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CURRENT CONCEPTS AND TECHNIQUES IN CARIES EXCAVATION: A REVIEW

Dental Science

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ABSTRACT

Dental caries is one of the most prevalent chronic diseases in children and adults which often leads to poor quality of life. Majorly, children are afraid of their dental visits and avoid dental appointments due to invasive dental treatment procedures which directly influence their dental health and leads to poor oral and general health. Over the years, to emphasize a biological and conservative approach, treatment modality from "drill and fill" to "minimal intervention" has been evolved. Minimal intervention techniques function to conserve the tooth structure, limit the pulpal exposure, increase the long-term prognosis and lastly, to increase the cooperation of patients and their parents as well. Change is the "only constant" in this evolving world, and thereby for ages, there has been the introduction of various non-invasive caries removal strategies to ease and condolence the patients and the operator as well. Now is the era where the fundamental key is to repair not to replace.

KEYWORDS

Caries excavation, Lasers, Ceramic burs, Chemomechanical removal, Dyes

INTRODUCTION

According to Sturdevant's

"Dental caries is an infectious microbiologic disease of the teeth that results in localized dissolution and destruction of calcified tissues."

Dental caries persists as the most prevalent chronic disease in both children and adults yet it is largely preventable. According to the World health organization (WHO, 2017), it is estimated that dental caries in permanent teeth is the most common health condition affecting approximately 3.5 billion people worldwide. More than 530 million children do suffer from dental decay in primary teeth too. For ages, there has been the introduction of various treatment modalities for treating dental caries to reduce discomfort and pain, thus contribute to a better quality of life. Conventionally, based on G.V. black concept of "extension for prevention" practitioners believed to use high-speed hand piece and burs for cavity preparation which in turn had many disadvantages for example 1) use of local anesthesia 2) deleterious thermal effects 3) adverse effects on pulpal pressure 4) removal of a healthy sound structure resulting in excessive tooth structure loss[1].

With the shift in paradigm from "drilling and filling" to "minimal intervention", conservation of healthy sound structure during cavity preparation gained popularity.

Well-articulated by John Knowles – "*Everything has to evolve or else it perishes.*"

Over the last 100 years, pediatric dentistry has been evolving at a pace in accordance to bestow comfort to children and eliminate their anxiety for dental treatment.

Children are frightened of the hand piece's awful voice and in turn, sometimes become anxious and nervous for dental appointments. Along with conservation of tooth structure, minimal intervention techniques also attribute to positive dental behavior in children. Commencement of newer caries removal modalities marshalled the field of dental caries treatment.

Newer modalities for caries excavation and removal includes (Table 1):

CATEGORY	TECHNIQUE
MECHANICAL – ROTAROY	Handpiece – Polymeric burs and ceramic burs
MWCHANICAL NON-ROTARY	Sono-Abrasion Air-Abrasion Fluorescence-aided Caries Excavation
CHEMOMECHANICAL	Sodium hypochlorite-based agents Caridex Carisolve
	Carie-care Papacarie Biosolv
PHOTOABLATION	Lasers

Table 1: Different techniques for caries excavation and removal

Further, the concept of partial caries removal, stepwise caries removal (complete caries removal) and no caries removal portrayed another matter in pediatric dentistry for patient's ease and to provide the best treatment outcome. There have been pieces of evidence in past for the same.

***The Conservative approach encompasses the following principles*[2]:**

- Elimination of demineralization by controlling the causative factor.
- Enhancing the Remineralization of early carious lesions
- Conservative or minimal intervention for cavity preparation
- For defective restorations, fundamental is to repair not replace.

Based on the above conception, we as pediatric dentists have been focusing on minimal intervention techniques for caries excavation which in turn is high yielding for patients, parents and dentists as well.

Stepwise Caries Removal (complete Caries Removal) Versus Partial Caries Removal – Two Opposing Notion

Chronologically, the first approach is complete caries removal (stepwise caries removal) where in the first appointment, residual carious dentin at the pulpal wall of the prepared cavity is left under a temporary restoration followed by a complete excavation at a second visit (generally 2–6 months later). But regrettably, it is time-consuming and costly and at a high risk of pulp exposure during the second visit. Contradictory, Partial caries removal is an excavation method by which carious dentine is removed from the peripheral walls of a deep cavitated caries lesion (excavated to hard dentine), followed by partial removal of soft dentine from the pulpal wall with a hand excavator or round bur [3].

To avoid pulp exposure, carious dentin remains close to the pulp and the cavity is sealed with a definitive restoration. This second approach is controversial among practitioners to date. This theory is based on substantial evidence that removal of all carious dentin in deep carious lesions is not required for successful lesion management, provided that the restoration should effectively seal the lesion from the oral environment. The rationalization behind partial caries removal would be centred on reducing the risk of pulp exposure, maintaining the integrity of tooth structure and thus owing to the long-term prognosis of pulpal health.

There is growing evidence reinforcing the use of more conservative techniques to treat carious primary and permanent teeth. A study was

done which compared three modalities: one-step partial caries removal (PCR) and total caries removal (TCR) and evaluated clinical and radiographic success at 2 years follow up in primary molars with deep carious lesions. Authors concluded that the mean incidence of pulp exposure was significantly lower in PCR (2%) than TCR (27.5%) [4]. Similarly, another study revealed that there is a marked reduction in pulpal exposure rates with both stepwise and partial caries removal (56% and 77% respectively) [5]. Homogenous to this, authors concluded that the incidence of pulp exposure was significantly less in partial caries removal technique and exhibits higher success rates both clinically and radiographically, preserving the vitality of tooth.[6].

"There is no conclusive evidence that it is necessary to re-enter the tooth to remove residual caries. As long as the tooth remains sealed from bacterial contamination, the prognosis is good for caries to arrest and reparative dentin to form to protect the pulp".– **American Academy of pediatric dentistry 2020** [7]

After culminating the pieces of evidence, it can be stated that minimal intervention with partial caries removal is one such modality that can be implied in practice and it should be always accompanied by tight restorative seal for long term prognosis.

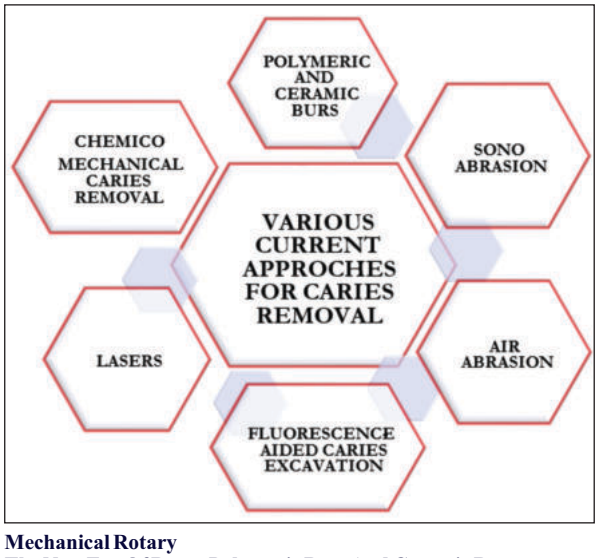
NO CARIES REMOVAL – TREATMENT MODALITY WITH DILEMMA

Focussing on minimal intervention approach, no caries removal concept is gaining popularity specially in primary dentition. In involves a three step methodology and claimed to be beneficial in young children.[8].

It was found that 38% silver diamine fluoride (SDF) as a non-invasive technique can effectively arrest caries among children. It can be a promising strategy to manage dental caries in young children and in special health care needs [9].

Unlike traditional restorative therapy, NRCC avoids anxiety and fear and attributes towards minimal invasive dentistry specially in children. Also, it increases awareness for enhancing oral hygiene measures altogether. But cautiously, this modality should not be performed in case of emergency treatment (for example - in case of sepsis or severe pain)

Various Current Approaches For Caries Excavation And Removal



Mechanical Rotary

The New Era Of Burs - Polymeric Burs And Ceramic Burs

Conventionally, there was a paradigm shift from the use of tungsten carbide burs to carbon-steel burs with the similar property of spiral-like cutting edges, although carbon steel burs were less expensive with increased susceptibility to corrosion. Tungsten and carbon steel burs are still the most effective in caries excavation in terms of time. Concerning minimal invasiveness, and bur prepared cavities, these burs tend to over excavate. Lately, to develop a selective caries removal rotatory bur, plastic bur of polyamide-imide (PAI) polymer was introduced. Unlike conventional burs, polymer burs have a straight cut edge. Commercial burs like smart prep and SS white burs containing PEKK – (polyether ketone ketone) came into action with a particular hardness of 50 KHN, which is higher than the hardness of carious dentin and lower than that of sound dentin attributing to the excavation of only soft infected carious dentin and leaving behind the layer of demineralized affected dentin [10]. Recently, an improved version of smart burs was introduced in primary teeth which anyhow leave the residual layer behind in cases of the arrested carious lesion because of the less hardness of burs than that of arrested carious dentin. Eventually, the second-generation burs (smart bur II), a self-limiting brand was fabricated with 4000 rpm speed efficient to remove carious dentin without damaging healthy sound dentin in the absence of local anesthesia in primary teeth. Contrary, using smart 2 burs when compared to conventional burs requires significantly longer caries removal time.

With the advancement in dentistry, the ceramic burs commercially available as Cera-burs made up of alumina-yttria stabilized zirconia was launched in different diameter sizes with the characteristic of providing tactile sensation (Figure 1) [11]. Of late, authors concluded that ceramic burs had better efficacy and cutting efficiency with less time required when compared to conventional burs in children [12]

Figure 1: Ceramic burs with different diameters – 10, 14, 18, 23 mm [11]

Mechanical Non-rotary

Excavation By Sono-abrasion

With the intervention of cutting tips coupled to high frequency, sonic, air scaler handpieces under water cooling, sono abrasion was introduced. The cutting efficiency was based on its vibration, abrasion and oscillations of less than 6.5 kHz. Sono-abrasion excavation with diamond-coated tips demonstrated similar efficiency (time required for excavation) as conventional hand excavation using dental spoons, but still taking more time than the carbide-bur excavation method. Although it has limited efficacy on cutting sound enamel but is a beneficial treatment modality in altered enamel conditions like enamel dysplasia, amelogenesis imperfecta, Molar Incisor Hypomineralisation, etc. In addition to its single-sided cutting design which helps to protect the adjacent teeth, the surface quality after sono abrasions is superficial with minimal enamel cracks (Figure 2) [13]. On contrary, the efficiency of excavating carious dentin is less when compared to the rotary mechanism. Rather, the removal of secondary, sclerotic dentin is more acceptable by sono abrasions. Therefore, treatment of cervical lesions and lesions with secondary hard dentin are more admissible for sono

abrasion technique.

Example of handpieces of the most recent generation is SONICFLEX Lux 2003L, KAVO, SF1LM, KOMET, etc (Figure 3).

Figure 2: Producing bevel-edge preparations for anterior proximal composites [13]

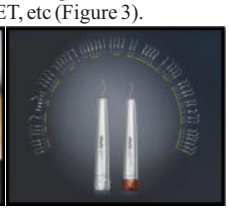


Figure 3: Air scaler KaVo SONICflex

Exacavation By Air Abrasion

Evolving from an alternative means of cavity preparation to an essential means of providing conservative cavity predation, Air abrasion was introduced and initiated by Dr Robert black. Air abrasion uses a stream of aluminium oxide particles generated from compressed air or bottle carbon dioxide for cavity preparation. The abrasive particle with the property of high cutting efficacy, chemical stability and low cost strikes the tooth with high velocity and remove carious tooth structure (Figure 4). Its cutting efficacy generally depends on various parameters [14]:

- **Air pressure:** it ranges from 40-160 psi, 100 psi for cutting and 80 psi for surface etching
- **Particle size:** they are generally 27 or 50 um in diameter. Large particle size allows practitioners to work faster through the cutting surface would be then extended resulting in a large cavity size.
- **Particle flow:** Higher particle flow rate will abrade the surface faster reducing operating time
- **Operating distance:** typical distance ranges from 0.5 to 2 mm. More distance produces scattered beam resulting in compromised cutting ability
- **Nozzle diameter and tip angulations:** tip angulations can be modified for the operator's ease and small nozzle diameter can be used for inaccessible cavity areas.

Figure 4: Air abrasion handpiece

Air abrasion has a wide range of uses in dentistry – cavity preparation, detecting pit and fissure caries, preparing small sections of class II caries with a conservative approach, treating abrasions and abfractions and removing existing restoration without damaging the sound tooth structure [14].

Additionally, the use of local anesthesia is minimal because of their cooling action through highpressure air. Examples of air abrasion systems available in the market today are Prep Master or Etch Master (Groman Inc.), Airbrator (North Bay/Bioscience, LLC), prep Start and Prep Air (Danville Engineering), or Crystal Mark (Crystal Mark Inc.), etc.

Fluorescence-aided Caries Excavation ("face")

Fluorescence aided caries excavation was launched to differentiate between affected and infected dentin clinically on the basis of orange red fluorophores produced by oral microorganisms as a result to their metabolism byproducts (porphyrins). Infected carious dentin does fluoresce specifically in red fractions owing to the presence of proto and Meso porphyrins [15]. FACE involves the use of fibre optic violet light source of 370-420 nm with slow speed handpieces which allow identifying and removing of infected dentin part selectively.

Studies have compared conventional excavation and fluorescence-aided caries excavation and concluded that latter is more effective in the removal of infected primary dentin [16]. Similarly, *another study* inferred that the FACE device may be an effective method for the detection of residual caries [17].

Recently, *a study* compared conventional caries excavation (CCE), caries detection dye (CDD), and fluorescence aided caries excavation (FACE) methods in children and concluded that the results were not statistically significant between the minimal invasive potential of examined groups [18].

Chemomechanical Caries Removal (cmcr)

Children usually are anxious about their dental appointments. Lately, the introduction of chemo mechanical caries removal has gained acceptance among children due to its non-invasiveness nature. CMCR is the application of chemical solution/gel to carious dentine part followed by removal with hand instruments like spoon excavators eliminating the use of high and slow speed handpieces.

Various agents introduced in chemo mechanical caries removal are (Table 2) [19][20]:

Name	Composition	Mechanism of action
Sodium hypochloritebased agents In early 1970s	5% NaOCl solution	Hydrogen bonds present in partially degraded collagens in carious dentin are chlorinated and discarded by hypochlorite agents followed by removal with hand instruments.
Caridex/GK-101E/Nmonochloroamino butyrate In 1984	Solution I: sodium hypochlorite Solution II: glycine, aminobutyric acid, sodium chloride and sodium hydroxide.	• Covert hydroxylproline to pyrrole-2- carboxylic acid • Phagocytose and digest the dead cells and collagens which consequently is chlorinated by chloramines. • Degradation of hydrogen bongs of secondary and tertiary dentin. This chemically softens the carious dentin and facilitates the removal of carious lesion
Carisolv In 1998	Comprised of 1st syringe: contains hypochlorite solution	sodium Although 3 amino acids are added but its mechanism of action is similar to Caridex.
	2ns syringe: contains three amino acids: lysine, leucine and glutamic acid, with carboxymethylcellulose to make it viscous.	Additionally, due to carboxymethylcellulose, its viscosity increases and thereby it is easier to handle during treatment.
	New Carisolv System (2013) was introduced to limit the caries excavation time. It is combination of conventional Carisolv gel with minimally invasive burs and Carisolv caries detector dye	
Papacarie gel In 2003	papain enzyme, a proteolytic enzyme which is derived from the latex of leaves and fruits of the green adult Carica papaya tree) chloramine, other trace amounts like toluidine blue, salts and preservatives, stabilizers and deionized water	• Degradation and destruction of proteoglycans present in the dentinal matrix by proteolytic enzyme. • It is bactericidal in nature and exhibits anti-inflammatory actions. • Removal of denatured tissues is boosted by chloramines.
Carie-care In 2010	contains papain with Clove oil.	• Breakage of peptide bonds by papain resulting in deprotonation of Cys-25 by His-159. • Clove oil works as natural analgesic and anesthetic agent.
Biosolv	pepsin enzyme in a phosphoric acid/sodium biphosphate buffer	• Dissolution of inorganic components of carious dentin by phosphoric acid • Disruption of denatured collagen fibers by pepsin selectively.
	Table 2: Various chemo mechanical agents with their composition and mechanism of action [19] [20]	

Therefore, it is inferred that chemo mechanical caries removal technique is patient's friendly as it eliminates the use of high and low-speed handpiece which directly diminish fear in children especially. Besides this, it also has bacteriostatic action although the time required is more as compared to conventional methods.

During COVID-19 times, in order to reduce the use of aerosol generating procedures, many dental professionals adopt the biological and conservative approach of caries removal which in turn favored positive dental behavior in children and thus enhanced the overall treatment outcome.

Attributing to the same, we explored various minimal invasive caries removal techniques including the use of Carisolv in pediatric population both in primary and permanent teeth (Figure 5, Figure 6)

Figure 5: Armamentarium included – Rubber dam set with topical anesthesia, Probe, Mirror, Tweezer, Spoon excavators, Carisolv and cotton rolls.

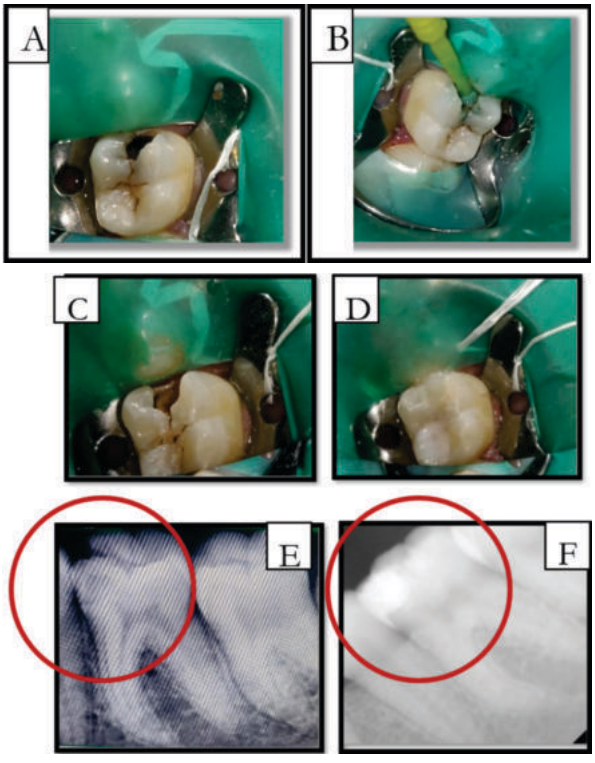


Figure 6 : Chemicomechanical caries removal with Carisolv done in relation to 36 in the department of pediatric and preventive dentistry

Figure 6 showing A) Preoperative clinical picture in relation to 36 , B) Intraoperative clinical picture applying carisolv, C) Post operative clinical picture after chemomechanical caries removal, D) Post operative clinical picture after proximal restoration and preventise resin restoration on occlusal surface, E) Preoperative radiographic picture, F) Postoperative radiographic picture

Photoablation

Lasers – A New Armament

LASER an acronym for "Light Amplification by Stimulated Emission of Radiation", produces coherent beam and high-intensity light. American Academy of Pediatric Dentistry has recommended the use of lasers in dentistry varying from low level laser therapy (LLLT), whitening, osseous tissue procedures, disinfection of root canals and periodontal pockets, photo biomodulation, soft and hard tissue surgeries, cavity preparation, etc.

Erbium laser family are the most acceptable in dentistry for its attributing trait of ablation of enamel and dentin. There are 2 types of laser system in erbium family laser [21]:

- The erbium-loaded yttrium-aluminum-garnet (Er:YAG) laser (wavelength 2.78 um)
- The erbium,chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser (wavelength 2.94 um)

Fundamentally, the water molecules present in enamel and dentin absorb the laser radiation leading to sudden heating and evaporation which consequently induce a vicious but controlled explosive forces targeted to hard tissue removal.[21]. Laser precluded conservative sound dentin removal thus resulting in smaller cavities compared to conventional excavation. But unfortunately, the considerable drawback is the time required for cavity preparation is significantly more when compared to conventional methods.

Figure 7: Explored the use of Er,Cr:YSGG laser for cavity preparation, in vitro.

Previously, Laser is compared to drilling method in deciduous and permanent teeth and systematically portrayed in Cochrane database of systematic reviews in year 2016 [22]:

Table 3: comparison between standard drill and laser in different clinical aspects[22]

Laser compared to standard drill in both deciduous and permanent teeth for caries removal			
Patient or population: people with caries in deciduous and permanent teeth *Settings*: primary and secondary care *Intervention:* laser for caries removal *Comparison*: standard drill for caries removal			
Outcomes	Illustrative comparative risks* (95% CI) Relative effect	No of participants (studies)	
	Standard drill	Laser	
Caries removal (during treatment)	995 per 1000	995 per 1000	90 participants; 256 teeth; 256 cavity preparations (2 studies)
Pain - 6-face rating scale (moderate and high pain) (during treatment)	760 per 1000	304 per 1000	143 participants (2 studies)
Need for anesthesia - children (during treatment)	97 per 1000	24 per 1000	217 participants (3 studies)
Durability of restoration - 6 months follow-up	8 per 1000	20 per 1000	236 participants; 682 teeth (4 studies)
Marginal integrity of restorations - 6 months follow-up	7 per 1000	7 per 1000	146 participants; 306 teeth (3 studies)
Pulpal inflammation or necrosis - 1-week followup	5 per 1000	7 per 1000	317 participants; 694 teeth; 752 cavity preparations (3 studies)

Pulpal inflammation or necrosis - 6 months follow-up	4 per 1000	4 per 1000	156 participants; 508 teeth; 554 cavity preparations (2 studies)

Corresponding to above comparison, it can be concluded that lasers exhibit advantage over conventional drilling in terms of need for anesthesia and pain perception. Durability of restoration is also higher in laser group although the pulpal inflammation does not show any significant difference.

Another modality is Excavation Aided by Laser-induced Fluorescence
DIAGNOdent (Kavo Dental; Biberach, Germany), a laser-fluorescence device of 655 nm has been developed to diagnose "hidden" occlusal caries. The principle is that the caries progression is directly proportional to the intensity of fluorescence beam emitting from DIANGNOdent to occlusal surface of tooth. Owing to the fluorescence readings, diagnostic values are provided for inference (Table 4) [23] :

Table 4: DIAGNOdent values and clinical inference [23]

Values	Clinical inference
0-13	Non active care is advised
14-20	Preventive care is advised
21-29	Preventive or operating care is advised depending on patient's caries risk assessment
>30	Operative care is advised

DIAGNOdent has proved to be one of the best diagnostic methods for caries removal which directly ease the protocol for caries removal. However, DIAGNOdent can sometimes present false positive results due to its close proximity to the pulp and also in conditions with sclerotic dentin. Previously, authors concluded that DIAGNOdent exhibits a greater accuracy in detecting secondary caries under primary molar restorations when compared to radiographs. [24]

American academy of Pediatric Dentistry (2017) Recognizes the use of lasers as an alternative and complementary method of providing soft and hard tissue dental procedures for infants, children, adolescents, and persons with special health care needs.[25]

Dentistry is evolving rapidly and securely as Progress is impossible without change!

"The conventional mind is passive – it consumes information and regurgitates it in familiar forms. The dimensional mind is active, transforming everything it digests into something new and original, creating instead of consuming." - Robert Greene

From conventional drill and fill conception to minimal invasive dentistry, there is an immense progress in caries treatment approach in both primary and permanent dentitions. In conclusion, we all are aware of current approaches and techniques, but now is the time to implement each modality in action with ease and condolence bracing up with more evidences in future.

Afterall, We Are Changing The World Through Dentistry!

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