD diamond bur and clinical procedure.

In both cases presented here, the patients did not complain of pain during cavity preparation with CVD diamond burs. In the same way, a pediatric case report documented that a 2-year-old patient did not complain of pain during cavity preparation.[21] The different movements of these burs compared with the conventional ones might explain this clinical observation.

The ultrasound-coupled CVD diamond burs present additional potential advantages, such as the capability of working at high inclination angles, resulting in safer proximal finishing with less chance of hitting the adjacent tooth. As a consequence, the CVD diamond burs system can be positioned very accurately, even at sites that are usually not accessible to the handpiece of conventional rotary instruments.

The CVD system does not lose superficial diamond during cutting, consequently extending the lifetime of the instrument.[1,22] Valera and colleagues,[22] using abrading and perforation tests on hard materials, concluded that the CVD diamond burs presented superior performance compared with the conventional ones. This feature significantly decreases the patient's risk of metal contamination. The evident biocompatibility, along with the corrosion resistance and notable mechanical integrity of the CVD diamond, suggest that diamond-coated surfaces may be highly desirable in a number of biomedical applications.[23]

The problems related to the sterilization of conventional burs appear to be related to the presence of the metallic binder between diamond particles.[17] Consequently, the CVD diamond burs, with their unique full diamond-coating structure and manufacturing methods, offer promising perspectives with regard to sterilization methods as a result of the high minimization of damage to the binder.[24]

It is well recognized that the grinding efficiency of conventional diamond burs deteriorates with repeated use.[25] Replacement of such instruments is necessary because of the wear of their tips where the diamond grains wear off faster than on the rest of the bur.[17,25] The diamond particles are frequently sheared off, causing the premature wear of the bur, which results in the smearing of the metallic binder onto the patient's teeth.[17,25]

Nowadays, as a result of the advances in the field of CVD technology, good-quality polycrystalline diamond films can be deposited, which display good adhesion. Most of the work performed with CVD technology has been carried out on flat silicon substrates, with only a few articles on nonplanar substrates, such as dental burs.[1,26,27] Sein and colleagues[28] demonstrated that diamond films were successfully deposited on an etched and abraded cemented tungsten carbide (nonplanar) substrate by using a modified CVD process.

Future work will concentrate on diamond growth optimization studies and on the performances of diamond dental tools such as burs and drills.[28,29] To date, there are no well-controlled or evidence-based clinical trials of CVD diamond burs. Consequently, it is always important to point out that new products should be carefully introduced to the clinical practice and used in a conservative manner.[30]

CONCLUSION

Based on the two clinical reports presented here, the CVD diamond burs promoted ultraconservative cavity preparations and satisfactory clinical outcomes.

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REFERENCES

1. Trava-Airoldi VJ, Corat EJ, Leite NF, Nono MC, Ferreira NG, Baranauskas V. CVD diamond burrs—development and applications. Diamond Relat Mater 1996;5:857–60.
2. Trava-Airoldi VJ, Corat EJ, Baranauskas V. Diamond chemical vapor deposition: emerging technology for tooling applications. Key Eng Mat 1998;138–40: 195–244.
3. Summitt JB. Conservative cavity preparations. Dent Clin North Am 2002;46:171–84.
4. Milicich G. The use of air abrasion and glass ionomer cements in microdentistry. Compend Contin Educ Dent 2001;22:1026–30, 1032–4, 1036–9, quiz 1045.
5. Mount GJ, Ngo H. Minimal intervention: early lesions. Quintessence Int 2000;31:535–46.
6. Osborne JW, Summitt JB. Extension for prevention: is it relevant today? Am J Dent 1998;11:189–96.
7. Murdoch-Kinch CA, McLean ME. Minimally invasive dentistry. J Am Dent Assoc 2003;134:87–95.
8. Arcuri MR, Schneider RL, Strug RA, Clancy JM. Scanning electron microscope analysis of tooth enamel treated with rotary instruments and abrasives. J Prosthet Dent 1993;69:483–90.
9. Gureckis KM, Burgess JO, Schwartz RS. Cutting effectiveness of diamond instruments subjected to cyclic sterilization methods. J Prosthet Dent 1991;66:721–6.
10. Van Meerbeek B, Munck J, Mattar D, Van Landuyt K, Lambrechts P. Microtensile bond strengths of an etch & rinse and self-etch adhesive to enamel and dentin as a function of surface treatment. Oper Dent 2003;28:647–60.
11. Ritter AV. Lasers in dentistry. J Esthet Restor Dent 2006;18:58.
12. Adams TC, Pang PK. Lasers in aesthetic dentistry. Dent Clin North Am 2004;48:833–60.
13. Rainey JT. Air abrasion: an emerging standard of care in conservative operative dentistry. Dent Clin North Am 2002;46:185–209.
14. Hugo B, Stassinakis A. Preparation and restoration of small interproximal carious lesions with sonic instruments. Pract Periodontics Aesthet Dent 1998;10:353–9.
15. Opdam NJ, Roeters JJ, van Berghem E, Van Berghem E, Eijsvogels E, Bronkhorst E. Microleakage and damage to adjacent teeth when finishing Class II adhesive preparations using either a sonic device or bur. Am J Dent 2002;15:317–20.
16. Liebenberg WH. Sonicsys Approx: an innovative addition to the restorative continuum. Pract Periodontics Aesthet Dent 1998;10:913–22.
17. Silva AP, Menezes MM, Araújo RM. Influence of cleaning and sterilization on the cut of diamond burs. J Bras Clin Odontol Integr 2002;6:239–45.

18. Lobo MM, Goncalves RB, Ambrosano GM, Pimenta LA. Chemical or microbiological models of secondary caries development around different dental restorative materials. J Biomed Mater Res B Appl Biomater 2005;74:725–31.

19. Pin ML, Abdo RC, Machado MA, Silva SM, Pavarini A, Marta SN. In vitro evaluation of the cariostatic action of esthetic restorative materials in bovine teeth under severe cariogenic challenge. Oper Dent 2005;30:368–75.

20. Trava-Airoldi VJ, Borges CFM, Moisan M. Improved optical diamond film coating on fused silica using a surface-wave-sustained plasma. Appl Opt 1997;36:4400–2.

21. Antonio AG, Primo LG, Maia LC. Case report: ultrasonic cavity preparation—an alternative approach for caries removal in paediatric dentistry. Eur J Paediatr Dent 2005;6:105–8.

22. Valera MC, Ribeiro JF, Trava-Airoldi VJ, Corat EJ, Peña AFV, Leite NF. CVD diamond stones. Rev Gaúcha Odontol 1996;44:104–8.

23. Tang L, Tsai C, Gerberich WW, Kruckeberg L, Kania DR. Biocompatibility of chemical-vapour-deposited diamond. Biomaterials 1995;16:483–8.

24. Borges CFM, Magne P, Pfender E, Heberlin J. Dental diamond burs made with a new technology. J Prosthetic Dent 1999;82:73–9.

25. Siegel SC, von Fraunhofer JA. Assessing the cutting efficiency of dental diamond burs. J Am Dent Assoc 1996;127: 763–72.

26. May PW, Rego CA, Thomas RM, Ashford MNR, Rosser KN. CVD diamond wires and tubes. Diamond Relat Mater 1994;3:810–3.

27. Trava-Airoldi VJ, Moro JR, Corat EJ, Goulart EC, Silva AP, Leite NF. Cylindrical CVD diamond as a high-performance small abrading device. Surf Coat Technol 1998;108–9:437–41.

28. Sein H, Ahmed W, Rego C. Application of diamond coatings onto small dental tools. Diamond Relat Mater 2002;11:731–5.

29. Trava-Airoldi VJ, Corat EJ, Ferreira NG, Leite NF. CVD-diamond: an overview of research and development at INPE. Braz J Phys 1997;27:88–92.

30. Donovan TE. Promising indeed: the role of “experts” and practitioners in the introduction and use of new materials and techniques in restorative dentistry. J Esthet Restor Dent 2004;16:331–4.

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