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CARIES EXCAVATION TECHNIQUES-CURRENT CONCEPTS AND APPROACHES

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Abstract : *The dawn of 'minimal invasive dentistry' has enormously changed the basic idea of cavity preparation. The current cavity preparations depend on the shape and extent of the carious lesion, and leaving the healthy tooth tissue as much as possible. New caries excavation techniques have been introduced like ceramic and polymeric burs, caries disclosing dyes, caries dissolving chemical agents, caries selective air and sonic abrasion, laser ablation and use of enzymes to dissolve caries. All these methods aim at minimal tooth preparation and maximum tooth preservation. All these methods are under constant modification for improvement.*

Keywords – *Caries excavation, Chemo-mechanical caries removal, Dental caries, Laser, Tooth preparation.*

I. INTRODUCTION

The conventional techniques for carious dentine removal were developed by GV Black, in 1893. The basic principles of cavity preparation were limited to the knowledge of disease process and restoration materials available during the period [1].

An ideal tooth cutting technique have:

- Comfort and ease of use in the clinical environment
- ·Requiring only minimum pressure since being painless and silent.

- The ability to discriminate and remove diseased tissue only
- While operating the generation of vibration and heat is nil, and
- Being affordable and easy to maintain.

Unfortunately, no method at present satisfies all these attributes

In more recent years, the concept of ''minimal-invasive dentistry'' has emerged [2,3]. It implies that heavily infected and irreversibly denatured dentine should be removed and potentially remineralizable tooth tissue should be preserved [4]

In light of minimal-invasive tooth preparation and with the intention to simplify and standardize caries-removal procedures, so-called 'self-limiting' caries-excavation techniques have been introduced recently. Apart from conventional carbon steel and tungsten-carbide burs, new rotary cutting instruments like round burs made of an alumina based ceramic material intended for slow-speed caries excavation (CeraBur K1SM, Komet-Brasseler, Lemgo, Germany) [5] or oscillating Sono-abrasion tungsten-carbide tips (Cariex system, Kavo, Biberach, Germany) [6] are now in use. Chemo mechanical excavation (CME) of carious dentine is another alternative especially in pediatric dentistry [7] and for anxious or medically compromised patients [8]· Examples are the sodium hypochlorite-based Carisolv (MediTeam, Go¨teborg, Sweden) [8] and the new experimental enzyme-based caries-removal gels (exp. SFC-V and VIII, 3M-ESPE, Seefeld, Germany) [9]. The latter consist of pepsin in a phosphoric acid/sodium biphosphate buffer that claims tomore selectively remove carious tissue [10]

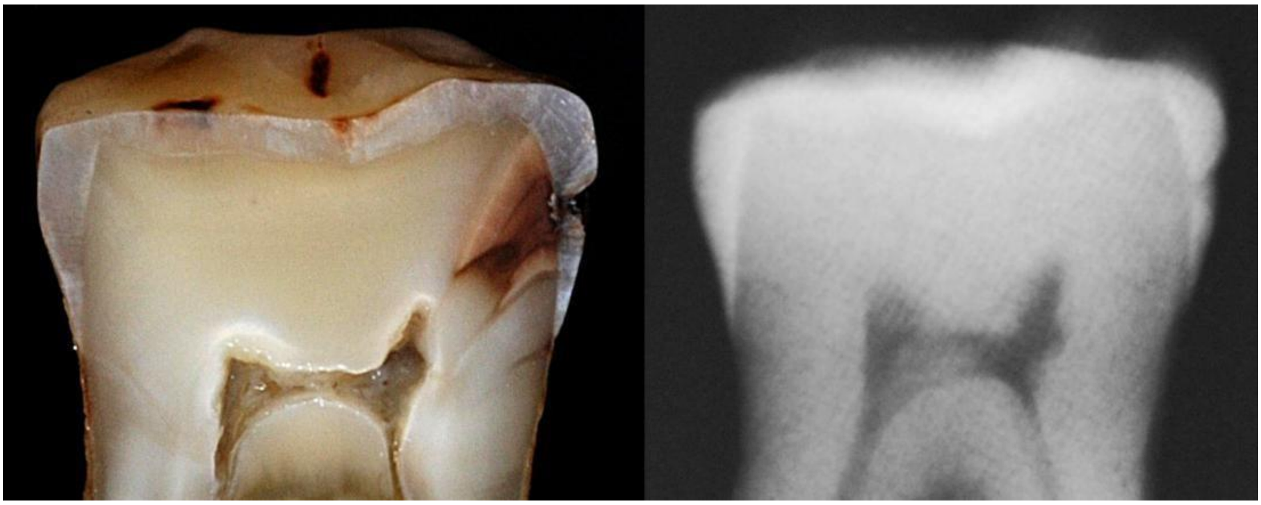
Caries excavation by "Sono-abrasion" uses cutting tips coupled to high-frequency sonic air-scaler handpieces under water cooling. The handpiece oscillates in the sonic region (< 6.5 kHz), while the tips perform an elliptical motion. Air-abrasion systems for cavity preparation use the kinetic energy of abrasive particles to cut tooth structure in a less invasive way. Pure Aluminum oxide particles are frequently used as the abrading agent due to their high cutting effectiveness, chemical stability, low cost, low affinity for water, and neutral color [11]. An alternative pseudo-mechanical method for dental tissue removal involves bombarding the tooth surface with high-velocity particles (Aluminium oxide) carried in a stream of air [12].

Based on the fact that caries-induced changes lead to increased dentinal fluorescence [13] due to the metabolic byproducts from microorganisms, Fluorescence-aided Caries Excavation (FACE) was developed. A laser-fluorescence device that irradiates at this particular wavelength has been developed to diagnose "hidden" occlusal carious lesions (DIAGNOdent, Kavo Dental; Biberach, Germany). A photodiode attached to the tip of the handpiece measures the feedback of fluorescence post initial irradiation, where the intensity of fluorescence at the occlusal surface is directly related to the degree of caries progression into dentin [14] An Er:YAG laser equipped with a laser-induced fluorescence feedback system (Key III, Kavo, Biberach, Germany) also claims to have self-limiting caries-removal potential. Researchers have postulated that lasers could be applied for cutting both hard and soft tissues in the mouth [15]. Studies have examined the possibility that carious dentine might be removed by using certain enzymes [16] but further laboratory research is required for validation of this technique.

II. HISTOPATHOLOGICAL ANALYSIS OF DENTINAL CARIES

After an initial lesion, the carious disease expands throughout the whole enamel thickness, reaches the dentino-enamel junction and penetrates into dentin, crossing the mantle dentin, and then infiltrating the outer part of circumpulpal dentin [17]. Only when thecaries lesion has progressed to a considerable length along the DEJ will the subjacent dentin be demineralized [18] and become recognizable by a yellow to dark-brown discoloration.

Fig 1.Cross-section of a primary molar showing the progression of caries activity deeper into the DEJ. Radiographically the caries is not much appreciable.



III. CARIES ESCAVATION TECHNIQUES

There are a number of techniques available for cutting tooth tissue. Some claim to remove demineralized dentine selectively whereas others may not even be able to remove softened tissue effectively. For this reason, it is important that the practitioner knows whatmight be expected from these various techniques.

TYPE	TECHNIQUE
MECHANICAL (ROTARY)	HANDPIECES-BURS
MECHANICAL (NON-ROTARY)	HAND ESCAVATORS, AIR ABRASION, ULTRASONICS, SONO-ABRASION, AIR POLISHING
CHEMOMECHANICAL	CARIDEX, CARISOLV
PHOTO ABLATION	LASERS
FLUORESCENCE	LASER INDUCED FLUORESCENCE, FLUORESCENCE-AIDED CARIES ESCAVATION(FACE)

TABLE 1. Classification of tooth cutting techniques

IV. CONVENTIONAL EXCAVATION WITH BURS

1.1 TUNGSTEN-CARBIDE /CARBON-STEEL/DIAMOND BURS

Rotary instruments have been used for tooth preparation including the removal of demineralized tissues for more than a century. The three most commonly used burs are steel, tungsten carbide and diamond. Steel burs perform well when used to cut dentineat low speed (<5000 rpm) but blunt rapidly when cutting enamel at high speed with a hardness of 800 VHN. Once dulled, the reduced cutting efficiency of steel burs create increased heat and vibration that could damage the pulp [19]. Tungsten carbide burs were introduced in 1947 that replaced steel burs when high speed headpiece was used. They operate at a range of 1250- 50,000 rpm. Carbide is stiffer and harder than steel (1650- 1700 VHN), hence less prone to wear during cutting. However, it is brittle and tends to fracture by chipping [20]. Early diamond rotary instruments were made by hammering diamond powder onto the surface of soft copper or iron blanks [21]. While the modern diamond burs introduced in 1932 by WH Drendrel was fabricated by attaching diamond particles to stainless steel either by sintering or galvanic metal bond [22]. Diamond rotary instruments have great clinical impactbecause of their long life and great efficiency in cutting both the enamel and dentine (4,50,000 rpm). The applied torque during tooth preparation can cause degradation of these rotary instruments, thus decreasing its cutting efficiency.

Fig 2.1; Stainless steel tungsten carbide rotary burs

Fig 2,2; Diamond rotary burs

V. NEWER MATERIALS AND METHODS

1.2 POLYMERIC BURS

In an attempt to develop a selective caries-removal rotating instrument, a “plastic” bur was made of a polyamide/imide (PAI) polymer, possessing slightly lower mechanical properties like hardness, than sound dentin. Therefore, the excavation process with a polymer bur is self-limiting as it cannot remove tissue which is harder than itself [23] with a speed of 500- 800 rpm. The blade design was developed to remove dentin by locally depressing the carious tissue and pushing it forward along the surface until it ruptures and is carried out of the cavity. The commercial version of these burs (SmartPrep, SSWhite Burs; Lakewood, NJ, USA) consisted of a polymer (polyether-ketone-ketone) shaft and blades in three different sizes of 004, 006, 008. They have a hardness of 50 KHN, which washigher than the hardness attributed to carious dentin (0 to 30 KHN), but lower

than that of sound dentin (70 to 90 KHN) [24]. As opposed to conventional carbide burs, their cutting edges were not spiralled but straight. Smart burs have an advantage of blunting out on touching, which avoids unnecessary removal of both affected and hard dentin. [25,26]
The next generation smart burs of the series are the Smartburs II (SSWhite Burs; Lakewood, NJ, USA) constructed of medical grade, glass-bead reinforced polymer with a speed of 5000-10,000 rpm and 50 KHN hardness. The bur blades are engineered to deform when they encounter harder, healthy dentin thereby enabling removal of carious dentin without harm to healthy or affected zones of dentin thereby excluding the use of local anesthesia.

There are a few drawbacks for these burs:

I. When caries was excavated from the center to the periphery in order to avoid contact with sound tooth tissue, the bur would be prematurely and irreversibly damaged [27]
II. Local anesthesia was said not to be needed but some patients still reported one or more episodes of pain sensation during treatment [28]
III. More residual caries was found in cavities excavated with SmartPrep burs than in cavities prepared with tungsten carbide burs.

Fig 3. Smartprep smart burs

Another commercially available polymer bur is the Polybur-1 (Komet, Mediteam, Sweden.).They are available in three different sizes of 014, 018, 023. They are used at a speed higher than the Smart bur at around 2000-8000 rpm [29].

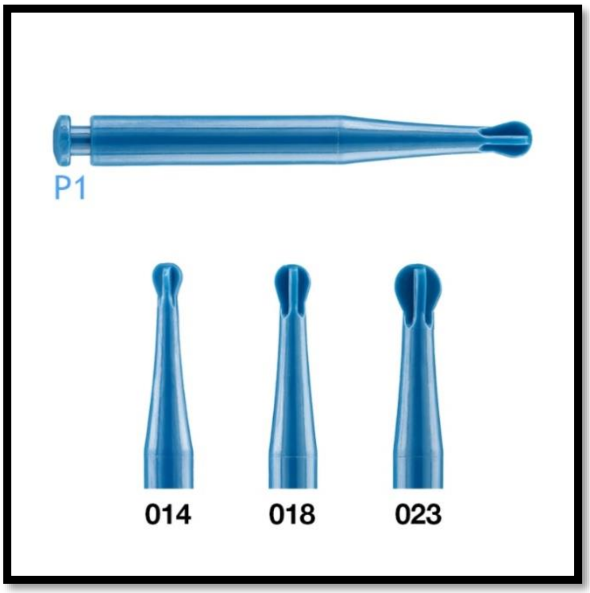


Fig 4. PolyBur P (Komet dental)

1.3 CERAMIC BURS

They are a new line of slow-speed rotary cutting instruments made of ceramic materials. The CeraBurs (Komet-Brasseler; Lemgo, Germany) are all-ceramic round burs made of alumina-yttria stabilized zirconia, available in different diameters (sizes 012, 014, 018, and 023). They are used in a slow-running handpiece at a speed of 1,000 to 1,500 RPM as like conventional carbide burs [30]. The manufacturer claims high cutting efficiency in removing infected, soft dentin with maximum preservation of the sound, and hard tooth structure. The use of this instrument for caries removal replaces both the explorer and the excavation spoon by simultaneously providing tactile sensation and reducing preparation time. An in vitro investigation of the caries-removal efficiency and efficacy did not show any significant difference between the ceramic and conventional tungsten-carbide burs [30].

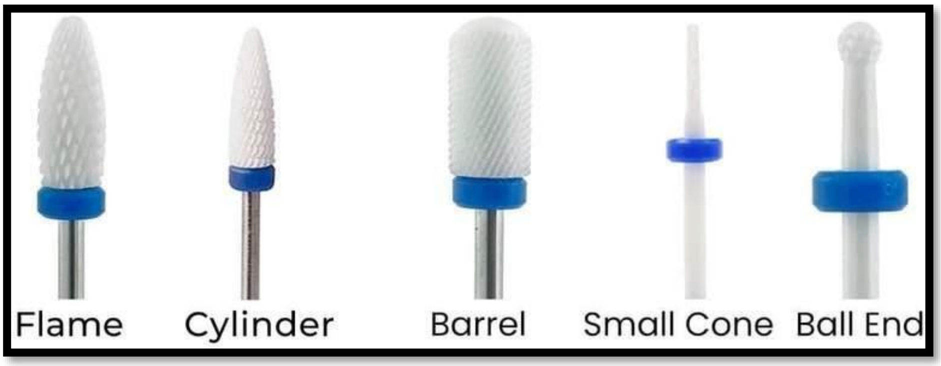


Fig 5. Ceramic burs of different types

1.4 CARIES-DISCLOSING DYES

Transmission electron microscopy and biochemical characterization of carious dentin revealed that the most superficial carious layer is necrotic, highly decalcified, and contains irregularly scattered granular crystals and irreversibly denatured collagen fibrils. Underneath this "caries-infected" dentin, the deeper "caries-affected" dentin layer comprises of needle-like apatite crystals, regularly attached to collagen fibrils with no signs of bacterial invasion [31]. An ideal caries-disclosing dye should stain solely the caries-infected, but not the caries-affected dentin.

1.5 .0.5 % BASIC FUCHSIN IN A PROPYLENE GLYCOL BASE

One of the first caries-disclosing dyes was based on a solution of 0.5% basic fuchsin in propylene glycol that claimed to stain exclusively the top, irreversibly destroyed carious layer, enabling differentiation from remineralizable dentin [32]. The exact mechanism is unknown, but it may be due to the irreversible collagen denaturation of caries-infected dentin, caused by breakdown of the intermolecular crosslinks through bacterial lactic acid [33]. The differential staining ability was attributed to differences in the degree of mineralization in the carious lesion [34]. Few drawbacks were,

I. The extent of dentin excavated by the fuchsin-guided method was larger than the extent of demineralized dentin [35]
II. When caries was removed using conventional tactile probing to determine the caries removal endpoint, both in primary and permanent teeth, the cavity walls and floors were still fuchsin-stainable [34]
III. Possible carcinogenic effects of fuchsin for intra-oral use [34]

1.6 1% ACID-RED IN PROPYLENE GLYCOL BASE

A 1% acid-red solution (Caries Detector, Kuraray;Tokyo,Japan) was launched as an alternative to fuchsin for intra-oral use [36]. Some drawbacks seen include:

I. More than half of the teeth judged clinically as having no caries at the DEJ could be stained with acid red [37,38]
II. Microbiological assessment of the caries-stained and stain-free dentin at the DEJ failed to disclose differences in level of infection [38]
III. At the pulpal floor, more than half of the teeth diagnosed as having "hard" and"sound" pulpal floors still took up some stain. [37]

VI. CHEMO MECHANICAL CARIES EXCAVATION

6.1 SODIUM HYPOCHLORITE BASED AGENTS

Goldman and Kronman reported possibility of removing carious material chemically using N-monochloroglycine (NMG, GK-101) in 1976 [39]. The first attempted chemical solubilizer had a sodium hypochlorite solution buffered with a mixture of amino butyric acid, sodium chloride and sodium hydroxide. Its capability to selectively remove carious dentin was attributed to the buffering effect of the amino acid mixture, originally intended to reduce the aggressiveness of sodium hypochlorite on sound dentin and to enhance the disrupting effect on degenerated collagen within carious dentin [40]. And the resultant friable collagen fibrils could be easily removed with a spoon excavator [41].

After further modifications, the Caridex system, containing N-monochloroD,L-2-aminobutyrate (NMAB, GK-101E), was introduced [42] which was developed as a chemico-mechanical method for carious dentineremoval, softened further by NMAB (GK-101E). Many studies found the technique to have advantages including increased patient compliance and a reduced need for local anaesthesia [43,44]. Brannström et al. showed it to be a successful way of removing soft carious dentine without any significant damage to the underlying dentine [45].

A new caries removing system, also based on sodium hypochlorite, was introduced in the form of a gel (Carisolv, MediTeam Dental; Sävedalem, Sweden) which contained 0.5% w/v sodium hypochlorite (first part), 0.1M of an amino acid mixture (glutamic acid, leucine and lysine) (second part), and water. NaCl, NaOH, erythrosine are added to make the gel visible during use. The two parts are thoroughly mixed in equal parts at room temperature before application, using the hand instrument, onto the exposed carious dentine and left for 60 seconds before gently abrading the softened dentine, to leave a hard, caries-free cavity. The solution has a pH of around 11 and the positively and negatively charged groups onthe amino acids are said to become chlorinated to further disrupt the collagen cross linkage in the matrix of the carious dentine. The gel consistency will allow the active molecules, access to the dentine for a longer period than the equivalent irrigating solution in the Caridex system. Also, the gel has a mechanical lubricating action for the hand instrument which will help in the removal of the softened tissue. Early results from clinicaltrials indicated an increased patient compliance to this technique over the use of the dental drill to excavate carious dentine [46].

However, drawbacks may include the prolonged operating time and the simple fact that the more conventional rotary methods are still necessary in order to gain access to the carious dentine to allow the gel to function. Therefore, the technique may only be useful in certain lesions Eg; exposed carious buccal, cervical root lesions or grossly cavitated, deep lesions in an attempt to minimize pulp exposures. It also appears to produce a cavity with an incomplete smear layer and evident open tubules [47]

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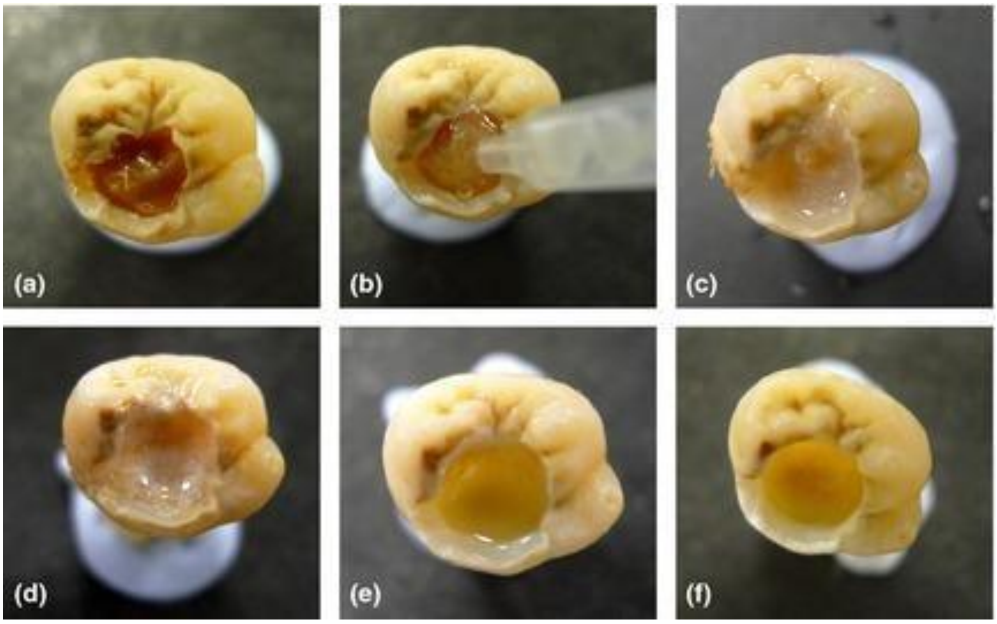

Fig 6**.** Chemo mechanical caries removal procedures using Carisolv gel (Medi Team Dentalutveckling AB, Sweden). (a) Dentinal caries lesion. (b) The carious lesion was treated with Carisolv gel and left for 30 seconds prior to excavating the dentine. (c) Excavation of the caries using Carisolv non-cutting instruments (Medi Team Dentalutveckling AB, Sweden) until the gel becomes cloudy and then rinsed-off with distilled water for 20 seconds. (d) The same process was repeated until successive application of the gel failed to become cloudy. (e), (f) post-excavation view of the lesion site [48].

6.2 PEPSIN BASED CARIES EXCAVATION

A new experimental gel consisting of pepsin in a phosphoric acid/sodium biphosphate buffer is being considered as an alternative chemo-mechanical caries excavation agent (SFC-VIII, 3M ESPE; Seefeld, Germany). The main advantage of this new enzyme-based solution is that it can be more specific by digesting only denatured collagen (after the triple-helix integrity is lost) than the sodium hypochlorite-based agents [49]. According to the manufacturer, the phosphoric acid dissolves the inorganic component of carious dentin, while the pepsin penetrates the organic part of the carious biomass and selectively dissolves the denatured collagen. To avoid over excavation, the SFC-VIII gel should be used in combination with a prototype plastic instrument having hardness between that of sound and infected dentin. An x-ray micro-CT evaluation of carious teeth excavated with SFC-V revealed that the new enzymatic caries-removing gel was able to remove equivalent volumes of carious dentin as Carisolv [50].

6.3. ENZYME BASED CARIES EXCAVATION

Papain is a proteolytic enzyme similar to human pepsin, having both bactericidal and bacteriostatic properties [51]. In 2003, a papain based chemo mechanical caries removal agent called Papacarie was introduced (Formula and Acao company in Brazil). Papacarie selectively softens the infected dentin by breaking down degraded collagen fibrils, enabling their easy removal. It provides painless caries removal and is less expensive than Carisolv [52]. The main disadvantage of Papacarie is its longer working time, high cost and short shelf life[52] . In 2011, the manufacturers introduced a modified gel called Papacárie Due™ which had an extended shelf life and high viscosity [53]

Fig 7.1. Deciduous molar with carious lesion, 7.2. Post application of Papacarie gel. 7.3. Tooth following removal of infected dentin using blunt instrument. [54]

An Indian innovation of the papain gel was introduced in 2011 called the Carie-Care™ (Uni-Biotech Pharmaceuticals Private Limited Chennai, with Mallya Scientific Research Foundation). Carie-Care™ can be directly applied on the carious lesion without any special equipments.[55] Carie-Care™ is less expensive and has a longer shelf life than Papacarie[56].

Fig 8. Chemo-mechanical caries removal (CMCR) using Carie-care (a) Preoperative image of the carious tooth (b) Application of Carie-care agent (c) Turbidity noted (d) Removal of carious lesion (e) Checking the surface with the probe (f) post-operative image showing clean cavity [57]

In 2012, Brix Medical Science company introduced a CMCR product called BRIX3000® also based on papain, a proteolytic enzyme extracted from green papaya (Carica papaya) [58]. The manufacturers claim a unique technology of bioencapsulation via Encapsulating Buffer Emulsion (EBE) technology which gives the gel an appropriate pH for its activity on the disrupted collagen in the carious lesions [59]. The product has a higher efficiency, longer shelf life (48 months), less disintegration in oral fluids and greater antibacterial, antifungal, and antiseptic properties [60].

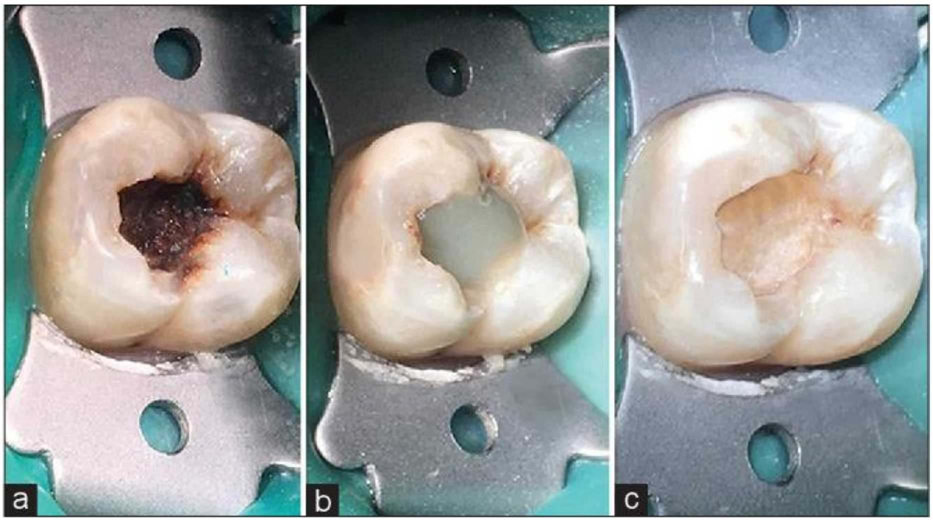

Fig 9. Caries excavation with BRIX3000. (a) Before excavation. (b) BRIX3000 Application. (c) After complete excavation [61]

VII. AIR ABRASION

Air-abrasion was originally developed by RB Black in 1945 who investigated for an alternative pseudo-mechanical method for dental tissue removal which involved bombarding the tooth surface with high-velocity particles (Al_2O_3) carried in a stream of air. This technique has the ability of abrading efficiently both sound dentin and enamel. Air-abrasion systems using 27-μm diameter alumina particles remove tooth staining or prepare shallow cavities. The larger the size and harder the particles, the greater is the transferred kinetic energy to the surface and thus the rougher the final finish. The speed of the particles can be altered by varying the air pressure. Reduced velocity will decrease the transferred kinetic energy to the tooth surface thus reducing the overall abrasivenessof the system [62,63]

The first units to be commercially manufactured were the Airdent machines. This method of cutting teeth seemed to dramatically reduce the problems of heat generation [64], vibration and other mechanical 7stimulation [65.66, 67 resulting in relatively pain-free procedures when compared with the dental drill. There have been reports to indicate that there were no significant differences in pulpal response between air abrasion and high-speed bur preparation using copious water spray [68]. Other particles like, spherical glass beads with different diameters were also tested. They showed improved removal of artificially softened dentin, but although at lower rates, sound enamel and dentin were also removed. Polycarbonate resin-crushed powder removed artificially softened dentin more selectively without cutting sound dentin or enamel [69] but further clinical investigations with these particles are still lacking.

A mixture of alumina and hydroxyapatite in a volume ratio of 3:1, with particle sizes ranging from 3 to 60 μm, was shown to be as efficient as conventional hand excavation with dental spoons, and was positively rated when related to the auto-fluorescence signature of the lesion [70]. An air abrasion system using bioactive glass powder (Bioglass, Novamin Technology; Alachua,USA) with a particle diameter between 25 and 32 μm was also explored wherein, the risk of unnecessary sound dentin removal was reduced because of the difference in cutting rate between sound and carious dentin [71]

Air-abrasion has been used for several different applications within the field of restorative dentistry including removal of external stains and calculus, minimal cavity preparations, crown preparations and fissure sealant/preventive resin restoration placement [72,73,74]. Disadvantages of the technique include the total loss of tactile sensation whilst preparing the cavity because the nozzle does not touch the surface of the tooth. This, coupled with the fact that the operator must be able to envisage the position of the cavity boundaries prior to cutting, leads to the significant risks of cavity over-preparation and inadequate carious dentine removal.

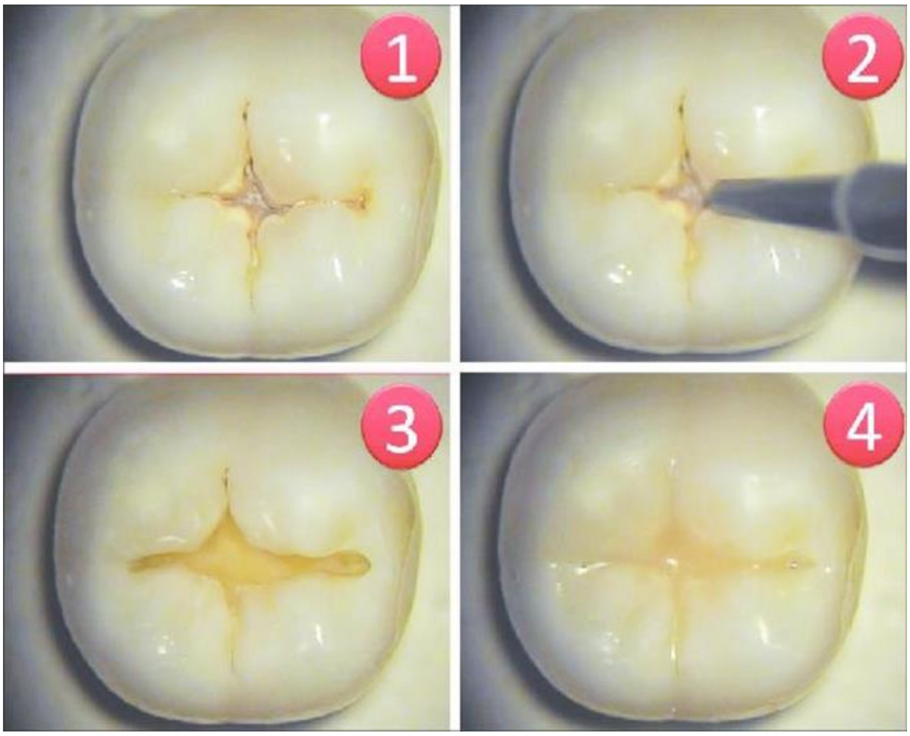

Fig 10. Air abrasion used to remove & restore pit & fissure caries using 27 micron-sized powder particles. 1) Fissure caries seen on occlusal surface of mandibular 2nd molar. 2)Tip of air abrasion device placed on molar. 3) Removal of caries with minimal cavity preparation width. 4) Cavity restored with preventive resin restoration[75]. (Seen at 16X underdental operating microscope)

VIII. SONO ABRASION

A recent development from the original ultrasonics is the use of high-frequency, sonic, air-scalers with modified abrasive tips-a technique known as 'Sono-abrasion'. The Sonicsys micro unit, designed by Drs Hugo, Unterbrink and Mösele in a venture betweenIvoclarVivadent and KaVo (KaVo Dental Ltd, Amersham, Bucks, UK), is based upon the Sonicflex 2000L and 2000N air-scaler handpieces that oscillate in the sonic region (< 6.5 kHz). The tips move elliptically in a transverse distance between 0.08 — 0.15 mm and a longitudinal movement between 0.055 — 0.135 mm. They are diamond coated on one side using 40 µm grit diamond and are cooled using water irrigant at a flow rate of 20–30 mL / min. The operational air pressure for cavity finishing should be around 3.5 bar. There are currently three different instrument tips: a lengthways halved torpedo shape (9.5 mm long, 1.3 mm wide), a small hemisphere (1.5 mm diameter) and a large hemisphere (2.2 mm). The torque applied to the instrument tips should be around 2 N. If the applied pressure is too great, the cutting efficiency is reduced due to damping of the oscillations.This technique was initially developed, using different shaped tips, to prepare predetermined cavity outlines but also works well in removing hard tissue when finishing cavity preparation. Favorable results from laboratory studies using Sono-abrasion to remove softened, carious dentine have indicated future use for this technique [76,77,78]

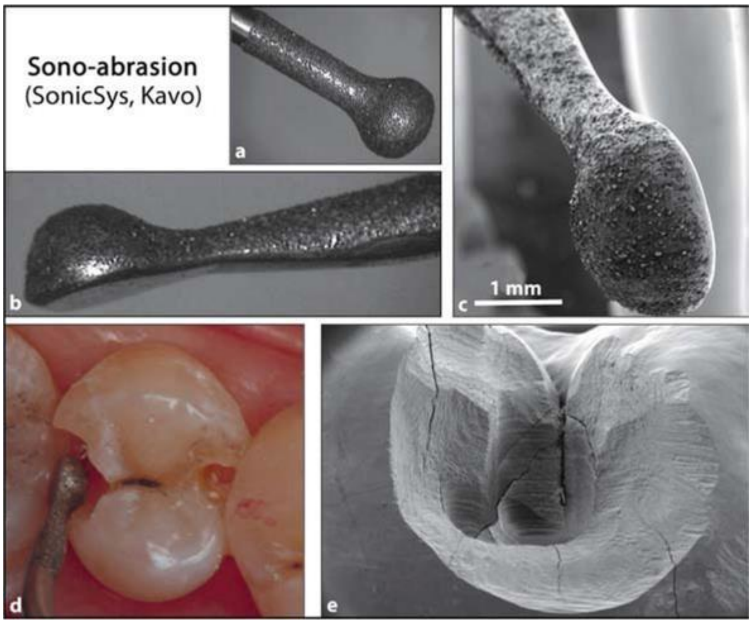

Fig.11 a, b Diamond-coated tip of the SonicSys system (Kavo). Only one side is coated with diamonds, so as to prevent damage to adjacent teeth. c Field-emission scanning electron microscopy photomicrograph of the same tip. d Clinical situation of two class-II cavities. e. Field-emission scanning electron microscopy photomicrograph of small class-II cavity entirely prepared by Sono-abrasion [79,80].

IX. ULTRASONIC TECHNIQUE

Nielson et al in 1955 designed a magneto-strictive instrument with a 25 kHz oscillating frequency [81].. This, used in conjunction with a thick Al2O3 and water slurry, created the cutting action, the mechanism of which was the kinetic energy of water molecules being transferred to the tooth surface via the abrasive through the high-speed oscillations of thecutting tip. Soft, carious dentine apparently could not be removed, but the harder, leathery, deeper layer was more susceptible [82]. Nielsen attempted to analyze the results by altering the pressure applied, the length of use of the instrument, the powder: water ratio in the slurry, the nature of the material cut and the type of abrasive used. Due to the unpredictable performance of the instrument, his results were inconclusive. The technique was favorable in terms of the reduced vibration and sound generated when compared with the dental drill [82].

X. AIR POLISHING

Air-polishing is the process by which water soluble particles of sodium bicarbonate alongwith added tricalcium phosphate (0.08% by weight) to improve the flow characteristics, are applied onto a tooth surface using air pressure, shrouded in a concentric water jet [83.84]. The bombardment of the hard tooth surfaces by these particles results in a continuous mechanical abrasive action which removes surface deposits [85]. Razzoog and Koka notedthat increasing the air pressure beyond 90 psi reduced the abrasiveness of the Microprophy System (Danville Engineering Co., Danville, CA). Due to a phenomenon called the 'choked flow'. In this scenario, as the air pressure exceeds the critical pressure, the mass flow of particles will reduce, thus limiting the system's abrasiveness [86] The commercially recommended use of this technique is to remove surface enamel stains, plaque and calculus well away from the gingival margins of healthy teeth [82]. However, dueto the non-selective, abrasive, detrimental surface attack of restorations and sound enamel and dentine, overzealous use could easily remove a considerable amount of healthy tooth structure especially at the cervical margin [83,84]. It has been suggested that air-polishing could be used for the removal of carious dentine at the end of cavity preparation [85]

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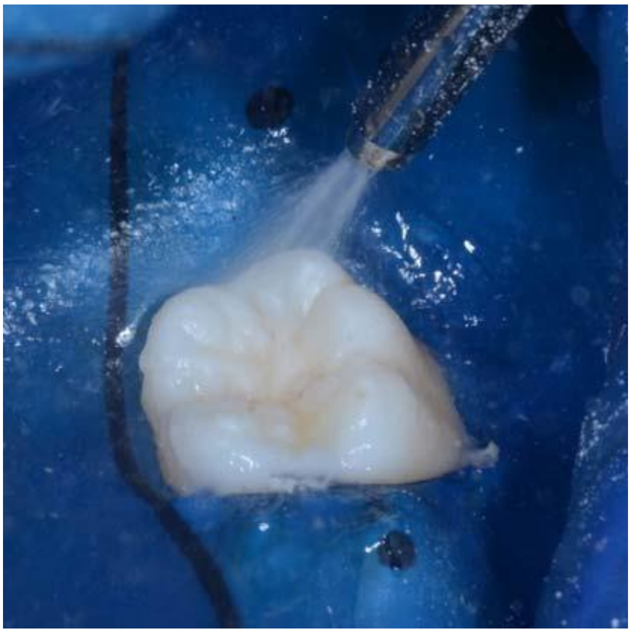
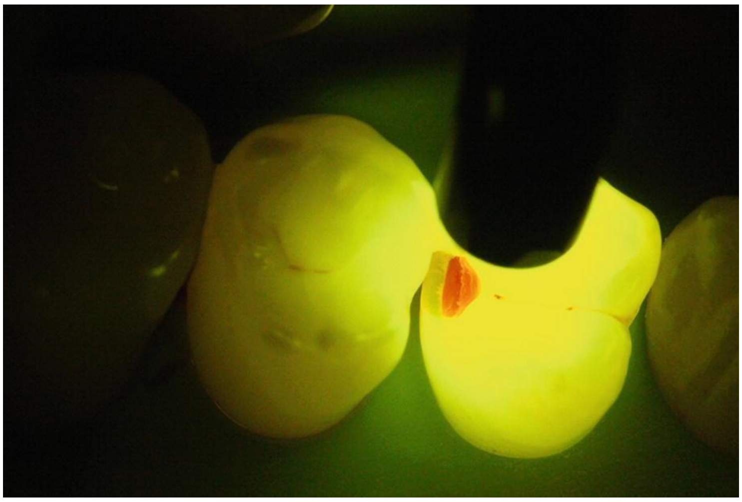


Fig 12. Air polishing using Combi [Mectron S.p.a][87]

XI. FLUORESCENCE-AIDED CARIES EXCAVATION ("FACE")

This technique was developed as a direct method to clinically differentiate between infected and affected carious dentin. Based on the fact that several oral microorganisms produce orange-red fluorophores as by-products of their metabolism (porphyrins), infected carious tissue will fluoresce especially in the red fraction of the visible spectrum [88] due to the presence of proto- and meso-porphyrins. By feeding a slow-speed handpiece with a fiber-optic violet light source (370 to 420 nm) and allowing the operator to use a 530-nm yellow glass filter, areas exhibiting orange-red fluorescence can be selectively identified and removed with the bur [89]. Compared to Caries Detector or the visual-tactile method for establishing the caries removal endpoint, the FACE method showed the highest sensitivity, specificity, percentage correct score, and predictive values for residualcaries detection, as evaluated using confocal microscopy [90]. Studies observed a significant reduction in the number of samples presenting residual bacteria after excavation with FACE, when compared to Carisolv or bur excavation guided by Caries Detector [91]. Another important aspect is that the increased caries-removal efficacy of FACE was apparently not associated with an increased cavity size or over excavation [92].



XII. EXCAVATION AIDED BY LASER-INDUCED FLUORESCENCE

Based on the fact that caries-induced changes lead to increased fluorescence of dentin at the 655-nm (red) wavelength [93] a laser-fluorescence device that irradiates at this particular wavelength has been developed to diagnose "hidden" occlusal carious lesions(DIAGNOdent, Kavo Dental; Biberach, Germany). A photo diode is attached to the tip of the handpiece, that measures the feedback of fluorescence after initial irradiation, where the intensity of fluorescence at the occlusal surface is directly related to the degree of caries progression into dentin [94]. Based on a diagnostic scale correlating the readings of fluorescence with the histological presence of caries, values above 30 should be considered a stage of caries progression demanding operative intervention [95].

XIII. LASER EXCAVATION

The word "laser" is an acronym for "Light Amplification by Stimulated Emission of Radiation", which means that laser devices produce beams of coherent and high-intensity light. The use of lasers in dentistry are nowadays broad, varying from caries diagnosis, disinfection of periodontal pockets or root canals, photodynamic therapy of oral tumors, soft-tissue surgery, caries removal, and cavity preparation [96]. Since the development of the first ruby laser by Maiman (1960), researchers postulated that it could be used to cutting both hard and soft tissues in the mouth. However, early studies found that the Ruby laser produced significant heat that caused damage to the dental pulp [96]. The erbium-loaded yttrium-aluminum-garnet (Er:YAG) and the erbium,chromium: yttrium- scandium-gallium-garnet (Er,Cr:YSGG) lasers are the two types of erbium-based devicesin common use. Both devices present very similar wavelengths (2.78 μm for Er,Cr:YSGG and 2.94 μm for Er:YAG) although the Er,Cr:YSGG laser is absorbed more by hydroxyapatite than Er:YAG [97]. The mechanism by which enamel and dentin are removed during Er:YAG irradiation consists of explosive subsurface expansion of water trapped interstitially in the dental hard tissues. During irradiation, the water molecules absorb theincident radiation, causing sudden heating and water evaporation resulting in a high- stream pressure, inducing an expansion and ejection of dental hard tissue components. The Er,Cr:YSGG laser system or "laser powered hydrokinetic system", delivers photons into an air-water spray directed to the target tissue. This phenomenon induces micro- explosive forces into water droplets, that contribute significantly to hard-tissue removal [98].

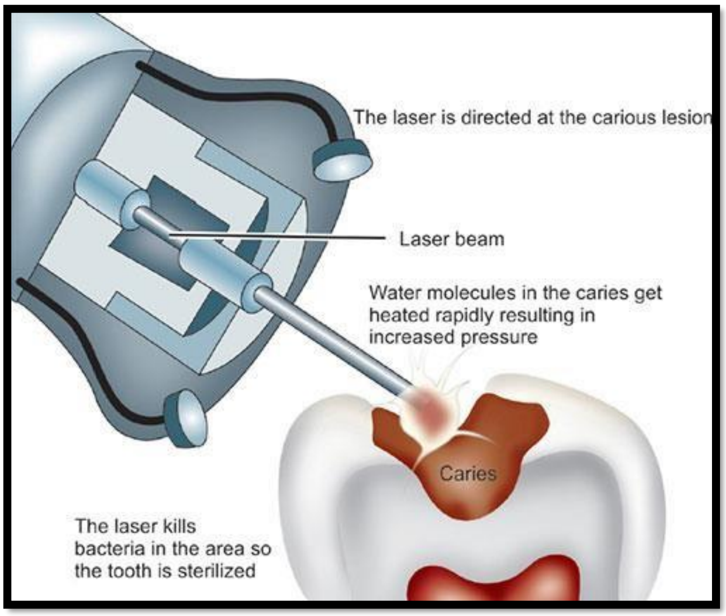


Fig. 14. schematic diagram illustrating the mechanism of LASER induced caries removal

Other lasers under study for tooth ablation are

a. Carbon dioxide lasers (CO2) — IR emission

b. Excimer lasers (ArF (argon: Freon) and XeCl (xenon: chlorine) — UV emission

c. Holmium lasers

d. Dye-enhanced laser ablation-exogenous dye, indocyanine green in conjunction with a diode laser [99].

Several advantages related to the use of laser irradiation in operative dentistry are;

- A more conservative cavity design,
- An alleged antibacterial activity [100]
  - Significant decrease of enamel solubility
  - Lower pain sensation
  - Absence of smear layer

On the other hand, the major drawback related to their use in operative dentistry is the relatively long time needed for cavity preparation.

- The time required for a complete excavation is, in general, twice that with rotaryinstruments,[100]
- Thermal irradiation of pulp
- Expense and size of the equipment.

XIV. ENZYMES

In 1989, Goldberg and Keil successfully removed soft carious dentine using bacterial Achromobactin collagenase, which did not affect the sound layers of dentine beneaththe lesion [101]. Also, a more recent study has used the enzyme pronase, a non-specific proteolytic enzyme originating from Streptomyces griseus, to help remove carious dentine [102]. However, further laboratory research is required for validation of this technique.

METHOD	SOUND ENAMEL	SOUND DENTIN	CARIOUS ENAMEL	CARIOUS DENTIN	NOTES
Hand excavators	-	-	+	++	
Rotary burs	+++	+++	+++	+++	Slow speed handpiece
Air abrasion	+++	+++	++	+	Depends on abrasive agent used
Air polishing	+	+	+	-	Need hard surface substrate as abrasive agent
Ultrasonics	+	+	+	-	Retrograde root filing cavity preparation
Sono abrasion	-	+	+	++	Further studies needed
Chemo-mechanical	-	-	-	+++	Incomplete access to dentin
Lasers	+	+	+	+	Depends wavelength, intensity, pulseduration etc.
Enzymes	-	-	-	+	Further studies needed

Table 2: Summary of different caries excavation techniques

XV. CONCLUSION

All the techniques remove carious dentine with differing levels of efficiency but, it is still unknown if these techniques will discriminate between the soft, outer, necrotic, highly infected zone that needs to be excavated from the inner, reversibly damaged, less infected zone which could be retained. If this discrimination does not take place, this could still lead to over preparation of cavities. Therefore, there is an important need to assess the effects of these techniques for their efficiency and extent of removal of carious dentine.

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