CARIES CHEMICAL-MECHANICAL REMOVAL AGENTS: A LITERATURE REVIEW

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ABSTRACT

Over the years, Dentistry has improved caries removal techniques to facilitate clinical routine, preserve healthy dental tissue, avoid pain and restore function and aesthetics. Among the recommended techniques are chemical-mechanical removal agents, a non-invasive technique that consists in the application of a proteolytic substance that smooths the infected tissue and preserves the affected one. Thus, the objective of this study was to conduct a review on the chemical and mechanical removal agents, indicating advantages and disadvantages, comparing caries removal time, amount of tissue removed (hardness), microbial flora reduction and whether or not anesthesia during lesion removal is necessary, in comparison with the conventional method of rotating instruments. This review was conducted by means of a search in PubMed and SciELO databases, using the following keywords, alone or in combination: “carious lesions”, “dentine carious”, “dental carious”, “Minimal Intervention Dentistry,” “selective caries removal”, “caries removal partial”, “excavation dentin”, “chemomechanical cavity preparation”, “chemomechanical caries removal”, in English and Portuguese. As a rule, the use of chemical-mechanical removal agents requires more time for caries removal and greater hardness of the residual dentin, compared with conventional removal technique, but these disadvantages are offset by the excellent acceptance of patients and less dependence of anesthesia. Moreover, the use of such agents exhibit effectiveness in reducing cariogenic microflora and no pain during treatment.

KEYWORDS:

Dental caries. Papain. Dentin. Temporary dental restoration. Pediatric dentistry.

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INTRODUCTION

Dental carie

The first foundation found to elucidate the concept of caries disease, since your initiation and progression, occurred in the years 1980 through the studies of Miller, chemical parasite theory. According to this theory, all species of a bacteria a found on the surfaces of the teeth were able to contribute to an acid attack on the tooth enamel, and the amount of bacterial plate was determined the process of disease.[1] The theory recognizes that the metabolism of carbohydrate by the oral bacterium with the acid generation, was the central event of the demineralization process of dental structure, leaving a unicausal process.[1]

The concept of dental caries like an infectious and transmissible disease, grew out of studies in early 1950,[2] by isolation some bacterium found in hamsters carious lesions.[3] This way, the "Discovery" of microorganism responsible by the carious lesion, come scientifically support the idea of unicasuality.[1]

From this microbial model, the Keyes Triad arose in 1960, which advocated that the etiology of caries was due to the intersection of some primary factors such as susceptible host, microbiota and cariogenic substrates.[2,3] The model was based on the absence of caries production if one of the primary factors cited was removed.[4] This thought was characterized as a multi-causal etiological model. This conception, which was present in the mid 70's and 80's, still has significant employment and acceptance in the XXI century.[1,5-7]

In 1983, Ernest Newbrun modified the explanatory model proposed by Keyes, including a fourth circle in the triad, time as an etiological factor, which must act simultaneously with the other factors to develop the lesion.[5,8] This diagram was called the modified Keyes model.

Since the 1990s, research has shown that the carious process depended not only on the frequent consumption of carbohydrates and the accumulation of acidogenic bacteria but also on the interaction with other host-modifying factors (genetic and environmental) saliva, bacterial flora, eating habits, exposure to fluoride, oral hygiene, salivary flow, salivary composition and tooth structure.[9]

Current concepts show that caries disease is multifactorial, resulting in a localized mineral loss in hard dental tissues caused by organic acids from the fermentation of dietary carbohydrates by a specific microbiota.[10] From the ecological point of view, it represents an imbalance in bacterial homeostasis, caused by the exacerbation of an environmental factor – excessive carbohydrate consumption (considered a behavioral disease) – which favors the predominance of specific cariogenic microorganisms.[9,11] The caries, therefore, is the result of the imbalance of a dynamic process of loss and mineral gain that occurs at the tooth / biofilm / plaque / saliva interface.[12-14]

Carious lesion on enamel

The enamel lesions at the beginning are not clinically or radiographically perceptible. The outer layer of the enamel is usually more resistant to dissolution than the subsurface layer, mainly due to a supersaturation of the enamel with the formation of fluorapatite as well as the mineral exchanges of the enamel with the saliva, which works with a protection for this layer.[8]

The mechanical control of plaque, in its total removal, potentiates the remineralizing function of the saliva, keeping the lesion of the enamel in the reversible stage for an indeterminate period. If the period of periodic plaque control is insufficient or the intake of cariogenic diet is more frequent, irreversible demineralizations may occur, but at the subclinical level, and caries lesions are not considered since they occur without signs. If under these subclinical lesion conditions there is a rebalancing of demineralization and remineralization, by means of sufficient periodic control or a less frequent cariogenic diet, this lesion may be paralyzed for a time, without being diagnosed as a caries lesion.[4]

Thus, if the imbalance continues for longer, due to a periodic control with a longer time interval or lack of control and a frequent cariogenic diet, this irreversible lesion may progress to clinical level, with lesions of enamel, presenting signs, determining a lesion of caries, in the case of white spot.[4]

Lesions active in enamel are clinically characterized by being whitish, opaque, with generally poorly defined and porous borders. When the white spot begins to reach the amelo-dentin junction, a brown discoloration already begins to appear in the dentin, representing the reaction of the dental tissues, transmitted through the enamel prisms in response to the cariogenic biofilm activity.[15] When the white spot becomes clinically visible this lesion probably already has a dentin involvement.[8]

Dentin caries lesion

Although the enamel is formed almost entirely by inorganic components (96%), and devoid of significant intrinsic moisture, the inorganic dentin phase accounts for only 70% of its weight. The organic phase of this tissue, 20% by weight, consists mainly of collagen type I (90%), and the other organic components present are represented by non-collagenous and proteoglycan proteins. The dentin is permeated by thousands of tubules that run through it in its entire extension (from the surface of the coronary chamber to the amelo-dentin junction). Among other components, such as odontoblastic extensions, these tubules are filled by fluid, which gives this tissue a natural intrinsic moisture (10% by weight).[16]

Due to the development of caries disease, two distinct layers can be identified in the lesion of dentin, macroscopically differentiated by their characteristics of cut resistance and staining.[17-19] Microstructurally, the more superficial layer (external, called infected dentin) presents extensive demineralization, denatured collagen fibrils, and absence of viable odontoblastic extensions, and, consequently, is not remineralized. The second layer, immediately below (internal, called the affected dentin), is characterized by moderate demineralization, healthy collagen fibrils, and presence of viable odontoblastic extensions, being biologically recoverable.[19-22]

As for the type of lesions, they can be active or inactive. The active ones are usually more sensitive lesions, with a softer consistency, with a higher humidity and with a lower pH (more acidic). Inactive lesions usually show no pain and a more rigid, leather-like consistency and a relatively higher pH, almost normal compared to active ones. Large dentures can present both active and inactive areas simultaneously. This is possible depending on the shape of the cavity, undermined cusps with greater accumulation of biofilm are usually active and regions that have greater access to brushing are more open and suffer a greater impact from mastication and may be inactive.[19]

Minimally invasive intervention

The philosophy of minimally invasive intervention was incorporated into the dentistry scenario as a result of the association between knowledge of karyology and the improvement of adhesive restorative materials, thus obtaining a less invasive cavity preparation and preservation of the healthy dental structure. It is used to designate a philosophy of health care based on the triad: diagnosis, risk assessment and disease control (paralysis and prevention).[23]

Lesions restricted to the enamel or dentin that does not prevent the patient from removing or disorganizing the biofilm can be controlled by controlling plaque, regulating the diet and using fluoride, not requiring restoration as a treatment.[24-26] On the other hand, if the patient can not remove or disorganized the biofilm, if the carious process extends to the dentin and results in a retentive cavitation, if there is a compromise to the pulp health by the depth of the cavity and the remaining dental structure is compromised, impairing the function or presenting risks of fracture of the dental element or having damage to the periodontium and affecting aesthetics, the indication of restorative treatment is essential[27].

For a long time, the recommended treatment for dentin caries consisted of the removal of all dentin, better known as total carious tissue removal (RTTC), in order to avoid future cariogenic activities and to provide a well-mineralized dentin base for the restoration.[16] However, the major disadvantage of this technique is the risk of pulpal exposure during treatment in deep cavities.[28-31] Due to the high risk of pulp exposure during the RTCC,[28] there was a search for more conservative (atraumatic) treatments in order to decrease and prevent pulpal exposure[13,32-34] supported by the knowledge that RTTC is not necessarily an indicator for the successful treatment of carious lesions.[34-35]

Minimally invasive dentistry comprises the maximum preservation of the healthy dental substrate in all dental procedures.[10,12,36] This vision of minimal intervention and maximum preservation of tissues makes important and indispensable the clinical distinction between infected dentin (necrosed) and affected dentin (mineralizable), since these characteristics are of fundamental importance and have a decisive character between what must be removed and what can or should be preserved during the removal of carious tissue.[37]

The isolation of caries lesions through sealing of the cavities promotes changes in the microenvironment, with a significant reduction of contamination due to the reduction of the nutrients of microorganisms,[37-42] resulting in a less complex surviving microbiota.[39] The technique of selective removal of carious tissue becomes interesting and preferable when compared to total removal of carious tissue, since healthy dental substrates are preserved, promoting a lower risk of pulpal exposure,[16,43] and consequently the sealing of the cavity promotes the paralysis of the lesion, stimulating the process of tubular sclerosis and deposition of tertiary dentin, thus reducing the permeability of the remaining dentin.[44]

The pain and discomfort associated with conventional methods of cavity preparation by the use of rotary drills, alone or in conjunction with manual cutting tools[45] led to the development by 1985 of Atraumatic Restorative Treatment. It is internationally known by the acronym ART (Atraumatic Restorative Treatment) and involves a set of educational and preventive measures associated with atraumatic restorations.[46]

The term atraumatic refers to the restorative technique employed in dentinal lesions, which dispenses with the use of anesthesia, absolute isolation and rotating instruments. Only manual instruments are used to remove most of the infected dentinal tissue (softened, demineralized, necrotic and irreversibly damaged) by caries disease,[10,46] allowing the maintenance of healthy dental structure (dentin affected), through the selective removal of caries with manual instruments and restoration with high viscosity glass ionomer cement (CIV);[47] in addition, it promotes a reduction in the number of pulp exposures, thereby reducing endodontics and exodontia and lower stress and anxiety in the patient, since it rarely causes pain.[43,47,48]

It has been described as an economical and effective method in the prevention and control of caries disease in vulnerable populations.[49] In addition, the application of this technique in places of the great demand for dental restorative treatment increases the number of discharges since the service is faster. The resolution of the ART technique also has a positive impact on reducing treatment costs when compared to conventional restorative treatments[47].

Since it allows reduction of clinical time and is less painful, it becomes an excellent alternative in Pediatric Dentistry.[50] It is considered a solid strategy based on health promotion and prevention of caries disease, allowing a large population to reach in public health.[48]

The ART is indicated for both deciduous teeth and permanent teeth in the following clinical situations: grooves and fissures adjacent to ART restorations and teeth that have recently erupted or have deep scarring and fissures in patients at high risk for caries and teeth with restricted carious lesion to the enamel;[47] teeth with carious lesions involving dentin whose cavity opening is at least 1.6 mm or sufficient to be used freely by the smallest dentin digger,[45,51] or that can be opened using the opener (ART Kit/ Dentsply) or the enamel ax, to allow the insertion of the lesser digger and the excavation of the carious dentin and demonstrate absence of pulp involvement determined by the presence of painful symptoms, abscess, fistula or mobility.[45]

The constant search for procedures that provide the patient with a less traumatic and more conservative treatment during dental procedures has led to the development of alternative technologies for cavitation preparation as a substitute for conventional rotary instruments in the high and low rotation. Such alternatives are air abrasion, a technology that allows rapid removal of enamel, dentin, carious tissue, and unsatisfactory restorations by bombarding the dental surface with high-speed aluminum oxide particles.[52] These particles are driven by a stream of compressed air at high speed against the dental surface, with sufficient energy to produce cut.[52,53] The aluminum oxide is a non-toxic and cost-effective substance.[53]

The Ultrasonic abrasion with CDV (Chemical Vapor Deposition) technology (CVDentus®), which produces wear due to the oscillatory movement,[54] in which diamond-coated tips are coupled to the ultrasound device. This technique consists of using enamel and dentin, not by mechanical cutting action as in high-rotation systems, but by vibration.[55]

The laser; low and high energy intensity. The low-intensity ones are used for therapeutic purposes, as they have an analgesic, anti-inflammatory and tissue repairing action. High-intensity radiation emits high-power radiation, that is, it has a photothermal cutting action.[56,57] Currently, two types of erbium laser are available in the market: the Er: YAG (erbium: yttrium-aluminum-garnet) laser with wavelength 2940 nm and the Er.Cr:YSGG (erbium, chromium: yttrium-scandium -gallium-garnet), which is the latest laser in dentistry and has a wavelength of 2780 nm.[56-58] The Er, Cr: YSGG and Er: YAG lasers act by ablation, which is a mechanism in which the water molecules on the surface of the dentin absorb the incident radiation, causing a rapid heating and increase of volume, resulting in high internal pressures that lead water vaporization and removal of the substrate in the form of microexplosions.[56,59-61] The Er: YAG laser provides a conservative caries removal treatment since it has a great affinity with the water molecule that is present in great quantity in the carious tissue. This allows the conservative removal of caries without extending the preparation for a healthy dental structure.[62]

The chemical-mechanical removal agents (GK 101™, GK 101E or Caridex™, Carisolv™, Papacárie®, Brix-3000® and New Carisolv™), which are characterized by the dissolving capacity of organic matter, from action of chemical and / or natural products that denature the collagen of carious dentin, allowing its removal with the use of dentine excavators[63-65].

The objective of the present study was to carry out a bibliographic review on the agents of chemical and mechanical removal, pointing out their advantages and disadvantages in relation to the removal time of carious tissue, amount of tissue removed (hardness), reduction of microbial flora and need anesthesia during the removal of the lesion, compared to the conventional method by rotating instruments.

SEARCH STRATEGY

This review was performed through a search in the Pubmed and Scielo databases, containing the following keywords isolated or combined: "carious lesions", "carious dentine", "dental carious", "minimal intervention dentistry", "Selective caries removal", "caries removal partial", "excavation dentin", "chemomechanical cavity preparation", "chemomechanical caries removal", in English and Portuguese.

After the initial selection, all the articles were repeated; those who did not contemplate at least two keywords in the title and/or abstract. Finally, the pre-selected articles were read in full, thus selecting the most relevant information among the study objective.

CHEMICAL-MECHANICAL REMOVAL AGENTS

The chemical-mechanical removal agents have appeared since 1972 and are characterized by the dissolution capacity of organic matter, from the action of chemicals on carious dentin, resulting in the dissolution of the soft tissue.[66-69]

The first published studies were in 1975 when a product called GK 101[70,71] appeared on the market. Such product removed the carious tissue through sodium hypochlorite solution present in its formulation. Habib, Goldman, and Kronmann (1975)[70] found that 5% sodium hypochlorite solution in contact with dentin caused the removal of the hypochlorite, but the hypochlorite at this concentration was unstable and aggressive for healthy tissues. Thus, Mcnierney & Petruzillo incorporated sodium hydroxide, sodium chloride and glycine (Sorensen

Buffer) into their formulation in order to improve the undesirable effects of hypochlorite. Even with some changes, the GK 101 still had the disadvantage of removing the carious tissue very slowly.[67-69,71,72]

From this, the GK 101 manufacturers removed it from the market and launched in 1985, a new product, the GK-101 E or Caridex™ (National Patent Dental Products, Inc., New Brunswick, NJ, USA), although currently obsolete. It was developed from the formula made of N-monochloroglycine and amino butyric acid.[73] It was presented as a two-tube system, where the first tube contained sodium hypochlorite and the second glycine, aminobutyric acid, sodium chloride, and sodium hydroxide. The preheated solution led to collagen falling on the carious dentin, softening the tissue and facilitating its removal.[74]

Despite the improvements, Caridex™ still had some limitations such as: the need for large volumes of solution to remove infected tissue (200-500mL), warming the product to its action, limited indications, prolonged treatment time (10-15 minutes), instability of the solution, since it was stable for only 1 hour, maintaining a pH = 11, requiring complex equipment to be used, thus generating a high product cost.[73-76]

At the end of 1997, Carisolv™ was launched by MediTeam Dental AB, Sweden, whose main difference in relation to previously released products was the presence of three amino acids in their composition (leucine, lysine and glutamic acid), instead of only one, which would have a different effect on carious dentin, besides reducing the toxic potential of sodium hypochlorite, which was still present, but this is the concentration of 0.95%.[68,69,77]

This product has a single mixing or multiple mixing systems (double syringes with two distinct compartments containing two solutions). In the single mixing system, 5 clear syringes containing a colorless gel and 5 white syringes containing clear liquid (0.95% sodium hypochlorite) are found. In the colorless gel is present the amino acids (glutamic acid, leucine, lysine) in addition to sodium hydroxide. In the multiple blending systems, a double syringe containing two gels is found, one clear (sodium hypochlorite present), and one white (present the three amino acids) in addition to sodium hydroxide, sodium chloride, carboxymethylcellulose, water and erythrosine,[78] which are mixed immediately prior to use through the mixer and plunger. In addition to this product, special non-cut curettes and blunt contact surfaces were developed to reduce the risk of removal of healthy dentin.

Chlorine reacts with the amine groups of dentin and the three amino acids with the protein chains in the denatured collagen, which has the capacity to neutralize the aggressive effect of sodium hypochlorite, preventing the removal of affected dentin.[78] The carboxyl methyl cellulose has the function of increasing the viscosity of the gel, facilitating its application, besides reducing the required quantity of the product in each procedure.[63]

The disadvantage of Carisolv™ was, in addition to its high cost, small shelf life, need to be kept under refrigeration (after opened and mixed it should be used for a maximum of two hours), odor and unpleasant taste, longer time the need to acquire a set of specific curettes, especially for the removal of infected dentin, which further increased the cost of the procedure and did not completely eliminate the use of rotating instruments, extensive training and professional registration.[66,67,79,80]

In 2003, a research project in Brazil led to the development of a new formula to universalize the use of the chemical-mechanical method to remove caries and promote their use in public health. The new formula was commercially known as Papacarie®.[64,78]

It is a material that is easy to apply and does not require the use of technological devices to perform the atraumatic chemical-mechanical removal of caries. It often eliminates the use of anesthesia, thus helping patient comfort and is indicated for patients who suffer from anxiety, fear, traumatized patients, infants, and special patients, is bactericidal and antiseptic.[64,66,81]

It is commercially presented in the form of a gel in a 3 ml syringe which basically contains papain (10%), a proteolytic enzyme obtained from latex of leaves and fruits of papaya (Carica Papaya) that acts as a chemical debridant,[63] chloramine-T (05%), thickeners and toluidine blue.[64]

The chemical debridement is the removal of the devitalized (necrotic) tissue present in the cavity, which aims to promote cleaning in the region, leaving it in adequate conditions to remineralize itself, as well as reducing the bacterial content, preventing its proliferation.[63] Thus, the papain interacts with the exposed collagen causing the dissolution of the minerals of the dentin and bacteria, making the infected dentin more softened, which facilitates its removal with the use of non-cutting instruments without the use of anesthesia and rotating instruments.[82,83] The chloramine T is a compound of chlorine and ammonia that has bactericidal and disinfectant activity: antiseptic action[84] and toluidine blue helps to visualize the remaining carious tissue.[64]

Papain acts only on necrotic tissue due to the occurrence of a plasma antiprotease, 1-antitrypsin, which prevents the action of proteolytic papain in normal tissues. Infected tissue does not contain 1-antitrypsin, so papain acts to degrade denatured collagen molecules. The application is made for the 30s in acute caries and 40-60s in chronic carious lesions. If all carious tissue has not been removed, the gel is reapplied until the cavity is vitreous.[68,78]

Some drawbacks have also been reported during its use as the execution time of the technique (some authors report that it requires more working time compared to the rotating instrument), gel consistency (a little fluid), need to be kept under refrigeration, has short durability and a little high cost.[68,73]

In 2012, BRIX-3000® (Brix Medical Science / Carcañá / Argentina, Ortodente / Belo Horizonte, MG), a chemical-mechanical agent also based on papain. The differential of this product according to manufacturers would be the amount of papain used (3,000 U / mg in a concentration of 10%), thus facilitating the repair process, by aligning the collagen fibers, acting as a healing agent[85] and the bioencapsulation thereof by E.B.E. Technology, which gives the gel the ideal pH to immobilize the enzyme and release it at the moment of exerting its proteolysis on the collagen, providing a high proteolytic activity and greater durability of the product, since there is no need for refrigeration[65].

The New Carisolv™ was launched in 2013 through an agreement between the Komet (Komet, Dental-Gbr Brasseler GmbH & Co., Lemgo, Germany) and Carisolv™ manufacturers of drill bits to reduce excavation time of caries (Carisolv, 2015). This system contains two types of drill bits, one ceramic (CeraBur K1SM) and one plastic (Polybur p1), both at low speed, designed for the removal of softened dentine dentin previously treated with New Carisolv™. The CeraBur K1SM Ceramic Drill helps distinguish healthy tissue from carious tissue in a tactile way; the Polybur p1 plastic drill is disposable and has as a characteristic to be softer than healthy dentin and is therefore self-limited and suitable for treatments near the pulp.[80]

DISCUSSION

The conventional method of plate removal may present as a drawback of abusive cavity movement and healthy paper removal, which may lead to pulp exposure, heating, exaggerated pressure on a pulp, vibration, painful stimulus, and a need for local anesthesia, which causes aversion in many patients.[86]

In order to minimize such problems and to make the restorative procedure more comfortable, techniques were developed for the treatment of the carious tissue, based on the concept of minimally invasive dentistry, through more conservative approaches such as partial removal of the caries lesion,[44] atraumatic restorative treatment and chemical removal agents[14,42,64,67,83] which make the chemical softening of the disorganized infected dentin, followed by manual removal rather than the conventional removal of the lesion by the use of manual instruments associated or not with the use of rotational instruments.

The Atraumatic Restorative Treatment (ART) deals with a non-invasive technique,[46] since it is only intended to remove the infected disease by proteolytic microorganisms, thus preserving the deep and remineralizing dentin;[87] use the control panels of decayed tissues, avoiding the use of dental and electrical equipment;[68] minimizing the use of local anesthesia, avoiding the degree of discomfort of the patient, maintaining this high level of acceptance among users[88]; causes minimal operative and postoperative sensitivity;[46,47] increases the chances of early intervention and preservation of affected dental structures, thus leading to an increase in the survival of decayed teeth.[89]

The low cost is one of the factors that makes this treatment a viable alternative in health promotion when compared to any conventional restorative technique.[90]

The chemical-mechanical method advocates minimizing the drawbacks of conventional methods using drills, which induce discomfort and pain, requiring as a consequence the local application of anesthetic agents. This method is based on the action of chemical agents on the structure of the collagen, facilitating the mechanical removal of infected tissue with manual instruments, which are applied with minimum tension. It is considered a noninvasive technique, which consists in the application of a proteolytic substance that softens the infected dentin tissue and preserves the healthy dental tissue.[33,63,65,68]

One of the disadvantages of chemical-mechanical removal of caries, reported in the literature, is the technical execution time.[73,91-93] Some authors have verified that this technique requires a longer time to remove carious tissue compared to the conventional removal technique[73,92], or equivalent to that required for the rotational technique[68,93].

Some studies conducted by Banerjee et al., 2000;[92] Maragakis et al., 2001;[84] Ansari et al., 2003;[94] Rafique et al., 2003;[95] Azrak et al., 2004;[96] Lozano-Chourio et al., 2006;[97] Oliveira et al., 2009[98] and Pandit et al., 2007[99] showed that the chemical-mechanical method of caries removal (CMCR) was more acceptable than the conventional method, but the mean time required for carious dentin was significantly higher when compared to the conventional method.

Saliba et al., 2009[100] report that although the mechanical-mechanical treatment with Carisolv™ and Papacárie® spent a long time to remove carious tissue compared to the manual mechanical method, there were no significant statistical differences ($p > 0.05$). In contrast, Kavvadia et al., 2004,[101] when comparing the mechanical to chemical-mechanical removal, with the use of Carisolv™ obtained statistically significant differences probably due to non-standardization of cavity size (medium and deep) before the treatments were performed. One of the probable factors responsible for the longer removal time of the carious tissue with the chemical-mechanical method may be related to the time of manipulation of the material and the wait for the action of the product.

Jawa et al., 2010[63] indicated that the mean time for complete caries excavation by the chemical-mechanical method using Papacárie® was 328.5 seconds compared with 124.6 seconds with the conventional caries excavation method. Similar studies conducted by Chowdhry et al., 2015[102] found that the average procedure time for removal of carious tissue by the conventional method was around 171.27 ± 23.22 seconds, being significantly lower in relation to Carisolv™ (375.33 ± 41 seconds) and Papacárie® (387.83 ± 38.53 seconds), respectively.

Some clinical trials Kochhan et al., 2011;[103] Singh et al., 2011[104] evaluated the time decay of excavation by mechanical chemical removal agents Papacárie® Carisolv™ and rotatable relative to the conventional method. All these studies reported no significant difference between the time of excavation using chemical-mechanical and conventional removal agents.

Boob et al. (2014) [105] verified the efficiency of Carisolv ™ and Papacárie® in relation to manual excavation as to the time required to remove the caries lesion. The time spent with Carisolv™ and Papacárie® were similar, but statistically higher when compared to manual excavation.

Following the reasoning that the conventional restorative treatment can cause a "psychological trauma" due to fear and anxiety, mainly in children and some adults, being the aversion to the noise of the rotating instruments and the anesthesia the main triggers of this situation,[106] such disadvantages are compensated by the patients' excellent acceptance, efficiency in the removal of carious tissue and less dependence on anesthesia.[107-110]

Motta et al. (2009)[111] and Alfaya et al., 2013,[112] assessed pain and the need for local anesthesia during the removal of carious tissue with the conventional and Papacárie® method in pediatric patients. In both techniques, anesthesia was not initially administered, and Facial Image Scale was used to classify pain sensation during the procedure. It was verified that the removal of caries performed by the chemical-mechanical method when using Papacárie® provided a lower degree of pain when compared to the conventional method, and there was no need for local anesthesia.

Geetha Priya et al., 2014,[113] conducted a randomized controlled trial to compare the behavioral and physiological responses of caries removal through the chemical-mechanical method (Carisolv™) and the conventional method in children between 7-11 years of age with the presence of bilateral caries lesions. Behavioral responses were assessed using the FLACC Scale and Facial Image Scale. There was no significant difference in relation to the physiological parameters evaluated between the two groups. Already the discomfort was significantly higher in the group where the conventional method was used and the time spent was significantly lower in the group where the conventional technique was used.

Torresi, Bsereni, 2017,[65] compared the efficacy and perception of pain in dentin caries removal using the conventional method (rotary instruments) and the chemical-mechanical method (papaya enzyme BRIX3000®). A convenience sample of 150 adult patients with at least 1 tooth with caries lesion was used, with no pulpal involvement or pain symptomatology. The patients were divided into two groups: 75 for the conventional group in which the removal was done with rotating instruments and 75 for the chemical-mechanical group in which the removal was done with the enzymatic gel of papain. The treatment with the enzymatic gel presented an efficiency similar to the conventional rotational system and produced less discomfort to the treated individuals.

Partial removal of the carious tissue, followed by sealing of the cavity, has emerged as an alternative to paralyze the carious process and also enable a possible remineralization of the remaining carious tissue.[16,31]

According to Banerjee, Kidd, Watson (2000a),[92] to perform the removal of carious tissue, the dentist is based on its consistency, which is an inadequate parameter, since the affected dentin located below the infected dentin, can be remineralized and can remain on the floor of the cavity.

Several methodologies are used for the evaluation of the remaining dentin, among which the microhardness tests. Since the advent of the Knoop hardness unit,[114] the surface microhardness analysis has been used as a method to evaluate the loss and reincorporation of minerals from the dental structure, since the reduction of the numerical value of hardness presents a linear relation with the mineral loss.[115]

The normal dentin of permanent teeth presents variable hardness values, according to the distance considered from the amelo-dentin junction to the ceiling of the pulp chamber. The mean dentin hardness value was 70 KHN and decreased toward the pulp. Typically, carious dentin has lower hardness values than those of normal dentin. However, in areas close to the pulp, carious dentin may show increased hardness compared to normal dentin. While the chronic caries lesion presents hardness values of 61-68 KHN, the acute caries lesion presents 4.3-17 KHN.[116]

Therefore, the hardness of the remaining dentin after chemical-mechanical treatment with Carisolv™ was evaluated by Hossain et al., 2003,[117] and verified that the hardness values ranged from 58-62 KHN, similar to those of hard dentin hardness adjacent, ranging from 59-64 KHN.

Reis, Bauer, and Loguércio (2003) [118] evaluated the Knoop hardness of the remaining dentin of deciduous teeth after removal of caries by 3 different methods (mechanical, with the use of drill in low rotation, guided by hardness after drilling), mechanic, with use of caries evidence) and chemical-mechanical (Carisolv™). They found that the mean hardness of the dentin in the mechanical removal groups was similar, and in these two groups, the mean dentin hardness was statistically higher than in the chemical-mechanical removal group.

Flückiger et al. (2005)[119] compared dentin microhardness after the use of the conventional caries removal method with curettes and the chemical-mechanical method (Carisolv™). The mean values of hardness were 51.04 in the Carisolv™ group, 51.74 in the manual digging group and 20.26 in the control group (caries).

Hamama et al., 2013[93] and Boob et al., 2014,[105] reported that the residual dentin microhardness after caries removal by the conventional method was higher than the residual dentin microhardness after the use of chemical-mechanical agents, which means a lower amount of demineralized dentin after removal of caries when compared to chemical-mechanical agents.

The clinical criteria used for removing carious lesions, such as hardness or color, do not ensure the absence of bacteria in the cavity even after the complete removal of tissue cariado.[35] As shown in some clinical studies by Mertz-Fairhurst et al., 1998;[120] Bjorndal et al., 2000[38] and Oliveira et al., 2006[35] even when the total removal of carious dentin is performed, microorganisms remain within some dentinal tubules. However, when the carious tissue is partially removed, a high number of bacteria will still be present in the dentin left in the deepest part of the cavity, which makes it imperative that the material applied on this dentin presents antibacterial and antimicrobial properties.[30]

An important feature in dental caries chemical removal systems is their bactericidal effect, which acts directly on the bacteria destroying them and consequently removing the etiological agent of caries.

Bortoletto et al. (2004),[121] conducted a study in vitro antimicrobial capacity as Papacárie® by agar diffusion technique and found that although having components with antibacterial properties, it showed no antimicrobial activity against S. mutans. These results are similar to studies of Pacheco et al., 2.005.[122]

A residual number of microorganisms 101 to 103 colony forming units (CFU) in the dentin after the cavity preparation is considered acceptable and not harmful to teeth.[96,123] Thus, Azrak et al., 2004,[96] compared the efficacy of chemo-mechanical method (Carisolv) and conventional method of removing caries in reducing the cariogenic microorganisms, and found that both methods produced statistically significant bacterial reduction. After removal of carious tissue 90.5% of the samples had bacterial count below 102 and 95.2% had lactobacilli amount of less than 102. According to the results, the effectiveness of removal by chemical-mechanical agents dentin carious in primary teeth was similar to that obtained by the conventional method.

Clinical research comparing the conventional method with the chemical-mechanical method Carisolv™ concluded that both methods are similar in terms of CFU reduction in the residual dentin.[96,124,125]

Motta et al. (2014)[26] examined the effectiveness of Papacárie® compared with the conventional method in reducing the total count of bacteria, Lactobacillus, and Streptococcus mutans whole in a sample of 40 deciduous teeth. The infected dentin was collected before the procedure and the remaining dentin was collected immediately after removal of carious tissue. The initial and final count of bacterial colonies was performed to determine if there was a reduction in the number of colonies forming units (CFU) of each of the microorganisms studied. As a result, there was a reduction in the number of total bacteria, total Streptococcus and Streptococcus mutans in both methods of caries removal.

A reduction in the number of CFU was also observed Lactobacillus, but this difference was not statistically significant. From this study, it was possible to conclude that Papacárie® has the same effectiveness as the conventional method and is an excellent option for the minimally invasive removal of the carious tissue. Ammari et al. (2014)[67] found similar results when comparing the efficacy of Carisolv™ and Papacárie® with that of manual excavators in reducing the cariogenic microbial population in the primary teeth cavity. Both Papacárie® as Carisolv™ showed similar results to those obtained by manual excavators. Some authors report that, when the cavity is deep, the application of papain gel does not prevent the occurrence of painful sensitivity and pulp exposure, indicating the use of anesthesia.[127]

According to Saliba et al., 2009,[100] when analyzing the presence of pain regarding mechanical and chemical-mechanical treatment, it was verified that in Group I (Mechanical and Carisolv™), 56% of patients reported pain during the removal of carious tissue with the mechanical treatment and of these, 33% reported as strong. In the treatment with Carisolv™, 31% of the patients presented pain, of which 40% indicated it as strong. However, this difference was not statistically significant ($p > 0.05$); on the other hand, Nadanovsky et al., 2001,[128] when assessing the presence of pain during caries removal through the conventional mechanical method and Carisolv ™, observed a greater absence of pain in the chemical-mechanical treatment, being statistically significant ($p=0.05$). As a result of complaints of severe pain, it was necessary to use anesthesia in 14.1% of the treated teeth. Similar results were observed by Kavvadia et al., 2004,[110] who underwent treatment using the chemical-mechanical method with Carisolv™, requiring anesthesia in 2% of the patients.

Goyal et al., 2015,[129] compared Papacárie® with the conventional method in terms of microbial flora reduction, pain, anxiety and general patient acceptance. The time required to remove carious tissue for each procedure was recorded with the help of a timer, and the patients' perception of pain was recorded through the Wong-Baker Facial Scale before, during and at the end of each procedure; the anxiety was recorded measured by the pulse rate. The time required for caries removal with Papacárie® was practically the same as with the conventional method (7.41 min and 6.99 min respectively). When Papacárie® was used, the mean pulse rate decreased during and after, whereas in the conventional group there was a slight increase during the procedure. Reduction of microbial flora was significantly reduced in both methods. Regarding the sensation of pain, there was a slight increase during and after the procedure with the conventional method and a significant reduction with the use of Papacárie® during and after the procedure. After analyzing the results, it was concluded that Papacárie® is a safe and effective method.

CONCLUSION

The use of chemical-mechanical removal agents, as a rule, requires a longer time to remove carious tissue and greater hardness of the residual dentin, compared with the conventional removal technique, but these disadvantages are compensated by the patients' excellent acceptance and less anesthesia dependence. In addition, the use of chemical-mechanical agents showed efficiency in reducing the cariogenic microbiota and a greater absence of pain during the treatment.

REFERENCES

1. Fejerskov O, Kidd E, Nyvad B, Baelum V. Dental caries: The disease and its clinical management. Oxford: Blackwell; 2008.
2. Keyes PH. The infectious and transmissible nature of experimental dental caries. Findings and implications. Arch Oral Biol. 1960 Mar;1:304-20.
3. Fitzgerald RJ, Keyes PH. Demonstration of the etiologic role of streptococci in experimental caries in the hamster. J Am Dent Assoc. 1960 July;61:9-19.
4. Lima JEO. Cárie dentária: um novo conceito. Rev Dental Press Ortod Ortop Facial. 2007;12(6):119-30.
5. Fejerskov O. Concepts of dental caries and their consequences for understanding the disease. Community Dent Oral Epidemiol. 1997 Feb;25(1):5-12.
6. Fejerskov O. Changing paradigms in concepts on dental caries: Consequences for oral health care. Caries Res. 2004 May-June;38(3):182-91.
7. Quock RL. Dental caries: a current understanding and implications. J Nat Sci. 2015;1(1):e27.
8. Kidd EA, Fejerskov O. What constitutes dental caries? Histopathology of carious enamel and dentin related to the action of cariogenic biofilms. J Dent Res. 2004;83 Spec No C:C35-8.
9. Kidd E. The implications of the new paradigm of dental caries. J Dent. 2011 Dec;39 Suppl 2:S3-8.
10. Frencken JE, Peters MC, Manton DJ, Leal SC, Gordan VV, Eden E. Minimal intervention dentistry for managing dental caries - A review: Report of a FDI task group. Int Dent J. 2012 Oct;62(5):223-43.
11. Kidd E, Fejerskov O, Nyvad B. Infected dentine revisited. Dent Update. 2015 Nov;42(9):802-6, 808-9.
12. Jingarwar MM, Bajwa NK, Pathak A. Minimal intervention Dentistry - A new frontier in clinical Dentistry. J Clin Diagn Res. 2014 July;8(7):ZE04-8.
13. Tassery H, Levallois B, Terrer E, Manton DJ, Otsuki M, Koubi S, et al. Use of new minimum intervention dentistry technologies in caries management. Aust Dent J. 2013 June;58 Suppl 1:40-59.
14. Ericson D. What is minimally invasive dentistry? Oral Health Prev Dent. 2004;2 Suppl 1:287-92.
15. Bjørndal L, Thylstrup A. A structural analysis of approximal enamel caries lesions and subjacent dentin reactions. Eur J Oral Sci. 1995 Feb;103(1):25-31.
16. Thompson VT, Craig RG, Curro FA, Green WS, Ship JA. Treatment of deep carious lesions by complete excavation or partial removal. J Am Dent Assoc. 2008 June;139(6):705-12.
17. Ogushi K, Fusayama T. Electron microscopic structure of the two layers of carious dentin. J Dent Res. 1975 Sept-Oct;54(5):1019-26.
18. Fusayama T. The process and results of revolution in dental caries treatment. Int Dent J. 1997;47(3):157-66.
19. Araujo NC, Soares MUSC, Silva MMN, Gerbi MEMM, Braz R. Considerações sobre a remoção parcial do tecido cariado. Int J Dent. 2010;9(4):202-9.
20. Kuboki Y, Ohgushi K, Fusayama T. Collagen biochemistry of the two layers of carious dentin. J Dent Res. 1977 Oct;56(10):1233-7.
21. Marshall GW, Marshall SJ, Kinney JH, Balooch M. The dentin substrate: Structure and properties related to bonding. J Dent. 1997 Nov;25(6):441-58.
22. Arnold WH, Konopka S, Kriwalsky MS, Gaengler P. Morphological analysis and chemical content of natural dentin carious lesion zones. Ann Anat. 2003 Oct;185(5):419-24.
23. Murdoch-Kinch CA, McLean ME. Minimally invasive dentistry. J Am Dent Assoc. 2003;134(1):87-95.
24. Rugg-Gunn A. Dental Caries: Strategies to control this preventable disease. Acta Med Acad. 2013 Nov;42(2):117-30.
25. Marsh PD. Dental plaque as a microbial biofilm. Caries Res. 2004 May-June;38(3):204-11.
26. Bradshaw DJ, Lynch RJM. Diet and the microbial aetiology of dental caries: new paradigms. I Int Dent J. 2013 Dec;63 Suppl 2:64-72.
27. Banerjee A, Frencken JE, Schwendicke F, Innes NPT. Contemporary operative caries management: Consensus recommendations on minimally invasive caries removal. Br Dent J. 2017 Aug 11;223(3):215-22.
28. Maltz M, Jardim JJ, Mestrinho HD, Yamaguti PM, Podestá K, Moura MS, et al. Partial removal of carious dentine: A multicenter randomized controlled trial and 18-month follow-up results. Caries Res. 2013;47(2):103-9.
29. Maltz M, Alves LS, Jardim JJ, Dos Santos Moura M, De Oliveira EF. Incomplete caries removal in deep lesions: A 10-year prospective study. Am J Dent. 2011 Aug;24(4):211-4.
30. Maltz M, Henz SL, De Oliveira EF, Jardim JJ. Conventional caries removal and sealed caries in permanent teeth: a microbiological evaluation. J Dent. 2012 Sept;40(9):776-82.
31. Maltz M, Oliveira EF, Fontanella V, Carminatti G. Deep caries lesions after incomplete dentin caries removal: 40-month follow-up study. Caries Res. 2007;41(6):493-6. Epub 2007 Oct 5.
32. Schwendicke F, Frencken JE, Bjørndal L, Maltz M, Manton DJ, Ricketts D, et al. Managing carious lesions: consensus recommendations on carious tissue removal. Adv Dent Res. 2016 May;28(2):58-67.
33. Mackenzie L, Banerjee A. Minimally invasive direct restorations: a practical guide. Br Dent J. 2017;223(3):163-71.
34. Corralo DJ, Maltz M. Clinical and ultrastructural effects of different liners/restorative materials on deep carious dentin: A randomized clinical trial. Caries Res. 2013;47(3):243-50.
35. Oliveira EF, Carminatti G, Fontanella V, Maltz M. The monitoring of deep caries lesions after incomplete dentine caries removal: Results after 14-18 months. Clin Oral Investig. 2006 June;10(2):134-9.
36. Tyas MJ, Anusavice KJ, Frencken JE, Mount GJ. Minimal intervention dentistry—a review. FDI Commission Project 1-97. Int Dent J. 2000 Feb;50(1):1-12.
37. Massara MLA, Alves JB, Brandão PRG. Atraumatic restorative treatment: clinical, ultrastructural and chemical analysis. Caries Res. 2002 Nov-Dec;36(6):430-6.
38. Bjorndal L, Larsen T, Thylstrup A. A clinical and microbiological study of deep carious lesions during stepwise excavation using long treatment intervals. Caries Res. 1997;31(6):411-7.
39. Paddick JS, Brailsford SR, Kidd EAM, Beighton D. Phenotypic and genotypic selection of microbiota surviving under dental restorations. Appl Environ Microbiol. 2005 May;71(5):2467-72.
40. Pinto AS, Araújo FB, Franzon R, Figueiredo MC, Henz S, García-Godoy F, et al. Clinical and microbiological effect of calcium hydroxide protection in indirect pulp capping in primary teeth. Am J Dent. 2006 Dec;19(6):382-6.
41. Wambier DS, dos Santos FA, Guedes-Pinto AC, Jaeger RG, Simionato MRL. Ultrastructural and microbiological analysis of the dentin layers affected by caries lesions in primary molars treated by minimal intervention. Pediatr Dent. 2007 May-June;29(3):228-34.

42. Duque C, Negrini TDC, Sacono NT, Spolidorio DMP, Souza Costa CA, Hebling J. Clinical and microbiological performance of resin-modified glass-ionomer liners after incomplete dentine caries removal. Clin Oral Investig. 2009 Dec;13(4):465-71.

43. Ricketts D, Lamont T, Innes NPT, Kidd E, Clarkson JE. Operative caries management in adults and children. Cochrane Database Syst Rev. 2013 Mar 28;(3):CD003808.

44. Kidd EAM. How 'clean' must a cavity be before restoration? Caries Res. 2004 May-June;38(3):305-13.

45. Navarro MFL, Leal SC, Molina GF, Villena RS. Tratamento restaurador atraumático : atualidades e perspectivas. Rev. Assoc. Paul. Cir. Dent. 2015;69(3):289-301.

46. Frencken JE. Atraumatic restorative treatment and minimal intervention dentistry. Br Dent J. 2017 Aug 11;223(3):183-9.

47. Frencken JE, Leal SC, Navarro MF. Twenty-five-year atraumatic restorative treatment (ART) approach: a comprehensive overview. Clin Oral Investig. 2012 Oct;16(5):1337-46.

48. Schwendicke F. Retracted: modern concepts for caries tissue removal. J Esthet Restor Dent. 2016 Mar-Apr;28(2):136.

49. Silva RP, Meneghim MC, Correr AB, Pereira AC, Ambrosano GMB, Mialhe FL. Variations in caries diagnoses and treatment recommendations and their impacts on the costs of oral health care. Community Dent Health. 2012 Mar;29(1):25-8.

50. Molina GF, Faulks D, Mazzola I, Mulder J, Frencken JE. One year survival of ART and conventional restorations in patients with disability. BMC Oral Health. 2014 May 7;14:49.

51. Navarro MFL, Rigolon CJ, Barata TJE, Bresciane E, Fagundes TC, Peters MC. Influence of occlusal access on demineralized dentin removal in the Atraumatic Restorative Treatment (ART) approach. Am J Dent. 2008 Aug;21(4):251-4.

52. Banerjee A, Watson TF. Air abrasion: its uses and abuses. Dent Update. 2002 Sept;29(7):340-6.

53. Hegde V, Khatavkar R. A new dimension to conservative dentistry: Air abrasion. J Conserv Dent. 2010 Jan;13(1):4-8.

54. Hugo B, Stassinakis A. Preparation and restoration of small interproximal carious lesions with sonic instruments. Pract Periodontics Aesthet Dent. 1998 Apr;10(3):353-9; quiz 360.

55. Antonio AG, Primo LG, Maia LC. Case report: ultrasonic cavity preparation — an alternative approach for caries removal in paediatric dentistry. Eur J Paediatr Dent. 2005 June;6(2):105-8.

56. Coluzzi DJ, Convissar RA. Laser Fundamentals. In: Convissar RA. Principles and practice of laser dentistry. Hardcover: Mosby; 2010. cap. 2.

57. Dostálová T, Jelínková H. Lasers in dentistry. In: Lasers for medical applications: diagnostics, therapy and surgery. Philadelphia: Woodhead; 2013. p. 604-27.

58. Montedori A, Abraha I, Orso M, D'Errico PG, Pagano S, Lombardo G. Lasers for caries removal in deciduous and permanent teeth. Cochrane Database Syst Rev. 2016 Sept 26;9:CD010229.

59. Kotlow LA. Lasers in pediatric dentistry. Dent Clin North Am. 2004 Oct;48(4):889-922, vii.

60. Olivi G, Genovese MD, Caprioglio C. Evidence-based dentistry on laser paediatric dentistry: review and outlook. Eur J Paediatr Dent. 2009 Mar;10(1):29-40.

61. Nazemisalman B, Farsadeghi M, Sokhansanj M. Types of lasers and their applications in pediatric dentistry. J Lasers Med Sci. 2015 Summer; 6(3): 96-101.

62. Schwass DR, Leichter JW, Purton DG, Swain MV. Evaluating the efficiency of caries removal using an Er:YAG laser driven by fluorescence feedback control. Arch Oral Biol. 2013 June;58(6):603-10.

63. Jawa D, Singh S, Somani R, Jaidka S, Sirkar K, Jaidka R. Comparative evaluation of the efficacy of chemomechanical caries removal agent (Papacarie) and conventional method of caries removal: an in vitro study. J Indian Soc Pedod Prev Dent. 2010 Apr-June;28(2):73-7.

64. Bussadori SK, Guedes CC, Bachiega JC, Santis TO, Motta LJ. Clinical and radiographic study of chemical-mechanical removal of caries using Papacárie: 24-month follow up. J Clin Pediatr Dent [Internet]. 2011;35(3):251-4.

65. Torresi F, Bsereni L. Eficácia do método de remoção químico-mecânica da cárie dentária como papaína em adultos. Rev Assoc Paul Cir Dent. 2017;71(3):266-9.

66. Dhamija N, Pundir P. A Review on agents for chemo-mechanical caries removal. Sch J Dent Sci J Dent Sci. 2016;3(9):264-8.

67. Ammari MM, Moliterno LFM, Hirata Júnior R, Séllos MC, Soviero VM, Coutinho Filho WP. Efficacy of chemomechanical caries removal in reducing cariogenic microbiota: a randomized clinical trial. Braz Oral Res. 2014;28(1):1-6.

68. Hamama H, Yiu C, Burrow M. Current update of chemomechanical caries removal methods. Aust Dent J. 2014 Dec;59(4):446-56; quiz 525.

69. Divya G, Prasad MG, Vasa AAK, Vasanthi D, Ramanarayanar B, Mynampati P. Evaluation of the efficacy of caries removal using Polymer Bur, Stainless Steel Bur, Carisolv, Papacarie — An in vitro comparative study. J Clin Diagnostic Res. 2015;9(7):ZC42-ZC46.

70. Habib CM, Kronman J, Goldman M. A chemical evaluation of collagen and hydroxyproline after treatment with GK-101 (N-chloroglycine). Pharmacol Ther Dent. 1975;2(3-4):209-15.

71. Schutzbank SG, Galaini J, Kronman JH, Goldman M, Clark RE. A comparative in vitro study of GK-101 and GK-101E in caries removal. J Dent Res [Internet]. 1978;57(9-10):861-4.

72. Schutzbank SG, Marchwinski M, Kronman JH, Goldman M, Clark RE. In vitro study of the effect of GK-101 on the removal of carious material. J Dent Res. 1975;54(4):907.

73. Beeley JA, Yip HK, Stevenson a G. Chemo-mechanical caries removal: a review of the techniques and latest developments. Ned Tijdschr Tandheelkd. 2001;108(8):277-81.

74. Robbins A. Efficacy of GK101E solution (Caridex 100) for caries removal. Gen Dent. 1987;35(5):392-6.

75. Scheutzel P. [Possibilities and limitations of Caridex System as an alternative to conventional caries removal]. Dtsch Zahnarztl Z. 1989;44(8):612-4.

76. Roth KK, Domnick E, Ahrens G. [Studies into the effectivity of Caridex in caries removal]. Dtsch Zahnarztl Z [Internet]. 1989;44(6):463-5.

77. Kumar J, Nayak M, Prasad KL, Gupta N. A comparative study of the clinical efficiency of chemomechanical caries removal using Carisolv and Papacarie - a papain gel. Indian J Dent Res. 2012 Sept-Oct;23(5):697

78. Jingarwar MM, Bajwa NK, Pathak A. Minimal intervention Dentistry - A new frontier in clinical Dentistry. J Clin Diagn Res. 2014 July;8(7):ZE04-8.

79. Brennan DS, Balasubramanian M, Spencer AJ. Treatment of caries in relation to lesion severity: Implications for minimum intervention dentistry. J Dent. 2015 Jan;43(1):58-65.

80. Lai G, Lara Capi C, Cocco F, Cagetti MG, Lingström P, Almhöjd U, et al. Comparison of Carisolv system vs traditional rotating instruments for caries removal in the primary dentition: a systematic review and meta-analysis. Acta Odontol Scand. 2015;73(8):569-80.

81. Pradeep Kumar R. A natural chemo-mechanical caries removal agent-Papacarie. Int J Pharma Bio Sci. 2014;5(4):P394-9.

82. Jain K, Bardia A, Geetha S, Goel A. Papacarie: a chemomechanical caries removal agent. IJSS Case Reports Rev. 2015;1(9):57-60.

83. Abdul Khalek A, Elkateb M, Abdel Aziz W, El Tantawi M. Effect of Papacarie and alternative restorative treatment on pain reaction during caries removal among children: a randomized controlled clinical trial. J Clin Pediatr Dent. 2017;41(3):219-24.

84. Maragakis GM, Hahn P, Hellwig E. Chemomechanical caries removal: a comprehensive review of the literature. Int Dent J. 2001;51(4):291-9.

85. Martins MD, Fernandes KPS, Pavesi VC, França CM, Mesquita-Ferrari RA, Bussadori SK. Healing properties of papain-based gel on oral ulcers. Brazilian J Oral Sci. 2011;10(2):120-3.

86. Corrêa FNP, Rocha RDO, Rodrigues Filho LE, Muench A, Rodrigues CRMD. Chemical versus conventional caries removal techniques in primary teeth: a microhardness study. J Clin Pediatr Dent. 2007 Spring;31(3):187-92.

87. Amerongen WE Van. Dental caries under glass ionomer restorations. J Public Health Dent. 1996;56(3 Spec No):150-4; discussion 161-3.

88. Lo ECM, Holmgren CJ. Provision of Atraumatic Restorative Treatment (ART) restorations to Chinese pre-school children - A 30-month evaluation. Int J Paediatr Dent. 2001 Jan;11(1):3-10.

89. Rabello T. Research proposal: evaluation of the ART approach in elderly patients. J Appl Oral Sci. 2006;14(Spec No.):30-3.

90. Figueiredo CH, Lima FA, Moura KS. Tratamento restaurador atraumático: avaliação de sua viabilidade como estratégia de controle da cárie dentária na saúde pública. Rev Bras Promoção Saúde. 2004;17(3):109-18.

91. Yip HK, Stevenson AG, Beeley JA. Chemomechanical removal of dental caries in deciduous teeth: Further studies in vitro. Br Dent J. 1999 Feb 27;186(4 Spec No):179-82.

92. Banerjee A, Watson TF, Kidd EAM. Dentine caries excavation: a review of current clinical techniques. Br Dent J. 2000;188(9):476-82.

93. Hamama HH, Yiu CKY, Burrow MF, King NM. Chemical, morphological and microhardness changes of dentine after chemomechanical caries removal. Aust Dent J. 2013;58(3):283-92.

94. Ansari G, Beeley JA, Fung DE. Chemomechanical caries removal in primary teeth in a group of anxious children. J Oral Rehabil. 2003 Aug;30(8):773-9.

95. Rafique S, Fiske J, Banerjee A. Clinical trial of an air-abrasion/chemomechanical operative procedure for the restorative treatment of dental patients. Caries Res. 2003 Sept-Oct;37(5):360-4.

96. Azrak B, Callaway A, Grundheber A, Stender E, Willershausen B. Comparison of the efficacy of chemomechanical caries removal (Carisolv) with that of conventional excavation in reducing the cariogenic flora. Int J Paediatr Dent. 2004 May;14(3):182-91.

97. Lozano-Chourio MA, Zambrano O, González H, Quero M. Clinical randomized controlled trial of chemomechanical caries removal (CarisolvTM). Int J Paediatr Dent. 2006 May;16(3):161-7.

98. Oliveira MT de, Bittencourt ST, Oliveira MDS, Hübe R, Pereira JR. Avaliação clínica do desempenho de TRA (tratamento restaurador atraumático) associado a um agente químico de remoção de cárie. Rev Odonto Ciênc. 2009;24(2):190-3.

99. Pandit IK, Srivastava N, Gugnani N, Gupta M, Verma L. Various methods of caries removal in children: a comparative clinical study. J Indian Soc Pedod Prev Dent. 2007 Apr-June;25(2):93-6.

100. Saliba NA, Lima DM de, Moimaz SAS, Saliba O, Okamoto AC. Avaliação clínica de três sistemas de remoção minimamente invasivos do tecido cariado. Revista da Faculdade de Odontologia de Araçatuba. 2010;30(1):63-8.

101. Kavvadia K, Karagianni V, Polychronopoulou A, Papagiannouli L. Primary teeth caries removal using the Carisolv chemomechanical method: a clinical trial. Pediatr Dent. 2004 Jan-Feb;26(1):23-8.

102. Chowdhry S, Saha S, Samadi F, Jaiswal JN, Garg A CP. Recent vs conventional methods of caries removal: a comparative in vivo study in pediatric patients. Int J Clin Pediatr Dent. 2015 Jan-Apr;8(1):6-11.

103. Kochhar GK, Srivastava N, Pandit IK, Gugnani N, Gupta M. An evaluation of different caries removal techniques in primary teeth: a comparative clinical study. J Clin Pediatr Dent. 2011;36(1):5-9.

104. Singh S, Singh DJ, Jaidka S, Somani R. Comparative clinical evaluation of chemomechanical caries removal agent Papacarie® with conventional method among rural population in India - in vivo study. Brazilian J Oral Sci. 2011;10(3):193-8.

105. Boob AR, Manjula M, Reddy ER, Srilaxmi N, Rani T. Evaluation of the efficiency and effectiveness of three minimally invasive methods of caries removal: an in vitro study. Int J Clin Pediatr Dent. 2014 Jan-Apr;7(1):11-8.

106. Mackenzie L, Banerjee A. The minimally invasive management of early occlusal caries: a practical guide. Prim Dent J. 2014 May;3(2):34-41.

107. Banerjee A, Kidd EA, Watson TF. In vitro evaluation of five alternative methods of carious dentine excavation. Caries Res. 2000;34(2):144-50.

108. Chaussain-Miller C, Decup F, Domejean-Orliaguet S, Gillet D, Guigand M, Kaleka R, et al. Clinical evaluation of the Carisolv chemomechanical caries removal technique according to the site/stage concept, a revised caries classification system. Clin Oral Investig. 2003 Mar;7(1):32-7.

109. Kakaboura A, Masouras C, Staikou O, Vougiouklakis G. A comparative clinical study on the Carisolv caries removal method. Quintessence Int. 2003 Apr;34(4):269-71.

110. Kavvadia K, Karagianni V, Polychronopoulou A, Papagiannouli L. Primary teeth caries removal using the Carisolv chemomechanical method: a clinical trial. Pediatr Dent. 2004 Jan-Feb;26(1):23-8.

111. Motta LJ, Martins MD, Porta KP, Bussadori SK. Aesthetic restoration of deciduous anterior teeth after removal of carious tissue with Papacarie. Indian J Dent Res. 2009;20(1):117-20.

112. Alfaya T, Guedes CC, Fernandes KP, Bussadori S, Matsumoto SF, Motta L. Assessment of chemomechanical removal of carious lesions using Papacarie Duo™: Randomized longitudinal clinical trial. Indian Indian J Dent Res. 2013 July-Aug;24(4):488-92.

113. Geetha Priya PR, Asokan S, John JB, Punithavathy R, Karthick K. Comparison of behavioral response to caries removal methods: a randomised controlled cross over trial. J Indian Soc Pedod Prev Dent. 2014 Jan-Mar;32(1):48-52.

114. Knoop F, Peters CG, Emerson WB. A sensitive pyramidal-diamond tool for indentation measurements. J Res Natl Bur Stand. 1939 July;23:39-61.

115. Featherstone JDB, Ten Cate JM, Shariati M, Arends J. Comparison of artificial caries-like lesions by quantitative microradiography and microhardness profiles. Caries Res. 1983;17(5):385-91.

116. Fusayama T, Okuse K, Hosoda H. Relationship between hardness, discoloration, and microbial invasion in carious dentin. J Dent Res. 1966 Jul-Aug;45(4):1033-46.

117. Hossain M, Yamada Y, Nakamura Y, Murakami Y, Tamaki Y, Matsumoto K. A study on surface roughness and microleakage test in cavities prepared by Er:YAG laser irradiation and etched bur cavities. Lasers Med Sci. 2003;18(1):25-31.

118. Reis A, Bauer JRO, Loguercio AD. Dureza da dentina após remoção de cárie: avaliação de diferentes métodos. RFO UPF. 2003;8(2). https://doi.org/10.5335/rfo.v8i2.1234

119. Flückiger L, Waltimo T, Stich H, Lussi A. Comparison of chemomechanical caries removal using Carisolv™ or conventional hand excavation in deciduous teeth in vitro. J Dent. 2005;33(2):87—90.

120. Mertz-Fairhurst EJ, Curtis JW, Ergle JW, Rueggeberg FA, Adair SM. Ultraconservative and cariostatic sealed restorations: Results at year 10. J Am Dent Assoc. 1998 Jan;129(1):55-66.

121. Bortoletto CC, Motisuki C, Ferrari JCL SD. Atividade antimicrobiana de um novo biomaterial utilizado para remoção químicomecânica da cárie. Rev Odontol UNESP. 2005;34(4):199-201.

122. Pacheco L et al. Avaliação da ação microbiana in vitro de dois sistemas de remoção química de cárie sobre Streptococcus mutans e Lactobacillus aciduphilus. Ver Biociên. 2005;11(1-2):39-45.

123. Lager A, Thornqvist E, Ericson D. Cultivatable bacteria in dentin after caries excavation using rose-bur or carisolv. Caries Res. 2003 May-Jun;37(3):206-11.

124. Lima GQ, Oliveira EG, Souza JI, Monteiro Neto V. Comparison of the efficacy of chemomechanical and mechanical methods of caries removal in the reduction of Streptococcus mutans and Lactobacillus spp in carious dentin of primary teeth. J Appl Oral Sci. 2005 Dec;13(4):399-405.

125. Subramaniam P, Babu KL NG. Comparison of the antimicrobial efficacy of chemomechanical caries removal (Carisolv) with that of conventional drilling in reducing cariogenic flora. J Clin Pediatr Dent. 2008;32(3):215-9.

126. Motta L, Bussadori S, Campanelli A, Silva A, Alfaya T, Godoy C, et al. Efficacy of Papacarie® in reduction of residual bacteria in deciduous teeth: a randomized, controlled clinical trial. Clinics (São Paulo). 2014 May;69(5):319-22.

127. Prabhakar AR, Kaur T, Basappa N. Avaliação comparativa do Carisolv na remoção da dentina cariada em molares decíduos: estudo in vitro. Pesqui Bras Odontopediatria Clin Integr. 2009;9(1):77-80.

128. Nadanovsky P, Cohen Carneiro F, Souza De Mello F. Removal of caries using only hand instruments: a comparison of mechanical and chemo-mechanical methods. Caries Res. 2001 Sept-Oct;35(5):384-9.

129. Goyal P, Kumari R, Kannan V, Madhu S. Efficacy and tolerance of papain gel with conventional drilling method: a clinico-microbiological study. J Clin Pediatr Dent. 2015 Winter;39(2):109-12.

130. McNierney HD, Petruzillo MA. A gentle approach to operative dentistry: the Caridex caries removal system. Gen Dent. 1986;34(4):282-4.

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