MINIMAL-INVASIVE METHODS OF CAVITY PREPARATION

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Abstract

Minimally invasive procedures are the new paradigm in health care. Everything from heart bypasses to gall bladder, surgeries are being performed with these dynamic new techniques. Dentistry is joining this exciting revolution as well. Minimally invasive dentistry achieves the treatment objective using the least invasive surgical approach, with the removal of the minimal amount of healthy tissues. This paper reviews in brief, the concept of minimal intervention in dentistry.

Keywords –Laser, Ozone therapy, Air abrasion, Micro retention.

1. Introduction

Minimally intervention dentistry (MID) adopts a philosophy that integrates prevention, remineralisation and minimal intervention for the placement and replacement of restorations. The objective is tissue preservation, preferably by preventing disease and intercepting its progress.This means performing treatment with as little tissue loss as possible. It expresses a very precise excision of what has to be removed, without causing any damage to adjacent tissue.

With the new techniques available[1](digital radiology with low radiation emission, diagnostic laser and the dental operative microscope) we can aim for both an early diagnosis and a minimally invasive therapy (ozone therapy, air abrasion, rotary instruments for micro preparation and the laser.[2]

2.Discussion:

The rules for cavity preparation were invented in the late 1800’s by Dr.G.V.Black, the father of modern dentistry.[3] Among the foremost of his rules was the concept of “extension for prevention”. The idea was to pre-empt the possibility of further decay on the surface of the tooth already afflicted with caries. The act of making a restoration therefore usually involved the removal of a substantial amount of tooth structure, more than was actually decayed. Hence, a lot of healthy tooth was destroyed in the process.

The minimally invasive approach in treating dental caries incorporates the dental science of detecting, diagnosing, intercepting and treating dental caries at microscopic level. This approach has evolved from an increased understanding of the caries process and the development of adhesive and biomimetic restorative materials. With minimally invasive dentistry, dental caries is treated as an infectious condition rather than an end product of it.

Now no longer radical "extension for prevention" is practised but has changed to "constriction with conviction".

A recent policy document produced for the World Dental Federation suggested that there are four basic principles that must be applied to fulfill the description of minimal intervention dentistry:

1. Control the disease through reduction of cariogenic flora.

2. Remineralise early lesions. Perform minimal intervention surgical procedures, as required.

3. Repair, rather than replace defective restorations.

It is suggested that these principles be followed in the modern times to deal with dental caries. Minimal intervention is a practice builder that can be implemented under three heads: Identify, Prevent and Control.

Risk Assessment

On the basis of risk development of caries, patients can be assessed and categorised into:

Low Risk

1. No caries in last 3 years

2. Coalesced or sealed pit and fissure

3. Good oral hygiene

4. Appropriate fluoride use

5. Regular dental visits

Moderate Risk

1. One carious lesion in last 3 years

2. Deep pits and fissures

3. Fair oral hygiene

4. White spots/ interproximal radiolucencies

5. Inadequate fluoride exposure

6. Irregular dental visits

7. Orthodontic treatment

High Risk

1. ≥2 carious lesions in last 3 years

2. Past smooth surface caries

3. Deep pits and fissure

4. No/little fluoride exposure

5. Elevated S. mutans count

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6. Poor oral hygiene
7. Frequent sugar intake
8. Inadequate saliva flow
9. Irregular dental visits
10. Inappropriate bottle feeding or nursing (infants)

Prevention Options for Risk Categories:

High Risk Category

1. Educational reinforcement
2. Brush with fluoride dentifrice
3. Restorations
4. Home fluoride (mouth rinse/1.1% NaF gel)
5. Professional topical fluoride at each visit

3-6 Months Recall

1. Dietary counselling
2. Monitoring s.mutans count
3. Antimicrobial agents
4. Fluoride supplements

Moderate Risk Category

1. Educational reinforcement
2. Brush with fluoride dentifrice
3. Restorations
4. Professional topical fluorides

6- 12 Months Recall

1. Dietary counselling
2. Fluoride supplements
3. Remineralization

Low Risk Category

1. Educational reinforcement
2. Maintenance of good oral hygiene
3. Fluoride dentifrice
4. Recall after every 6- 12 months

Remineralising Agents

1. Casein Phosphopeptide- Amorphous Calcium Phosphate (CPP-ACP): Researchers from the University of Melbourne have identified CPP as an anti caries component of milk, the remineralisation effect of 0.5- 1.0% of CPP-ACP solution being equivalent to 500 ppm of fluoride. CPP- ACP binds readily to the surface of the tooth, under acidic conditions, this localized CPP- ACP buffers the free calcium and phosphate ions, substantially increases the level of calcium phosphate in plaque and, therefore, maintains a state of supersaturation that inhibits enamel demineralisation and enhances remineralisation.[4]

2. Combination of CPP-ACP and fluoride: There are many studies indicating a synergism in remineralising potential when CPP-ACP is combined with fluoride.

3. Novamin: Chemically known as calcium sodium phosphosilicate. The compound is a bioactive glass composed of minerals naturally occurring in the body and reacts when it comes into contact with water, saliva, or other body fluids. This reaction releases calcium, phosphate, sodium and silicon ions resulting in the formation of new hydroxycarbonate apatite. The products containing this unique formula today have desensitization as their prescribed use and are available in the form of tooth pastes, varnishes and a root desensitizer .

4. TiF4 technology: Titanium ion can readily hydrolyzeH_2O (as compared to Sn) to expel proton (H+) and render the low pH value. This is because, TiF4 solution is very acidic. This great affinity of titanium ion to oxygen imparts a strong tendency to form titanium phosphate complex (i.e., titanium ion reacting with the oxygen atom of the phosphates of the tooth structure). The bond of the complex thus formed is so strong that it is not easily substituted by protons (H+) even at low pH (pH,1) thereby rendering the altered tooth surface more resistant to demineralization.[5]

5. Resin infiltrant technology: Combining this ultraconservative restorative approach (which is considered microinvasive) with a substantial caries remineralisation program may provide therapeutic benefits and significantly reduce both long-term restorative needs and costs, thus complementing the concept of minimal intervention dentistry.

6. Tri calcium phosphate: Tricalcium phosphate has the chemical formula $Ca_3(PO_4)_2$, and exists in two forms, alpha and beta. Alpha TCP is formed when human enamel is heated to high temperatures and is relatively insoluble in aqueous oral environment. Particles of TCP or TCP cements can be coated with sodium lauryl sulphate (SLS) or other surfactants. It has been suggested that the organic coating prevents undesirable interactions with fluoride, but may dissolve away when particles contact saliva.

7. Nano hydroxyapatite: Nano-hydroxyapatite (n-HAp) is considered one of the most biocompatible and bioactive materials and has gained wide acceptance in medicine and dentistry in recent years. Nano-sized particles have similarity to the apatite crystals of tooth enamel in morphology and crystal structure. $ZnCO_3$ and nanohydroxyapatite combination is also equally effective.[6]

8. Enamelon: Enamelon consists of unstabilized calcium and phosphate salts with sodium fluoride. The calcium salts are separated from the phosphate salts and sodium fluoride by a plastic divider in the centre of the toothpaste tube. An inherent technical issue with Enamelon™ is that calcium and phosphate are not stabilized, allowing the two ions to combine into insoluble precipitates before they come into contact with saliva or enamel.[7]

Minimal intervention techniques:

Chemomechanical Cavity Preparation

Chemomechanical elimination of carious dentin has so far been promising particularly in pediatric dentistry especially for anxious or medically compromised patients. This new method of treatment involves the chemical softening of carious dentine followed by its removal by gentle excavation. It can also be applied to patients where the administration of local anaesthesia is contraindicated, since local anaesthesia is not necessary for 82-92% of the patients with this technique.

The indications for using chemomechanical caries removal are exposed buccal lesions, cervical or root caries, very deep carious lesions[8](potential pulp exposure may be reduced) as well as the treatment of the uncooperative paediatric patient or the older, frightened child.

Contraindications include sessions that necessitate short treatment time and pit and fissure caries that are not deep where rotary preparation will suffice to remove caries with little discomfort and the removal of hard eburnated part of the lesion.

Preparations Available for Chemomechanical Cavity Preparation

1. Caridex- Though currently obsolete, Caridex™ was developed from a formula made of N-monochloroglycine and amino butyric acid. It was presented as a two-bottle system: the first contained sodium hypochlorite and the second, glycine, aminobutyric acid, sodium chloride and sodium hydroxide. Both solutions were mixed immediately before use to give the reagent with a pH approximately equal to 11 that was stable for one hour.[9]The delivery system of Caridex consisted of a reservoir for the solution, heater and pump which passed the liquid warmed to the body temperature through a tube to a hand piece and applicator tip (20 gauge hypodermic needle, the tip of which had been modified into spoon shape). However, the unpleasant taste and the lengthy procedure (10-15min), in addition to the large volumes of solution needed (200-500ml) and the fact that the delivery system was no longer commercially available, limited the use of caridex clinically.

Carisolv- is available in two forms

1. Single mix system- A new, modified gel has been developed. The original Carisolv™ red gel contained three differently charged amino acids which were mixed with sodium hypochlorite prior to treatment.It contains half the concentration of amino acids and a higher concentration of sodium hypochlorite 0.475%.

The system is available as 5 transparent syringes containing an uncoloured gel and 5 white syringes containing transparent liquid.

(a) The uncoloured gel contains: amino acids (glutamic acid, leucine, lysine), sodium chloride, Na-CMC 1300-2200 mPas, purified water and sodium hydroxide, pH 11.

(b) Hold the syringes with their openings upwards. Remove the corks, keep the syringes upright and screw them together.

(c) Mix the liquids by pressing alternately on the ends of the syringes until the liquids are homogeneous. Press all the liquid into one of the syringes.

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(d) Pour the mixed liquid into a suitable container or keep it in the transparent syringe and apply it to the cavity using a cannula with a Luerlock.

(e) Drops of the gel are removed from the container with a Carisolv™ instrument and applied to the carious dentine. Make sure that the carious lesion is thoroughly soaked by the gel.

The transparent liquid contains: sodium hypochlorite solution 0.95%.

2. Multi mix system- Twin syringe containing an uncoloured gel, 1.7 ml, and a transparent liquid, 1.7 ml. Remove the end cap and hold the syringe upright. Attach the plunger and carefully push out the fluids and empty them into a suitable container. The end cap should be replaced immediately.[10]

Mix the fluids well to produce a homogeneous solution using an instrument. Replace the end cap as quickly as possible. Once the gel has been mixed, its effect will begin to decline after about 30 minutes.

Mode of Action- The softening effect on the carious tissue is the result of several reactions that act in concert to disrupt the fiber structure of collagen. The three amino acids are differently charged, which allows for an electrostatic attraction to different areas of the proteins in the carious dentine. The peptide chains of all proteins, including collagen, are made up of hydrophilic (positively or negatively charged) and hydrophobic (non- charged) patches. So each of the three chloro-amino acids in Carisolv® electrostatically attract one of these patches, effectively bringing reactive power to the full length of the collagen fiber, while minimizing unwanted side-reactions from hypochlorite.

The chemical result of these processes is a breakdown of degraded collagen characteristically found in the demineralised portion of a carious lesion. The gel only softens the carious dentine, while healthy tissue is unaffected. The degraded collagen has an open structure and is therefore more susceptible to penetration by CARISOLV and this dentin can be easily scraped off.

Disadvantages: i) extensive training and registration of professionals and (ii) customised instruments which increased the cost of the solution.

Papacarie- In 2003, a research project in Brazil led to the development of a new formula to universalise the use of chemo-mechanical method for caries removal and promote its use in public health. The new formula was commercially known as Papacarie®.

Papain acts only in the necrotic tissue due the occurrence of a plasma antiprotease, 1-antitrypsin, which prevents the action of proteolytic papain in normal tissues. The infected tissue did not present the 1-antitrypsin. Hence papain acts to degrade the denatured collagen molecules.

Formulation- The Papacárie ® is presented in the form of a gel containing papain 10%, chloramine-T 0.5%,thickener and toluidine blue.

Papain Gel Application Procedure

Use of papain gel for caries tissue removal must be as follows- (1) Dental prophylaxis using a rubber cup, pumice and use of rubber dam. The application of Papacárie is done for 30s in acute caries and 40 to 60s in chronic carious lesions. After this period, the softened infected dentin is removed with a blunt instrument manually. If all carious tissue has not been removed, the gel is reapplied until the cavity presents with a glassy finish. After this phase, it should be washed, dried and restoration is completed.

No need to rinse the cavity between applications. There are still few studies in the literature about Papacarie. However, the results available seem promising with regard to its biocompatibility, removal of caries, antimicrobial effect, reducing the use of anaesthetic and acceptance by patients. Studies also show that the results are similar to Papacárie with the use of Carisolv.

Air Abrasion- Air abrasion was originally developed by Robert Black in 1945 as an alternative pseudo-mechanical method for dental tissue removal and the first air abrasion unit marketed was called the Airdent by SS White.[11]

This technique involved bombarding the tooth surface with high velocity aluminum oxide particles (Alumina) carried in a stream of air. Recently, several new air-abrasive cutting instruments have been introduced; such systems utilize air pressure of 7-11 atm with alumina powder ranging 27-50 μm to cut dental tissue. This method of cutting is relatively painless.However, the total loss of tactile sensation and the ability of alumina particles to remove sound tooth structure rather than the carious substrate in addition to the potential risk of inhalation should also be considered at the time of selection. The water jet helps the abrasives not to escape far from the operating field; however, the detrimental surface attack of sound tooth structure could be the result of non-selective nature of this procedure. So, several researchers suggested the use of this technique only for removing carious dentine at the end of cavity preparation.

The powder volume to air volume ratio- "The correct proportion of powder volume to air volume exiting the nozzle is of elemental importance, if successful tooth reduction is to take place at all air pressures. Furthermore, for each air pressure and each nozzle diameter chosen, there is an ideal powder volume. This powder volume is generally from 0.8 to 1.4 grams/minute powder flow rate. If the abrasive flow rate can be maintained and adjusted to stay within this range, maximum performance will be achieved at any and all air pressures utilized.

Dr. G.V. Black regarding patient sensitivity noted that air pressures as low as 35 PSI needed to be utilized if patient comfort was to be maintained. Also, the range of operating pressures was maintained between 35 and 75 PSI.[12]Low air pressure is the principle of this modality. In order to remove carious dentin at low air pressures, powder should be metered accurately into the air stream so that the ratio of powder volume to air volume remains in the desired window. Should the air stream become too rich or lean with powder, then the cutting performance will be severely hampered and this "dysfunctional" abrasive stream does nothing but lowers pulpal temperature, which in turn creates a pain response from the patient.

Contraindications- It should be avoided in cases involving severe dust allergy, asthma, chronic obstructive lung disease, recent extraction or other oral surgery, open wounds, advanced periodontal disease, recent placement of orthodontic appliances and oral abrasionsor subgingival caries removal. Many of these conditions increase the risk of air embolism in the oral soft tissues.

Ultrasonic Instrumentation- High frequency ultrasonic vibrations have been recommended since the 1950s to remove proximal carious lesions in both anterior and posterior teeth, with the aim of achieving a more conservative cavity preparation. This technique does not physically excise the dentine, but abrades it using a diamond-coated tip oscillating at a frequency of about 6.5 kHz ranging to a maximum frequency of 20-40 kHz.

Recently, sono-abrasion has been developed as a modification of the original ultrasonic method. Sono-abrasion is a technique for the selective preparation of enamel and dentine offering excellent efficacy, quality and safety. This technique utilizes high frequencysonic air-scalers with modified abrasive tips. Whichare diamond coated on the cutting side, cooled using water at a flow rate of 20-30 ml/min and operated by 305 bar air pressure for cavity finishing.

Using the different shapes of the tips helps in preparing predetermined cavity outlines and also works well in removing softened, carious dentine.

Advantages- The ultrasonic procedure has the advantage of minimising or eliminating noise, vibration, heat and pressure. The use of the ultrasonic technique can be helpful to modify the approximal preparation procedure in order to protect adjacent teeth against iatrogenic damage caused by the use of dental burs.

Disadvantages-Low abrasion and high hub excursion of the tips and the weakening of enamel rods with the associating cracks adjacent to the prepared sites.

Ozone- During the last few years, reversal of caries using Ozone has also been suggested based on the fact that the remineralised tooth tissues are known to be more resistant to decay than sound tooth structure. Ozone therapy causes remineralisation of incipient pit and fissure caries as well as incipient root caries. Its usefulness in open lesions has also been demonstrated.

Ozone readily penetrates through decayed tissue, eliminating the ecological niche of cariogenic micro-organisms as well as priming the carious tissue for remineralisation. As ozone readily penetrates through decayed tissue, eliminating any bacteria, fungi and viral contamination, it would be expected that this ‘clean’ lesion would remineralise. The remineralisation process will then take place with the aid of a topically applied remineralising solution and the recommended patient’s maintenance kit. Ozone has the effect, through its powerful oxidizing properties, of not only removing the protein protection and being bactericidal, but also oxidising the biomolecules that allow the niche to survive and expand. For example, the acid Pyruvate, one of the strongest naturally occurring acids manufactured by bacteria, and implicated in the progression of caries, is oxidised by ozone to acetate acid and carbon dioxide. Acetic acid is less acidic than pyruvate, and this de-carboxylation reaction leads to mineral uptake due to the more alkaline conditions in a carious lesion. The lesion will become populated with normal mouth commensals which do not produce acid, after ozone therapy.The loose debris is first cleaned away, until a leathery base is reached. This can be done with hand instruments. Ozone is applied, the lesion wetted with a remineralising wash and then the glass ionomer (Fuji VII) can be applied. This modified ART technique has been reported by Holmes.

This simple fast novel approach avoids the need for local anaesthesia, drilling and filling, however, its application is restricted to treat the superficial enamel and root caries.Heal Ozone was the first dedicated dental ozone unit. With the advent of new units with different delivery systems, dental treatment with ozone has become fast, predictable, and has now expanded into every facet of dental care. It must be stated that ozone is a substance that needs to be carefully controlled, as high concentrations at ground level have been known to cause respiratory distress.

Systems and Clinical Procedure- There are various dental ozone devices available (for example, the Heal Ozone and DentOzone unit.)[14]Both these dental ozone units deliver ozone gas at pre-set concentration. At the end of a 30 to 60s ozone exposure, a mineral wash is placed over the treated area to kick-start the remineralisation process. Once ozone treatment has been completed, the patient is sent away with an ‘at-home care kit’.

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One important factor that needs to be remembered is that during the initial stages, the treated areas of decay will be relatively soft and will not support any restoration. Therefore, if a restoration is planned after ozone treatment, it should be planned at the review appointment at 2-3 months after the initial ozone treatment by which time, the research data suggests, the remineralisation process will be well advanced, the lesion static and reversed, and the tissue hard enough to support a transitional restoration.

Lasers: After a period of uncertainty concerning the use of lasers in dentistry at the end of the 1990s, three wavelengths available for clinical use in hard dental tissue management were developed.[13]These included the

1. Erbium:yttrium-aluminum-garnetEr:YAG (λ =2.94µm)

2. Erbium-chromium:yttrium-scandium - gadolinium-garnet Er,Cr: YSGG, (λ = 78µm)

3. Er:YSGG (λ =2.79µm).

Clinical applications

Lasers are found to be effective in cavity preparation, caries removal, restoration removal, etching and treatment of dentinal sensitivity, caries prevention and bleaching. Based on developments in adhesive dentistry and the propagation of minimum intervention principles, lasers may revolutionise cavity design and preparation.

Caries prevention

The laser irradiation of dental hard tissues modifies the calcium to phosphate ratio, reduces the carbonate to phosphorous ratio and leads to the formation of more stable and less acid soluble compounds, reducing susceptibility to acid attack and caries.

Rezaei Y et al., have indicated that enamel surfaces exposed to laser irradiation are more acid resistant than non-laser treated surfaces. However, the actual mechanism of acid resistance by laser irradiation is still unclear. The threshold pH for enamel dissolution is reportedly lowered from 5.5 to 4.8 and the hard tooth structure is four times more resistant to acid dissolution.

The combination of lasers and fluorides seem to be very promising in caries prevention. It was stated by Flaitz CM et al., that the application of acidulated phosphate fluoride (1.23% gel for 4min) before or after argon laser exposure resulted in a significant reduction in lesion depth when compared with argon laser alone or other methods. Comparable results were obtained in another study by Zezell DM et al., showing that treatment with APF solution after irradiation with a Nd:YAG laser caused a remarkable increase in acid resistance of the enamel.

Caries Removal

Carious material contains a higher water content compared with surrounding healthy dental hard tissues. Consequently, the ablation efficiency of caries is greater than that for healthy tissues. In an in-vitro study conducted by Bader C and Krejci I, it was found that the Er: YAG laser ablated carious dentin effectively with minimal thermal damage to the surrounding intact dentin.

Cavity Preparation

Utilisation of the Er:YAG laser has been considered an effective instrument for cavity preparation and is able to cut as high-speed turbines, stimulate the secondary dentin and have an antibacterial effect. The radiation with Er:YAG laser may modify the dentin structure as it removes the smear layer of the dentin and exposes the dentinal tubules, which theoretically makes the surface more favorable to adhesion with the adhesive systems and thereby improving sealing of the restorations.

According to Vissuri et al., and Groth et al., it is able to provide acceptable microretention for adhesive materials, roughening the dentin similar to acid-etching.

3.Conclusion

"The preservation of that which remains is of utmost importance than the meticulous replacement of that which has been lost."

It is not possible to really imitate natural tooth structure on a long term basis, so it is best that it should be retained as far as possible. Now the profession has a better understanding of prevention of dental disease, with the advent of adhesive and bioactive restorative materials but there is reluctance in a wide group of dental professionals to use these materials and techniques. The reasons can be traced to lack of knowledge and adequate training for use of these procedures. Moreover, cost of the equipment and the consumable materials and items also becomes a deciding factor for most practitioners. But what needs to be put into perspective is that these techniques and materials are not only true to the philosophy of "patient centred simplification" but also are practice builders. The future of remineralisation dentistry lies in the development of agents that have the capability to remineralise dentinal lesions as well as smart biomimetic materials to restore the lost tooth structure by shifting the equilibrium towards remineralisation.

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