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Digital image analysis method to assess the performance of conventional and self-limiting concepts in dentine caries removal

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ABSTRACT

Objective: To assess dentine caries removal effectiveness (CRE) and minimal invasiveness potential (MIP) of carbide and polymer burs.
Methods: Sectioned carious molars were photographed. Digital images were taken, before and after caries removal, using a Digital Single Lens Reflex camera. The following regions of interest were measured using visual criteria: Residual Infected Dentine (RI), Residual Affected Dentine (RA), Removal Sound Dentine (RA), Prepared Cavity (PC) and Removed Sound Dentine (RS). CRE was determined on basis of: relative residual infected dentine (RI/II), relative residual carious-affected dentine (RA/IA) and total relative residual dentine (RI + RA/II − IA). MIP was determined on basis of: infected dentine cavity size (PC/II), total relative cavity size (PC/II + IA), and corrected relative cavity size (PC − RS/II + IA).
Results: The polymer bur showed the highest preservation of carious-affected dentine after excavation, when the RA/IA ratio was studied. Both kind of burs showed similar values after assessing the RI/II and RI + RA/II − IA ratios. The infected dentine relative cavity size (PC/II) was higher when the carbide bur was used. Both burs attained similar PC/II + IA and PC − RS/II + IA ratios.
Conclusions: Polymer burs accomplished the concept of minimal-invasive dentistry, showing its self-limiting ability. The minimal-invasiveness potential showed that carbide burs resulted in the worst compromise between effective and selective infected-caries removal.

1. Introduction

Dental caries is the localised destruction of susceptible dental hard tissue by acidic by-products from bacterial fermentation of dietary carbohydrates.[1] It is a bacterial driven, generally chronic, site-specific, multifactorial, dynamic disease process that results from the imbalance in the physiologic equilibrium between the tooth mineral and the plaque fluid. The pH drop

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Abbreviations: RA, residual carious-affected dentine; IA, initial carious-affected dentine; RA/IA, relative residual carious-affected dentine; RI, residual infected dentine; II, initial infected dentine; RI/II, relative residual infected dentine; (RA + RI)/(IA + II), total relative residual dentine; PC, prepared cavity; PC/(II + IA), total relative cavity size; RS, removed sound dentine; (PC − RS)/(II + IA), corrected relative cavity size; PC/II, infected dentine relative cavity size.

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results in net mineral loss over time.[2] A caries/carious lesion is also a detectable change in the tooth structure that comes from the biofilm–tooth interactions occurring due to the disease caries.[1] It is the clinical manifestation (sign) of the caries process, *i.e.*, the dynamic sequence of biofilm–tooth interactions that can occur over time on and within a tooth surface.[1] Thus, the caries process occurs in the biofilm, and the interaction of the biofilm with the tooth surface may result in the formation of the caries lesion, the consequence or reflection of the process.[3] The caries lesion, initially is noncavitated (*i.e.*, macroscopically intact), but might progress to cavitation, eventually. Dental caries is not the cavity in the tooth; therefore, we cannot remove all the caries.[4]

When the caries lesion has progressed to a considerable length along the dentine–enamel junction will the subjacent dentine be demineralised and become recognisable by a yellow to dark-brown discoloration.[5] Dentine is a mineralised tissue permeated by cellular extensions from odontoblasts, which are located at the peripheral zone of the pulp adjacent to the predentine.[6] This model dentine is far from the clinically more relevant substrate remaining after caries removal, which includes carious, sclerotic, eroded and sound dentine. Two layers are described in carious dentine. The superficial layer is called caries-infected dentine (CID), and it refers to the heavily infected, extensive decalcified, irreversibly denatured outer dentine, and physiologically unrecalcifiable dentine. The deeper layer is the caries-affected dentine (CAD), which is bacteria-free, potentially and physiologically recalcifiable dentine with expanded odontoblastic processes, sound collagen fibres, and apatite crystals bound to the fibres.[7,8]

The minimal intervention approach concept implies that caries-infected dentine should be removed selectively, in order to preserve as much as possible caries-affected dentine.[9,10] Intact collagen forming the demineralised, slightly softened inner dentine layer of a caries lesion can be remineralised, *i.e.*, hardened, and therefore, from a biologic and therapeutic point of view, must not necessarily be eliminated.[11] Carious dentine has been removed mechanically with hand excavators or burs,[12,13] using tactile and optical parameters as criteria for the removal of tissue. During excavation, practitioners tend to include all soft and discolored tissues in order to ensure complete elimination of the infected layers.[14] Diamond and tungsten carbide burs can remove caries-infected and caries-affected simultaneously, with possible extension into the underlying sound dentine.[15] Carbide burs in low-speed counter-angle handpieces are the most efficient method to excavate carious lesions in term of time and are the most widely used caries-excavation method.[5] A novel, self-limiting concept in mechanical caries removal, the polymer bur, has been developed with a particular hardness and wear resistance that reportedly enable it to remove only the soft caries-infected, leaving the caries-affected dentine intact.[5,15,16] This polymer bur is harder than infected dentine but softer than normal, sound dentine and even than sclerotic dentine, and it is supposed to provide a very selective caries removal.[16] Although the self-limiting concept of caries removal appears to have potential merits, the efficacy of the polymer bur to remove infectious carious tissues and to limit the invasiveness potential, have not been completely established, and still remains controversial.

Emerged as an alternative to conventional methods, digital imaging is a field of rising interest in dentistry with a wide range of applications, due to its potential to capture accurate color of the sample, as well as form and texture.[17,18] The image processing and/or digital image analysis are the ideal complement for any digital image acquisition process because they represent a non-destructive method and powerful tools for the study of a wide range of materials and parameters, and are lately extensively used in dentistry.[19–21] The use of digital imaging and subsequent image analysis is therefore expected to successfully assess the performance of different types of burs in the carious excavation process.

The objective of the present study is to assess the performance of carbide and polymer burs in the dentine caries removal effectiveness and minimal invasiveness potential, employing digital image analysis. Two null hypotheses will be tested: (1) the caries-affected dentine is not preserved, regardless the type of bur used (carbide *vs* polymer) and (2) there is no difference in the amount of caries-affected dentine removed by carbide or polymer burs.

2. Material and methods

2.1. *Specimen preparation*

Thirty extracted permanent molars with caries were employed. The teeth were collected after the patients' informed consent under a protocol approved by the Institution Review Board. They were immediately stored at 4 °C in 0.1% thymol solution for less than 3 months.

The teeth had their roots embedded in a mould of acrylic resin and were then bisected through the centre of the carious lesion with a low-speed diamond saw (IsoMet, Buehler, IL, USA). Before caries removal, one cut surface of each tooth was digitally photographed (Sony α300, Sony Corp, Japan) and all images were assigned to the ''pre stack''. The teeth halves were reassembled with cyanoacrylate from the outer surface of the crown matching both halves together to remove the carious lesion. The teeth were separated into two different experimental groups of 15 teeth each. The experimental groups were defined as follows:

Group 1 – Conventional Round Carbide Bur (ISO sizes 014-018, Komet Brassler). New burs were used in a slow-speed hand-piece with an approximate speed of 1500 rpm without water-cooling. Carious dentine was removed with circular movements starting from the periphery to the centre of lesion. Dentine excavation was stopped (caries removal end-point) when hard dentine was detected using a non-flexible dental probe. Dentine was considered hard when, at applying a firm pressure, the probe was not able to penetrate into dentine.[22]

Group 2 – Polymer Bur SmartBurs® II (#6 and #8, SS White, Lakewood, NJ, USA). New burs were used with a slow-speed hand-piece with an approximate speed of 1500 rpm Carious dentine was removed with circular movements starting from the centre of the lesion to the periphery as recommended by the manufacturer. Dentine excavation was stopped when the instrument was no longer able to remove tissue.[23] The presence of hard tissue was also checked with a probe. For each tooth several new polymer burs were used.