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Recent Methods in Caries Removal in Operative Dentistry

A Graduation Project Submitted to

The College of Dentistry, University of Baghdad, Department of Restorative and Aesthetic Dentistry
in Partial Fulfillment for the Bachelor of Dental Surgery

BY

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Certification of the Supervisor

I certify that this project entitled "Recent method in Caries removal in Operative Dentistry" was prepared by the fifth-year student Fatima Essam Kadhim under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Dr. Yasameen Hasan Motea

Date :

Dedication

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional, and financial support.

To my brothers, sister, friends, and classmates who shared their words of advice and encouragement to finish this study .

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Introduction

In recent years, the management of dental carious lesions changes from a traditional surgical approach to a “biological” or “medical” approach. **Davis and Makinson** described a completely new approach for “Minimal Treatment” of dental caries and first termed it **“Minimal Intervention Dentistry” (MID)** **(Frencken JE et al, 2012).** On one hand, an important concept, that governed the development of MID, is the ability to reduce the need for cutting away healthy tooth tissues by removal of the `infected` dentin as part of the cavity preparation process and preserving the “affected” dentin **(Frencken JE. et al, 2012).** The differences between infected and affected dentin are described in Table 1 **(Robles A., 2019).**

Table 1. Difference between infected and affected dentin

CARIES DENTIN DIFFERENTIATION

Infected dentin	Affected dentin
• soft (cottage cheese) superficial layer • yellowish to brown • can be deformed by pressing an instrument into it • can be easily removed by gently scraping with minimal force • total removal is required • irreversible destruction of collagen cross-linking • lack of mineral content • high bacterial concentrations • unable to undergo remineralization	• firmer and light brown than infected dentin (leather like) • no deformation when an instrument is placed into it • can be scraped off with medium pressure • the inner layer, located under the infected dentin • it is preserved after preparation • presence of the collagen network • some mineral content • reversibly denatured • no bacteria • potential for remineralization

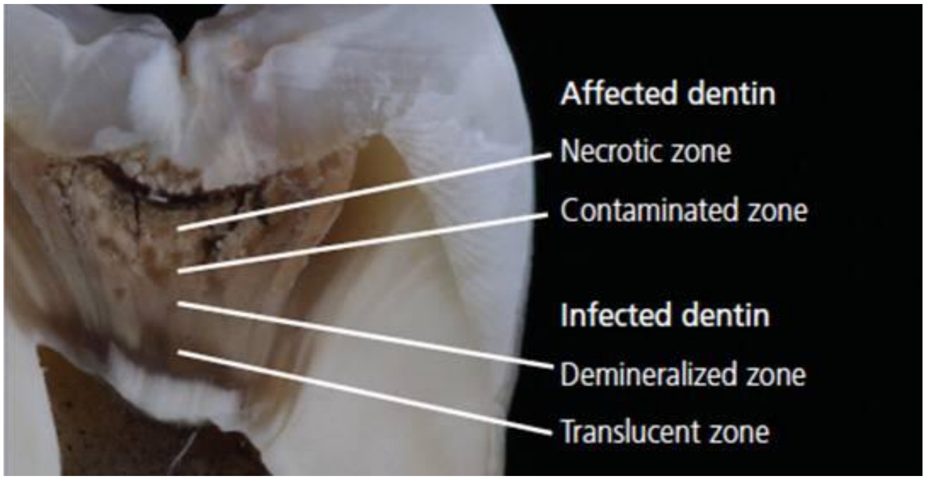

Fig.1 Difference between infected and affected dentin

On the other hand, the use of alternative and complementary methods reducing the need for local anesthesia and obtaining minimal or no pain during cavity preparation also contributes greatly to attaining the primary aim of MID. According to the concept of MID, the so-called 4S principle as a minimally invasive approach in behavioral dentistry is developed. It is based on removing four of the major primary sensory triggers for dental anxiety when in dental setting – **sight** (air turbine drill), **sounds** (drilling), **sensations** (high-frequency vibrations), **smells**. It is used most commonly in conjunction with other alternative methods to mitigate anxious behaviors and their consequences **(Hmud R, 2009)**.

The dentists' choice of method for excavation should be guided by the clinical requirements and outcomes. The characteristics of the method for caries removal include selective removal of infected dentin, being a reliable and effective method, painless and silent, minimal pressure caused during excavation, no vibration and heat generation, convenient and easy to use in the dental office. The common distinct features of these alternative techniques involve a conservative, selective excavation of carious dentin with irreversibly denatured collagen fibers and maximum preservation of the structures with a potential for remineralization. The main distinctions between these techniques are based on the techniques and means for excavation, the amount and type of excavated dentin, different methods for control in the process of excavation **(Senthilkumar V., 2020).**

Aim of the study

The aim of this project is to review the alternative methods for caries removal and their advantages and disadvantages to be discussed.

1. Tissue Removal Techniques

There are a number of techniques available for cutting tooth tissue (Table 2). Some claim to remove demineralised dentine selectively whereas others are not able to make this distinction and indeed, may not even be able to remove softened tissue effectively. For this reason, it is important that the practitioner knows what might be expected from these various techniques.

Table 2 Classification of various tooth-cutting techniques

Category	Technique
Mechanical, rotary	Handpieces + burs
Mechanical, non-rotary	Hand excavators, Air-abrasion, Air-polishing, Ultrasonics, Sono-abrasion
Chemo-mechanical	Caridex™, Carisolv™, Enzymes
Photo-ablation	Lasers

The ideal cutting instrument should fulfil certain factors to satisfy both operator and patient. These factors might include:

- Comfort and ease of use in the clinical environment
- The ability to discriminate and remove diseased tissue only
- Being painless, silent, requiring only minimal pressure for optimal use
- Not generating vibration or heat during periods of operation.
- Being affordable and easy to maintain.

No mechanical method at present benefits from all these attributes. Indeed, clinical progress in this field seems, relatively speaking, to be lagging behind that in restorative material science and even the theory and rationale of caries treatment**. (A. Banerjee et al, 2000)**

2. Caries Excavation Procedures

2.1 Conventional Excavation with Burs

2.1.1 Carbon-steel or tungsten-carbide burs

Tungsten-carbide burs replaced carbon-steel burs once the process of hardening steel with tungsten carbide was introduced to the dental bur industry. Microscopic tungsten-carbide particles are held together in a matrix of cobalt or nickel at the head (working end) of the bur **(Samaranayake LP,1998)**. The head has typical spiral-like cutting edges with or without additional cross cuts to improve cutting efficiency. Carbon-steel burs possess the same caries-removing properties as tungsten-carbide burs and are less expensive, but they are much more prone to corrosion and dulling **(Bayne SC, 2002)**. For caries removal, a round bur is recommended with diameters corresponding to the size of the carious lesion. Water irrigation is optional because generally low-speed (700 to 800 rpm) counter-angle Handpieces are employed. It is generally advised to start carious dentin excavation from the periphery towards the center of the lesion in order to minimize the risk of infection in case of accidental pulp exposure. Larger burs are recommended for this reason as well (**Aline de Almeida Nevesa et al, 2011).**

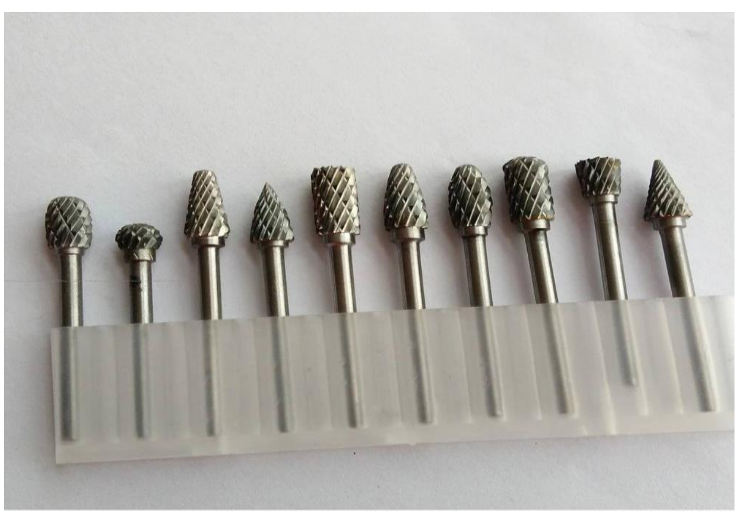

Fig. 2 tungsten carbide burs

2.1.2 Polymer burs

The use of the polymer burs is an alternative to the conventional stainless steel burs for the excavation of carious dentin. Their main advantage is the selective removal only of the infected dentin owing to the material hardness which does not allow an excessive preparation. Once all soft, carious dentin has been removed, the instruments automatically blunt on hard healthy dentin **(Marques MG et al, 2020).** When compared to the diamond and steel burs, the polymer burs remove dental tissues selectively but require two to three times longer for the caries-removal procedure **(Banerjee A. et al, 2000).** The main disadvantages are the excessive excavation of healthy dentin when high pressure is applied, breaking of the bur when it comes into direct contact with the enamel, the sensitivity of the technique, the use of polymer burs in combination with steel or diamond burs is required when we work in the enamel. However, in comparison with the alternative methods for caries removal, the mechanical excavation with rotary instruments is a non-selective removal of carious tissue, provokes discomfort and pain, as well as increased vibrations and contact pressure, risk of overheating of the surrounding tissues along with the unpleasant stressful sound of the rotary instruments. MID may involve the use of the conventional rotary instruments – high speed Handpieces, only to get access to the carious tissues **(Frencken JE. et al, 2012).**

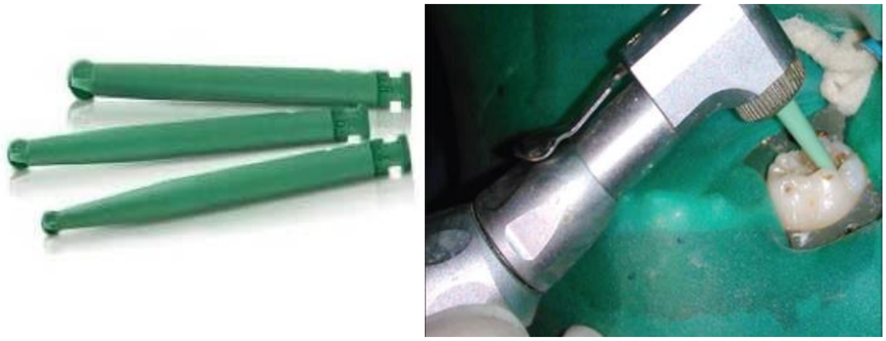

Fig 3 polymers burs

2.1.3 Ceramic burs

A new line of slow-speed rotary cutting instruments made of ceramic materials is now commercially available for removal of carious dentin. The CeraBurs are all-ceramic round burs made of alumina-yttria stabilized zirconia and are available in different diameter sizes. The manufacturer claims that besides its high cutting efficiency in infected, soft dentin, the use of this instrument for caries removal replaces both the explorer and the excavation spoon (commonly needed to evaluate the degree of decay removal) by simultaneously providing tactile sensation, self-evidently reducing preparation time. However, an in vitro investigation of the caries-removal efficiency (time consumption for excavation) and efficacy (ability to remove all carious material from the cavity) did not show any significant difference between the ceramic and conventional tungsten-carbide burs **(Dammaschke T, 2008).** Nevertheless, one important aspect to be emphasized – and which applies to all kinds of bur instruments – is its no specificity. Especially if no tactile instrument is used to check the cavity for its hardness, areas of underprepared dentin are likely to be left, **(Kidd EA, 1996)** as can be observed in the 3D volumetric reconstruction of a carious tooth when caries was excavated using ceramic burs. Further in vivo studies testing the effectiveness of these new burs are unfortunately still lacking. (**Aline de Almeida Nevesa et al, 2011).**

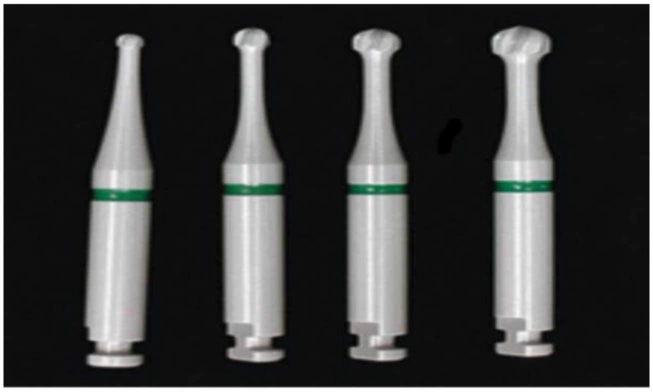

fig 4 ceramic burs

Even though the rotary bur is in universal use, there are still problems that need to be overcome. Five factors are potentially responsible for the discomfort and pain that is associated with cavity preparation: **(A. Banerjee et al, 2000)**

- The sensitivity of vital dentine.
- Pressure on the tooth (ie, mechanical stimulation).
- Bone-conducted noise and vibration.
- The high-pitched noise of the air-turbine handpiece.
- Development of high temperatures at the cutting surface (ie thermal stimulation).

Several studies have showed that temperatures at the cutting surface of burs and stones could easily rise above the pain threshold and, even with water spray lubrication, some damage to the underlying pulp might still occur **(A. Banerjee et al, 2000)**. The rotating bur easily cuts through carious dentine to eventually open up healthy tubules deeper in the tissue and in conjunction with water stimulation of odontoblast processes, this will result in the pain associated with cavity preparation using this technique. Even if the operator maintains continuous bur movement over a large surface area and keeps the bur speed and pressure constant throughout use, the type and size of bur used (for example, a large diameter round bur) can all help to reduce these detrimental factors to some degree; however, they are not completely eradicated and thus still pose a significant problem. In current practice, having gained access to the carious dentine using the high-speed air turbine handpiece and bur, the slow-speed bur or hand excavator can be used for carious dentine excavation. As the hand excavator will remove softened tissue with more sensitive tactile feedback than a bur, this method is the more self-limiting of the two **(A. Banerjee et al, 2000).**

2.2 Air abrasion

Air-abrasion was originally developed by **RB Black in 1945** who instigated preliminary investigations into an alternative pseudo-mechanical method for dental tissue removal which involved bombarding the tooth surface with high-velocity particles (conventionally aluminum oxide (Al_2O_3)) carried in a stream of air **(A. Banerjee et al, 2000)**

Depending on the nature of the abrasive used, this technique has the ability of abrading efficiently both sound dentine and enamel. There are several parameters that can be altered in order to adjust the cutting characteristics of the instrument: the type and size of abrasive particle will affect the coarseness of the abraded surface, 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 altered by varying the air pressure, the distance between the nozzle and tooth surface and the length of cutting time will also play an important part in adjusting the effectiveness of the instrument, reduced velocity will reduce the transferred kinetic energy to the tooth surface thus reducing the overall abrasiveness of the system **(A. Banerjee et al, 2000).**

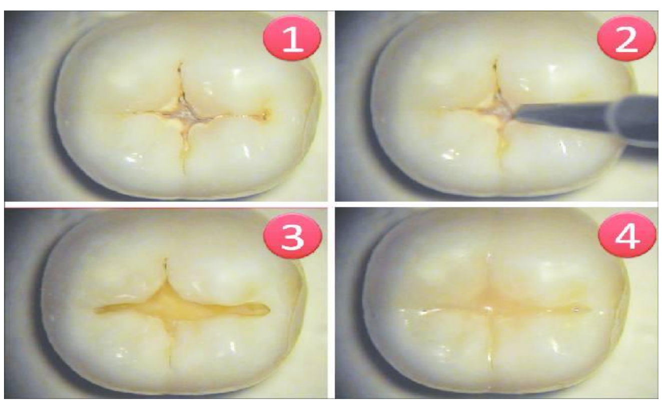

fig 5 caries removal using air abrasion

The first units to be commercially manufactured were the Airdent machines. Early patient surveys indicated that this technique was greatly favoured by patients and dentists alike **(A. Banerjee et al, 2000)** This method of cutting teeth seemed to dramatically reduce the problems of heat generation, vibration and other mechanical stimulation **(A. Banerjee et al, 2000)** 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 **(Laurell K, 1993)**. 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 **(Goldstein R E, 1994)**. Note that to date, these applications using commercially available alumina abrasive do not include the efficient removal of softened, carious dentine. 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 **(Goldstein R E, 1994)**. It must be emphasised that the aluminium oxide abrasive particles will remove sound enamel and dentine very efficiently, whereas clinically soft, carious dentine is not removed due to the reduced hardness of the carious substrate when compared with the alumina particles themselves **(A. Banerjee, 2000).**

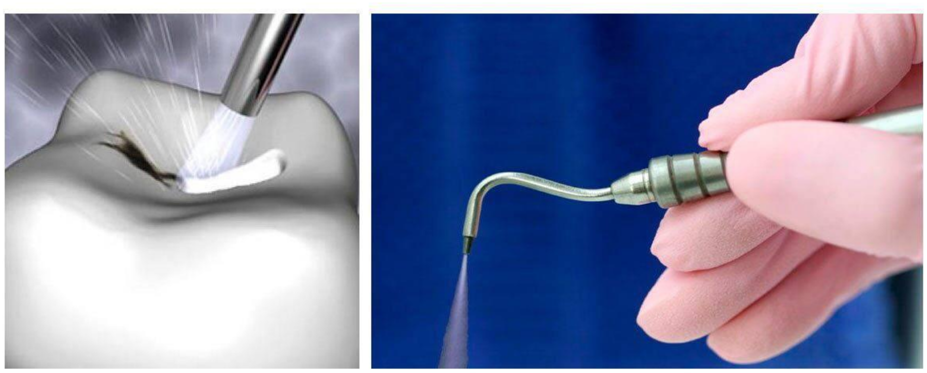

Fig 6 air abrasion

To minimize the inhalation of particles by the patient, the use of a rubber dam and special face masks are required. The advantages of air abrasion include the higher level in the cooperation in patient`s behavior, elimination of the risk of overheating, vibration and mechanical stimuli. The main disadvantage is the loss of tactile sensation during caries excavation. **(Maria Shindova, 2021).**

2.3 Air-polishing

Air-polishing is the process by which water-soluble particles of sodium bicarbonate, to which has been 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 **(Horning G., 1987)** This is the important difference between this technique and that of air abrasion. The fact that the abrasive is water soluble means it does not escape too far from the operating field **(Boyde A., 1987)**. The bombardment of the hard tooth surfaces by these particles results in a continuous mechanical abrasive action which removes surface deposits **(Boyde A., 1984).** Razzoog and Koka noted that increasing the air pressure beyond 90 psi actually reduced the abrasiveness of the Microprophy System (Danville Engineering Co., Danville, CA). This was due to a phenomenon found in one-dimensional, two phase fluid dynamics ‘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 **(Razzoog M E, 1994)**. 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 **(Horning G., 1987).** However, due to 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 **(Lubow RM, 1986).** It has been suggested that air polishing could be used for the removal of carious dentine at the end of cavity preparation **(A. Banerjee, 2000).**

Fig 7 air polishing

2.4 ULTRASONIC CARIES REMOVAL SYSTEM

The ultrasonic caries removal includes the use of different diamond coated ultrasonic tips, ensuring selective removal of the decayed tissues and preserving the healthy enamel. The method presents advantages such as production of less vibrations and mechanical trauma as well as elimination of the unpleasant sound of the air turbine **(Cardoso M. et al, 2020).** The unilateral use of the diamond-coated tip one side only in proximal cavities ensures the preservation of the healthy enamel of the adjacent tooth. Piezon Master 600 is a combined ultrasonic system for preventive procedures, periodontal treatment, endodontic treatment, minimally invasive treatment of fissure caries, preparation of the occlusal surface before a sealant application. The Vector system is a new method combining both ultrasonic effects and micro abrasive action of quartz crystal suspension **(Banerjee A. et al, 2000).**

Fig 8 ultrasonic tips

2.5 Sono-abrasion

A recent development from the original Ultrasonics mentioned above is the use of high-frequency, sonic, air-scalers with modified abrasive tips – a technique known as 'sono-abrasion'. Is based upon the Sonic flex 2000L and 2000N air-scaler handpieces that oscillate in the sonic region (< 6.5 kHz). The tips describe an elliptical motion with a transverse distance of between 0.08 – 0.15 mm and a longitudinal movement of between 0.055 – 0.135 mm **(Banerjee A., 1999).**

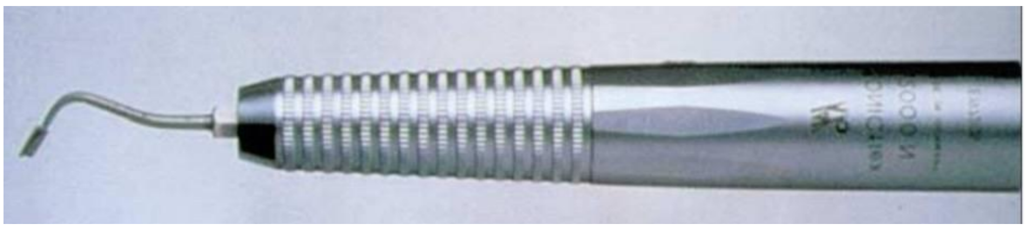

Fig 9 air-scaler handpiece with diamond-coated tip

They are diamond coated on one side using 40 µm grit diamond and are cooled using water irrigant at a flow rate of between 20–30 mL / min. The operational air pressure for cavity finishing should be around 3.5 bar (ie the nominal pressure at the coupling). 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 in the region of 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 help prepare predetermined cavity outlines (Sonicsys approx) but also works well in removing hard tissue when finishing cavity preparation. Favourable results from laboratory studies using sono-abrasion to remove softened, carious dentine have indicated another possible use for this technique in the future **(Banerjee A., 2000).**

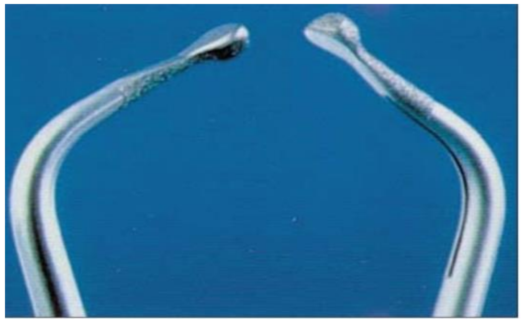

fig 10 Sonicsys micro diamond-coated hemispherical cutting tips

2.6 Chemo-mechanical methods:

2.6.1 Caridex and Carisolv

In the previous sections, various mechanical methods of tooth tissue removal have been discussed. There is, however, another alternative **Goldman and Kronman in 1976** reported on the possibility of removing carious material chemically using N-monochloroglycine (NMG, GK-101). Subsequently, after modification, the Caridex system, containing N-monochloro D, L-2-aminobutyrate (NMAB, GK-101E), was introduced (Schutzbank SG, et al 1978) This system was developed as a chemico-mechanical method for caries removal. Carious dentine, softened further by NMAB (GK-101E), should have been readily removed by lightly abrading its surface with the applicator tip. Several early studies found the technique to have advantages including increased patient compliance and a reduced need for local anesthesia **(Zinck JH et al, 1988)**. **Brannström et al in 1980** showed it to be a successful way of removing soft carious dentine without any significant damage to the underlying dentine, but other studies showed no beneficial effect of the system in excavating carious dentine when compared with a control system using water alone, no reduction in operating time and the need for copious volumes of solution **(Barware O et al, 1991).** Further studies also indicated that in permanent teeth, the ability of carious dentine removal using NMAB was no greater than that using a control solution of isotonic saline. In deciduous teeth, however, addition of urea to the solution significantly improved carious dentine excavation compared with the same control solution without urea **(Yip H K et al,1999).**

Following on from this a gel-based system was developed and recently Carisolv gel has been introduced, to be used with specially designed non-cutting hand instruments to abrade the carious dentine surface. Carisolv consists of two carboxymethylcellulose based gels: a red gel containing 0.1 M amino acids (glutamic acid, leucine and lysine), NaCl, NaOH, erythrosine (added in order to make the gel visible during use); and a second containing sodium hypochlorite (NaOCl — 0.5% w/v). The two are thoroughly mixed in equal parts at room temperature before use and then applied, using the hand instrument, onto the exposed carious dentine and left for 60 seconds prior to gently but firmly abrading away the softened dentine to leave a hard, caries-free cavity. The solution has a pH of around 11 and it is postulated that the positively and negatively charged groups on the amino acids become chlorinated and 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. It is also highly probable that the gel has a mechanical lubricating action for the hand instrument which will also aid in the removal of the softened tissue **(Banerjee A., 2000).**

Fig 11 use of Carisolv gel

Early results from clinical trials indicated an increased patient compliance to this technique over the use of the dental drill to excavate carious dentine **(Ericson D et al, 1998).** However, drawbacks may include the prolonged operating time (when compared with rotary instrumentation) 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 e.g. exposed carious buccal, cervical root lesions or grossly cavitated, deep lesions in an attempt to minimise pulp exposures. Results from initial lab-based experiments testing its efficiency and effectiveness have shown this technique to have the potential to be a more selective method of carious dentine removal **(Banerjee A., 1999).** It also appears to produce a cavity with an incomplete smear layer with open tubules evident. This point may have clinical relevance to the dentine bonding ability of adhesive materials and requires further investigation **(Banerjee A., 2000).**

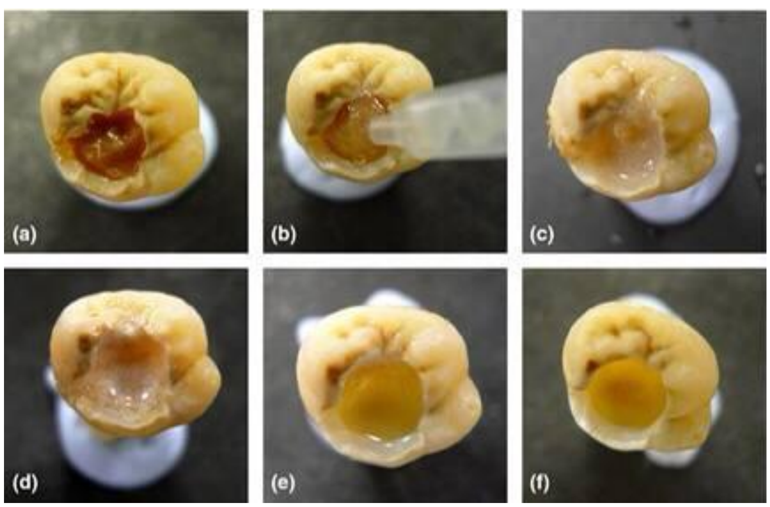

Fig 12 Carisolv gel for caries removal

2.6.2 enzymes

Enzymes Studies have examined the possibility that carious dentine might be able to be removed by using certain enzymes. **Goldberg and Keil In 1989,** successfully removed soft carious dentine using bacterial Achromobacter collagenase, which did not affect the sound layers of dentine beneath the lesion. Also, a more recent study has used the enzyme pronase, a non-specific proteolytic enzyme originating from Streptomyces griseus, to help remove carious dentine **(Norbø H. et al, 1996)**. This might have significant clinical implications but further laboratory research is required for validation of this technique **(Banerjee A., 2000).**

2.7 laser

Since the development of the first ruby laser by **Maiman in 1960,** researchers postulated that it could be applied 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 **(Adrian J C et al, 1971).** Since these early beginnings, the field of lasers has developed considerably and many new types of laser are available to cut dental hard tissues. The efficacy of the lasers will depend on numerous factors including the wavelength characteristics, pulse energy, repetition rate and the optical properties of the incident tissue **(Seka W et al, 1996)**.

Lasers that are currently being investigated for more selective hard tissue ablation include:

- Er: YAG (erbium: yttrium-aluminiumgarnet) and Nd: YAG (neodymium: YAG) — mid-IR to IR emission
- Carbon dioxide lasers (CO_2) — IR emission
- Excimer lasers (ArF (argon: Freon) and XeCl (xenon: chlorine) — UV emission

• Holmium lasers

• Dye-enhanced laser ablation —– exogenous dye, indocyanine green in conjunction with a diode laser **(Adrian J C et al, 1971).**

In terms of carious dentine removal, the UV emission of excimer lasers (377 nm) has the potential to be more selective in the ablation of carious dentine and there may be a possible use of dye-enhanced laser ablation to develop this selectivity further **(Wigdor H A et al, 1995).** In addition to caries removal, studies have shown that, in the presence of a suitable photo-sensitiser, low-power laser light has the ability to destroy Streptococcus mutans. Lasers have also been used to cut and seal dentine tubules, reducing the possibility of postoperative sensitivity **(Mercer C., 1996).** At present, there is significant interest in these instruments but problems still persist regarding thermal irritation to the pulp, the control of the procedure and the possible alteration /destruction of the adjacent sound tissue. These factors coupled with the expense and size of the equipment have meant their use in general practice as a hard tissue cutting tool has been effectively limited to date **(Banerjee A., 2000).**

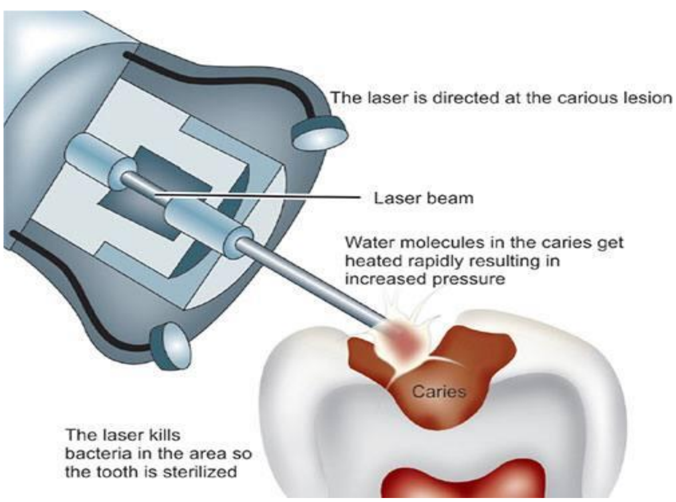

Fig 13 use of laser for caries removal

3. Conclusion

All the techniques will remove carious dentine with differing levels of efficiency but more importantly, it is still unknown if these techniques will discriminate between the soft, outer, necrotic, highly infected zone that needs to be excavated and 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 with little control over the quality and quantity of tissue removed by individual operators. There is, therefore, an important need to assess the effects of these techniques for their efficiency and extent of removal of carious dentine.

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