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Original Research

Chemomechanical Caries Removal: An Update

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ABSTRACT:
It is well-known fact that traditional method of caries removal using the "dental bur" is the most common technique for caries removal in dental practice. However, this technique is always associated with many disadvantages such as the perception by patients that drilling is unpleasant, frequent requirement of local anesthesia, drilling can cause deleterious thermal effects, can also cause pressure effects on the pulp, and use of drill may result in excessive removal of sound tooth structure. An innovative approach called "chemo-mechanical caries removal" technique which is minimally invasive and painless has been developed to overcome the shortcomings of traditional approach of caries management. This method of caries removal involves chemical softening of carious dentin followed by its removal with gentle excavation. The present review of literature will address different systems of chemo-mechanical caries removal in detail.
Keywords: Dental Caries, Chemomechanical Caries Removal, Caridex, Carisolv

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INTRODUCTION

Dental caries has always been a public health challenge worldwide, especially amongst the younger generations. It has been and still remains the most prevalent disease worldwide, burdening billions of people, especially children with pain and subsequently poorer quality of life and general wellbeing.[1] Restoration of carious teeth in children with conventional drill is considered traumatic mainly due to the fear and anxiety among them.[2] The aversion to the noise of rotary instruments and dental anesthesia are the main factors for this situation, which results in delay of the treatment leading to the advancement of the caries process to emergency situations.[3] Dental cares management has evolved drastically from G.V. Black's "Extension for prevention" to "Construction with conservation."[4] The concept of Minimal Invasive Dentistry (MID) has gained popularity with the development of newer dental restorative materials, caries removal agents, better understanding of the caries process and the tooth's potential to remineralize.[5]

Minimal Intervention Dentistry is of great eminence in today's scenario. One of the techniques includes Chemomechanical Caries Removal. As the name suggests, Chemomechanical Caries Removal involves the application of a chemical solution to the carious dentine followed by gentle removal with hand instruments. It has seen to be very efficient in its caries removal effectiveness while maintaining its

minimal invasive potential. It is based on biological principles which involve removal of only the infected dentine while retaining the affected dentin.[6] The present review of literature will address different systems of chemo-mechanical caries removal in detail.

EVOLUTION OF CHEMO-MECHANICAL CARIES REMOVAL AGENTS

The earliest attempt to remove caries used hand drill, which was soon succeeded in 1871 by treadle instrument invented by James Morison. Since that time, various drills have been developed to improve the efficiency of rotary instruments. Conventional caries removal and cavity preparation involves the use of burs. Disadvantages of this system include perception of patients that drilling is unpleasant. Frequent requirement of local anesthesia probable deleterious thermal effects of drilling, probable pressure effects of drilling on the pulp, and the use of a hand piece may result in removal of softened, but uninfected dentin, ensuingan excessive loss of sound tooth tissue. This resulted in a growing demand for materials or procedures that help in caries management.[7]

The principle of chemo-mechanical caries removal is based on studies done by Habib *et al.*in the decade of 1970.They reported the effect of a nonspecific proteolytic agent called sodium hypochlorite on the removal of carious dentin. They noticed that 5% sodium hypochlorite was too corrosive for use on healthy tissue and incorporated Sorensen's buffer into it. Sorensen's buffer contained glycine, sodium chloride and sodium hydroxide. Later it was found that form N-monochloroglycine (NMG), which was prepared by chlorination of glycine, was more efficient in caries removal and was made available as the first Chemomechanical caries removal agent, GK-101 in 1972.Limitation of GK-101 was, it had a slow action and softened only the first layer, but not the second layer.

In later studies, it was found that the system was more effective if amino butyric acid replaced glycine, hence the product N-monochloroaminobutyric acid (NMAB) was formulated which was also called GK-101E. In 1975, the NMAB system was patented in the United States and received US Food and Drug Administration approval for use in 1984 and later marketed with the name Caridex.[8-9]

CLASSIFICATION OF CHEMO-MECHANICAL CARIES REMOVAL AGENTS

The chemical agents used can be broadly classified into sodium hypochlorite based agents and enzyme based agents.

SODIUM HYPOCHLORITE (NAOCL)-BASED CHEMOMECHANICAL CARIES REMOVAL AGENTS

NaOCl-based chemomechanical caries removal agents depend on NaOCl derivatives, which chlorinate and disrupt hydrogen bonds of partially degraded collagen in carious dentine, thus facilitating its removal. From 1972, a 5% NaOCl solution was used as a Chemomechanical caries removal agent; however, it was unstable and lacked selectivity and removed both caries infected and caries-affected, as well as sound dentine. To overcome this problem, amino acids were added to the subsequent versions.[10]

GK-101

Around 1970, the need for an alternative to conventional rotary led to a research by Habib et al. (1976) who studied the effect of sodium hypochlorite, which is a nonspecific proteolytic agent on the removal of carious material from dentine. Sodium hypochlorite itself however was too corrosive for use on healthy tissue and very unstable. So they decided to incorporate it into Sorensen's buffer (which contains glycine, sodium chloride and sodium hydroxide) in an attempt to minimize this problem. Quite fortuitously, a reaction occurred which resulted in a product which was more effective in removal of carious dentine than a saline placebo. This involved the chlorination of glycine to form N-Monochloroglycine (NMG) and the reagent subsequently became known as GK 101 and marketed in 1972 as first CMCR agent (Goldman et al., 1976).[9]

GK-101 consisted of 0.05% N-monochloroglycine (NMG) and NaOCl, and was prepared by mixing two solutions. Solution A consisted of 25 mL each of 2M NaCl, 2M NaOH and 2M glycine, and solution B consisted of 10 mL of 4–6% NaOCl.13 GK-101 required a special delivery system consisting of a reservoir (for warming the freshly prepared solution to 41 °C) and a pump (similar in shape to a straight handpiece) attached to a 20-gauge needle delivery tip. The delivery tip was applied to the carious lesion with minimal pressure via a paintbrush-like motion, since it was reported that excessive pressure led to an increase in the patient's pain response and blocked solution flow through the needle tip. GK-101 disrupted the organic structure of dentine by conversion of hydroxyproline (an essential factor for the stability of collagen) to pyrrole-2-carboxyglycine. [10-11]

According to Kurosaki et al. (1977), GK 101 would soften only the first layer of carious dentine, and would not affect the second layer, and it has a very slow action. It was the major disadvantage and limitation of the GK 101.[12]

GK-101E (CARIDEX)

GK 101 turned out to act slowly and additional efforts to speed up the procedure resulted in GK 101E. In 1984, a caries removal system called Caridex gained FDA approval which was based on GK 101E.

GK-101E is the ethyl derivative [N-monochloro-DL-2 amino butyrate (NMAB)] of GK-101 (NMG). It was claimed this formula increased the specificity of the solution towards denatured protein of caries infected dentine.[13]

MECHANISM OF ACTION

The mechanism of action of N-monochloroglycine and N-monochloroaminobutyric acid on collagen is unclear. Originally, it was thought that the procedure involved chlorination of the partially degraded collagen in the carious lesion and the conversion of hydroxyproline to pyrrole-2-carboxylic acid. Further work suggests that cleavage by oxidation of glycine residues could be involved. This causes disruption of the collagen fibrils which become more friable and can then be removed. [7-14]

Goldman and Kronman done a study to show the biocompatibility of Caridex and concluded that Caridex is the best alternative for conventional method of caries removal. Although it takes more time for caries removal, it reduces the anxiety, need of anesthesia, pain, and removes only infected dentin. Thereby, preserving tooth tissue combined with a patient-friendly approach. Thus, it can bring promising results in children, old patients, anxious patients, and special care need children.[9]

CARIDEX SYSTEM

It consists of two solutions:-

1. Solution I: 1% NaOCl
2. Solution II: Glycine, Aminobutyric acid, NaCl and NaOH

The two solutions are mixed immediately before use to give the working reagent [pH 12] which is stable for 1 hour.[7] Delivery system available for Caridex consists of a reservoir for the solution, a heater and a pump which pass the liquid, warmed to body temperature through a tube to a hand piece and an applicator tip (in various shapes and sizes). The solution is applied to the carious lesion by means of this application which is used to loosen the carious dentin by a gentle scraping action, the debris together with the spent solution being removed by aspiration. Application is to be continued until the remaining dentin is deemed sound by normal clinical tactile criteria. With suitable accessible soft lesions, after 15 to 20 min treatment, only clinically sound dentin remains.[14]

One of the most important drawbacks of the Caridex system was its complex delivery equipment Yip et al. reported that the addition of urea to Caridex enhanced the efficiency of caries excavation in deciduous teeth. The clinical usage and acceptance of both GK-101 and GK-101E solutions was very limited because neither showed a significant improvement in caries excavation compared with the conventional caries removal methods.[15]

CARISOLV

Medi-Team in Sweden developed Carisolv which was in the form of a pink gel that can be applied to the carious lesion with specially designed hand instruments.[16] Carisolv is an improved system of Caridex. The shortcoming of the Caridex was addressed in the development of the Carisolv. The original Carisolv was red in colors and it consisted of two syringes; one containing carboxymethylcellulose-based gels and amino acids (glutamic, leucine, and lysine); the other containing 0.25% NaOCl. It is two gel components which consist of a red gel and transparent fluid. Red gel contains glutamic acid, leucine, lysine, sodium chloride, erythrosine, water, and sodium hydroxide. Transparent fluid contains 0.5% sodium hypochlorite. It has the advantage that it requires neither heating nor a special delivery system because of its gel form.[17]

MECHANISM OF ACTION

Ericson et al. reported that the chemical structure and the mechanism of action of Carisolv were similar to Caridex, except that the monoaminobutyric acid was replaced by three different amino acids (listed above). The amino acids were shown to react with different moieties of carious lesions. Furthermore, the addition of carboxy methylcellulose created a higher viscosity of the Carisolv gel, which enhanced its handling properties compared to the Caridex solution.[18,19]

COMPOSITION OF CARISOLV

ORIGINAL GEL (BEFORE2004)

a) Syringe A: Carboxymethylcellulose-based gels, coloring agent, and amino acids (glutamic, leucine, and lysine)
b) Syringe B: About 0.25% NaOCl in another.

MODIFIED GEL (AFTER 2004) MULTI MIX SYRINGE

The red coloring agent was removed, the amino acid concentration was reduced by half and the NaOCl concentration was increased to 0.475%.

NEW CARISOLV SYSTEM™ (2013)

Incorporation of minimally invasive burs and special Carisolv caries detector dye to the modified Carisolv gel to shorten the caries excavation time.

ENZYME-BASED CHEMOMECHANICAL CARIES REMOVAL AGENTS

PAPACARIE

Though carisolv is the most successful agent, it has its own share of disadvantage which includes extensive training and customized instrument which increases the cost of the solution. Due to this, there was a limited use. To control these limitations of carisolv system, a new reagent was developed in Brazil. In Brazil 2003, papain gel as papacarie for chemomechanical caries removal agent, Formula eacao by Sao Paulo, was introduced. Papacarie is a

national product; patented, registered and approved by ANVISA in Brazil. Its main ingredients are papain, chloramine and toluidine blue.[20]

Table no 1: Component of Papacarie	
Papain	• Papain is an enzyme obtained from the latex of leaves and fruits of the adult green papaya, Carica papaya. It is an endoprotein like as human pepsin which has a bacteriocidal, bacteriostatic and antinflammatory activity, and debriding agent. • It does not damage healthy tissue, but accelerates the cicatricial process and has bacteriostatic and bactericidal action. Acts by cleaving collagen molecules slightly destroyed by the action of caries, and is able to digest dead cells and eliminating the fibrin coat formed by the caries process.
Chloramine	• A compound comprised by chlorine and ammonia has bactericidal and disinfectant properties. • It is used as a canal irrigant of radicular canals for softening the carious dentine chemically. The decayed portion of the carious dentine collagen is chlorated by the chloramine and is easily removed with excavator.
Toluidine blue	Originally, the malachite green was used as colouring agent, however, after a few studies toluidine blue was found highly effective against Streptococcus mutans. • It is a photosensitive pigment that gets fixed into the bacterial membrane.

MODE OF ACTION

When papacarie is applied on the carious teeth, within a minute it causes chemical debridement, which is due to the papain gel. Degradation and elimination of fibrin mantle (formed by carious process) followed by breakdown of collagen molecules. The degraded collagen is then chlorinated by chloramines, which also liberates oxygen, resulting in bubbling action and blearing of gel. The effervescence disturbs the hydrogen bond and affects secondary and quaternary structure which leads to softening of dentin and facilitating removal of carious tissue.[21-22]

BIOSOLVE

Biosolv is a new experimental enzymatic CMCR agent. The information about Biosolv remains very limited and is based mainly on the manufacturer's claims. The Biosolv gel is not commercially available, however, based on the manufacturer information; it consists of pepsin enzyme in a phosphoric acid/sodium biophosphate buffer. It is claimed that the phosphoric acid can dissolve the inorganic components of caries-infected dentine, while permitting the pepsin to selectively disrupt the denatured collagen fibers. Meanwhile, this softened mass can then be easily removed by the specially designed plastics instruments without affecting sound tissue.[22]

BRIX-3000

In 2012, the BRIX-3000 was released, a chemical mechanical agent, also papain-base, with a proteolytic enzyme obtained from leaves latex and fruits of green papaya (Carica Papaya) that acts as a chemical debridant. The differential of this product according to the manufacturers is the amount of papain used (3,000 U/mg in a concentration of 10%) and the bio encapsulation thereof by EBE (Encapsulating Buffer Emulsion) technology, which gives the gel the ideal pH to immobilize the enzymes and liberate them at the moment of exerting its 22 proteolysis on the collagen. Torresi and Bseremi verified the efficacy of BRIX-3000 for the removal of carious tissue comparing 75 patients treated with the mechanical chemical agent (BRIX 3000) and 75 by the traditional rotary method. It was found that the gel was effective for 62 patients (82.7%) with a single application of the product.[23]

Table no 2: Review of literature	
Author	**Observation**
Rompen and Charpentier et al. (1989)	Investigated the antibacterial efficiency of Caridex™ and Papacarie. It was noted that Papacarie has more bacteriostatic action than the Carisolv.[24]
Bulut G et al. (2004)	Author investigated the effect of Carisolv on exposed human pulp and suggested that Carisolv is biocompatible with human pulp tissue and may have a haemostatic effect. [25]
El-Tekeya et al. (2012)	Evaluated the effect of two CMCR methods (Carisolv and Papacarie®) on residual cariogenic bacteria in the dentin of deciduous teeth compared with the effects of traditional manual excavation. The results demonstrated that CMCR (Carisolv and Papacarie) led to significant reductions in total bacteria, Streptococcus mutans group and lactobacilli. The authors also found that

	Papacarie® was significantly more effective with respect to its reduction in residual cariogenic bacteria compared with both Carisolv and manual excavation.[25]
Priya G et al. (2014)	Author evaluated and compared the behavioural and physiological responses to chemo-mechanical caries removal and conventional drilling method. The study concluded that chemo-mechanical caries removal was effective in caries removal and ensured excellent patient comfort. The discomfort level was less in chemo-mechanical caries removal group though the time taken for caries removal was more than conventional drilling method.[27]
Kumar J et al. (2012)	The study was to conducted to compare the clinical efficiency of chemomechanical caries removal using Carisolv and Papacarie - a papain gel. The time for caries removal with Carisolv and Papacarie were, respectively, 11.67 ± 3.25 minutes and 10.48 ± 2.96 minutes (P>.05). The mean volume of carious tissue removed with Papacarie (135.99 ± 66.43 mm^3) was higher than that with Carisolv (126.33 ± 53.56 mm^3); however, the difference was not significant. The study concluded that the Carisolv and Papacarie have similar clinically efficiency as chemomechanical agents for dentinal caries removal.[28]

DISCUSSION

In the current scenario, different treatment modalities have been introduced for the removal of carious tissue while maintaining the maximal preservation of the healthy dental structure. The development of caries removal techniques in pediatric dentistry is aiming toward a more biological and conservative direction. The chemical-mechanical method of caries removal became a new arena in dental research field due its concept of tissue preservation. As only infected dentin is removed, the painful removal of sound dentin is avoided. Hence, a painless technique is one of the keys to avoid dentally fearful and uncooperative children, and a skill every pediatric dentist should strive to master.[29,30]

Painless dentistry, minimal intervention and thus giving relief, comfort, and solace and thereby instilling a positive attitude toward dental treatments, are some of the factors justifying the specialty of pediatric dentistry. It is well known fact that traditional method of caries removal using the "dental bur" is the most common technique for caries removal in dental practice. However, this technique is always associated with many disadvantages such as (i) the perception by patients that drilling is unpleasant, (ii) frequent requirement of local anesthesia, (iii) drilling can cause deleterious thermal effects, (iv) can also cause pressure effects on the pulp, and (v) use of drill may result in excessive removal of sound tooth structure.[31, 32]

Chemomechanical caries removal is an alternative technique of caries removal. It's also gentle and does not damage the tooth structure. It does not have any complication during the procedure. It was known as a non-invasive method of removing carious dentine. Chemomechanical technique has gained acceptance, especially from children and patient with anxiety. Minimal intervention dentistry not only reduces the pain associated with caries removal, but it also reinforces in children a positive attitude toward dentistry. Among all techniques, a traumatic restorative technique is the most documented alternative to traditional drilling for dentine caries removal, but CMCR holds a lot of promise as an effective alternative to the traditional method.[33]

CONCLUSION

Despite the decline of its prevalence, caries continues to affect a significant portion of world population and treatment of the decay is still a challenge for researchers. In children, especially those with dental anxiety, caries removal by means of conventional instruments is considered an unpleasant step of the restorative process mainly because of pain, drilling and noise. Furthermore, drilling results in rapid and excessive removal of tooth structure and may cause harmful thermal and pressure effects to the pulp. Chemo-mechanical caries removal agents are introduced to dentistry as an alternative to conventional drilling methods. Chemo-mechanical caries removal is primarily indicated to overcome the inconvenience of using burs and local anesthesia, hence preserving healthy dental structure and causing less discomfort to patients. Variety of materials is available commercially which increases the accessibility and affordability. Further research should be taken up on effectiveness of Chemomechanical caries removal compared to conventional methods.

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