operative Dentistry

Scanning electron micrographic effects of air-abrasion cavity preparation on human enamel and dentin

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Recent developments in technology and restorative materials have renewed interest in air abrasion as a means of tooth preparation. The technique, also called kinetic cavity preparation, uses kinetic energy to remove tooth structure. The purpose of this investigation was to use scanning electron microscopy to compare the effects of this technique to those of high-speed burs on extracted human teeth. Class V buccal preparations were made on five teeth with a No. 34 carbide bur used at 400,000 rpm and on 23 teeth with kinetic cavity preparation using differing combinations of aluminum oxide particle sizes and delivery pressures. Features of the specimens prepared at high speed included sharp line angles, chipping of the cavo-surface margin, and striated internal surfaces. Kinetic cavity preparations had rounded cavo-surface margins and internal line angles. The surfaces were microscopically rough and the dentinal tubules were occluded. There was little difference in appearance between specimens treated with various combinations of particle sizes and delivery pressures. (Quintessence Int 1995;26:139-144.)

Introduction

Air abrasion for the preparation of teeth for restoration is not a new technology. The technique utilizes kinetic energy (E_k) from alumina particles entrained in a high-velocity stream of air to remove tooth structure; the technique has been recently termed kinetic cavity preparation (KCP). The term kinetic energy was coined by Lord Kelvin and is defined mathematically by the equation E_k equals one half the mass times the square of the velocity.

Kinetic cavity preparation was popular during the 1950s and early 1960s in clinical practice, but its use declined following the introduction of the high-speed, air-driven turbine. Operators discovered that high-speed rotary instrumentation was more efficient and allowed a more sharply defined preparation, a prerequisite at that time for placement of amalgam restorations. Early abrasive equipment could not compete against these advantages, although a loyal following of practitioners continued its use for many years. They believed that the advantages of lack of vibration and pain during preparation of the tooth outweighed advantages of high-speed instrumentation.

Recent advances in microabrasion technology allow a metered flow of alumina particles, higher operating pressures, and almost instantaneous initiation and termination of the abrasive stream. This enables new systems to remove enamel and dentin more precisely and efficiently than could previously available systems.

Progress in the development of dental materials has greatly altered the theory of preparation design for direct-placement restorative materials. Avoidance of sharp internal angles in amalgam preparations is now advocated to relieve internal stress. The advent of enamel and dentinal etching for the placement of composite resin, glass-ionomer cement, and resin-bonded ceramic restorations dictates a beveled cavosurface margin and rounded preparation in many instances.
Treatment modalities of experimental specimens

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
<th>Pressure (psi)</th>
<th>Particle size (μm)</th>
<th>Group size (n)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Bur</td>
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<td>160</td>
<td>5</td>
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<td>2</td>
<td>Abrasive</td>
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<td>3</td>
<td>Abrasive</td>
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For these reasons, air abrasion should be reevaluated as a means of preparing teeth for restorative procedures.

Although the pulpal effects and macroscopic appearance of KCP-treated teeth have been investigated, no reports of the microscopic effects of this technique are available. The intent of this study was to use scanning electron microscopy (SEM) to compare preparations made with high-speed burs to those made with kinetic cavity preparation of teeth.

Method and materials

Twenty-eight freshly extracted human teeth were randomly sorted into five groups. Class V buccal cavity preparations were made midfacially; a different technique was used for each group (Table 1). The specimens prepared at high speed (group 1) were treated with a new No. 34 inverted-cone high-speed carbide bur used at approximately 400,000 rpm with water spray (10 mL/min) and high-volume evacuation suction. Four KCP groups were prepared with an air-abrasion device (KCP 2000, American Dental Technologies) that delivered a measured flow of aluminum oxide (alpha alumina) particles in air from a 320-μm orifice. All specimens were prepared to a depth of approximately 0.5 mm into dentin by an operator experienced with the air-abrasion technique.

Each tooth was split parallel to its long axis from the occlusal surface through the preparation with a mallet and chisel. The split sections (sides A and B) were air dried, mounted, coated with gold-palladium, and examined on a Jeol 840a scanning electron microscope at 10 KV.

Results

When viewed by SEM, the cavity preparations of the high-speed specimens had sharply defined cavosurface margins, tapered walls, and flat gingival floors (Fig 1). Higher magnification revealed that the cavosurface margins showed areas of cracking and microchipping that ranged from 10 to 100 μm in width (Fig 2). Several fine cracks appeared in association with the chipped enamel. The axial walls had rough, striated surfaces (Fig 3).

In contrast, cavities made with KCP were without sharp internal line angles (Fig 4). At a lower magnification, the borders of the preparations showed well-defined, finely textured surfaces that created a "halo" effect (Fig 5). Greater magnification revealed uniform roughness of the enamel in the haloed areas up to a depth of approximately 5 μm (Fig 6). Most of the cavosurface margins were well rounded and uniformly abraded (Figs 7 and 8). However, where the delivery tip was placed very close to the surface (less than 1.0 mm away) during preparation, a sharper margin was produced and no halo effect was noted (Fig 9). The lateral walls and axial floors were rounded, sometimes producing a scalloped appearance (see Fig 4).

The difference in the appearance of the surfaces between the KCP groups was slight. The roughest textured surfaces were found in group 2 (160 psi and 50-μm alumina particles) (see Fig 5), while the smoothest were the specimens from group 5 (80 psi and 27-μm particles) (see Fig 9). High magnification of enamel and dentin showed a microscopic "chipping" in which the defects ranged in width from 1 to 20 μm. The treated surfaces of the enamel and dentin were indistinguishable in appearance from one another in all of the KCP groups (see Fig 8). Enamel rod prisms (see Fig 7) and dentinal tubules were not identifiable (Fig 10). Higher magnification at the split surface indicated that dentin debris was crushed into or folded over the tubules, occluding the openings (Fig 11).

Although elemental analysis of this debris detected the presence of aluminum, no remnants of the alumina particles were identifiable on any of the specimens examined.
Fig 1. Tooth prepared with a No. 34 high-speed carbide bur. Note the flat line angles and chipping of the cavosurface margin (arrow).

Fig 2. Chipping at the cavosurface margin of a tooth prepared with a high-speed bur. Cracks (arrow) were common on the high-speed specimens.

Fig 3. Axial wall of a cavity prepared at high-speed. Fine striations were produced by the rotary cutting action of the bur.

Fig 4. Tooth prepared with air abrasion at 160 psi using 27-μm alumina particles. Note the rounding of the internal line angles and the cavosurface margin. The scalloped appearance of the gingival floor is common with KCP preparations. The separation (arrow) at dentinoenamel junction is an artifact.

Fig 5. Finely textured halo effect surrounding the margin of a cavity prepared at 160 psi with 27-μm alumina particles. This area of microscopic roughness is suitable for resin retention without acid etching.16,17

Fig 6. Transition (arrow) between unaffected enamel (A) and enamel (B) in the halo region. The depth of enamel removed appears to be less than 5 μm when prepared at 160 psi with 50-μm alumina particles.
Fig 7 Cavosurface margin of a preparation made with KCP at 80 psi and a 50-μm particle size. The normal enamel prism morphology is not evident on this finely chipped surface.

Fig 8 On the surface of the axial wall, the transition between enamel (A) and dentin (B) is not distinguishable. However, the dentinoenamel junction (arrow) is easily seen on the split surface of the tooth. The beveled cavosurface margin is ideal for placement of composite resin.

Fig 9 Sharp cavosurface margin obtained by holding the delivery tip less than 1.0 mm from the tooth surface. This margin would be suitable for placement of amalgam.

Fig 10 Opened dentinal tubules (A) on the split surface of the tooth. However, the tubules appear to be sealed on the treated surface (B).

Fig 11 Detail of the axial wall of a cavity prepared by KCP. The openings of the dentinal tubules appear to be blocked by debris (arrow).
Microchipping and cracking of enamel during preparation with high-speed burs have been reported previously and were confirmed by this investigation. However, the preparation of teeth for examination by SEM may introduce artificial cracking. The rounded contours of the KCP prepared specimens have also been reported, but the nature of the resultant surface has not been previously reported. It appears that the kinetic impacts of the particles fracture away minute pieces of tooth structure, which are then evacuated by the air stream. Because each kinetic impact is small compared to the impacts caused by the flutes of a high-speed bur during tooth preparation, less stress is placed on the surrounding tooth structure. The result is a microscopically roughened surface in which the defects are limited to a width of 1 to 20 μm.

The radius of curvature of the cavosurface margin of the KCP specimens is dependent on the distance of the tip of the handpiece to the tooth surface. The halo effect and rounding of the margins is caused by a “fanning” of the abrasive particles as they exit the orifice. The cutting diameter increases in proportion to the distance to the tooth due to particle scatter. However, the abrasion provided by the peripheral portion of the stream is less efficient because of the lower velocity and concentration of alumina particles. This phenomenon causes all internal line angles to be rounded and accounts for the scalloped appearance frequently found at the pulpal floor of KCP preparations. The peripheral scatter of the stream also accounts for the halo and the rounded margins. The effect is minimized when the tip is placed less than 1.0 mm from the tooth, where fanning is negligible. Therefore, for preparations that require a beveled cavosurface margin (ie, acid etch-retained resin restorations), the instrument tip should be placed approximately 2.0 mm from the tooth surface. For restorations requiring a butt joint (ie, amalgam and porcelain), the orifice should be placed approximately 0.5 mm from the tooth.

The bond strength of resin to enamel and dentin treated with KCP has been reported to be similar to the bond strength resulting from acid etching. The air-abrasion surface effects observed in the present study could account for a mechanical retention of the resin. In addition, the rounded cavosurface margin and internal line angles conform to currently held theories of preparation for direct composite resin restoration.

The apparent blockage of the dentinal tubules found in this investigation may account for the lack of pain reported by patients during most air-abrasion preparations. If the tubules are continually being sealed as the preparation progresses, fewer changes in pulpal pressure could result. Further investigation of this relationship is warranted.

### Summary

Scanning electron microscopic examination of preparations made with a No. 34 high-speed bur revealed flat, striated, well-defined walls and sharp cavosurface margins that exhibited microchipping and cracking. In comparison, KCP preparations demonstrated the following characteristics:

1. Rounded cavosurface margins and internal line angles
2. A halo of abraded enamel surrounding the cavity's outline
3. Microscopic roughness of the treated enamel and dentinal surfaces
4. Apparent closure of dentinal tubules

### References

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