Chemo-mechanical method:  
A valuable alternative for caries removal

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Abstract

Dental caries is considered one of the most serious dental diseases that results in localized dissolution and destruction of the calcified tooth tissues. Neglecting the treatment of this disease could also endanger the tooth pulp. However, caries treatment procedures are usually associated with unpleasant patients’ sensation. Several approaches for removing and treating dental caries have been tried seeking for more comfort, but none of them seems ideal. The chemo-mechanical caries removal approach has been suggested a long time ago, and the interest regarding this method has recently increased. This innovative method seems to be efficient in removing infected dentine without altering the healthy dental tissue or harming the adjacent oral mucosa. In addition, the bonding quality of most dentine adhesives and polyalkenoate cements is not affected by using this approach for preparing dentine surfaces. This brief review provides simple ideas about the benefits and the drawbacks of both classic and modern approaches of caries removal. The development as well as the clinical and laboratory assessment of the chemo-mechanical caries removal systems is also presented. The available data has prompted the introduction of the chemo-mechanical approach as an acceptable alternative for caries removal especially at the time of treating fear expressing and pediatric patients. *First published in Dental Update 2002; 9 (3): 16-22.*

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Introduction

Dental caries is currently considered as one of the most common chronic diseases. This disease results in localized dissolution and destruction of the calcified tooth tissues and sometimes causes an eventual infection of the dental pulp. Usually dentine caries could be recognized as two distinct successive layers, which are different in their clinical features, as well as in their microscopic and chemical structures. The outer layer (infected dentine) is highly de-calcified, infected with bacteria and
could be selectively stained in vivo by such caries detector dyes. In spite of the possible discoloration, the inner layer (affected dentin) is less decalcified with intact collagen fibers and no bacterial invasion. Moreover, it is more resistant to the proteolytic attack and the progression of carious lesions. In this instance, there is no necessity to continue preparing the tooth until the dentin is stain-free, but the ability to discriminate and remove only the diseased tissue remains as essential. In 1893, GV Black proposed his principle “extension for prevention” in the operative treatment of carious lesions. The principle proposed the removal of sound tooth structure and the anatomical form at sites that might encourage plaque stagnation to help in minimizing the caries onset and progression. The fact is that the Black’s principle was constrained by both the knowledge of disease process and restorative materials presented at that time, but the demand of removing sound enamel and dentin has been dramatically changed as a result of developing the adhesive restoratives and the alternative approaches of both caries removal and cavity preparation.

Different approaches of caries removal

The earliest attempt to remove caries involved the use of a hand drill, which was soon surpassed in 1871 by James Morison’s treadle instrument developed from the mechanism of Isaac singer’s sewing machine. Currently, the conventional treatment of caries is usually carried out with a high-speed hand piece to access the lesion and a low speed hand piece to remove the caries. This method involves quick and efficient caries removal, however it may result in unnecessary removal of the healthy or even the affected dentine that shows the ability for remineralization. Caries removal utilizing the conventional technique is usually associated with pain and patients’ discomfort. The bone-conducting noise and vibration and the possibility of producing thermal and mechanical injuries to the dental pulp are also considered between the major shortcomings of the drilling approach. In the last few decades and as a result of the former drawbacks, a growing interest has been noticed to develop alternative minimally invasive techniques. Air-abrasion was originally developed by Robert Black in 1945 as an alternative pseudo-mechanical method for dental tissue removal. This technique involved bombarding the tooth surface with high velocity aluminum oxide particles (Alumina) carried in a stream of air. Recently, several new air-abrasive cutting instruments have been introduced; such systems utilize air pressure of 7-11 atm with alumina powder ranges 20-50 µm to cut dental tissue. This method of cutting is relatively painless when compared with dental drills. However, the total loss of tactile sensation, and the ability of alumina particle to remove sound tooth structure rather than the carious substrate in addition to the potential risk of inhalation problem should also be considered at the time of selection. Air-polishing is another technique utilizing a mixture of water-soluble sodium bicarbonate and tricalcium phosphate particles that is applied onto the tooth surface using air pressure and shrouded in a concentric water jet. The water jet helps the abrasives not to escape far from the operating field, however the detrimental surface attack of such restoration and sound tooth structure could be the result of non-selective abrasion characteristic of this method. Relative to this fact, several researchers suggested the use of that technique only for removing carious dentine at the end of cavity preparation. The ultrasonic instrumentation has also been tried. This method depends on transferring the kinetic energy of water molecules to the tooth surface via the abrasives in presence of high-
speed oscillations of the cutting tip. The ultrasonic procedure has the advantage of minimizing or eliminating noise, vibration, heat and pressure. The limited availability of instrument tips, slowness of action and the inability to remove soft carious dentine were the main limiting factors regarding the acceptance of that technique. Recently, sono-abrasion was developed as a modification of the original ultrasonics. This technique utilizes high frequency, sonic, air-scalers with modified abrasive tips which describe an elliptical motion with a transverse distance of 0.08-0.15 mm and a longitudinal movement ranges from 0.055 to 0.135 mm. These tips are diamond-coated on the cutting side, cooled using water at a flow rate of 20-30 ml/min and operated by 305 bar air pressure for cavity finishing. Other tips shaped length ways halved torpedo, small hemisphere and large hemisphere are currently available. Using the different shapes of the tips helps in preparing predetermined cavity outlines, and also works well in removing softened, carious dentine. On the other hand, the relatively low abrasion and high hub excursion (0.4 mm) of the tips were known as disadvantages of this system. The limited application and the weakening of enamel rods with the associating cracks adjacent to the prepared sites were also reported. Another approach was postulated with the development of the first ruby laser by Maiman in the 1960s. However, early studies had found that the ruby laser produced significant heat that caused damage to the pulp. In spite of the drawbacks of that beginning, new types of laser are now available to cut dental hard tissues with the priority of selecting Excimer Lasers (Ultraviolet emission of 337 nm) for ablating carious dentine. The non-touch application of energy impulse (Lasing) seems advantageous to regular drilling as it provides less pain, noise and pressure. Moreover, it is believed to have minimal vibration and the ability to produce a sterile cut surface. In spite of these benefits, still there is a risk of heat generation with its subsequent effect on the tooth structure (carbonization, melting and cracking) and dental pulp (inflammation and necrosis). Moreover, the high price and the disability to use laser in the presence of intraroral metal restorations are additional limiting factors. During the last few years, reversal of caries using Ozone has also been suggested based on the fact that the remineralized tooth tissues are known to be more resistant to decay than sound tooth structure. The technique uses laser detection of caries and Ozone treatment for less than 2 minutes. Ozone readily penetrates through decayed tissue, eliminating the ecological niche of cariogenic microorganisms as well as priming the carious tissue for remineralization. The remineralization process will then take place with the aid of a topically applied remineralizing solution and the recommended patient’s maintenance kit. This simple fast novel approach avoids the need for local anesthesia, drilling and filling, however its application is restricted to treat the superficial enamel and root caries, and the use of conventional drilling and filling are still recommended to treat deep carious lesions. It is obvious that most of the proceeding trials are trying to achieve a conservative approach for removing dental caries. This issue stimulated the development of the currently known atraumatic restorative treatment (ART) approach. This method includes excavation and removing of the caries with hand instruments only and subsequently restoring the cavities with such adhesive restorative material. However, a potential risk of leaving infected carious dentine still exist. On the other hand, Goldberg and Keil in 1989 have discovered the efficacy of the
collagenase enzyme, released from Achromobacter bacterial species, in removing soft carious dentine 2-5 hours after its application. A residual sound layer of dentine will result with no bacteria seen within the exposed collagen of the dentinal floor. Another enzyme named Pronase has also been discovered for the same application. In spite of the potential effectiveness, the slow action of this approach for caries removal limits its clinical application. Combining the last two approaches resulted in developing what is known these days by the chemo-mechanical caries removal. The details regarding the development and the assessment of this innovative method are covered in the following section.

The chemo-mechanical Caries removal method (CMCR)

The idea of chemo-mechanical caries removal has been developed in 1970s by Goldman who was primarily an endodontist, while using sodium hypochlorite (NaOCl) in removing organic materials in the root canals. This chemical got the ability to dissolve carious dentine and since that time, the idea of removing caries chemically was borne. However, NaOCl itself was too corrosive to be used on healthy tissues because of its high reactivity and its ability to decompose non-necrotic tissue, subsequently NaOCl was diluted and buffered with sodium hydroxide, sodium chloride and glycine producing a solution of 0.05% N-monochloroglycine (NMG) having a pH of 11.4. This solution is commercially known as GK101. Goldman et al. in 1976 documented the effectiveness of the GK101 in removing carious tooth material, while its mechanism of action was later on described by Kurosak et al. The GK101 material is normally going to soften only the infected layer of carious dentine by selective attack on the degenerated collagen fibers. The attack causes cleavage of the polypeptide chains and hydrolyzes the cross-links of collagen fibrils. The surprise is that this chemical agent has no ability to affect the sound collagen fibers in the inner affected and normal dentine, causing no or slight effect on the teeth pulps. GK101 system was found to be more effective if the glycine is replaced by aminobutyric acid, the product then being N-monochloro-D-2 aminobutyrate (NMAB) and named as GK101E and marketed in the United States in 1984 as “Caridex”. The Caridex was presented as a two-bottle system; the first contains sodium hypochlorite and the second contains glycine, aminobutyric acid, sodium chloride and sodium hydroxide. Both solutions are mixed immediately before use to give the warning reagent with a pH approximately equal to 11 that becomes stable for one hour. The delivery system of Caridex consisted of a reservoir for the solution, heater and pump which passed the liquid warmed to the body temperature through a tube to a hand piece and applicator tip (20 gauge hypodermic needle, the tip of which had been modified into spoon shape). Caridex system was claimed to involve the chlorination and disruption of the partially degraded collagen fibers in carious dentine with NMAB. The carious dentine then becomes easier to remove by excavation using the modified needle tip. An additional attempt was carried out to improve NMAB reagent incorporating urea in its formula. The action of this modification involves the two amino groups of urea being chlorinated by sodium hypochlorite to form mono or dichloro derivatives. These intermediate compounds along with NMAB then attack and break down the partially degraded collagen in carious dentine. Scanning electron microscope (SEM) examination of dentine after caries removal revealed that NMAB reagent selectively removes carious dentine leaving a surface with many overhangs and undercut.
This surface is believed to be the interface between carious and sound dentine. The appearance of dentine scales is also a frequent feature while dentinal tubules seem to be patent and occluded\textsuperscript{55}. In 1994 Yip et al.\textsuperscript{56} used both the back-scattered electron (BSE) imaging and electron probe microanalysis (EPMA) to compare the calcium and phosphorus levels of normal dentine with those of dentine remaining after chemomechanical caries removal using NMAB. The results indicated no remnants of the demineralized dentine were detected after treatment and the remaining dentine was chemically and clinically sound. The clinical trials\textsuperscript{57} showed high acceptance and preference of Caridex caries removing system that showed this system could be a valuable alternative for dentinal caries removal, with the advantage of reducing the use of conventional drilling and the need for local anesthesia. These findings nominated that system for treating anxious, medically compromised and pediatric dental patients. On the other hand, the biocompatibility studies\textsuperscript{58,59} indicated no adverse effect of NMAB on dental pulp. However, the unpleasant taste indicated by few patients and the lengthy procedure (10-15min), in addition to the large volumes of solution needed (200-500ml) and to the fact that the delivery system was no longer commercially available, limit the use of NMAB chemomechanical caries removal system\textsuperscript{60}. Recently, the Carisolv system has been developed by the Swedish Medi Team. This system works through the same mode of action as Caridex, however it utilizes three naturally occurring amino acids (glutamic acid, leucin and lycine) with different charges. All of these charges help the electrostatic attraction of either the hydrophilic (positively or negatively charged) or hydrophobic (noncharged) patches that normally form the peptide chains of all proteins including collagen\textsuperscript{61}. The new system is marketed in two syringes, one containing 0.5% sodium hypochlorite solution and the other containing pink gel of the three amino acids. Carboxymethyl cellulose and erythrocin are also added to make the gel viscous and readily visible in use. The contents of the two syringes should be mixed immediately before use as its effectiveness begins to deteriorate after 20 minutes. The mixed gel is applied to the carious lesion for 30 seconds and then the carious dentine can be gently removed, using Carisolv specially designed, non-traumatic hand instruments. The same procedure is continuously repeated until removing clear gel is achieved. The average time required for complete caries removal is about 9-12 minutes and the volume of gel utilized for this purpose is only 0.2-1.0 ml\textsuperscript{60}. The clinical efficiency and safety of Carisolv system was documented by Ericson et al.\textsuperscript{62} in 1999. These findings were then confirmed through different in vivo and in vitro studies\textsuperscript{63-67}, which showed a wide range of patients’ acceptance and comfort. The Carisolv system also seemed very successful in selective removal of carious dentine with no pain demonstrated and no need for local anesthesia, however its slowness was the only apparent drawback. Laboratory assessment of cavities treated with Carisolv using light microscope indicated sound, caries-free dentine having the same chemistry of that dentine left after conventional drilling\textsuperscript{68}. Another study\textsuperscript{69} showed no penetration to the residual dentine and accordingly pulp damage would not be expected with this system. Young et al.\textsuperscript{70} confirmed this finding in 2001 through histological and immuno-histochemical examination. Other studies\textsuperscript{71-73} utilizing fancy microscope technology revealed no harmful threat either on healthy or affected dentine. The bactericidal effect of the Carisolv system was also observed as well as its stimulating ability for reactive
dentine formation. On the other hand, no harm was noticed clinically when the oral mucous tissues was subjected to 3 minutes contact with the Carisolv solution. The former observation has gained a histological support when no significant increase in the number of inflammatory cells has been detected after exposing the gingival tissue to the same chemical agent. The effect on certain restorative material was also evaluated. Minor influence was demonstrated on the surface topography of ceramic restorations after 20 minutes contact with Carisolv gel, however this effect could not be noticeable in case of accidental contact.

**Bonding to dentine after CMCR**

Enhancing the dentine-adhesive bond seems desirable to achieve longevity of restorations and to minimize the postoperative complications. However, the quality of bonding to dentine could be affected to a great extent by the mode of caries removal. The chemo-mechanical caries removal showed more irregular and rougher surfaces with modified smear layer when compared with the conventional rotary preparation. Moreover, acid etching of the chemo-mechanically treated dentine exposed a clear peritubular and intertubular collagen network. This finding for sure could affect the quality of the formed hybrid layer and therefore the longevity of the adhesive restorations. Some researchers registered a comparable adhesion of glass ionomer cements either to the chemo-mechanically or conventionally treated dentine surfaces. At the same time, bonding quality of modern adhesive systems to dentine seems not to be affected in presence of chemo-mechanical caries removing agents. However, certain reports indicated higher bond strength values with the chemo-mechanically prepared dentine than those exhibited with conventionally prepared dentine. In addition no difference in microleakage parameters was observed when either CMCR system or conventional bur caries removal technique is used to prepare a cavity for composite resin restoration.

**Summary**

Patient acceptance and comfort are important at the time of caries treatment. This could be achieved by using the chemo-mechanical method for removing dental caries. Utilizing this approach, especially with using the Carisolv system, provides efficient removal of dental caries with no harm expected either on the healthy dentine or the pulp tissues. Considering the other advantages regarding the adhesive bonding, and the compatibility with both soft tissues and restorative materials, the lengthy procedure is probably the only apparent drawback of the chemo-mechanical caries removal method. Consequently, the chemo-mechanical approach seems to be a valuable alternative for caries removal especially in fear demonstrating and pediatric patients.

**摘要**

牙齿被认为是造成龋病和其它牙齿疾病的重要因素之一。如果不及时治疗，牙齿的疾病会危及牙齿和口腔的健康。然而，传统的治疗过程常常会因为病人的不适和恐惧而止于中途。随着现代技术的发展，尤其是化学-机械牙脱的方法，寻求更安全、更有效的治疗方法成为了关注的焦点。化学-机械牙脱的方法在很久以前就已经被提出来了，对于这一方法的兴趣在近期有所提高。这种创新的方法似乎为移除受感染的牙质而不影响健康的牙组织或伤害相邻的口腔粘膜方面有所改善，此外，使用该方法的牙质表面不会影响大多数牙质粘合剂和粘结剂的粘合质量。本文简要的评论提供了有关传统及现代脱酸方法的益处及缺点的简单概念，也描述了化学-机械牙脱的发展以及临床和实验室评估结果。现有数据促使引入了化学-
La caries dental es considerada una de las enfermedades dentales más serias que resulta en la disolución y destrucción localizada de tejidos dentales calcificados. Descuidar el tratamiento de esta enfermedad podría también poner en peligro la pulpa dental. Sin embargo, los procedimientos de tratamiento de caries son usualmente asociados a sensaciones desagradables para los pacientes. Se han tratado varios métodos para remoción y tratamiento de la caries dental buscando mayor comodidad para el paciente, pero ninguno de ellos parece ser idóneo. Se ha sugerido por mucho tiempo el método quimiomecánico de remoción de caries y recientemente ha aumentado el interés en el mismo. Este método innovador parece ser eficaz en la remoción de dentina infectada sin alterar el tejido dental saludable o dañar la mucosa oral adyacente. Además, la cualidad de fijación de la mayoría de los adhesivos dentinales y cementos polialquenoatos no es afectada cuando se usa este método para preparar superficies dentinales. Este breve estudio proporciona ideas simples sobre los beneficios y desventajas de los métodos clásico y moderno para remoción de caries. Asimismo, presenta el desarrollo y evaluación de laboratorio de los sistemas quimiomecánicos de remoción de caries. La información disponible ha impulsado la introducción del método quimiomecánico como una alternativa aceptable para remoción de caries, especialmente al tratar pacientes que expresan temor y pacientes pediátricos. Publicado primero en Dental Update 2002; 9 (3): 16-22

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