the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 9 Number 2 February 1, 2008

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

Lívia Azeredo A. Antunes, DDS, MsC; Áurea Simone Barrôso Vieira, DDS, MsC; Márcia Pereira Alves dos Santos, DDS, MsC; Lucianne Cople Maia, PhD, DDS, MsC

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 120º point angles, whereas distance influenced the 90º 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 120º point angles yielded inclined, shallow V-shaped preparations, whereas the 90º 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 techiniques

Citation: Antunes LAA, Vieira ASB, Alves dos Santos MP, Maia LC. Influence of Kinetic Cavity Preparation Devices on Dental Topography: An *in vitro* Study. J Contemp Dent Pract 2008 February;(9)2:146-154.

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 airbrasive,[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 RONDOflex 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).

Table 1. Distribution of samples according to angulation, internal diameter, and point-tooth distance.

Angulation	120°				90°			
Internal Diameter (mm)	0.46	0.64	0.46	0.64	0.46	0.64	0.46	0.64
Point/Tooth Distance (mm)	1		2		1		2	
Groups	G1 (n=6)	G2 (n=6)	G3 (n=6)	G4 (n=6)	G5 (n=6)	G6 (n=6)	G7 (n=6)	G8 (n=6)

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 LTDA, 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 90º tips (G5, G6, G7, and G8) produced the deepest preparations, and the 120º 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 90º tips produced deeper preparations and 120º tips produced more shallow ones regardless of the diameter and distance (Table 2).

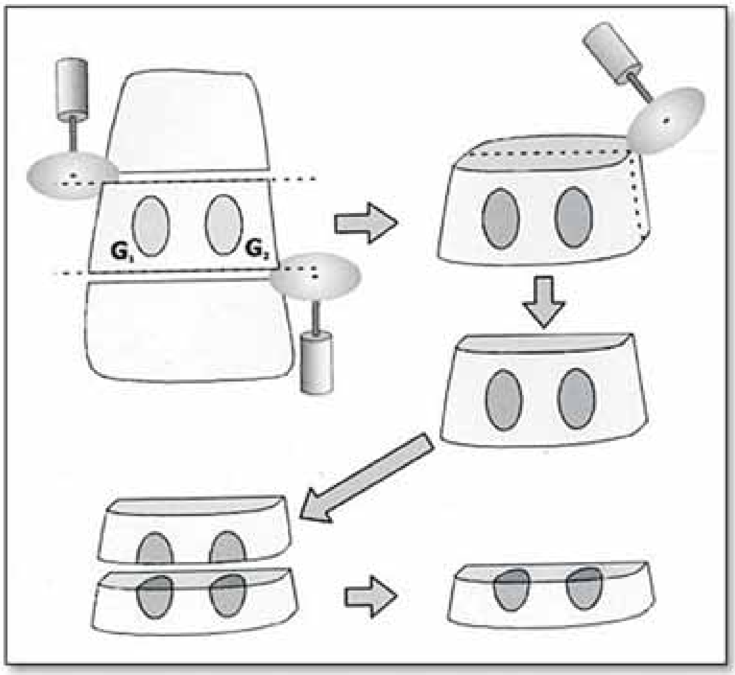


Figure 1. Diagram representing the fragments containing the preparation groups.

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

Groups (n=40)	Dispersion Halo Effect (mm)	Preparation Depth* (mm)	Preparation Size* (mm)
G1	0.64 ±0.12	0.70 ±0.16	2.18 ±0.25
G2	000.72 ±0.97	0.66 ±0.10	3.26 ±0.59
G3	0.53 ±0.12	0.67 ±0.08	2.00 ±0.28
G4	0.70 ±0.13	0.77 ±0.13	2.58 ±0.47
G5	0.58 ±0.16	1.67 ±0.22	1.37 ±0.15
G6	0.60 ±0.80	1.68 ±0.19	1.57 ±0.25
G7	0.53 ±0.13	1.64 ±0.16	2.02 ±0.15
G8	0.63 ±0.12	1.65 ±0.91	2.31 ±0.32

- Scheffe's test
- * 5% significance level

Table 3. Analysis of the groups in preparation depth and size associating variables by pairs.

Alterned Variables	Groups	Preparation Depth (p value)	Preparation Size (p value)
Diameter	G1 x G2	0.30 [1]	0.00* [1]
	G3 x G4	0.11 [1]	0.04* [1]
	G5 x G6	0.86 [1]	0.17 [1]
	G7 x G8	0.70 [1]	0.11 [1]
Distance	G1 x G3	0.75 [2]	0.33 [2]
	G2 x G4	0.07 [2]	0.08 [2]
	G5 x G7	0.85 [2]	0.00* [2]
	G6 x G8	0.77 [2]	0.00* [2]
Angle	G1 x G5	0.01* [2]	0.00* [2]
	G2 x G6	0.00* [2]	0.00* [2]
	G3 x G7	0.00* [2]	0.89 [2]
	G4 x G8	0.00* [2]	0.30 [2]

Note: [1]Paired Student's t- test; [2]Student'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).

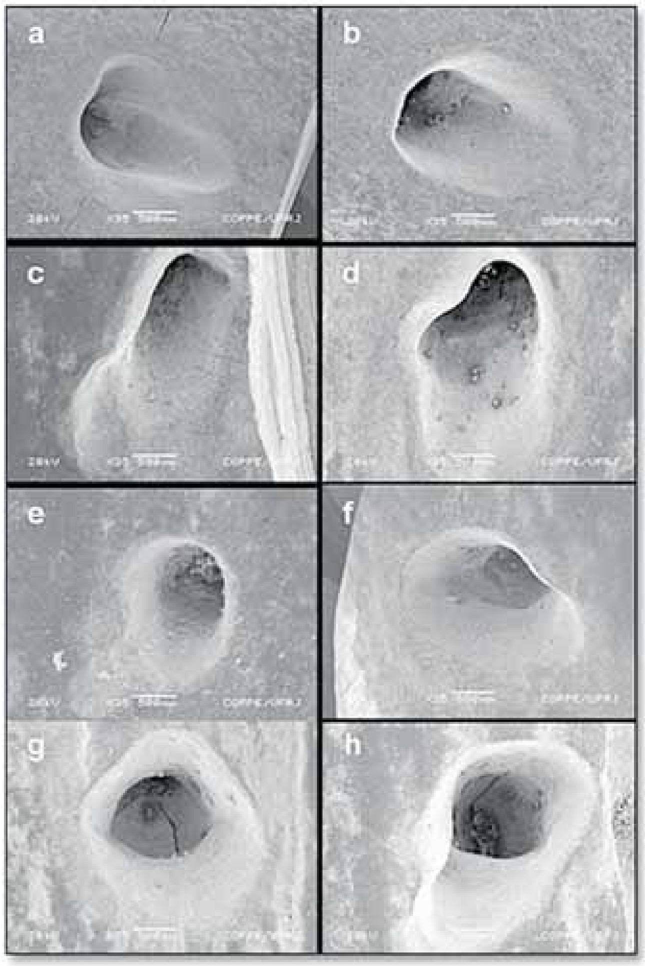


Figure 2. Comparison between cavity preparations according to tip angulation used, 120º (a-G1; b-G2; c-G3; and d-G4) and 90º (e-G5; f-G6; g-G7; and h-G8). The difference in the shape of the contours of the cavosurface angles of both preparations and the DHE is shown (SEM, 35x).

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

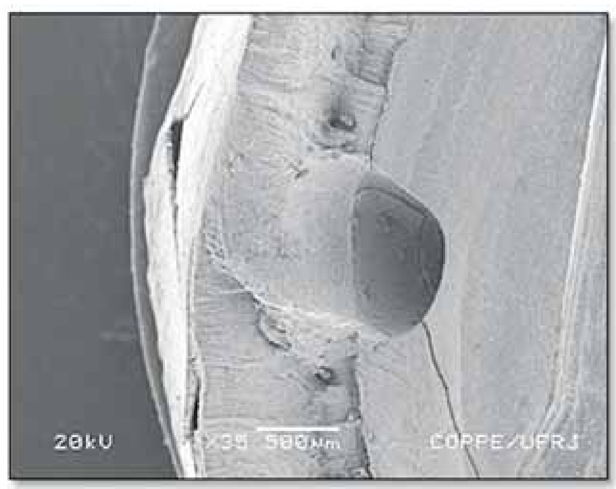


Figure 4. A photomicrograph showing a kinetic cavity preparation with a 90º tip. It has a deeper and more rounded angulation of the cavosurface margin with a less expulsive termination (SEM, 35x).

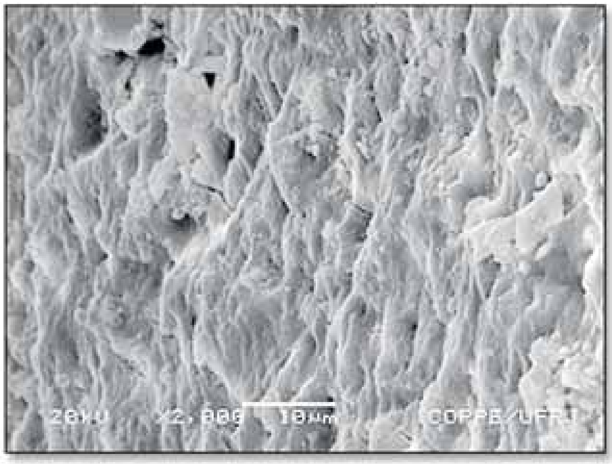


Figure 5. Topographical aspect of enamel with 120º point: surface irregularity owing to impact, exposure of enamel prisms, and scattered aluminum oxide particles (SEM, 2000x).

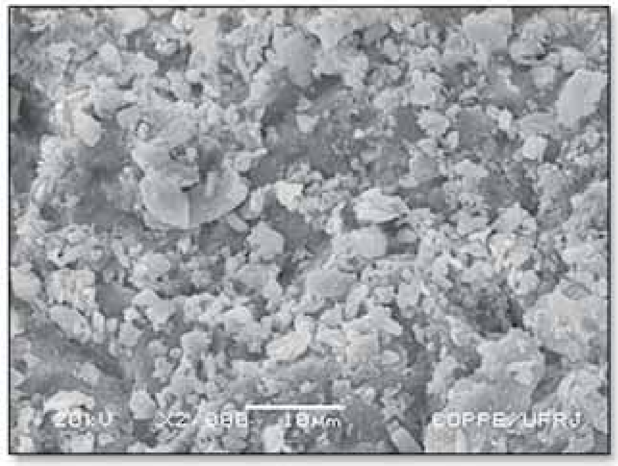
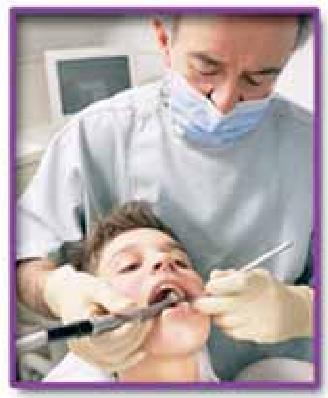


Figure 6. Topographical aspect of dentin with 90º point: presence of smear layer saturated with aluminum oxide particles, which covered almost completely the dentinal tubules (SEM, 2000x).

Due to the more shallow depth of the cavity preparations performed with 120º 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 90º tips which suggest the appearance of the entrance of dentinal tubules (Figure 6) as the preparation reached the dentin layer.



Discussion

Studies[7,12,13,15,16] 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.[7,18] 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 90º tip angles, regardless of their internal diameter. With respect to cavity depth, this device (using a 90º angle tip) was not influenced by the distance nor by the internal diameter of the tip.

In the present study, the 120º angle tips have been listed as those which produced more shallow and larger preparations, whereas the 90º 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 90º angle tips and V-shaped preparations produced with 120º tips that were shallower and larger. Both analyses suggest a 90º 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, 120º 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 80º tip angles instead of 45º angles. In the present study the SEM observations confirmed this relationship between the 90º and 120º tip angles. The greater inclination (120º angle) resulted in shallow preparations, thus, making it more difficult to reach the dentin layer. The same authors[12] 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.,[12,13] and Peruchi et al.[15] 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.[21,22]

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.[10] 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 90º 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.[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.[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 120º tip angles produced Class V cavity contours which are larger and flattened, whereas the 90º tip angles yielded Class I contours which are deeper and narrower. The 120º tip is indicated for cervical and occlusal preparations and the 90º tip angle for grooves and clefts.

References

1. Rainey JT. Air abrasion: an emerging standard of care in conservative operative dentistry. Dent Clin North Am 2002; 46(2):185-209.
2. Rosenberg S. Air abrasive microdentistry: a new perspective on restorative dentistry. Dent Econ 1995; 85(9):96-7.
3. Banerjee A, Watson TF, Kidd EAM. Dentine caries excavation: a review of current clinical techniques. Br Dent J 2000; 188(9):476-82.
4. Goldstein RE, Parkins FM. Air-abrasive technology: its new role in restorative dentistry. J Am Dent Assoc 1994; 125(5):551-7.
5. Horiguchi S, Yamada T, Inokoshi S, Tagami J. Selective caries removal with air abrasion. Oper Dent 1998; 23(5): 236-43.
6. Yip K, Samaranayake LP. Caries removal techniques and instrumentation: a review. Clin Oral Invest 1998; 2(4):148-54.
7. Black RB. Techinic for nonmechanical preparation of cavities and prophylaxis. J Am Dent Assoc 1945; 32(8):955-63.
8. Silva PCG, Gonçalves M, Nonaka TC, Vinha D. Dental enamel: qualitative evaluation of the surface after application of aluminum oxide (microetching) using the scanning electron microscope. Pesq Odontol Bras 2000; 14(4):334-9.
9. Black RB. Airabrasive: some fundamentals. J Am Dent Assoc 1950; 41(6):701-10.
10. Laurell KA, Hess JA. Scanning electron micrographic effects of air-abrasion cavity preparation on human enamel and dentin. Quintessence Int 1995; 26(2):139-44.
11. Murdoch-Kinch CA, McLean ME. Minimally invasive dentistry. J Am Dent Assoc 2003; 134(1):87-95.
12. Santos-Pinto L, Peruchi C, Marker VA, Cordeiro R. Effect of handpiece tip design on the cutting efficiency of an air abrasion system. Am J Dent 2001; 14(6):397-401.
13. Santos-Pinto L, Peruchi C, Marker VA, Cordeiro R. Evaluation of cutting patterns produced with air-abrasion systems using different tip designs. Oper Dent 2001; 26(3):308-12.
14. Antunes LAA, Pierro V, Maia LC. Case report: air abrasion cavity preparations for caries removal in paediatric dentistry. Eur Arch Paediatr Dent 2007; 8(Suppl 1):12-4.
15. Peruchi C, Santos-Pinto L, Santos-Pinto A, Barbosa, Silva E. Evaluation of cutting patterns produced in primary teeth by an air-abrasion system. Quintessence Int 2002; 33(4):279-83.
16. Manhart J, Kring G, Mehl A, Hickel R. Influence of different parameters on the effectiveness of substance removal by using air abrasion. J Dent Res 1997; 76:165;Abstr 1214.
17. Antunes LAA, Pedro RL, Vieira AS, Maia LC. Effectiveness of high speed instrument and air abrasion on different dental substrates. Bras Oral Res. (in press).
18. Myers GE. The abrasive technique: a report. Br Dent J 1954; 7:291-5.
19. Bailey R, Phillips R. Effect of certain abrasive materials on tooth enamel. J Dent Res 1950; 29:740-8.
20. Chan DC, Summitt JB, Garcia-Godoy F, Hilton TJ, Chung KH. Evaluation of different methods for cleaning and preparing occlusal fissures. Oper Dent 1999; 24(6):331-6.
21. Hamilton JC, Dennison JB, Stoffers KW, Welch KB. A clinical evaluation of air-abrasion treatment of questionable carious lesions: A 12-month report. Am Dent Assoc 2001;132(6):762-9.
22. Hicks MJ, Parkins FM, Flaitz CM. Kinetic cavity preparation effects on secondary caries formation around resin restorations: a polarized light microscopic *in vitro* evaluation. ASDC J Dent Child 2001; 68(2):115-21.
23. Nordbo H, Leirskar J, Von Der Fehr FR. Saucer-Shaped cavity preparations for posterior approximal resin composite restoration: observations up to 10 years. Quintessence Int 1998;29(1):5-11.
24. Laurell KA, Carpenter W, Daugherty D, Beck M. Histopathologic effects of kinetic cavity preparation for the removal of enamel and dentin. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995; 80(2):214-25.
25. Gwinnett AJ, Berry EA. Morphological characteristics of enamel and dentin prepared with air abrasion. J Dent Res 1996; 75:127;Abstr 877.
26. Nikaido T, Kataumi M, Burrow MF, Inokoshi S, Yamada T, Takatsu T. Bond strengths of resin to enamel and dentin treated with low-pressure air abrasion. Oper Dent 1996; 21(5):218-24.

About the Authors

Lívia Azeredo A. Antunes, DDS, MsC

Dr. Antunes is a Pediatric Dentist and Professor in the Department of Pediatric Dentistry and Orthodontics of the School of Dentistry at the Rio de Janeiro Federal University in Rio de Janeiro, Brazil.

e-mail: liviaazeredo@yahoo.com.br

Áurea Simone Barrôso Vieira, DDS, MsC

Dr. Vieira is a Pediatric Dentist and Professor in the Department of Pediatric Dentistry and Orthodontics of the School of Dentistry at the Rio de Janeiro Federal University in Rio de Janeiro, Brazil. Her clinical interest is focused on the treatment of disabled children.

Márcia P. Alves dos Santos, DDS, MsC

Dr. dos Santos is a PhD student in the Department of Pediatric Dentistry and Orthodontics of the School of Dentistry at the Rio de Janeiro Federal University in Rio de Janeiro, Brazil.

Lucianne Cople Maia, PhD, DDS, MsC

Dr. Maia is a Pediatric Dentist and an Associate Professor in the Department of Pediatric Dentistry and Orthodontics of the School of Dentistry at the Rio de Janeiro Federal University in Rio de Janeiro, Brazil.

Acknowledgements

The authors would like to acknowledge the technical assistance provided by Leonardo Antunes. We also would like to thank the Electronic Microscophy and Microanalysis Laboratory (PEMM/ COPPE/ UFRJ) for SEM services and Professor Ronir R. Luiz (NESC/UFRJ) for providing statistical support.