

# The Effectiveness of Alumina Powder on Carious Dentin Removal

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## Clinical Relevance

When an air abrasion system is used, 27 and 50  $\mu\text{m}$  aluminum oxide particles remove carious dentin with maximum preservation of sound structure when compared to 125  $\mu\text{m}$  particles.

## SUMMARY

This study determined the size of aluminum oxide particles used in an air abrasion system that is able to remove carious dentin tissue with maximum preservation of sound structure. Thirty extracted and carious-free third molars were used in this study. The dentin sample was obtained by sectioning the middle of the crown longitudinal to the long axis of the tooth in a mesio-distal direction. One half of the crown corresponded to the sound dentin group (SD), while

the other half was used to develop artificial caries, constituting the carious dentin group (CD). The specimens were air abraded for 15 seconds. The SD and CD groups were each randomly divided into three subgroups (N=10) according to the particle diameter employed (27, 50 and 125  $\mu\text{m}$ ). The prepared cavity was perpendicularly cut in half, and the profiles of all hemi-fragments were observed using SEM microscopy. The cavity measurements were made using a modified cephalometric analysis. The 27, 50 and 125  $\mu\text{m}$  aluminum oxide particles did not present selectivity in the removal of carious dentin. However, when using the air abrasive technique for carious dentin treatment, the use of 27 and 50  $\mu\text{m}$  aluminum oxide particles is recommended, due to their capacity to remove less sound tissue than the 125  $\mu\text{m}$  particles.

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## INTRODUCTION

Early in the 20<sup>th</sup> century, dental caries treatment was based on the principle of "extension for prevention." The complete infected dentin and part of the sound tooth structure were removed to ensure elimination of disease and prevent the development of new lesions (Black & Black, 1924). In addition, to improve retention of the restorative materials of that time, the cavities needed to present specific forms, weakening even more of the tooth crown.

Following studies related to the caries process, Fusayama (1979) observed that carious dentin consisted of two layers, each having different morphological and biochemical characteristics. The superficial carious dentin, greatly softened by demineralization and tubules invaded by bacteria, should be totally removed; whereas, the deeper layer must be preserved, since it is not infected and reversibly denatured and remineralizable.

Due to the knowledge of caries pathology and with the advent of adhesive restorative materials, the practice of "extension for prevention" gave way to "minimally invasive dentistry." This new philosophy incorporates the early diagnosis, prevention and control of the disease and extremely conservative interventions (Mertz-Fairhurst & others, 1998; Tyas & others, 2000; Maltz & others, 2002; Murdoch-Kinch & McLean, 2003; Fejerskov, 2004). Following this new cariology paradigm, new techniques for dental caries treatment have been introduced, such as the air abrasion system. This technology uses the kinetic energy of abrasive particles to promote the cut of the tooth structure. When compared to the high-speed bur, the air-abrasion technique provides more conservative preparations (Banerjee, Kidd & Watson, 2000a; White & Eakle, 2000; Peruchi & Santos-Pinto, 2001).

With regards to the abrasive agent used in the air-abrasion machine, pure aluminum oxide seems to be the most frequently employed particle. This is due to its favorable characteristics, such as cutting effectiveness of the tooth structure, chemical stability, low cost, ease of purchase, no great affinity to water and its neutral color (Black, 1945). These particles do not present evidence of any health hazard to patients or operators, since they are properly protected (Van Leeuwen & Rossano Jr, 1952; Wright & others, 1999; Mayer & others, 2003) and the exposure limit of 15mg/m<sup>3</sup> is respected (Occupational Safety & Health Administration, 2001).

Although some studies have demonstrated the effectiveness of the abrasive technique in carious dentin removal (Horiguchi & others, 1998; Banerjee, Watson & Kidd, 2000b), there are still some doubts regarding which alumina particle size should be recommended. Taking this into consideration, this study determined the size of the aluminum oxide particle used in an air abrasion system which removes carious dentin tissue with maximum preservation of sound structure. The null hypothesis to be tested was that aluminum oxide particles of different diameters (27, 50 and 125 µm) remove carious dentin in the same manner.

## METHODS AND MATERIALS

Subjects who contributed molars for this research provided their informed consent for the protocol

(#215/2002), which had been approved by the Committee on Human Research of Araraquara Dentistry School—UNESP. Thirty extracted, caries-free, unrestored third molars were used in this study. Each tooth was hand scaled and cleaned with a slurry of pumice and water using a prophylaxis cup in a low-speed handpiece. The teeth were then stored in 0.1% thymol solution for no more than six months before use (Goodis & others, 1993; Ziskind & others, 2003).

The dentin sample was obtained by sectioning the middle of the crown longitudinal to the long axis of the tooth in a mesio-distal direction using a low-speed diamond blade (Isomet-Buehler, Lake Bluff, IL, USA) under running water. One half of the crown was placed in plastic tubes and embedded in dental wax, leaving the exposed dentin surface upward and parallel to the base. This sample corresponded to the sound dentin group (SD).

The other half of the crown received a layer of epoxy resin (Araldite, Huntsman Advanced Materials, B-3078 Everberg, Belgium) to coat the enamel surface and two layers of nail varnish (Colorama, Maybelline New York, Clark, NJ, USA). Thus, only the dentin surface was susceptible to the development of artificial caries, constituting the carious dentin group (CD). The specimens were then transferred to a beaker containing brain-heart infusion culture medium supplemented with yeast extract, 0.5% glucose, 1% sucrose and 2% young primary culture of *Streptococcus mutans* (ATCC 25175) and *Lactobacillus acidophilus* (ATCC-IAL-523) (Klein, Kanellis & Drake, 1999). The specimens were incubated at 37°C in a candle jar (BBL GasPak system, Becton-Dickinson, Franklin Lakes, NJ, USA). Every 48 hours, the specimens were transferred to a new media and inoculated with fresh primary cultures. After 28 days, the specimens were washed in deionized water and placed in a plastic tube, as was the SD group.

To determine the aluminum oxide particle size capable of removing the maximum amount of carious dentin and to preserve maximum sound structure, three diameters were selected for this study: 27, 50 and 125 µm (NMartins and Teixeira Ltda, Curitiba, PR, Brazil). The air abrasion machine (Microetcher II, Danville Engineering, San Ramon, CA, USA) and the specimen were fixed in a specially designed device, with the nozzle tip positioned perpendicular to the sample surface and with a nozzle-sample distance of 1 mm. The nozzle diameter was 1.2 mm, and the abrasive stream was applied on the dentin surface for 15 seconds on an area between the pulpal roof and the dentinoenamel junction. The air pressure was regulated for 70 psi.

The SD and CD groups were randomly divided into three subgroups each (N=10), according to the particle diameter employed (SD27, SD50, SD125, CD27, CD50, CD125) (Table 1).



Table 1: Experimental Conditions							
Particle	Time	Nozzle Diameter	Nozzle-sample Distance	Group	Particle Diameter	Subgroup	N
Al <sub>2</sub> O <sub>3</sub>	15 seconds	1.2 mm	1 mm	Sound Dentin (SD)	27 µm	SD27	10
					50 µm	SD50	10
					125 µm	SD125	10
				Cariou s Dentin (CD)	27 µm	CD27	10
					50 µm	CD50	10
					125 µm	CD125	10

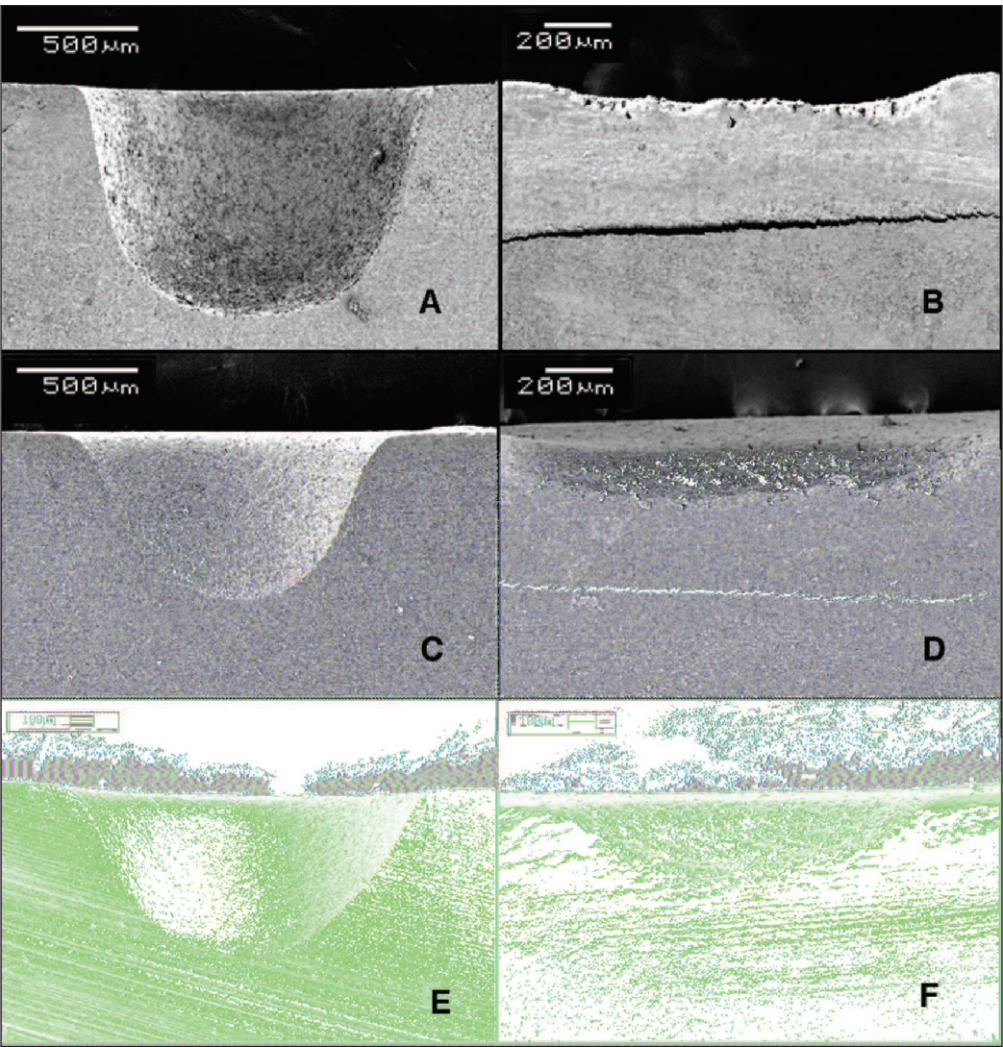


Figure 1. A, C & E: Air-abraded sound dentin with 125, 50 and 27 µm alumina powder, respectively; B, D & F: Air-abraded carious dentin with 125, 50 and 27 µm, respectively.

The independent variables analyzed were the dentin condition (sound and carious) and particle diameter (27, 50 and 125 µm) used as an abrasive agent. The dependent variables observed were the depth and width of the cavity produced.

After cavity preparation with the air abrasion system, the specimens were removed from the plastic tube and the new cavity was perpendicularly cut in half, using a low-speed diamond blade under running water.

The hemi-fragments from the CD group were fixed in buffered and isotonic aldehyde and tetroxide osmium solutions and dehydrated in ascending grades of acetone followed by freeze drying to critical point. This process was utilized to avoid the collapse of structures present on the surface of the specimens.

All the hemi-fragments (SD and CD Group) were sputter-coated with gold to observe the profile of the cavity using SEM microscopy (LEO 435 VP, Cambridge, England).

The cavity measurements were made using a modified cephalometric analysis (DF Plus 6.5 1995, Dentofacial Software Inc, Toronto, Canada). The depth and width of the cavity preparations were obtained through three measured points: the occlusal cavosurface angle, the cervical cavosurface angle and the deepest point of the cavity.

After testing the data for the normality and variance homogeneity using the Shapiro Wilk's and Bartlett tests, respectively, data were analyzed using linear two-way ANOVA ( $p<0.001$ ) and Tukey's Studentized range procedure for multiple comparison tests ( $p<0.05$ ).

RESULTS

The cavities obtained in sound and carious dentin were similar in morphology but different in their dimensions when the abrasive particle size was varied. Figure 1 (A-F) shows the rounding of the cavosurface margin, the internal line angles and the different widths and depths

of the cavities when different particle diameters were used.

The depth and width means of the cavities are summarized in Table 2 based on the particle size and dentin condition. The cavity measurements were significantly larger in sound dentin (SD group) than in carious dentin (CD group) ( $p < 0.05$ ).

The particle size had a significant effect on the abraded depth and width ( $p < 0.05$ ) (Table 3). The 27 and 50  $\mu\text{m}$  particles removed significantly larger amounts of carious dentin than the 125  $\mu\text{m}$  particles ( $p < 0.05$ ). In sound dentin, shallower cavities were observed when the 27 and 50  $\mu\text{m}$  particles were used ( $p < 0.05$ ), while the 125  $\mu\text{m}$  particles produced significantly narrower preparations than the 27  $\mu\text{m}$  particles ( $p < 0.05$ ).

## DISCUSSION

Currently, the conventional method of carious dentin removal is the bur used in a contra-angled handpiece. However, in looking for a minimally invasive treatment, alternative techniques, such as the air-abrasion system, are being introduced to the market. Banerjee and others (2000a,b) observed that, for carious dentin removal, the air-abrasive technique presented an effectiveness similar to hand excavation and was a more conservative technique than the bur technique.

The air abrasion cutting principle is based on the kinetic energy of abrasive particles. Some factors, such as tip diameter (Peruchi & others, 2002), air pressure (Horiguchi & others, 1998; Laurell & Hess, 1995), tip angle (Santos-Pinto & others, 2001a, b), tip-to-tooth distance of the abrasive stream application (Peruchi & others, 2002) and particle type and size (Horiguchi & others, 1998), may vary the energy of the particles and, consequently, influence cavity preparation. For this reason, to evaluate only the effect of the particle type, all the other variables were constantly maintained in this study.

The surface condition, where the particles collide, may also influence the morphology and dimension of the cavity preparation. In this study, the abrasive technique performance was evaluated on two different substrates: sound dentin and carious dentin. Zheng and others (2003) demonstrated that different types of dentin caries present different degrees of hardness. Therefore, to standardize the caries dentin used in this study, avoiding possible interference in results, the authors opted for artificial caries lesions.

Table 2: Width and Depth Means From Cavities Obtained in the Different Groups

Group	Width ( $\mu\text{m}$ )		Depth ( $\mu\text{m}$ )	
	Mean	SD	Mean	SD
SD27	1591.44	75.73	680.79	78.57
SD50	1547.16	79.74	683.54	131.10
SD125	1518.21	77.57	869.64	43.23
CD27	1360.03	175.72	219.84	101.81
CD50	1375.31	91.37	239.45	33.14
CD125	1231.25	101.77	100.76	12.93

Table 3: Effect of Alumina Particle Size on Abraded Width and Depth in Sound (SD) and Carious Dentin (CD)

Particle Size	Width		Depth	
	SD	CD	SD	CD
27 $\mu\text{m}$ vs 50 $\mu\text{m}$	NS	NS	NS	NS
27 $\mu\text{m}$ vs 125 $\mu\text{m}$	S	S	S	S
50 $\mu\text{m}$ vs 125 $\mu\text{m}$	NS	S	S	S

S = significant ( $p \leq 0.05$ ); NS = not significant

The cavity morphology stayed constant, regardless of tissue condition (Figure 1). The rounding of the cavo-surface margins and internal angles are characteristic of those found in cavities prepared by the air abrasion technique and were probably caused by lower efficiency of the peripheral portion of the stream due to the lower concentration and velocity of particles in this area (Peruchi & others, 2002; Laurell & Hess, 1995).

With regard to cavity size, the three diameters of aluminum oxide particles tested (27, 50 and 125  $\mu\text{m}$ ) produced significantly deeper and wider cavities in sound dentin than in carious dentin. The same findings were observed by Horiguchi and others (1998) when they used 49, 74 and 125  $\mu\text{m}$  aluminum oxide particles. This phenomenon is due to differences in hardness between sound and carious dentin. Due to the softer consistency of the infected tissue, some of the particles had their energy absorbed during impact, reducing the force necessary to cut the dental structure.

Evaluating the particle diameter, Tables 2 and 3 demonstrate that the 125  $\mu\text{m}$  alumina particles were more invasive than the 27 and 50  $\mu\text{m}$  particles, showing that the former produced deeper cavities in sound dentin and shallower cavities in carious dentin. The ability of larger diameter particles to provide a deeper cut in sound dentin may be explained by the kinetic energy theory ( $E = 1/2mv^2$ , where  $m$  is the mass and  $v$  the speed of the particle). Increasing particle mass, the kinetic energy can be increased and, consequently, the cut of the abrasive stream will be more effective. However, in carious dentin, the increase in particle mass could make tissue removal difficult, since the heavier particles penetrate the soft surface.



The 27 and 50  $\mu\text{m}$  alumina particles removed significantly greater amounts of carious tissue and smaller amounts of sound dentin when compared to the 125  $\mu\text{m}$  particles. This finding suggests that, during dental caries treatment, smaller diameter particles may preserve a greater quantity of healthy structure (Tables 2 and 3).

Although the 50  $\mu\text{m}$  alumina particles present greater mass than the 27  $\mu\text{m}$  particles, there was no significant difference in the cut effectiveness for the two substrates tested in this study. When smaller particles are used, a more intense powder flow rate (mg/minute) is produced when compared to larger particles; thus, a larger quantity of 27  $\mu\text{m}$  particles hit the dental surface, producing an energy dose similar to that generated with a smaller quantity of 50  $\mu\text{m}$  particles. In addition, during impact, such large particles make contact with a larger surface area than do smaller particles, expending the available energy over a larger area and reducing the stress necessary to cut the dental structure.

In contrast to the results of this study, Horiguchi and others (1998) verified that, with larger aluminum oxide particles, more carious dentin is removed. The authors speculate that this result may be due to the difference in tip-to-tooth distance and the air pressure used, both which are variables that may influence the quantity of particles kinetic energy (Peruchi & others, 2002; Laurell & Hess, 1995). A different model of artificial caries used by these authors might also have produced a different surface condition from that of the current study.

### CONCLUSIONS

The 27, 50 and 125  $\mu\text{m}$  aluminum oxide particles do not present selectivity in the removal of carious dentin when a 1.2 mm nozzle tip, tip-to-tooth distance of 1 mm and an air pressure regulated to 70 psi are used in the air abrasion system. However, when using the air abrasive technique for carious dentin treatment, the use of 27 and 50  $\mu\text{m}$  aluminum oxide particles are recommended due to their capacity to remove less sound tissue than the 125  $\mu\text{m}$  particles.

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