Influence of Kinetic Cavity Preparation Devices on Dental Topography: An in vitro Study

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Abstract

Aim: The objectives of this study were to assess the influence of four different kinetic cavity preparation devices on cavity preparation taking into account tip angulation, internal tip diameter, and distance to the dental substrate. The dental topography itself was also evaluated after the use of these devices.

Methods and Materials: Quantitative parameters using pertinent statistical tests as well as qualitative parameters were used to assess the topography in terms of the dispersion halo effect (DHE), size, and depth of the preparation.

Results: The DHE did not present differences among the groups. In relation to the preparation size, the internal diameter influenced 120° point angles, whereas distance influenced the 90° ones. Considering the preparation depth, the 90° point angle yielded the deepest. In the qualitative analysis, both angles provided cavity preparations with rounded cavosurface angles. The 120° point angles yielded inclined, shallow V-shaped preparations, whereas the 90° angles presented U-shaped preparations reaching the dentin. The enamel had an irregular aspect and exposed prisms; dentin had a loose smear layer with aluminum oxide residues.

Conclusion: The kind of device may influence the kinetic cavity design.
Clinical Significance: It is the clinician that knows how to select the appropriate devices to adopt in order to achieve the desired cut, depth, and shape of cavity preparations.

Keywords: Kinetic cavity design, dental instruments, dental air abrasion, dental cavity preparation, caries removal techniques


Introduction
Minimally invasive dentistry is based on the removal of irreversibly damaged dental tissue while abolishing further preventive angle conformation and retention in cavity design. This new approach to dental caries lesions has been made possible by the improvement of adhesive restoration materials\(^1,2\) and alternative methods for removing carious tissue such as the use of ultrasonic instruments, chemomechanical processes, laser therapy, and the air abrasion instruments.\(^3,4,5,6\)

Cavity preparation using air abrasion was introduced to dentistry by Black,\(^7\) in 1945, and since then it has been presented in the literature using terminology such as airabrasive,\(^7\) microblasting, or aluminum oxide blast,\(^8\) and currently, kinetic cavity preparation. This term is used because the technique uses the kinetic energy of aluminum oxide particles at high speed and air flow to remove tooth structure.\(^9,10\)

Cutting standards in kinetic cavity preparation may vary according to several parameters adopted, such as angulation, internal diameter of the tip, distance to the tooth, pressure, particle size, and flow.\(^7,11,12,13\)

Several obstacles to the use of air abrasion systems for cavity preparations are reported in the literature including the following:\(^4,14,15\)
- The absence of instrument-tooth contact which precludes any tactile sensitivity during the cutting procedure.
- The difficulty in determining the final size and shape of the preparation.
- Insufficient knowledge of how to deal with the enamel erosion on the occlusal surface during cavity preparation.

The primary objective of this in vitro study was to assess the influence of four different kinetic cavity preparation devices taking into account angulation, the internal diameter of the tip, and the distance to dental substrate. In addition, the study assessed the dental topography after the use of these devices.

Methods and Materials
Bovine incisors (n=24) with no structural alterations were selected for the study following evaluation with an optical microscope (40x magnification). Teeth were then stored in saline solution, at room temperature. The solution was replaced every seven days until the experiment was conducted.

Two cylindrical cavity preparations were made on the facial surface of each tooth, one in the mesial and the other in the distal portion by using a RONDOLflex 2013 (KaVo™, Biberach/ Riss, Germany) air abrasion system with 50 μm aluminum oxide particles under 80 psi pressure over a standardized period of two minutes. During the first preparation of each facial surface, the portion not being prepared was attached to a wax-covered glass plate and a lead film was placed over the tooth to protect it from being worn by the scattered aluminum oxide particles which could influence the second preparation.

The preparations (n=48) were distributed into eight groups according to angulation, internal diameter of the tip, and tip-tooth distance (Table 1).
The evaluation of the cavity preparation topographies was performed with consideration of quantitative parameters such as the influence of the angle of kinetic cavity preparation devices, the internal tip diameter, and the tip-tooth distance. A qualitative parameter, the topography after kinetic cavity preparation, was also considered.

Quantitative Analysis  
For the quantitative analysis, forty preparations were analyzed. The variables used were the dispersion halo effect (DHE) and the size and depth of the cavity preparation. Measurements were made by two evaluators (ICC = 0.94) with the help of a digital caliper (Mitutoyo Corporation, Kawasaki, Japan).

The DHE was determined by measuring the most external wear point caused by the dispersion of aluminum oxide particles in three distinct areas of the preparation margins. The sizes of the cavity preparations were measured by registering the height (cervicoincisal) and width (mesiodistal) of each and computing the mean of these dimensions. For the depth measurement, the teeth were sectioned into segments containing both preparations by careful use of double-faced diamond discs. After sectioning, the segments were separated to prevent any contact between the disk and preparation (Figure 1). The mean was obtained by measuring from the cavosurface angle to the bottom of the preparation.

The influence of tip angulation, internal tip diameter, and tooth-tip distance on the size and depth of the DHE were considered after obtaining the means. For group comparison, the data were descriptively analyzed and statistically treated according to the Pearson’s correlation test, multiple analysis with the Scheffe’s test, Student’s t-test, and the paired Student’s t-test at a 5% significance level for all tests.

Qualitative Analysis  
For the qualitative analysis, all preparations were metalized and then analyzed using a scanning electronic microscope (SEM - JEOL–8059, Japan Electro Optics Laboratory LTD, Akachima, Tokyo, Japan) at 35x magnification. Eight preparations were used to analyze the contours left by the tips on the DHE (cavosurface angle). The other 40 preparations were used not only for observing their contours but also the topographical aspect left by the aluminum oxide particles on enamel and dentin after the use of different devices at 2000x magnification.

Results  
Quantitative Analysis  
Among the groups, it was possible to compare the sizes of the DHE and the preparations (Pearson’s Correlation: r = -0.524; p=0.001; r=0.314; p=0.049; r = -0.352; p=0.026).

The mean dimensions of the DHE, preparation depth, and size can be seen in Table 2. The DHE produced by all devices at both distances were similar, with no statistically significant difference (Scheffe’s test, p>0.05). With regard to preparation depth and size of all groups the 90° tips (G5, G6, G7, and G8) produced the deepest preparations, and the 120° tips tended to produce the largest preparations over a standard period of two minutes (Table 2). The preparation depth was only influenced by tip angulation as 90° tips produced deeper preparations and 120° tips produced more shallow ones regardless of the diameter and distance (Table 2).
Figure 1. Diagram representing the fragments containing the preparation groups.

Table 2. Values (mean ± standard deviation) of the dispersion halo effect (DHE), depth, and size of the cavity preparations according to the group.

<table>
<thead>
<tr>
<th>Groups (n=40)</th>
<th>Dispersion Halo Effect (mm)</th>
<th>Preparation Depth* (mm)</th>
<th>Preparation Size* (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.64 ±0.12</td>
<td>0.70 ±0.16</td>
<td>2.18 ±0.25</td>
</tr>
<tr>
<td>G2</td>
<td>0.00 ±0.97</td>
<td>0.66 ±0.10</td>
<td>3.26 ±0.59</td>
</tr>
<tr>
<td>G3</td>
<td>0.53 ±0.12</td>
<td>0.67 ±0.08</td>
<td>2.00 ±0.26</td>
</tr>
<tr>
<td>G4</td>
<td>0.70 ±0.13</td>
<td>0.77 ±0.13</td>
<td>2.58 ±0.47</td>
</tr>
<tr>
<td>G5</td>
<td>0.58 ±0.16</td>
<td>1.67 ±0.22</td>
<td>1.37 ±0.15</td>
</tr>
<tr>
<td>G6</td>
<td>0.60 ±0.80</td>
<td>1.68 ±0.19</td>
<td>1.57 ±0.25</td>
</tr>
<tr>
<td>G7</td>
<td>0.53 ±0.13</td>
<td>1.64 ±0.16</td>
<td>2.02 ±0.15</td>
</tr>
<tr>
<td>G8</td>
<td>0.63 ±0.12</td>
<td>1.65 ±0.91</td>
<td>2.31 ±0.32</td>
</tr>
</tbody>
</table>

- Scheffe’s test
- * 5% significance level
Table 3. Analysis of the groups in preparation depth and size associating variables by pairs.

<table>
<thead>
<tr>
<th>Alterned Variables</th>
<th>Groups</th>
<th>Preparation Depth (p value)</th>
<th>Preparation Size (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>G1 x G2</td>
<td>0.30 ¹</td>
<td>0.00* ¹</td>
</tr>
<tr>
<td></td>
<td>G3 x G4</td>
<td>0.11 ¹</td>
<td>0.04* ¹</td>
</tr>
<tr>
<td></td>
<td>G5 x G6</td>
<td>0.86 ¹</td>
<td>0.17 ¹</td>
</tr>
<tr>
<td></td>
<td>G7 x G8</td>
<td>0.70 ¹</td>
<td>0.11 ¹</td>
</tr>
<tr>
<td>Distance</td>
<td>G1 x G3</td>
<td>0.75 ²</td>
<td>0.33 ²</td>
</tr>
<tr>
<td></td>
<td>G2 x G4</td>
<td>0.07 ²</td>
<td>0.06 ²</td>
</tr>
<tr>
<td></td>
<td>G5 x G7</td>
<td>0.85 ²</td>
<td>0.00* ²</td>
</tr>
<tr>
<td></td>
<td>G6 x G8</td>
<td>0.77 ²</td>
<td>0.00* ²</td>
</tr>
<tr>
<td>Angle</td>
<td>G1 x G5</td>
<td>0.01* ²</td>
<td>0.00* ²</td>
</tr>
<tr>
<td></td>
<td>G2 x G6</td>
<td>0.00* ²</td>
<td>0.00* ²</td>
</tr>
<tr>
<td></td>
<td>G3 x G7</td>
<td>0.00* ²</td>
<td>0.89 ²</td>
</tr>
<tr>
<td></td>
<td>G4 x G8</td>
<td>0.00* ²</td>
<td>0.30 ²</td>
</tr>
</tbody>
</table>

Note: ¹Paired Student's t-test; ²Student's t-test; *5% significance level

As shown in Table 3, larger cavity preparations were created with 120° tips with a larger internal diameter (0.64 mm) at tip-tooth distances of 1.0 mm and 2.0 mm (G2>G1* and G4>G3*) than with the 90° tips (G5=G6ns and G7=G8ns). At these tip-tooth distances, such a variation in the internal diameter appeared to only influence preparations done using 120° tips (Table 3).

No difference in preparation size was found for 120° tips with 0.64 mm and 0.46 mm internal diameters regardless of the tip-preparation distances (G2=G4ns and G1=G3ns) used. However, the largest preparations were those made at longer tip-tooth distances (G7>G5* and G8>G6*) using 90° tips regardless of its diameter. Variation in distance was more likely to influence 90° point angle tips (Table 3).

At the 1.00 mm tip-tooth distance, significant differences in the preparation sizes (G1>G5* and G2>G6*) were observed as the 120° tips produced larger preparations than the 90° tips regardless of the diameters (0.46 or 0.64 mm) or angles (120° or 90°). However, no statistically significant difference was found in the preparation size (G3=G7ns and G4=G8ns) at the 2.00 mm tip-tooth distance suggesting the tip angle variation had more influence on cavity preparations at shorter distances (Table 3).

Results

Qualitative Analysis

In the descriptive analysis, the contours of both haloes and preparations were evaluated by observing the different forms of particle dispersion caused by the 120° and the 90° point angles. The cavity contours produced by 120° tip angles (Figure 2 a, b, c, and d) were found to be inclined, whereas those made by 90° tip angles (Figure 2 e, f, g, and h) were characteristic of Class V and Class I preparations, respectively.

The 120° tip angles produced more expulsive cavosurface angles and less inclined V-shaped preparations, usually at the enamel level (Figure 3). On the other hand, the 90° point angle yielded rounded cavosurface angles and deep U-shaped preparations reaching the dentin (Figure 4).
Figure 2. Comparison between cavity preparations according to tip angulation used, 120° (a-G1; b-G2; c-G3; and d-G4) and 90° (e-G5; f-G6; g-G7; and h-G8). The difference in the shape of the contours of the cavosurface angles of both preparations and the DHE is shown (SEM, 35x).

Figure 3. Photomicrograph showing kinetic cavity preparation with 120° tip. A wide, shallow preparation short of the dentin layer can be observed as well as its rounded cavosurface margin (SEM, 35x).

Figure 4. A photomicrograph showing a kinetic cavity preparation with a 90° tip. It has a deeper and more rounded angulation of the cavosurface margin with a less expulsive termination (SEM, 35x).
Due to the more shallow depth of the cavity preparations performed with 120° angle tips it was possible to observe an irregular topography in the enamel caused by the impact of the aluminum oxide particles. This impact resulted in the presence of exposed enamel prism heads and scattered aluminum oxide particles (Figure 5). A loosely adhered smear layer was found in preparations created with 90° tips which suggest the appearance of the entrance of dentinal tubules (Figure 6) as the preparation reached the dentin layer.

Discussion

Studies 3,12,13,15,16 on alternative forms of performing cavity preparations (e.g., high-speed rotation) have been conducted with the objective of finding new strategies for improving clinical outcomes such as the conservation of tooth structure using conservative preparations and the improvement of the adhesion of restorative materials.

To accomplish this goal, the present study was carried out under conditions similar to those found in the clinical setting without using resources or devices to enhance the consistency and reliability of the clinical outcomes. The employment of such devices has been questioned by Santos-Pinto et al. 13

The use of bovine teeth in this study was justified because of the similar behavior of bovine, permanent and deciduous teeth, in studies related to topography and the presence of a smear layer

which suggests these different substrates can be compared to each other. 17 As a result, bovine teeth have been used as a substrate and are commonly used in various studies due to the difficulties in obtaining human permanent and deciduous teeth.

Despite the differences in the types of preparations created with the kinetic cavity preparation system they are all extremely conservative 15,16 as demonstrated by the mean dimensions of the cavity preparations in the present study (Table 2).

Particle dispersion, reported by Laurell et al. 10 as ‘fanning’, is related to the distance between tooth and instrument tip 10 in which the DHE is formed in cavity preparations using the kinetic system. The authors of that study concluded the nearer the tip is to the tooth, the smaller the DHE. However, this finding was not confirmed in the present
study. The DHE was found to be present for all devices used, although the halo size was the same regardless of the parameters used in the analysis (Table 2).

Distance and angulation of the device in relation to the surface to be treated are determinants in the kind of cut to be performed.18 As stated by Bailey et al.,19 greater tooth-tip distances change the impact of the abrasive particles, reducing the cutting efficiency and resulting in larger shallow preparations. Concerning the dental substrate, the positioning of the tips in the air abrasion KaVo™ RONDOflex 2013 system (KaVo™, Biberach/Riss, Germany) showed statistical significance only for 90° tip angles, regardless of their internal diameter. With respect to cavity depth, this device (using a 90° angle tip) was not influenced by the distance nor by the internal diameter of the tip.

In the present study, the 120° angle tips have been listed as those which produced more shallow and larger preparations, whereas the 90° tips are those yielding deeper preparations (Tables 2 and 3). This was verified through quantitative as well as qualitative evaluations. The SEM facilitated observation of narrower, deeper U-shaped preparations made with 90° angle tips and V-shaped preparations produced with 120° tips that were shallower and larger. Both analyses suggest a 90° tip angle positioning might be indicated for performing minimally invasive Class I preparations of grooves and clefts which demonstrated a significantly favorable seal reported by Chan et al.20 or for cavities requiring deeper preparations. On the other hand, 120° tip angles could be indicated for Class V or larger preparations.

Santos-Pinto et al.12 noted the cutting depth was significantly greater when cavities were prepared using 80° tip angles instead of 45° angles. In the present study the SEM observations confirmed this relationship between the 90° and 120° tip angles. The greater inclination (120° angle) resulted in shallow preparations, thus, making it more difficult to reach the dentin layer. The same authors12 suggest these findings may be explained by the incidence angle of the aluminum oxide particle spray in terms of straight vs inclined angles of the tip. The different directions of the spray prevent the abrasive particles from reaching the tooth with the same impact.10

The increase in the tip angle is directly proportionate to the increase in the wall angles.7,18 In the present study the qualitative evaluation revealed the tips produced cavosurface angles as well as rounded internal contours in both angulations, which is in accordance with Hamilton et al.,20 Hicks et al.,22 Santos-Pinto et al.,12,15 and Peruchi et al.16 This rounded contour associated with the typical characteristics of air abrasion cutting (e.g., rough surface and DHE) is considered important if a longer durability of adhesive restorations is to be achieved.23 This finding is based on a reduction of fracture incidence, as compared to preparations with defined acute angles, because the rounded contour enables a gradual transition between tooth/restoration and reduced stress caused by polymerization contraction due to the rounded internal angles. This characteristic also favors good adhesion and restoration seating, thus, reducing microinfiltration.21,24

Following the kinetic cavity preparation the SEM analysis of the enamel revealed irregularities, indentations, and linear prism-like superficial depressions caused by the particle impact as described by Silva et al.8 However, according to Laurell et al.24 and Laurell et al.16 enamel prisms were not clearly observed which was justified by the presence of aluminum oxide residues. In this study it was possible to observe topographic irregularities as well as the presence of prisms even with the presence of aluminum residue.

On the other hand, the topographical characteristics of the dentin in the preparations created with a 90° tip angle were found to be different from the ones described by Laurell, et al.10 Those investigators observed a dense smear layer inside of and/or placed over the openings of dentinal tubules which impeded their view. In the present study the smear layer was found to be ‘loosely adherent’ and rich in aluminum oxide which suggested open tubules.

The presence of smear layer after the use of air abrasion is not yet fully understood. Further research is needed to resolve controversial issues surrounding this phenomenon. Gwinnet
et al.\textsuperscript{25} noted the absence of smear layer, debris, and plugs on dentin surfaces prepared by air abrasion which revealed open dentinal tubules and a rougher surface over a large area. However, Nikaido et al.\textsuperscript{26} did not observe the existence of dentinal tubules indicating a strong presence of smear layer.

The quality of the remaining enamel and the type of smear layer suggest the use of another kind of acid conditioning, such as self-etching primers. Surface treatment methods can influence preparation quality which in turn leads to an improvement in the quality of the final restoration using kinetic cavity preparation techniques. As a result of the inconsistent findings in the studies mentioned above, further research into the effectiveness of kinetic cavity preparation systems is needed.

Conclusions
The kind of kinetic instrument tip may influence cavity design. Thus, it is important to allow the clinician to know which devices should be employed in order to achieve the appropriate cut, depth, and shape of preparation. The 120° tip angles produced Class V cavity contours which are larger and flattened, whereas the 90° tip angles yielded Class I contours which are deeper and narrower. The 120° tip is indicated for cervical and occlusal preparations and the 90° tip angle for grooves and clefts.
References

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