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Performance of Four Dentine Excavation Methods in Deciduous Teeth

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Key Words

Autofluorescence · Carbide bur · Confocal laser scanning microscopy · Dentine caries · Er:YAG laser · Excavation · Hand excavator · Polymer bur

Abstract

This in vitro study aimed to assess the speed and caries removal effectiveness of four different new and conventional dentine excavation methods. Eighty deciduous molars were assigned to four groups. Teeth were sectioned longitudinally through the lesion centre. Images of one half per tooth were captured by light microscope and confocal laser scanning microscopy (CLSM) to assess the caries extension. The halves were then reassembled and caries removed using round carbide bur (group 1), Er:YAG laser (group 2), hand excavator (group 3) and a polymer bur (group 4). The time needed for the whole excavation in each tooth was registered. After excavation, the halves were photographed by light microscope. Caries extension obtained from CLSM images were superimposed on the post-excavation images, allowing comparison between caries extension and removal. The regions where caries and preparation limits coincided, as well as the areas of over- and underpreparation, were measured. Steel bur was the fastest method, followed by the polymer bur, hand excavator and laser. Steel bur exhibited also the largest overpreparation area, followed by laser, hand excavator and polymer bur. The largest underpreparation area was found using polymer bur, followed by laser, hand excavator and steel bur. Hand excavator presented the longest coincidence line, followed by polymer and steel burs and laser. Overall, hand excavator seemed to be the most suitable method for carious dentine excavation in deciduous teeth, combining good excavation time with effective caries removal.

Dentine caries removal is normally accomplished using mechanical procedures like rotary carbide burs and hand excavator. The first is mostly associated with noise, pain, overheating, vibration and discomfort [Anusavice and Kincheloe, 1987; Banerjee et al., 2000a]. Hence, hand excavation is often preferred by dental practitioners on non-cooperative children or for performing stepwise excavation. Hand excavation provides better tactile control and less discomfort than the bur, without generating high temperatures. A further concern in caries excavation is of the amount of tissue to be removed. It is well known that only the superficial layer (infected dentine) is strongly infected with viable microorganisms. A remineralisation of this dentine cannot be expected because of the

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irreversible denaturation of the collagen. Softening and discoloration fronts always precede the bacterial invasion front of the lesion towards the pulp [Fusayama et al., 1966]. During excavation, practitioners tend to include all soft and discoloured tissues in order to ensure complete elimination of the infected layers. To evaluate the consistency and colour of the prepared cavity, tactile and optical judgements are used. These criteria were shown to be adequate to ensure removal of most of the infected dentine [Kidd et al., 1993]. However, they are still clinical and subjective parameters, dependent on the operator's judgement and experience [Fusayama, 1980]. Dyes are often used to stain carious dentine but are not considered absolutely reliable. Dyes stain the demineralised but still remineralisable organic matrix of the lesion rather than bacteria [Kidd et al., 1993; Yip et al., 1994; Ansari et al., 1999; Banerjee et al., 2003]. Thus, their use frequently results in unnecessary removal of tissue with reduced mineral content like affected dentine, EDJ and circumpulpal dentine [McComb, 2000; Banerjee et al., 2003].

The search for a more gentle, comfortable and conservative caries excavation has led to the development of methods which aim at providing minimal thermal changes, less vibration and pain, and removal of infected dentine only. Recently developed techniques such as laser, chemomechanical excavation and air abrasion have been shown to be more or less successful in overcoming these problems [Ericson et al., 1999; Keller et al., 1998; White and Eakle, 2000; Kato et al., 2003; Takamori et al., 2003]. Any of these methods offer interesting advantages in comparison to the conventional approach, but are still far from fulfilling all requirements. In most cases they are more time consuming than bur preparation [Banerjee et al., 2000c], require more investment and space, and are still dependent on conventional burs to gain access to the lesion and to finish the preparation margins. Moreover, some of them tend to over- or underprepare [Banerjee et al., 2000c] or do not completely eliminate the smear layer [Banerjee et al., 2000b]. A new polymer prototype bur was developed and presented by Boston [2003]. Basically, its blades are designed to only cut soft tissues and abrade when encountering dentine at or above the preselected hardness, thus avoiding the removal of affected and sound dentine. Most recently, a new polymer bur with the same principle was launched on the market. According to the manufacturer, this material is harder than infected dentine but softer than normal, sound dentine and also even softer than sclerotic, discoloured dentine, thus allowing a very selective caries removal. As dentine tubules are not opened, less or no pain is also suggested. The aim of this study was to assess the speed and caries removal effectiveness and selectivity of one new and three conventional excavation methods on dentinal lesions in deciduous teeth.

Materials and Methods

Eighty extracted deciduous molars were chosen. All samples presented an open occlusal cavitation reaching dentine either confined to the outer half of dentine (D3) or reaching the inner half of dentine (D4). The teeth had been extracted under general anaesthesia in several appointments performed at the Department of Paediatric Dentistry of the University of Bern and were immediately stored at –20°C. No storing solutions were added in order to avoid possible chemical, physical and optical changes in dentine [Strawn et al., 1996; Habelitz et al., 2002]. During the experiment, the teeth were stored in individual plastic containers and thawed at room temperature (ca. 24 ± 1°C) for at least 14 h prior to being excavated. To avoid dehydration of the samples during these 14 h, a paper towel soaked in distilled water was placed at the bottom of each individual container, while each tooth was stuck to the tube wall with modelling clay. This procedure ensured 100% humidity in the closed container avoiding contact between the samples and the humidifying solution. After cleaning them from gingival tissues with a scaler, the teeth were numbered and classified according to lesion size as small (caries lesion extending over up to half of the occlusal surface) or large (caries lesion extending over more than half of the occlusal surface).

The teeth were then allotted to four different experimental groups of 20 samples each. Finally, 10 teeth of each group were assigned to two different operators. Small and large cavities were equally distributed between operators in each experimental group. The teeth had their roots embedded in acrylic resin in a mould and were then bisected mesiodistally through the centre of the carious lesion with a low-speed diamond saw, thickness 300 μm (IsoMet, Buehler, Ill., USA). One cut surface of each tooth was digitally photographed under light microscope, magnification 12.5× (Leica M420, Leica, Heerbrugg, Switzerland). In order to determine the limits of the caries lesion, all samples were then examined by confocal laser scanning microscopy (CLSM 410® Carl Zeiss, Oberkochen, Germany) at 488 nm (final magnification 12.5×, objective 1.25×, numerical aperture 0.035). The autofluorescence image of each lesion was captured and digitally saved for further comparisons [Banerjee and Boyde, 1998; Banerjee et al., 1999, 2000c, 2003]. The limits of the lesions were defined according to the autofluorescence limits of the decayed dentine. The teeth halves were then reassembled with light-curing resin from the outer surface of the crown matching both halves together as shown in figure 1e. If needed, enamel margins were eliminated with cylindrical diamond burs in the high-speed handpiece in order to improve access to caries. Ten specimens in each group were then excavated by each operator according to the following criteria:

Group 1 – Conventional Round Carbide Bur. Brand-new burs # 0.10, 0.14, 0.16, 0.18 and 0.25 (Dentsply Maillefer, Ballaigues, Switzerland) were used in a slow-speed handpiece, according to the size of the lesion. Dentine excavation was stopped when hard den-

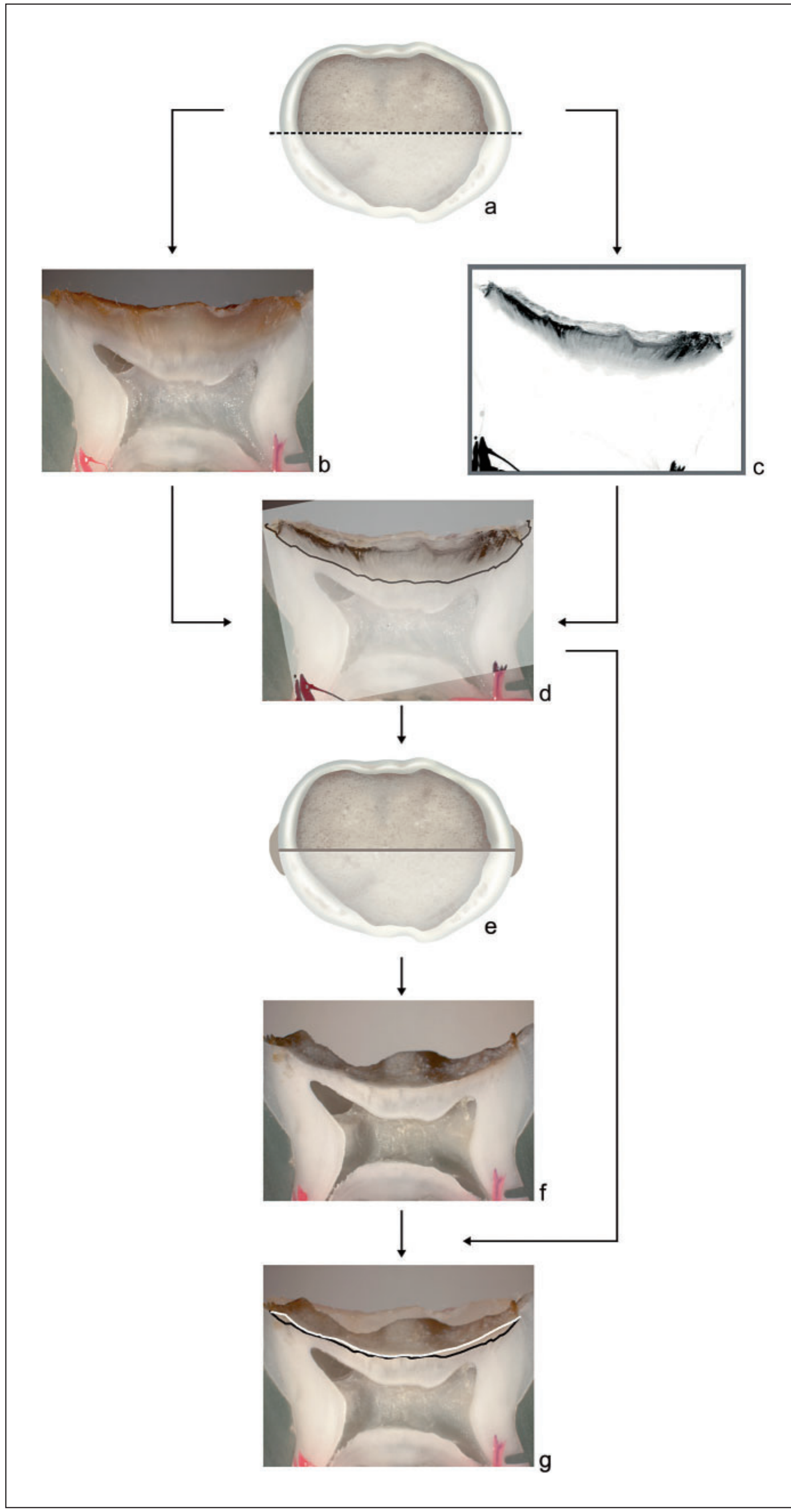

Fig. 1. Diagram of the entire experiment procedure step by step: (**a**) mesiodistal cut through the lesion centre; (**b**) light microscope and (**c**) CLSM images (12.5 ×) before excavation; (**d**) superimposition of light microscope and CLSM pre-excavation images; (**e**) reassembly of both halves with resin; (**f**) light microscope image (12.5 ×) after excavation; (**g**) superimposition of light microscope post-excavation picture and pre-excavation images (**d**) (black line). The white line represents the preparation limits.

tine 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.

Group 2 – Er:YAG Laser. Cavities were prepared by an Er:YAG laser (KaVo, Biberach, Germany) with an emission wavelength of 2.94 μm, pulse energy 200 mJ and frequency 4 Hz. Caries removal took place under water spray cooling (7 ml/min) with the handpiece No. 2061, non-contact mode, provided by the manufacturer for cavity preparation. The working distance was approximately 12 mm. Laser emission was stopped when dentine was detected hard to the probe.

Group 3 – Hand Excavator. Caries was removed using two different brand-new excavators: No. 591/3 (wide and large) and No. 591/4 (narrow and short) (Neos Vanadium, Hawe Neos Dental, Bioggio, Switzerland). Which one was used was determined by the size of the lesion. During excavation, dentine hardness was checked and caries removal completed when hard dentine was detected with the probe.

Group 4 – Polymer Bur. The new version of SmartPrep™, the now called SmartBurs™ (SS White, Lakewood, N.J., USA) with reinforced blades, was used with a slow-speed handpiece. Carious tissue was removed with circular movements starting from the centre of the lesion to the periphery as recommended by the manufacturer. Excavation was stopped when the instrument became macroscopically abraded and blunted and was no longer able to remove tissue. The presence of hard tissue was also checked with a probe. Bur # 6 was applied as its size was compatible with all cavities in this group. For each tooth a new polymer bur was used.

For groups 2 (Er:YAG laser) and 4 (polymer bur), a training session was carried out for both operators to familiarise them with the devices. The time taken for the whole procedure, including caries excavation and probing for clinical hardness in each tooth, was recorded in each group and for each operator. After finishing the caries removal procedures, the fixed tooth halves were separated and a new picture of the cut surface was taken with the light microscope as before to caries excavation.

The autofluorescent signal outlines corresponding to the caries limit were first digitally delineated from the CLSM images and then superimposed on the pre-excavation pictures obtained with the light microscope with the aid of a design program (Adobe Photoshop 6.0). The resulting image was in turn superimposed on the light-microscope post-excavation picture. In this way, the caries extent and removal were compared as seen in figure 1. The areas of over- and underpreparation were measured in mm^2. The location of these areas was also recorded. The length of the preparation limits that neither exceeded nor achieved the limits of caries (coincidence line) were measured in mm. All these measurements were performed using IM 500 software (Leica, Heerbrugg, Switzerland). The results obtained were registered for each operator and each excavation method.

Data Analysis

The time each operator employed for excavation with each method was compared according to cavity size. As the data were not normally distributed, non-parametric tests were used. Pearson χ^2 test (Systat, Inc., Evanston, Ill., USA) was used to assess significance in distribution of the different cavity sizes among groups. Statistical significance for the time employed to prepare the different type of lesions (D3, D4) in each group and statistical significance for the time employed by both operators was analysed by Kruskal-Wallis and Mann-Whitney U test. Likewise, the efficiency of the different excavation methods and operators was analysed by Kruskal-Wallis and Mann-Whitney U tests. In all tests the level of significance was set at 0.05.

Results

From a total of 80 teeth in this study, 3 were excluded as the carious lesions reached the pulp. From the remaining 77 cavities, 34 were small and 43 were large. According to the CLSM findings, a total of 7 lesions in the bur group, 4 in the laser group, 5 in the hand excavation group, and 5 lesions in the polymer bur group extended up to the outer half of dentine (D3 lesions). While a total of 13, 16, 13, and 14 in the groups bur, laser, hand excavation and polymer bur respectively had already reached the inner half of dentine (D4 lesions). In the steel bur group, 10 teeth showed a small cavity while 10 presented a large cavity. In the laser group, 9 teeth had a small caries and 11 a large caries. In the group hand excavator, 4 teeth presented a small caries and 14 a large caries. In the polymer bur group, 10 teeth showed a small lesion while 9 presented a large lesion.

Overall, no statistically significant differences were registered between operator 1 and operator 2 in the time employed to excavate the cavities. As can be seen in table 1, bur was the fastest of the four methods and Er:YAG laser was shown to be the slowest excavation technique. The differences in time between all four excavation procedures were all statistically significant ($p < 0.05$). Both bur and laser were cavity size dependent. In both cases, the time employed to remove caries from small cavities was significantly shorter than the time employed to excavate large cavities. Table 2 lists the general efficiency of each method expressed in terms of amount of tissues eliminated (overpreparation, underpreparation and coincidence line). No significant differences were detected between operators in the excavation efficiency when using laser, hand excavation or polymer bur. By contrast, steel bur excavation did exhibit a significant difference between operators. When applying steel bur excavation independent of cavity size, operator 1 tended to underprepare while operator 2 tended to overprepare. This tendency was shown to be statistically significant ($p < 0.05$). Among all the methods, steel bur excavation removed the largest amount of sound tissues (overpreparation) and left the smallest amount of carious tissues (underpreparation). Polymer bur presented the smallest area of overpreparation and the largest area of underpreparation

Table 1. Mean time (±SEM) in seconds employed for excavation by the four methods

Cavity size	Operator	Steel bur	Laser	Hand excavator	Polymer bur
Small	Operator 1	118 ± 18	239 ± 25	127 ± 0	170 ± 17
	Operator 2	101 ± 10	280 ± 54	227 ± 39	141 ± 28
	Mean	109 ± 10^{a}	262 ± 31^{b}	202 ± 37	157 ± 19
Large	Operator 1	173 ± 29	448 ± 71	213 ± 19	158 ± 11
	Operator 2	156 ± 28	360 ± 43	302 ± 53	258 ± 58
	Mean	165 ± 19^{a}	408 ± 44^{b}	258 ± 30	208 ± 33
Total		137 ± 12^{c}	342 ± 32^{c}	245 ± 25^{c}	178 ± 18^{c}

All four methods were statistically significantly different when considering the total time (^{c}). Groups with the same superscripts were statistically significantly different.

Table 2. Caries excavation efficiency of each method expressed by areas of over- and underpreparation (mm^2) and coincidence lines (mm) (±SEM)

Method	Operator	n	Overprepared mm^2	Underprepared mm^2	Coincidence mm	Proportion coincidence
Steel bur	Operator 1	10	0.14 ± 0.04^{a}	0.56 ± 0.12^{b}	0.42 ± 0.7	
	Operator 2	10	1.06 ± 0.21^{a}	0.09 ± 0.04^{b}	0.26 ± 0.1	
	Mean	20	0.60 ± 0.15^{c}	0.33 ± 0.08^{f}	0.34 ± 0.06^{h}	6.03%
Laser	Operator 1	10	0.56 ± 0.087	0.47 ± 0.14	0.28 ± 0.09	
	Operator 2	10	0.43 ± 0.15	1.20 ± 0.41	0.08 ± 0.04	
	Mean	20	0.49 ± 0.09^{d}	0.84 ± 0.23^{g}	$0.18 \pm 0.05^{h,\ i}$	3.06%
Hand excavator	Operator 1	8	0.35 ± 0.15	0.66 ± 0.19	0.49 ± 0.15	
	Operator 2	10	0.23 ± 0.092	0.68 ± 0.15	0.62 ± 0.15	
	Mean	18	0.28 ± 0.08^{e}	0.67 ± 0.12^{f}	0.6 ± 0.1^{i}	8.06%
Polymer bur	Operator 1	9	0.21 ± 0.19	1.81 ± 0.34	0.36 ± 0.15	
	Operator 2	10	0.03 ± 0.018	1.42 ± 0.28	0.71 ± 0.3	
	Mean	19	$0.12 \pm 0.09^{c,\ d,\ e}$	$1.61 \pm 0.22^{f,\ g}$	0.5 ± 0.2	8.34%

Distribution of samples between operators and among groups (n). Groups with the same superscripts were statistically significantly different.

($p < 0.05$), together with one of the longest coincidence lines.

Hand excavation exhibited the longest coincidence line of all four techniques. This value was statistically significantly higher than that of laser, which showed the shortest coincidence line. However, no statistical significance was found between coincidence lines after hand excavation and laser, polymer bur or steel bur preparation. No significant differences were registered in the performance (overpreparation, underpreparation and coincidence line) and the preparation time of the different excavation methods between excavating D3 and D4 lesions. The laser excavation often resulted in a sort of uncontrolled, random pattern, in which deep overprepared areas and wide underprepared zones were found in the same cavity.

Discussion

The autofluorescence of carious dentine detected by CLSM was shown to be a reliable marker of infected dentine [Banerjee et al., 1999, 2000c; Foster, 1999]. This method was selected for validation since it offers the possibility of delimitating dentine caries at a high resolution without applying any dyes that could bias the operator's decisions during excavation. It is very difficult to give accurate guidelines for sound and hard dentine differentiation. This issue is very prone to subjectivity and very dependent on the operator's perception and experience. Moreover, it was the aim of this study to analyse the operator's influence on the performance of the different excavation techniques. Thus, no calibration between both operators was attempted for determination of dentine hardness in this study. However, in those cases where doubt arose, both operators analysed the particular situation until consensus was reached. Conventional burs normally present a negative rake angle, which means that the blade is ahead of the perpendicular to the surface being cut. In order to keep the blade in contact with this surface, increased downward pressure is needed. This can lead to a less controlled movement of the instrument through the surface. Our results showed that carbide bur tends to be a fast and rather non-conservative method for dentine caries removal, which is in agreement with Banerjee et al. [2000c]. Its speed and mode of function may make this technique less sensitive and more difficult to control, so that it is prone to being influenced by the operator's criteria, as was confirmed by our results (one operator tended to underprepare while the other tended to overprepare). Like conventional burs, polymer bur's rake angle is also negative. We hypothesise that unlike carbide bur, the downward pressure applied by the polymer bur against the tissues is dissipated as the bur starts to abrade when it encounters hard dentine. In the present study, polymer bur excavation led to one of the largest coincidence lines and the smallest area of overpreparation. However, it also exhibited the biggest underprepared area of all methods. Dentine hardness at the microbial front of chronic (arrested) caries was shown to exhibit an average hardness of 39.2 KHN (range 16.0–61.0 KHN), while with acute (active) caries the average value was 6.7 KHN (range 4.4–11.2 KHN) [Fusayama et al., 1966]. As the mean hardness of the polymer bur was 26.6 ± 1.2 KHN (preliminary experiments), it can be assumed that the instrument does not perform similarly in both cases.

As shown in many studies, certain clinical parameters like dentine discoloration cannot be reliably related to caries activity and infection [Kidd et al., 1993; Kidd, 2004]. Even if dentine hardness and moisture correlate better with microbiological activity, these are still subjective parameters, and many lesions can be incorrectly classified or remain unclassified [Hojo et al., 1994]. For that reason, no classification of the lesions into active or arrested was attempted in the present study. When using polymer burs, soft, light-discoloured lesions were easier to excavate than hard, brown-discoloured caries. In these cases the remaining dentine appeared hard and burnished. However, based only on these clinical findings, it is not possible to state if the difficulty of the polymer burs to excavate hard, dark discoloured dentine can be considered as a positive or a negative aspect of the method. Further tests should be carried out to assess the behaviour of the different excavation methods in active and arrested caries lesions by means of microbiological validation. Knoop hardness is significantly higher for superficial than for deep dentin [Fuentes et al., 2003] In the present study, however, no significant differences were found in the performance of the excavation methods between both caries depths. This issue should be further analysed on a broader sample of D3 lesions. Another issue to be analysed is the different behaviour of polymer bur excavation in permanent as opposed to deciduous teeth. Due to the difference in dentine hardness in both dentitions [Hosoya et al., 2000] discrepancies can be expected. Hand excavation exhibited one of the smallest areas of over- and underpreparation together with the highest coincidence values for operator 1 as well as for operator 2. Our results support the findings of a previous study which assessed a high correlation between caries and hand excavation limits [Banerjee et al., 2000c]. When looking at the location of these coincidence areas in the different cavities, most of them were situated at the cavity floor. The enamel-dentinal junction, however, was not always adequately reached for caries removal. Hand excavation would result in a more tactile, controlled caries excavation technique in comparison to bur. However, the areas located immediately below enamel could not always be properly accessed. The additional use of diamond burs is, in almost all cases, a necessary step for cavity preparation.

Laser was the slowest of all methods, needing almost 2.5 times longer than steel burs to prepare cavities of similar size. These results are in accordance with Keller et al. [1998]. The difference in time between bur and the other three methods is probably less in the clinical situation for, according to previous in-vivo reports, the use of laser, hand excavator or polymer bur should make anaesthesia not always necessary, reducing the whole treatment time [Anusavice and Kincheloe, 1987; Keller et al., 1998]. Moreover, the time employed on caries removal by laser and bur was shown to be cavity size dependent.

The beam of the laser device used in this study was emitted in a non-contact mode, so controlled caries excavation was sometimes difficult. The irregularity of the tooth surfaces hampered an adequate tactile feedback. Hence, a proper clinical hardness assessment with the probe may be hindered. Based on our results, it can be concluded that steel bur was the fastest method on any cavity size and for both operators. However, it was also the least conservative and the most likely to be influenced by the operator's handling. Polymer bur and laser left the largest amount of decayed tissues unexcavated (under-preparation), while hand excavator presented the longest coincidence line. On the whole, hand excavator seemed to be the most suitable method for carious dentine excavation in deciduous teeth, combining a good excavation time with effective caries removal.

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