Original Article

Effect of rotatory instrument speed on its capacity to remove demineralized and sound dentin

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ABSTRACT

Objectives: The aim of this study was to evaluate the capacity of two rotatory instruments (controlled speed electric motor [CSEM] – 300 rpm; conventional slow handpiece [CSHP] – 18,000 rpm) to remove sound and demineralized dentin, by examining prepared cavity walls using the scanning electron microscopy (SEM) and assessing loss of mass. **Materials and Methods:** A total of 40 blocks of human occlusal dentin, measuring 5 mm × 5 mm × 4 mm ($L \times W \times H$), were divided into two groups according to the substrate type in which the cavity preparation was performed: D - demineralized dentin; and S - sound dentin (control group). The groups were subdivided according to the rotatory instrument used for cavity preparation ($n = 10$): CSEM (300 rpm); and CSHP (18,000 rpm). In half of the dentin blocks, caries lesion induction was performed for 6 weeks. The preparation of the cavities was performed on a standardizing machine, using a cylindrical tungsten carbide burr. Before and after the preparation, specimens were dehydrated in an incubator at 60°C for 30 min. The initial and final mass (in mg) of each dentin block was measured 3 times using the digital precision balance to obtain the mean weight Following cavity preparation, all specimens were hemisected and SEM was used to blindly assess each half so that the lateral walls of the prepared cavity were measured in µm, accepting the average of two measurements as the total depth of the preparation. Non-parametric Mann-Whitney analysis was performed with a 5% of significance level. **Results:** Regarding the weight difference (mg), no significance was detected between the groups. Regarding depth (µm), a significant difference was found between the groups, so that the CSRM showed lower cavity depth when compared with CSHP, both in sound and demineralized dentin. **Conclusions:** Controlled speed rotatory instruments were found to be more conservative in removing both sound and demineralized dentin, in terms of preparation and depth.

Key words: Dentin, demineralized, rotatory instrument, removal

INTRODUCTION

The techniques for carious tissue removal are developed based on biological concepts and tooth conservation. This is possible due to a better understanding of the etiology, progression and prevention of caries, as well as novel excavation methods and the development of adhesive restorative materials.[1] Such minimally invasive intervention philosophy takes into account the carious dentin on two levels: The external layer, with a high level of infection, also known as infected dentin, which must be removed; and an internal layer of dentin, affected by caries and due to a low level of infection and remineralization capacity, should be preserved.[2,3] Therefore, the traditional method of caries removal and cavity preparation based on Blacks principles of extension for prevention has gradually been replaced by a more cautious approach, with conservative removal of carious tissue.[4,5]

Regarding the excavation methods for carious tissue, the use of conventional burrs associated to

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a conventional slow handpiece (CSHP) rotatory instrument has been demonstrated to cause an excessive amount wear on the tooth structure,[6,7] thermal damage,[8,9] pulp pressure,[10] pain and the frequent need for anesthesia.[11] The tendency to over-excavate with a burr associated to a CSHP occurs as a result of low control levels during excavation, since the burrs have a high cutting efficiency with a low tactile feedback.[12] Consequently, methods to remove carious dentin and to prepare cavities have been developed in an attempt to reduce the unnecessary loss of tissue.[13]

Endodontic methods have also progressed onto new techniques to facilitate root canal preparation in an efficient, safe and faster manner.[14] This has led to the development of instruments with specific mechanical rotatory movements, using electric motors with a constant speed of 300-350 rpm.[15] Endodontic rotatory systems are used for improved shaping and cleaning of root canals, as well as for reducing operative time and operator fatigue.[16,17]

Some studies[7-9] have evaluated the effectiveness of dentine excavation with CSHP using steel burrs, taking into account the depth of wear, complete carious tissue removal and the time spent excavating. However, no studies have been performed using a combination of steel burrs and endodontic controlled speed electric motors (CSEMs), as a dentin excavation approach, quantifying tooth loss following excavation. In a clinical situation, if electric motors used in endodontics are able to provide the conservative removal of dental structure (mainly carious dentin), it can be used during caries removal, without removing excessive dental structure.

The aim of this study was to evaluate rotatory instrument activity at different rotation speeds (electric motors used in endodontics) compared with conventional low speed rotatory instruments, both using steel burrs to remove demineralized and sound dentin, in terms of loss of mass and cavity depth by means of scanning electron microscopy (SEM). The null hypothesis was that the electric motors used in endodontics and the conventional low speed rotatory instruments would have the same ability in removing carious and sound dentin.

MATERIALS AND METHODS

The Ethics Committee for Research (CEP) at the São Leopoldo Mandic School of Dentistry and Dental Research Center approved this study on December the 8th 2011, registration number 2011/0303.

Experimental design

The factors under study were

- Type of dentin substrate on two levels: D - Demineralized dentin and S - Sound dentin (control group)
- Dentin removal method: R - CSEM used in endodontics and C - CSHP.

The experimental unit consisted of 40 fragments of human dentin randomly distributed into four experimental groups ($n = 10$)[18] The response variables were the loss of mass (mg) using a precision balance that provides values to 1/10,000 and the measurement of the wall depth of the cavity (µm), using SEM.

The experimental groups are described in Table 1.

Tooth selection and preparation of standardized dentin blocks

A total of 40 recently extracted human third molars were cleaned using a periodontal curette and maintained in aqueous solution of 0.1% thymol.

The blocks were obtained from the thickest part of the dentin, namely the coronal portion. The occlusal enamel was removed using a flexible high concentration diamond disk of 104 mm diameter × 0.3 mm thick (15 HC series, Buehler Ltd., Lake Bluff, Illinois, USA), mounted on an electric precision water-cooled diamond saw (Isomet 1000 Precision Diamond Saw, Buehler Ltd., Lake Bluff, Illinois, USA), exposing the occlusal dentin. At this time, dentin was visually checked to assure that only fragments with sound dentin were selected. Subsequently, a further cut 4 mm from the first was made, standardizing the depth of the fragment. The fragment was cut once again mesio-distally and bucco-lingually, in order to produce one central fragment per crown, approximately 5 mm × 5 mm.

The fragments of dentin were double-checked for enamel remains using a stereomicroscope (×40 magnification) and if found, excluded. The 40-dentin blocks were polished using a water-cooled polisher

Table 1: Experimental groups in the present study

Group	Excavation method	Sub group	Dentine type
R	Controlled rotatory (300 rpm)	D	Demineralized
C	Conventional rotatory (18,000 rpm)	D	Demineralized
R	Controlled rotatory (300 rpm)	S	Sound
C	Conventional rotatory (18,000 rpm)	S	Sound

(Politriz Aropol 2V, Arotec, São Paulo, SP, Brazil) and aluminum oxide sandpaper (Imperial Wetordry, 3M, Sumaré, SP, Brazil) by hand, in descending order of grain (#600 and #1200), to a final depth of approximately 3 mm for each block.

The specimens were divided into two groups: sound dentin (S) and demineralized dentin (D). In the S group, the specimens were stored in a moist environment (receptacle containing damp gauze swabs), in an incubator at 37°C (EL 1.3 Digital, Odontobrás, Ribeirão Preto-SP, Brazil) until use. In the D group, the area to be demineralized and subsequently prepared was outlined using an adhesive tape previously cut in 2 mm × 3 mm dimensions fixed at the center of the fragment. The remainder of the fragment was covered with red nail varnish (Colorama, L'Oréal Brazil Comercial de Cosméticos Ltda, Rio de Janeiro-RJ, Brazil).

Demineralized dentin

Specimens in group D underwent caries development protocol. The fragments were individually immersed in 5 mL of the cariogenic solution, consisted of a brain-heart infusion culture medium (sterilized using an autoclave at 121°C for 15 min [Acumedia, Lasing, Michigan, USA]). Streptococcus *mutans* ATCC 25175 was for 6 weeks, changing the culture medium every 2 days. The specimens were subsequently stored in a moist environment, in an incubator at 37°C (EL 1.3 Digital, Odontobrás, Ribeirão Preto-SP, Brazil), until cavity preparation. This protocol was adapted from Raucci-Neto *et al.*[18] After the protocol of caries development, caries lesions were clinically perceived as a softened tissue.

Initial loss of mass

For evaluation of initial loss of mass, the test specimens were dried using absorbent paper and handled with a pair of universal clinical forceps, avoiding hand contact, which could lead to contamination by oils and other substances that could interfere with the results. The samples were dehydrated in an incubator at a 60°C (EL 1.3 Digital, Odontobrás, Ribeirão Preto-SP, Brazil) for 30 min, in accordance with previously performed pilot tests and weighed using an adventurer digital precision balance (OHAUS Corp. USA), which provides values to 1/10,000. The fragment value was the average of three weightings. One evaluator blindly performed all measures. Data was recorded as initial values prior to cavity preparation.

Cavity preparation

The test specimens were randomly divided into two subgroups (n = 10) according to the preparation method used, which was carried out by a single operator. The first subgroup underwent cavity preparation with conventional cylindrical tungsten carbide burrs no. 56 (JET, Beavers Dental, Canada), attached to an endodontic rotatory motor system (CSEM) (VDW. SILVER, Munich, Germany), set at 300 rpm, under a standardized penetration pressure of 0.5 mm in a preparation standardizing machine in a unidirectional movement. The evaluator was calibrated by an expertise researcher for adequate use of the machine and positioning of dentin fragments. After training, the cavity preparations begun. The burr was replaced after every five preparations. In the second subgroup, the cavity preparation was performed using the conventional cylindrical tungsten carbide burrs no. 56 (JET, Beavers Dental, Canada), attached to a CSHP (micromotor CE-N270 and contra-angle CE-0434, Dabi Atlante, Ribeirão Preto-SP, Brazil), at 18,000 rpm, under a standardized penetration pressure of 0.5 mm, as described above.

No cooling method was used for either method of preparation to simulate caries removal with low speed rotatory instruments. The cylindrical burr no 56 produces cavities with two straight walls, facilitating the measurement of depth.

Final loss of mass

Following cavity preparation, the test specimens were dried with absorbent paper, dehydrated in an incubator at 60°C (EL 1.3 Digital, Odontobrás, Ribeirão Preto-SP, Brazil) for 30 min and weighed as previously described for initial loss of mass. The total loss of mass was considered to be the difference between initial and final loss of mass.

Preparation depth using SEM

The prepared specimens were hemisected using a double-sided flexible diamond disk (KG Sorensen, Cotia-SP, Brazil), thus dividing the cavity into two, in order to allow the measurement of depth for each sample.

Trisodium ethylenediaminetetraacetic acid (EDTA) (Biodinâmica, Ibiporã-PR, Brazil) was used for 3 min to individually clean and remove the smear layer. The specimens were then rinsed with distilled water and ultrasonically washed (Unique, São Paulo, SP, Brazil) for 10 min-cycles until all residues were removed.

The specimens were mounted on aluminum stubs and covered in gold for 60 s. They were then examined under an SEM (Jeol 5900 LV, Jeol Ltd., Tokyo, Japan), operating at 10 kV. Preparation depth was assessed, photographed and measured by the equipment's software, at × 85-100 magnification.

The height of the lateral walls on each side of the preparation, for each half, was measured, from the cavosurface edge to the deepest aspect of the cavity. The total depth was calculated from the average of two measurements [Figure 1]. The evaluator blindly performed the SEM analysis and was previously calibrated regarding the use of the microscope and cavity walls localization.

Analysis of results

The distribution curve of the data was analyzed using IBM SPSS Statistics 20.0 (IBM, Chicago, IL, USA) and it did not show a normal distribution, therefore, parametric tests were excluded, as no transformation method could be used. Non-parametric Mann-Whitney test was selected to analyze the outcome variables (weight and depth), with a significance level of 5% adopted.

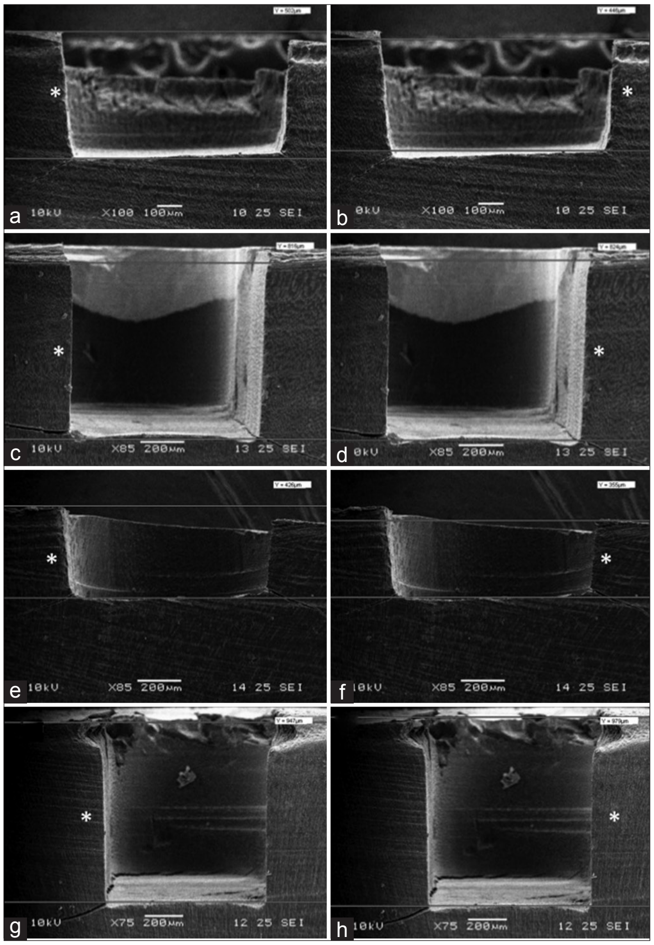

Figure 1: Micrographs showing the measurements of the cavity walls by scanning electron microscopy. The asterisks indicate which side of the wall was measured. (a and b) Controlled speed electric motor (CSEM)/demineralized dentin; (c and d) Conventional motor/demineralized dentin; (e and f) CSEM/sound dentin; (g and h) Conventional motor/sound dentin

RESULTS

Considering the weight analysis [Table 2], the Mann-Whitney test showed that, regardless of tissue condition (sound or demineralized), there was no significant difference (*P* = 0.0974) between CSEM and CSHP devices. The same condition was observed when type of dentin substrate was considered. There was no statistical difference (*P* = 0.9888) between sound and demineralized tissue, regardless of the method for tissue removal (CSEM or CSHP). There was a significant difference between the groups in terms of depth (μm) using SEM, as shown in Table 3.

In terms of depth [Table 3], it was verified that The CSEM showed significantly lower depth values when compared with CSHP (*P* = 0.0001), regardless of type of dentin (sound or demineralized). However, when the type of dentin was compared, it was observed no statistical differences between sound and demineralized dentin (*P* = 0.2584).

DISCUSSION

The traditional techniques for carious tissue removal using low-speed rotatory instruments that envisage to improve efficiency has the disadvantage of excessive removal of sound tissue.[7,9] In addition, one of the greatest problems encountered with all methods available for caries removal, for clinical use, is the lack of markers that can be controlled and sensed by the professional, since the methods currently used, such as visual and tactile markers, have a high subjectivity downfall, which causes difficulty establishing a limit for tissue removal.[6,19]

The understanding of the progression of caries into dentin has allowed a differentiation into two layers of carious tissue: The infected dentin, which must be removed; and the affected dentin, which can be remineralized and therefore should be preserved. Based on this evidence, there has been a growing interest in conservative approaches to removing carious tissue.[20,21]

The conventional method for carious tissue removal at low-speed, with burrs, is widely used, but it is known to be less conservative of tissue that could

Table 2: Median (lowest and highest values) of weight difference (mg)

	Controlled rotatory	Conventional rotatory	Grand median
Sound	0.00287 (0.0008-0.00517)	0.00372 (0.00117-0.01537)	0.00313 A (0.0008-0.01537)
Demineralized	0.00307 (-0.00090-0.00370)	0.00360 (0.00253-0.00563)	0.00327 A (-0.00090-0.00563)
Grand median	0.00300 a (–0.0009-0.00517)	0.00360 a (0.00117-0.01537)	

Grand medians followed by the same letters (lowercase in the horizontal and capital in the vertical) are statistically similar (Mann-Whitney test)

Table 3: Median (lowest and highest values) of depth (μm) by SEM

	Controlled rotatory	Conventional rotatory	Grand median
Sound	256.5	632	458.25 A (148.9-1075)
Demineralized	380.5	846	483.75 A (170-1265)
Grand median	333.25 a (148.9-603)	686.0 b (141-1265)	

Grand medians followed by the same letters (lowercase in the horizontal and capital in the vertical) are statistically similar (Mann-Whitney test).

be remineralized, although effective in terms of total caries removal.[7,22,23] However, as well as the lack of limits as to what should be removed, such method still has the disadvantage of causing pain, thus requiring the use of anesthetics for the procedure.[9] Furthermore, there is the vibration and friction of the burr, which can often induce pulp trauma, not only due to the cutting action but also by heat generation, which can have an additional effect on an already damaged pulp.[24]

Rotatory instruments used in endodontic treatment (mainly Ni-Ti instruments) were developed to optimize cleaning and the quality of root canal preparation, thus reducing clinical time.[17] Such devices, namely here controlled speed endodontic motors (CSEM), are electric motors with a constant speed of 300-350 rpm. The idea that CSEM would be able to remove carious and sound dentin in a more conservative manner lead us to think about an alternative method for caries removal. That was possible because as the conventional design of a steel burr for carious removal allows a precise adaptation into a CSEM contra-angle. So, this study proposed a comparison between the cavity preparations both in demineralized and sound dentin, with the view of clarifying a potentially more conservative capacity of such motors when removing dentin.

Regarding the effectiveness of tissue removal, as measured through specimen weight, there was no significant difference between the two methods. There are few studies (Colucci *et al*.[25] and Limongi *et al*.[26]) using loss of mass by sample weighing as a parameter to evaluate methods of dentin excavation. In the study by Colucci *et al*.[25] samples of both dentin and enamel were included. They were all cleaned and immersed in distilled water for 24 h at 4°C following mechanical planning using sandpaper, with the intention of rehydrating the substrate. The samples were then kept at 37°C for 24 h and subsequently removed from the water, dried with absorbent paper for 20 s and weighed individually in an analytical precision balance. There is no mention of age standardization of the teeth donors. The results were not so contrasting, thus showing more homogeneity. Limongi *et al*.[26] assessed dentin wear obtained from a rotatory system at three different speeds. The test specimens were kept in 1% sodium hypochlorite for 7 days and subsequently removed and left at room temperature for a further 7 days, when the initial weighing was performed. Following root canal preparation, EDTA was used to remove the smear layer so that it did not interfere with the final weight. Seven days after preparation, the samples were removed from their receptacles and again left at room temperature for a further 7 days, when the final weight was measured.

In contrast to the Colucci *et al*.[25] and Limongi *et al*.[26] studies, in this study the drying process was carried out in an incubator at 60°C for 30 min. It is speculated that this low drying time (30 s) was not sufficient to dry dentin homogenously. The prepared cavities were cleaned using only water and air spray before the final weighing, whereas Limongi *et al*.[26] used EDTA to remove the smear layer prior to the final weighing. It is possible to suggest that the smear layer may have influenced the final weight, contributing for the large amplitude of data. Due to the limitations of the loss of mass methodology, one may think that other methodologies used for the evaluation of tissue removal after cavity preparation may be employed.

Conversely, there was a significant difference between the two methods when measuring cavity depth by SEM [Table 2, Figure 1], where the

CSEM was found to be more conservative in tissue removal because the rotation speed of the burr was significantly lower than that for the conventional method (300 rpm × 18.000 rpm) therefore, reducing the cutting efficiency of the bur. Hence, the null hypothesis was partially rejected. In other words, regardless of the condition of the substrate, the CSEM removed less dental tissue. Clinically, the CSEM may represent a method for caries removal, since it was able to remove carious and sound dentin in a more conservative manner, counterbalancing the undesirable effects of conventional motors (such as excessive removal of dentinal tissue).

It is important to note that during preparation using a standardizing machine, the vibration and noise produced by the CSEM was evidently lower, to the point of being difficult to notice the burr action. This is due probably to the system being electric. It may suggest that there could be less trauma and heat clinically, which could be beneficial in maintaining pulp vitality. In addition, pain perception could be minimized, thus avoiding the need for anesthetics. Further studies focusing on patient perception may support this suggestion, which could play an important role in the use of this method as a routine approach for dental caries.

It should be highlighted that this is the first study on both demineralized and sound dentin excavation, comparing the use of a CSEM with a CSHP. To confirm the results of the present study, further studies must be carried out using, for example, polarized light microscopy to determine the amount of tissue removed, to check for persistent demineralized tissue and to establish the effectiveness of the two methods. Some studies[13,24,27] that used SEM to analyze the substrate to compare methods of carious tissue removal have highlighted the presence and distribution of a smear layer; therefore, the aim of those studies were not to verify the presence of persistent carious tissue when comparing the excavation methods. For that purpose, some studies[19,22] used light microscopy and obtained a more precise analysis on the effectiveness of carious tissue removal by superimposing micrographs before and after excavation. Besides this, to introduce CSEM in ordinary dentistry, other aspects may be taken into account such as the time spent during caries removal. This was not considered in the present study, but may be the goal of future ones. Other technologies for caries removal or cavity preparations such as lasers[28] have demanded more time to remove dental tissue, what may be a limitation for the use of new or alternative technologies. By the conclusion of *in vitro* studies, if CSEM can be suggested as possible devices for conservative caries removal, clinical trials may be developed with the aim to verify the real viability of using endodontic devices in caries removal procedures.

CONCLUSIONS

With the limitations of this *in vitro* study, it was possible to conclude that the use of a controlled speed motor produced lower cavity depths when compared to the conventional hand piece, thus making it a more conservative method for both sound and demineralized dentin removal, using the same type of steel burr. However, there was no significant difference in loss of mass between the two methods of excavation.

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