REVIEW ARTICLE

EVOLUTION OF CARIES EXCAVATION : FROM THE ERA OF BLACK TO INFRARED

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ABSTRACT

With continuous research & invention, approach toward caries excavation has changed. Specially in post covid phase, dental treatment demands application of newer techniques that generate less aerosols. But this evolution was started soon after the time when G.V Black gave us structural outline for caries affected tooth & now we look forward to try our hands on infrared laser technologies for caries removal. In this essay it has been explained how the concepts has been evolved & what are the newer techniques introduced in between the two eras.

KEY WORDS

ART, Air Abrasion, Minimal Invasive Dentistry, Laser

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INTRODUCTION

The initial accepted technique used for caries removal has been developed since 1983, when GV Black proposed the principle of 'extension for prevention' in treatment of carious lesions. These principles of cavity preparation were based on the knowledge of the disease process and the restorative materials available at that time. In recent era the potential to bond restorative materials to tooth structure has altered the general principles of cavity preparation given by GV Black. However, the extent to which carious dentin should be removed to achieve a mechanically and biologically successful restoration is still a matter of debate. In particular, no clinical objective demarcations have been set for where to stop in carious tissue removal procedure that enables complete removal of infected tissue without overextending cavity preparation. So, Hardness is easy to assess and relatively reliable by the clinician to remove carious tissues for daily practice. The rationales behind the different newer caries removal techniques, other than availability of adhesive materials include- reasonably less working fatigue for clinician, minimal patient's discomfort while performing caries removal & optimal tissue removal with maximum preservation of tooth structure.

AIM

With modernization of concepts the historical protocols of carious tissue removal has changed. Newer approaches say that in attempt to heal a carious lesion, all the contaminated dental hard tissues need not to be removed. Instead, emphasis should be given on dietary restriction & regular biofilm removal at patient level. Microbial activity at tooth surface can be controlled by sealing the bacteria by placing suitable restoration on it or can be preceded after excavating some amount of dentin (to ensure sufficient retention & hermetic seal of restoration). Because soft dentin is thought to be associated with reduction in bond strength of subsequent restorations[1].

But it poses a great challenge for a clinician to assess how to leave during carious excavation. Moisture, colour change or dye staining do not accurately represent the extent of contaminated &

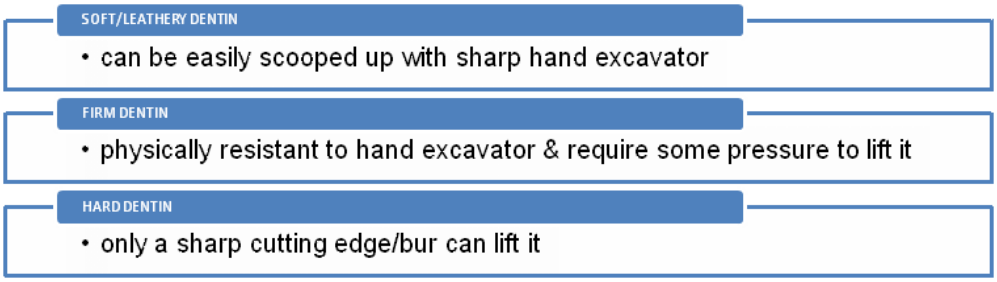

Illustration1: Dentin with variable hardness in respect to excavation

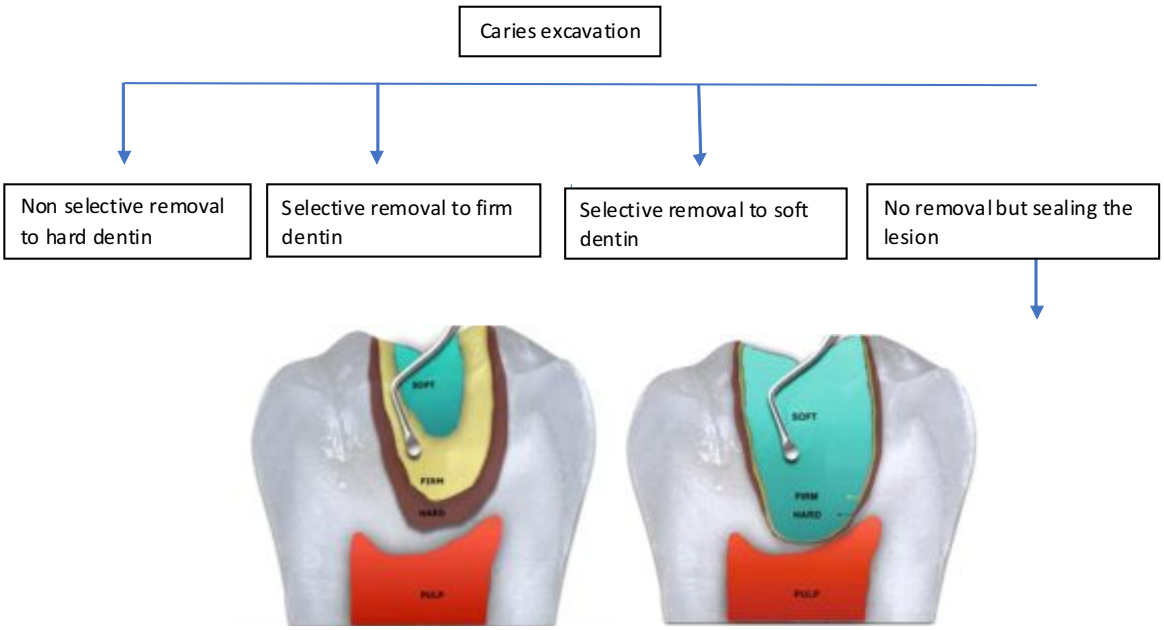

Illustration 2: evolution of concepts on excavation limits in different scenarios[21]

non-contaminated dentinal changes. Laser fluorescence techniques have done some promising achievement but still require some time to be available in the market. Moreover, well demarcated histopathological zones of dentin quality can't be replicated clinically. So, it is much valid to describe & assess carious lesion in terms of its hardness (illustration 1).

Based on all these understandings of the disease number of removal strategies have been introduced which would enhance longevity of placed restoration & allow the pulp to retain its viability whenever possible (illustration 2).

Non-selective removal: formerly also known as "complete removal" because carious tissue removal is stopped when only hard dentin remains. No longer used due to its potential to damage pulpal tissues and weakening the tooth structure. G.V Black proposed his cavity outlines based on this strategy.

Selective removal to firm dentin: it is recommended for shallow or medium deep lesions. Here at the periphery complete removal can be done but in the pulpal aspects of the cavity, firm dentin should be left.

Selective removal to soft dentin: To reduces the risk of pulpal exposure in case of deep carious lesions a layer of carious (soft, leathery) dentin can be left. Peripherally removal can be proceeded till hard dentin/sound enamel is achieved.

Sealing-in lesions builds on the logic that sealing protects the tooth structure by providing a diffusion barrier against acids and arrested carious lesion by restricting the supply nutrition to sealed bacteria leave them to starve. preformed stainless steel crowns, the Hall Technique have been introduced based upon this principle.

Following principles have been postulated by International Caries Consensus Conference (ICCC) for carious removal[2]:

(1) procedure should be performed with minimal discomfort/pain and dental anxiety

(2) preservation of tissues that has not undergone demineralization & which still have chances to re-mineralize

(3) to achieve an adequate seal onto sound dentin

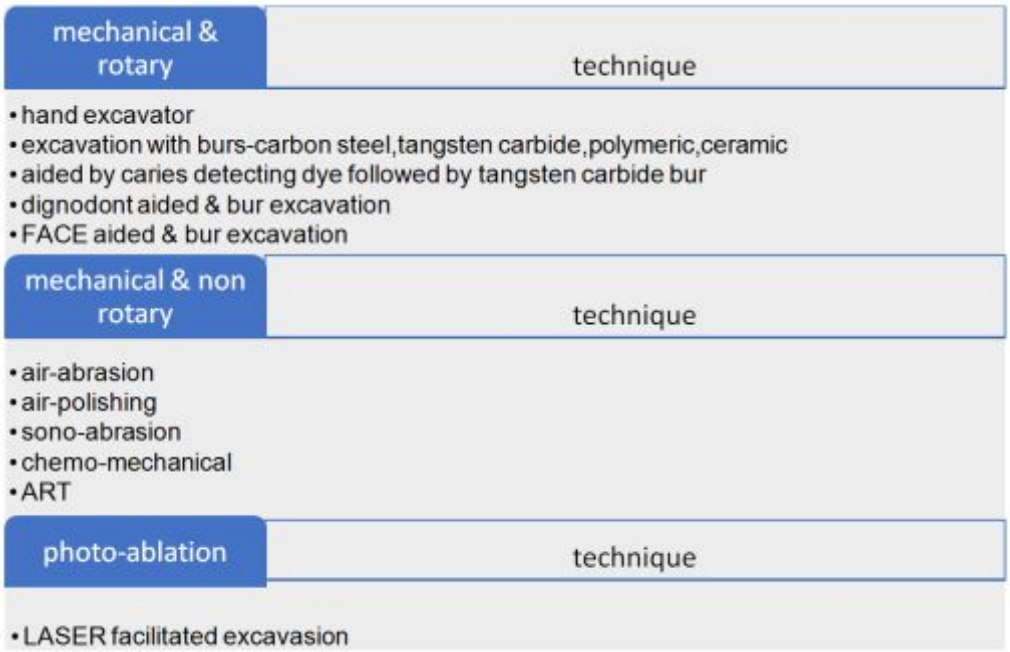

Illustration 3: Categorization of different caries excavation techniques (Adapted from Banerjee et al., 2000)

and/or enamel to arrest the lesion progression and inactivating remaining bacteria

(4) unnecessary pulpal insult should be avoided & if it demands to leave a layer of soft dentin for protection the clinician should not hesitate.

(5) removal should be judicious so that it ensures sufficient remaining tooth structure is available to hold the restorative material & maximize longevity of the restoration.

All these concepts convert the conventional Black's approach of "extension for prevention" to "prevention of extension" & introduce new technique for carious excavation (illustration 3)

1. Mechanical technique using excavator or with hand-pieces & burs-

In general access to the carious tissues is gained either by using the high-speed air motor handpiece and bur, the slow-speed handpiece-bur or by hand excavators. The rotating bur cuts through carious dentine with great ease & open up deeper healthy tubules. Clinician can assess the resultant surface with an explorer & mark sufficient when the surface offers similar hardness as the normal dentin. Though it is one of time saving options there are some problems associated with rotary burs like generation of high temperature at cutting surfaces, annoying noise from air-turbine handpieces, dentin sensitivity etc even using with a water coolant[3]. All of these often end up making over-excavation or unintentional pulpal exposure (Celiberti et al., 2006). This might be overcome to some extent by continuous bur movement over a large surface area and maintaining the bur speed and pressure constant throughout use but complete obsoletion is inevitable. An alternative to conventional tungsten-carbide burs is the polymeric burs that have been introduced with a self-limiting approach. it claims to remove only demineralized dentin & trigger less pain (Dammaschke et al 2006). Smart Prep, burs are commercially available[4]. These burs have unique design in term of cutting edge as they are not spiralled but shovel like straight, when comes in contact with affected/sound dentin, it will wear down & make the final cutting impossible. But studies[5] have pointed out to have more residual caries left in cavities with these polymeric burs when compared with conventional burs (Allen et al.,2005). More clinical trials are needed to establish their efficacy.

When compared with burs, hand excavator removes softened tissue with more sensitive tactile feedback than burs but are more tedious for dentists to perform. Study done by Banerjee et al[6] showed that effectiveness of caries removal was highest with air motor, followed by hand excavation & least by carisolv. However, when efficacy was determined by Ericson et al.[7] findings, out of the three options (stated above) air motor stands highest which is almost comparable to carisolv & least by hand instrument.

2. Fluorescence aided caries excavation-

Fluorescence is the emission of visible light by certain substances as a result of incident radiation that has a shorter wavelength (Lakowicz, 2006). It's relivence in dentistry was found in 1927 when Bommer first reported an orange and red fluorescence from oral biofilm. Since then,

investigations were carried out on auto-fluorescence of dental plaque and carious lesions through ultraviolet or laser irradiation. Koenig and Schneckenburger found that compared to healthy dental tissues, carious lesions showed a distinguished red-orange fluorescence, which indicated the possibility of differentiation between healthy and carious tissue (Koenig and Schneckenburger, 1994)[8]. Metabolites (porphyrins) produced by several types of oral bacteria are thought to be the major contributor to this auto-fluorescence. As it can be used as a marker for bacteria-infected dentine, auto-fluorescence signals have been applied as aid for diagnosing dentine caries and monitoring caries excavation. Based on this principle, a laser fluorescence device (DIAGNOdent - KaVo, Biberach, Germany) was invented for caries diagnosis. This device does not produce an image, instead it displays numerical values ranging from 0 to 99 presenting the intensity of fluorescence. It has been recommended as a promising device for detection of occlusal caries measurement of carious lesions adjacent to orthodontic brackets, detection of recurrent caries and residual caries and so on. In 2002, a novel caries removal system, fluorescence-aided caries excavation (FACE) was described as a direct method to distinguish between outer infected and inner affected carious dentin clinically (Buchalla and Lennon, 2002)[9]. Unlike DIAGNOdent and Er: YAG laser, this system uses fiber-optic violet light (370-430 nm) instead of the red laser as the excitation light. The light source is integrated into a slow-speed handpiece. The operator is allowed to see the fluorescent areas through a yellow glass filter of 530 nm. Only carious dentin emitting red-orange fluorescence is removed selectively, which is much more objective than Caries Detector or the conventional visual-tactile method. Since the introduction, FACE showed the highest sensitivity and specificity as evaluated by confocal microscopy (Buchallaand Lennon, 2002;). Lennon et al in 2007[10] have found that FACE is more effective in removing bacteria-infected dentin without significantly increasing cavity size and requires shorter excavation time, when compared to other excavation methods, including conventional techniques, caries detector dye-aided excavation and chemo-mechanical excavation. In addition, histological investigation has shown samples presenting bacteria after using FACE were significantly fewer than that with conventional excavation method (Lennon et al., 2006b)[11]. However, there is no clinical trial of testing this method until now & need quicker approaches to bring it in clinics.

3. ART

The atraumatic restorative treatment (ART) technique is an alternative approach for outer carious lesions using hand instruments only and subsequently, the cavity is restored with a glass ionomer restoration. It was first developed in Tanzania in the mid-1980s and introduced in remote areas of developing countries, where electricity supplies were limited and dental treatment was not readily available or affordable.

Nowadays, ART is becoming more accepted in developed counties & by children. In clinical practice, noise made by rotary instruments would frighten children, trigger unpleasant memories and cause discomfort. Besides, the needle used in local anaesthesia also induces emotional discomfort, or even physical pain. Consequently, ART is recommended to be a suitable approach to be used in children, the elderly, special needs patients, or patients who have fear and anxiety towards dental treatment.

4. Chemo-mechanical methods-

The idea of using chemicals to assist in caries excavation was first developed in the middle of 1970 by Goldman, an endodontist, while using sodium hypochlorite (NaOCl) in root canal therapy (Goldman and Kronman, 1976)[12]. NaOCl is able to remove the organic materials in the root canals and dissolve the carious dentine tissues. However, as it is too corrosive and decompose non-necrotic tissues, NaOCl was diluted and buffered with sodium hydroxide, sodium chloride and glycine producing a solution of 0.05% N-monochloroglycine (NMG) having a pH of 11.4, which is also known as GK101 (Goldman and Kronman, 1976). The GK101 system was shown to only attack the degenerated collagen fibers and soften the inner layer of carious dentine. After applying the solution onto the caries surface, a special hand instrument is used to scrape the surface and remove the lesion tissues. Later it was found that if the glycine is replaced by aminobutyric acid, the GK101 would be more effective (Schutzbank et al., 1978)[13]. Subsequently, the GK101E, which consists of a freshly prepared aqueous solution of N-monochloro-D, L-2-aminobutyrate (NMAB), was marketed in 1984 as “Caridex” system. The Caridex is a two-bottle system, one of which contains sodium hypochlorite and the other of which contains glycine, aminobutyric acid, sodium chloride and sodium hydroxide. The mixture of the two solutions produces a pH approximal to 11 and is stable up to one hour. Because of the number of disadvantages associated with Caridex system, such as the large volumes of liquid used per cavity preparation and the increased time required, Carisolv (Medi Team Dental, Göteborgsvägen, Sweden) has been introduced as a replacement. It makes use of three naturally occurring amino acids (glutamic acid, leucin and lycine) with different charges, but works equally to the Caridex system (Elkholany et al.,2009)[14]. Compared to the Caridex system, it is simplified into two syringes, one containing sodium hypochlorite (0.5%) and the other containing the combination of glutamic acid, lysine, leucine, carboxymethylcellulose, sodium chloride, sodium hydroxide and a red dye. The mixed gel is

applied onto the caries surface and causes proteolytic degradation of the already partially broken-down collagen in the outer carious dentine, followed by the removal of lesion using specially designed non-invasive instrument. This procedure is repeated until all carious tissues are removed. It does not attack the sound dentin as it is alkaline; hence, over-excavation of the cavity is prevented. After excavation, the cavity dentin is sound or normally calcified without the formation of smear layer compared with the excavation using rotary instruments (Ricketts and Pitts, 2009)[15]. This is beneficial for the enhancement of dentine-adhesive bonding strength to achieve longevity of restorations.

5. Air-abrasion

R B Black in 1945, while investigating an alternative way to conventional caries removal technique accidentally introduced air abrasion when he noticed high-velocity aluminium oxide (carried through a stream of air) upon bombarding abrade the dentinal surface[16]. Efficiency of this cutting instrument depends on various factors like type/size of the abrasive particles, alteration of air pressure, distance between nozzle and cutting surface etc. in general, larger diameter, higher velocity particles transfer more kinetic energy that enhance abrading capability of the instruments. Airdent was the 1st machine available commercially on this technique. lower heat generation, relatively pain free procedures using air-abrasion machine increase their acceptance both from patients & dentists. It has been popularized by the concepts of removing carious dentine selectively that are of equivalent hardness, while healthier, sound tissue remains unscratched. Only drawbacks are loss of tactile sensation unlike mechanical drilling & potential hazard associated with particle inhalation. Recently U.S FDA has approved it as safe on use of 27.5 µm alumina particles[17] though, clinically it fails to ensure complete carious tissue removal as hardness of carious dentin is less than these aluminium particles[18]. So, the micro abrasion technology needs more improvements to overcome its shortcomings & become a successful alternative in the field of operative dentistry.

6. Air-polishing

In this method a specially designed device delivers mechanical abrasive action by a continuous spray of water with dissolved sodium bicarbonate on the tooth surface under air pressure. But due to its non-selective nature overzealous use may attack & remove sound dentin/enamel or restorations especially at cervical region[19]. So, it has been suggested this technique can be used to remove carious dentin at the end of cavity preparation, not particularly during establishing cavity margins.

7. Lasers-

Lasers have already secured its place in dentistry specially in soft tissue ablation. For carious excavation hard tissue laser mainly ER: YAG (with micro second pulse duration) has gained popularity since last few years. It emits electromagnetic rays in near-infrared region which on application to tooth surface, supposed to get absorbed by water molecules between crystals. Water molecules once heats up become vapourisable & directs micro ablation of tooth minerals leads to cavity preparation. Studies claimed less pain or discomfort of patients while using ER: YAG laser[20] though pulpal health evaluation needs more investigations & follow-ups. In future lasers may replace many techniques if it will come with more promising features like shorter pulse duration with minimal residual energy (potential for pulp damage) etc.

Impact of covid-19 on caries excavation: current trend-

COVID-19 possess multiple challenges to all medical stuffs including dentists. Due to the unpredictable clinical course & infectious nature of the disease, access to any intra-oral intervention presents great concern. Minimizing the generation of any kind of aerosols produced in a dental clinic during the use of high-speed handpieces is one of the demands for this situation. So, at present the minimally invasive dentistry (MID) is an alternative approach to caries excavation (including no carious tissue removal to selective removal) considered as low aerosol producing technique. It neither requires local anaesthesia nor the long operating time. There by reducing the discomfort, natural aerosol spread & long wating period for the patients in clinics. There are many professional applications of MID that can be performed in today's situation (illustration 4)

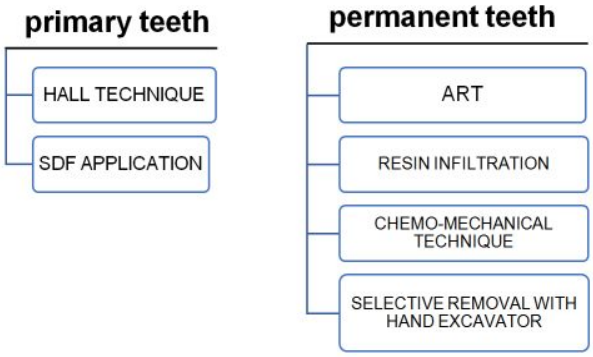

Illustration 4 : Current options with least invasive approach

CONCLUSION

Previously caries excavation aimed at total eradication bacteria from the tooth structure to allow healing of the presumed infection. But now with changes in concepts brings more self-limiting approaches for tissue removal. So, discrimination between what is to be left & what to remove is very important. If it could not be decided, leads to overpreparation of cavities with little control over the quality and quantity of tissue removed by individual operators. All the newer excavation techniques are so plausible based on its own fundamentals are better based on their own advantages. Still their precision of excavation needs more in-vivo investigations to get acceptance in conservative dentistry.

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