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Efficiency of the Polymer Bur SmartPrep Compared with Conventional Tungsten Carbide Bud Bur in Dentin Caries Excavation

T Dammaschke • TN Rodenberg
E Schäfer • KHR Ott

Clinical Relevance

By comparing polymer bur SmartPrep with conventional tungsten carbide bud burs *in vitro*, SmartPrep seems to be less effective in carious dentin excavation.

SUMMARY

SmartPrep is a rotating instrument for dentin caries excavation made from a special polymer. The manufacturer's product information stated that SmartPrep removes carious dentin selectively. This *in vitro* study compared the efficiency of SmartPrep with conventional tungsten carbide bud burs. Fifty extracted teeth were split in the center of a carious lesion. The 100 specimens were randomly divided into five groups. Five dentists were asked to excavate 10 teeth each: one half with SmartPrep and the corresponding half with conventional bud burs. The time needed for the caries excavation was measured. Subsequently, histological specimens were produced from all cavities and analyzed by light-microscope after Mallory-Azan-staining. The thickness of the remaining caries was measured (<1 mm or >1 mm). The time expended was analyzed using the paired *t*-test. The results were analyzed for the remaining caries and thickness of the carious layer for every tooth, using the non-parametric Wilcoxon test for combined random samples. A binary logistical regression was performed to determine the influence of the three variables (tooth, sections or bur) on the criteria "caries" or "carious layer thickness (>1 mm)." The average time to excavate a cavity with SmartPrep was 208.1 seconds, and it was 228.32 seconds with conventional bud burs. The difference between the recorded times was not statistically significant ($p>0.05$). In 37 of 50 teeth, the number of carious sections was higher in the SmartPrep group than in the bud bur group. In nine teeth, the quantity of carious sections was higher in the bud bur group than in the SmartPrep group. Four teeth showed no differ-

*Till Dammaschke, Dr med dent, associate professor, Poliklinik für Zahnerhaltung, Westfälische Wilhelms-Universität, Münster, Germany

Timo Norman Rodenberg, cand med dent, student, Poliklinik für Zahnerhaltung, Westfälische Wilhelms-Universität, Münster, Germany

Edgar Schäfer, Prof Dr, associate professor, Poliklinik für Zahnerhaltung, Westfälische Wilhelms-Universität, Münster, Germany

Klaus Heinrich Reiner Ott, Prof Dr, chairman of the department, Poliklinik für Zahnerhaltung, Westfälische Wilhelms-Universität, Münster, Germany

*Reprint request: Waldeyerstr 30, D-48149 Münster, Germany; e-mail: tillda@uni-muenster.de

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ence in the number of carious sections. The results were statistically significantly different ($p<0.001$). In 30 teeth, the number of carious sections with a carious layer thicker than 1 mm was higher in the SmartPrep group compared with the bud bur group. In nine teeth, the number of carious sections was higher in the bud bur group than in the SmartPrep group. Eleven teeth showed no difference in thickness of the carious dentin layer. These results were statistically significantly different ($p=0.003$). Binary logistical regression showed that only the variable "bur" (bud bur or SmartPrep) influenced the results concerning the criterion "caries" ($p<0.001$).

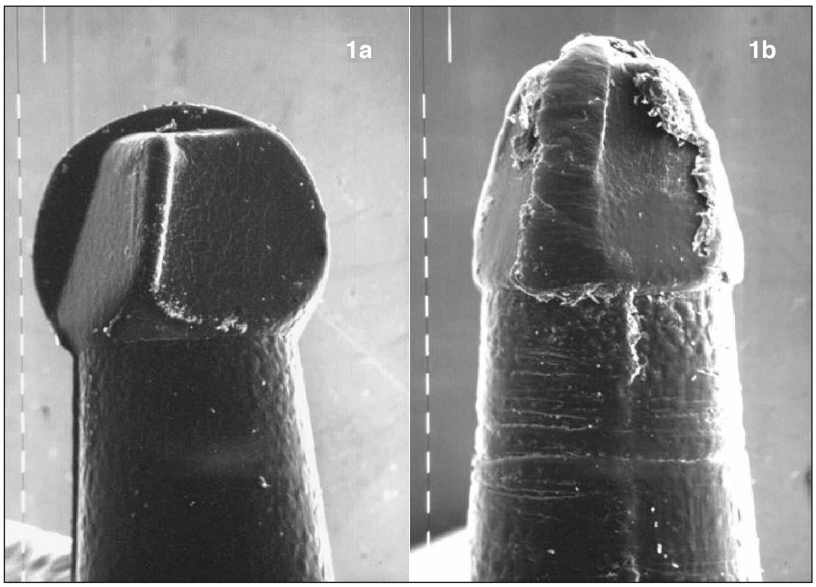

Figure 1. *SmartPrep instrument ISO 018 before (Figure 1a) and after (Figure 1b) use. Scanning electron microscope micrograph. Bar represents 100 µm. Original magnification 40x.*

INTRODUCTION

Dentin caries can be divided into several different layers. The superficial or outer layer is contaminated with bacteria, which dissolves the mineralized tissue of dentin and damages the collagen matrix so that remineralization becomes impossible. This layer must be completely removed during caries excavation. The inner layer is less frequently or, at best, not contaminated with bacteria. However, bacteria also dissolves mineralized tissue in this layer, but the cross-banded ultra structure of the collagen matrix will remain. If these bacteria and their metabolic products—the main cause for caries—are removed, the inner layer of dentin caries can remineralize (Ogushi & Fusayama, 1975). Hence, there is no need during caries excavation to remove the inner carious dentin layer.

The manufacturer's product information on SmartPrep (SS White, Lakewood, NJ, USA) states that this polymer bur will be able to distinguish between these two layers of carious dentin during (rotary) excavation. This minimally invasive excavation has the advantage of fewer dentin tubules being cut and, thereby, less pain sensations being triggered compared to using conventional bud burs.

At first sight, SmartPrep instruments look like conventional bud burs, but they are not manufactured from metal; instead, they are manufactured from a special polymer material. The cutting edges are not spiral-like but shovel-like straight. The polymer material has a Knoop Hardness of 50 and was developed with the aim to be harder than carious, softened dentin (Knoop Hardness 0-30) but softer than healthy dentin (Knoop Hardness 70-90). The manufacturer's product information on SmartPrep states that it will remove carious dentin selectively; whereas, healthy dentin is not affected. The polymer cutting edges will wear down in contact with harder materials, such as healthy dentin, and will go blunt. Thus, the SmartPrep instruments are self-limiting and determined for single-use only (Freedman & Goldstep, 2003) (Figures 1a,b).

Horiguchi and others (1998), in their study, used a material softer than healthy dentin (Vickers Hardness 70 HV) to remove carious dentin. They developed a special crushed powder made of a polycarbonate resin with a Vickers Hardness of 40-50 HV that selectively removed carious dentin by air abrasion only.

The SmartPrep burs are available in three ISO sizes 010, 014 and 018. Like conventional bud burs, SmartPrep instruments are used in a slow-running handpiece at a speed of 500 to 800 rpm. However, in deference to conventional bud burs, excavation is not carried out from the periphery to the center of the lesion; instead, it is carried out from the center to the periphery to avoid contact with the harder enamel. SmartPrep burs should be used with a light pressure to excavate the carious-affected dentin in single layers.

To the best of the authors' knowledge, no scientific examination has been published that investigates the efficiency of SmartPrep burs in dentin caries excavation until now. Therefore, the aim of this *in vitro* study was to compare the efficiency of SmartPrep instruments with conventional bud burs in a split-teeth model.

METHODS AND MATERIALS

Fifty carious human teeth were selected for this *in vitro* study. They were stored in PBS buffer (pH 7.2) and kept in a refrigerator at 5°C for no more than one week after extraction. All the teeth had an occlusal and/or cervical carious lesion in the dentin. They were

split in the center of a carious lesion under permanent water cooling using a diamond saw (Modell 1600, Leitz, Wetzlar, Germany) in order to obtain two corresponding halves from each tooth.

The 100 specimens were randomly divided into five groups with 10 teeth in each group. Five dentists excavated 10 sample teeth each: one half were randomly selected and excavated with SmartPrep (SS White, Lakewood, NJ, USA); the corresponding half was excavated with conventional tungsten carbide bud burs (H1 SE, Komet, Lemgo, Germany). All bud burs were new and had the same ISO sizes (010, 014 and 018) compared to the SmartPrep instruments. All dentists were trained in the SmartPrep excavating technique and had to excavate 10 additional sample teeth before commencement of the main study. The results of these training excavations were clinically evaluated by one of the authors (TD) and discussed with the dentists. During the experiment, the dentists were not limited to how many SmartPrep burs they used. Excavation was repeated with each kind of bur until the dentist estimated the dentin to be caries-free or there was no more caries to be removed. The following parameters were used to assess the caries-free status of dentin: hardness on probing, dentin coloration and the unique sound of unaffected dentin on probing ("cri dentaire"). The amount of time involved was measured from starting the handpiece until the final probing for dentin hardness.

After excavation, all teeth were embedded in a mold using epoxy resin (Paladur farblos, Heraeus-Kulzer, Wehrheim, Germany) using a mold for histological examination. Longitudinal serial sections 200 µm thick were obtained from each sample by cutting through the extent of the cavity with a diamond saw (Modell 1600, Leitz, Wetzlar, Germany) parallel to the first sectional plane, which was obtained by splitting the tooth into two halves. As many sections as possible were produced to cover the complete cavity and the adjoining dentin for examination; whereby, the number of sections obtained (between 5 and 12) depended on the size of the cavity. Every section was pasted on an object plate (Thermanox Plastic Coverslips 174985, Nalge Nunc International, Rochester, NY, USA). The sections were then stained with Mallory-Azan. All teeth were stained separately. The sections were first stained for 15 minutes with acid fuchsine (0.25%), then, after removing the surplus with filter paper, a second staining with 2C 084 Anilinblau-Orange Mallory (0.5 g Aniline blue, 2 g orange, 1 g phosphowolfram acid in 100 ml Aqua dest; Chroma-Gesellschaft mbH & Co, Münster, Germany) was performed. Finally, the sections were rinsed with ethanol (90%). After drying with filter paper, the sections were histologically evaluated with a microscope (Wild Photomakroskop M 400, Leica Mikrosysteme Vertrieb GmbH, Wetzlar, Germany) at 32-fold magnification by an examiner who did not know how the specimens were treated. The remaining caries appeared red after staining and was recorded for every section (yes/no decision). The thickness of the remaining caries was also measured (more or less than 1 mm).

The amount of time expended for caries removal was analyzed using the paired *t*-test. The percentage of carious and non-carious sections in every specimen (tooth) was determined in order to evaluate the efficiency of the different burs. The results for every tooth was evaluated using the non-parametric Wilcoxon test for combined random samples. The percentage of carious sections with a carious layer thicker than 1 mm in each specimen (tooth) was evaluated in the same manner.

A binary logistical regression was performed to determine the influence of the three variables (tooth, sections or bur) on the results of the statistical evaluation concerning the criteria "caries" or "carious layer thickness (> 1 mm)."

RESULTS

Time Consumption for Excavation

It took, on average, 208.10 seconds to excavate a split tooth with SmartPrep and 228.32 seconds to excavate a split tooth with bud burs, respectively. This difference was not statistically significantly different ($p>0.05$).

Results of the Caries Excavation

A total of 631 sections were obtained from 50 teeth. Of the 631 sections, 382 had remaining caries (60.5%) and 249 sections were caries free (39.5%). Three hundred and twenty sections were obtained and stained from the SmartPrep-treated teeth. Of those, 74.4% (238 out of 320) showed remaining caries; whereas, 25.6% (82 out of 320) were caries-free. In the control group (bud bur), 311 sections were evaluated: 46.3% (144 out of 311) were not caries-free and 53.7% (167 out of 311) were caries-free. By subtracting the percentage of carious sections of each tooth treated with SmartPrep (variable 2) from the percentage of carious sections of the same tooth treated with bud bur (variable 1), it become obvious that nine specimens (tooth) had a positive rank (>0), 37 specimens (tooth) had a negative rank (<0) and 4 specimens (tooth) showed no difference (=0). These results show that the number of carious sections was higher in the SmartPrep group than in the bud bur group in 37 out of 50 teeth. The number of carious sections was higher in the bud bur group compared to the SmartPrep group, which had nine teeth, and four teeth showed no difference in the prevalence of caries between the two groups of burs. Analysis of the data with the non-parametric Wilcoxon test for combined random samples (two-sided) showed that the results were statistically significantly different ($p<0.001$). Bud bur excavation showed statistically significantly more

frequent caries-free results than SmartPrep excavation.

Evaluation of the Thickness of the Remaining Caries

The remaining caries was thicker than 1 mm in 301 of the 382 carious sections (78.8%). The remaining caries, after SmartPrep excavation, was thicker than 1 mm in 85.3% (203 of 238) of the sections and in 14.7% (35 of 238) of the thinner than 1 mm sections; whereas, in the bud bur group, 69.5% (100 out of 144) were thicker than 1 mm and 30.5% of the sections (44 out of 144) were thinner than 1 mm. By subtracting the percentage of carious sections with a carious layer thicker than 1 mm of each tooth in the SmartPrep group (variable 2) from the percentage of carious sections with a carious layer thicker than 1 mm of each tooth in the bud bur group (variable 1), it became obvious that nine specimens (tooth) had a positive rank (>0), 30 specimens (tooth) had a negative rank (<0) and 11 specimens (tooth) showed no difference (=0). These results show that the number of carious sections with a carious layer thicker than 1 mm was higher in the SmartPrep group than in the bud bur group in 30 of 50 teeth. The number of carious sections was higher in the bud bur group than in the SmartPrep group in 9 teeth, and 11 teeth showed no difference in the prevalence of caries between the two different groups of burs. Analysis of the data with the non-parametric Wilcoxon test for combined random samples (two-sided) stated that the results were statistically significant different (p=0.003). The SmartPrep excavation showed statistically significantly more often a carious layer thicker than 1 mm compared to conventional bud bur excavation.

Logistical Regression

Binary logistical regression clearly showed that only the variable "bur" (bud bur or SmartPrep) influenced the results concerning the criteria "caries" (p<0.001). The variable "tooth" (p=0.837) or "sections" (p=0.955) had no influence on the results. Only the variable "bur" (bud bur or SmartPrep) influenced the results concerning the criteria "thickness (>1 mm) of the carious layer" in carious sections (p<0.001); whereas, the variable "tooth" (p=0.895) or "sections" (p=0.971) had no influence on the results. Therefore, it can be concluded that only the method of excavation (SmartPrep or bud bur) influenced the results.

DISCUSSION

The sample teeth, extracted for various reasons, were stored in PBS buffer solution in a refrigerator. PBS buffer does not alter carious dentin. Other storage media such as alcohol, formalin or glutaraldehyde may react with the dentin collagen structure and may lead to a hardening of the dentin caries. In contrast, PBS buffer possesses a light antibacterial effect without changing the collagen structure of the dentin or denaturated proteins (Ericson, 2003, personal communication).

Excavating corresponding cavity halves minimizes differences in the excavation results due to the different extension, depth, localization and structure of the caries. Five trained dentists performed the excavation in order to minimize individual mistakes during bur handling and/or dentin probing.

Histological evaluation was performed by one examiner who evaluated the histological sections without knowing how the specimens were treated.

Caries diagnosis, merely by clinical criterions such as surface hardness and dentin color, can be used in a scientific examination only with restriction, because the individual dentist might be influenced by subjective experience. Therefore, a histological examination is necessary in order to obtain reproducible results (Scheutzel, 1989). For histological staining, it has to be noted that dentin caries can be divided into distinct layers. The outer layer is contaminated by bacteria, causing a non-remineralizable necrotic collagen matrix. In contrast, bacteria are less frequently observed in the inner layer, and the collagen has been reversibly denaturated but retains the crossbanded ultrastructure. If the acid challenge is removed, the inner layer has the potential to remineralize (Ogushi & Fusayama, 1975). Mallory-Azan staining allows for distinguishing between these two layers (Ogushi, 1973). Healthy, non-altered collagen will stain blue; whereas, affected carious dentin will appear red (Böck, 1989). In conclusion, Mallory-Azan staining is a quite large-scale method that allows for obtaining very exact results (Ogushi, 1973). This reliable method has been used in other similar studies (Scheutzel, 1989; Dammaschke & others, 2001).

Statistical evaluation was performed using the non-parametric Wilcoxon test for combined random samples. Because the same statistical test had been undertaken on the same data twice (first for the evaluation of remaining caries, then for thickness of the remaining caries), a Bonferroni correction had to be performed. Normally, α is set at 0.05. In this case, α had to be divided by the number of performed tests (two). Therefore, α was set here at 0.025. Nevertheless, the results are significant (p<0.001 for the remaining caries, and p=0.003 for the caries thickness). In addition, binary logistical regression showed that only the variable "bur" (SmartPrep or bud bur) influenced the results, but neither the variables "tooth" nor "section."

The concept of removing only the outer or superficial layer of carious dentin has also been followed by Carisolv, a viscous gel for chemo-mechanical caries removal (Ericson & others, 1999). As found in several *in vitro* investigations, Carisolv is able to remove carious dentin, but it needs prolonged time for excavation com-

pared to rotary instruments (Banerjee, Kidd & Watson, 2000; Dammaschke & others, 2001; Yazici & others, 2003). In contrast to chemo-mechanical caries excavation, the SmartPrep system is similar to conventional bud burs working in a rotary motion driven by a handpiece. Until now, no data were available as to whether SmartPrep is effective in dentin caries removal. Within the limitations of this *in vitro* study, SmartPrep was significantly less effective in removing carious dentin than conventional tungsten carbide bud burs. Only 25.6% of the SmartPrep treated specimens were histologically caries-free; whereas, the bud burs showed 53.7% caries-free samples. It is interesting to note that even after excavation with conventional bud burs, less than 60% of the specimens were caries-free. However, the results of this study are in accordance with similar studies (Scheutzel, 1989; Dammaschke & others, 2001). One reason may be that dentists had difficulty in handling the small, split sample teeth. Although, in a more clinical type of experiment, both bur systems might show better histological results, but it can be assumed that the relation of caries-free specimens between SmartPrep and bud bur will be similar, because the difference was statistically highly significant.

In some cases, the microtensile bond of several dentin bonding systems was significantly lower after the SmartPrep preparation than after the carbide bur excavation (Silva & Thompson, 2003). The reason for these results may be insufficiently removed dentin caries in the polymer bur group, because the bond strength of dentin adhesives to sound dentin is significantly higher than to carious dentin (Yoshiyama & others, 2002).

All dentists reported the same subjective impression: even though they felt the need to excavate more dentin, which clinically appeared to be in carious conditions, the new SmartPrep burs were not able to remove this dentin. As soon as the burs touched the dentin, the polymer was worn. To increase the efficiency of the SmartPrep system, the polymer should be harder. Another problem reported by all dentists was that, in small cavities, the polymer bur easily touched the enamel by chance and the SmartPrep bur went blunt.

CONCLUSIONS

It can be concluded that, using materials harder than carious dentin but softer than non-altered dentin, is a new approach in developing new methods in dentin caries excavation. However, within the limitations of this *in vitro* study; the SmartPrep polymer bur seems to be less effective in the excavation of carious dentin when compared with tungsten carbide bud burs.

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