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Minimally Invasive Cavity Preparation Techniques

Sameerah Jameel Tarfa*, Mohammed Rashid Al Jubouri

Department of Restorative and Aesthetic Dentistry, College of Dentistry, University of Baghdad, Iraq

ABSTRACT

Regardless of the reality that the preponderance of dental caries has declined in recent decades, it represents the most common disease internationally. The conventional operative treatment of the dental caries was based on the removal of carious lesions along with sound dental structures in order to provide mechanical retention for restorative materials that were used at that time. With the current understanding of the caries process and the advancement of adhesive restorative materials, this type of intervention is considered a devastating method and should not be performed. A few decades ago, the concept of Minimally Invasive Dentistry (MID) was introduced and it advocates the selective removal of carious lesions while at the same time preserving intact tissues. The main MID pillars are early diagnosis, disease prevention and minimal surgical intervention for the cavitated lesions. This paper aims to provide a brief review of the existing literature about minimally invasive dentistry principles, different types of minimally invasive cavity preparation techniques and some of the advantages and disadvantages of these techniques.

Key words: Minimal invasive dentistry, Chemomechanical caries removal, A traumatic restorative treatment, Antibacterial photodynamic therapy

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Corresponding author: Dr. Sameerah Jameel Tarfa
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INTRODUCTION

Dental caries can be defined as a localized degradation of tooth structures by the bacteria in the dental plaque that ferment the carbohydrates and then produce acids that are in turn responsible for this degradation. It's a multifarious disease that is triggered microbiologically by biofilm changes and is influenced by the following variables: Oral hygiene, fluoride exposure, salivary contents and stream and sugar intake frequency [1]. Regardless of the reality that the preponderance of dental caries has declined in recent decades, it represents the most common disease internationally. Dental caries has a remarkable influence on the international clinical and economic load [2]. Several approaches have been utilized in the excavation of the infected dental structures to prohibit dental caries advancement. After the excavation of the infected tissues, the cavity must be filled with a suitable restoration. "Fillings are not permanent," as all dentists are aware. By the time they become weakened and damaged, which leads to the development of micro leakage, the smaller restorations have to be changed with larger ones. As a result of this type of intervention, more sound dental structures will be excavated every time the restoration replacement needs to be done [3]. In contrast to the past, dental practitioners are now able to treat dental caries with minimally invasive and ultraconservative techniques due to our improved comprehension of dental caries and the advent of dental materials; the traditional surgical methods that reflected the principle of how to provide dental treatment have evolved into the modern approach termed "minimal intervention dentistry". MID pillars include early identification and disease prevention, accompanied by minimal surgical intervention. MID is a method that tries to preserve tooth functionality as long as possible [4]. MID entails the removal of densely infected and irrevocably denaturized dentin tissue in a selective manner to aid in the preservation and remineralization of dental structures. The soft and moistened decayed dentin lesions should be excavated because they contain the majority of bacterial aggregation. The excavation procedure should be continued to the point where the tissue is felt to be hard enough and this will indicate the presence of demineralized dentin, which has the remineralization capability [5]. Cavity preparation concepts have evolved far beyond the suggested principles of Dr. GV black, the father of operative dentistry, with his most famous quote, which says the "extension for prevention" in the excavation of caries lesions with the removal of intact dental tissues for retentive purposes. Because at that time, dental caries disease was not fully understood as it is now and the limitations in the dental materials required this type of intervention, which is regarded as a devastating method in caries management [6]. The fundamentals of cavity preparation have evolved as a result of adhesive techniques. Retentive measures can be decreased to a minimum by preserving the dental tissues that were previously excised for retentive objectives. The saucer shaped cavity design is a modern method of non-carious tooth preservation that makes great use of the adhesive technique. The preparation of the tunnel cavity constituted a novel approach to the management of carious lesions in the molars and premolars to preserve the integrity of the marginal ridges. In primary approximal caries lesions, the tunnel preparation filled with glass ionomer cement is not a typically satisfactory alternative [7,8]. Dr. Robert black invented the air abrasion technology in 1945. He established this system in an effort to overcome the drawbacks of slow rotary hand pieces at that time. Unfortunately, the clinical applications of this technique had been reduced because of the innovation of the high speed turbine. In recent years, the air abrasion technique has been reactivated with the launch of the “MID” concept [9,10]. Since the 50’s of the past century, ultrasonic and sonic systems have been used to excavate carious lesions in a less traumatic and less invasive manner. They can be used, especially when patient apprehension is expected regarding dental treatment [11] in the 1950’s. A German dentist, EA Fiseh, pioneered the use of ozone therapy in dental practice. Ozone therapy is considered one of the minimal intervention treatment modalities in the caries management of the pitted and fissured tooth surfaces as well as proximal and root caries [12]. In the 60’s of the past century, with the first development of the laser, the dentistry world has witnessed a great focus on its applications in dental practices, especially in caries management and cavity preparation. Multiple laser devices have been launched onto the market with comparable wavelengths [13]. In the 1960’s, Antibacterial Photodynamic Therapy (APDT) has been started when Macmillan utilized a photosensitizer chemical called toluidine blue to combat the bacteria. He noticed that 99% of the bacteria were destroyed during a half hour of radiation from the light source at 632 nm from a “continuous wave gas laser” [14]. In the mid-1980’s Atraumatic Restorative Treatment (ART) was started to provide dental caries treatment for children in low income countries. This method relies on the use of hand instruments and adhesive fillings alone [15]. In the 1976’s, the chemo mechanical caries removal approach was started with the first agent, which was named GK-101, because of its drawbacks, including the pain experience, time consuming procedure and the necessity to use the burs. The GK-101E (caridex) was developed in 1984 to overcome these drawbacks, but unfortunately, both of them were not effective in caries removal. In 1998, Original carisolv red color gel was launched onto the market [16]. And later on, the launch of modified new carisolv colorless agents to aid in the softening and excavation of carious dentin ultra-conservatively using hand instruments [17]. In spite of its performance, carisolv has some drawbacks, including the need for significant training and a specialized instrument that raises the overall cost of the treatment. As a result of these issues, its use was restricted. In 2003, a new product known as papacarie was created in Brazil to address the drawbacks of Carisolv [18]. In 2003, a new type of bur known as a polymer bur (Smart Prep) was introduced to excavate the carious dentin lesions in a selective manner without removing the intact dentin structure [19].

Minimal invasive dentistry principles: The following principles should be considered regarding caries management:

- Early caries diagnosis.
- Classification of caries depth and progression.
- Assessment of individual caries risk.
- Optimal caries preventive measures.
- Remineralization of early lesions.
- Minimally invasive cavity preparation techniques.
- Repair rather than replacement of the defective restoration [20,21].

LITERATURE REVIEW

Early caries diagnosis

Diagnosing caries involves more than just detecting the carious lesion. The assessment of caries activity is more critical and can be a challenge. Keeping in mind that caries activity cannot be detected simultaneously, it should be monitored over a long period of time. In most cases, radiographs and clinical findings are employed to establish this determination [20]. X-ray radiography represents the earliest and most dependable method since its development to detect dental caries, especially in the proximal area of the tooth. But it is undependable when it comes to occlusal caries diagnosis, especially in the enamel and outer one third of dentin [21]. But new diagnostic technologies are on the rise. When it comes to occlusal decay, there are a number of different procedures that may be used to detect it. Some of the more recent technologies used in dentistry include “laser fluorescence”, “tuned aperture computed tomography” and “optical coherence tomography”.

Classification of caries depth and progression

In 1997, Mount GJ and Hume WR developed a modern classification for carious lesions in contrast to Dr. GV black's old classification. This novel classification enables the dental practitioner to identify the location, size and complexity of the cavity while simultaneously encouraging a conservative approach to aid in the preservation of intact dental tissues. It is intended to enhance the enamel and dentin capability for healing [22]. Table 1 the current understanding of preventive measures such as disease control and remineralization of dental tissues should encourage dental practitioners to leave the old black classification that was dependent on “extension for prevention” to a contemporary classification that relies on caries treatment by minimal surgical intervention and maximum conservation of dental tissues unaffected by the disease process [23].

Table 1: New classification of caries depth and progression.

Site/Size	Site 1: Pit and fissure	Site 2: Proximal surfaces	Site 3: Cervical surfaces
Minimal	1.1	2.1	3.1
Moderate	1.2	2.2	3.2
Large	1.3	2.3	3.3
Extensive	1.4	2.4	3.4

Mount GJ and Hume WR classification [22].

Assessment of individual caries risk

Caries risk is described as "the probability of future caries disease development". Dental caries can be classified as primary caries, which means a new carious lesion, or secondary caries, which means a progression or reactivation of a carious lesion [21].

Patient's assessment and classification based on their risk of developing caries

Low risk: There have been no cases of caries in recent years, coalesced or plugged fissure and pit, maintaining proper oral hygiene, appropriate fluoride application, dental examinations on a regular visit [24,25].

Moderate risk: There has been one carious lesion in the previous year, deep fissures and pits, adequate oral hygiene, white spots, Radiolucencies in the proximal area, insufficient exposure to fluoride, and inconsistent dental visits.

High risk: Two or more carious lesions with in the last three years, caries on smooth surfaces in the past. Deep fissures and pits. No/minimal exposure to fluoride. Low oral hygiene. Frequent sugar consumption. An insufficient flow of saliva. Inconsistent dental visits [24,25].

Optimal caries preventive measures

Early carious lesions can be reversed by diet modification and eradication of dental biofilm. These measures have a positive impact by reducing the need for surgical intervention and making it restricted to severe cases when the destruction goes beyond the remineralization process. Dental caries can be prevented by applying multiple measures that include: Combating the microorganisms that induce caries, diet modification and raising the resistance of dental tissues to decay [26].

1) **Combating the microorganisms that induce caries:** Antibacterial solutions have been recommended, such as mouthwash, with the purpose of lowering cariogenic bacteria. Chlorhexidine digluconate (CHX) is a widely utilized antimicrobial agent due to its capacity to drastically lower the number of cariogenic microorganisms in the oral cavity [27,28].

2) **Diet modification:** The majority of initiatives to reduce sugar intake in the community are ineffective. The same association has been discovered in other countries among caries preponderance, sugar intake and extensive use of fluorides [29].

The diet modification can be achieved through some of the following strategies:

a) Cheese consumption is important because it contains calcium phosphate, which neutralizes the acidic environment caused by sugar intake.
b) Sugar substitutions, including a large number of sugar types with minimal or no cariogenic effect, such as xylitol and sucralose [26].

3) **Raising the resistance of dental tissues to decay:** This can be achieved by using fluorides, pit and fissures sealant treatment methods to strengthen the teeth, while lowering sugar exposure, which has an effect on the cariogenic bacteria and acid formation in dental plaque [30].

Remineralization of early lesions

The remineralization of enamel can happen when the pH level is elevated and the supersaturation condition is regained, through which the enamel can recover some of the minerals that were lost by the demineralization process. Both biofilm fluid and saliva contain calcium and phosphate, which can be redeposited in the enamel after the biofilm removal by tooth brushing. But the amount of calcium and phosphate that can be regained is less than what was lost [31]. So various agents can be used to achieve the remineralization of early lesions, these agents are Casein Phosphopeptide Amorphous Calcium Phosphate (CPP-ACP), a combination of CPP-ACP and fluoride, TiF_4 technology, Tricalciumphosphate, Nanohydroxyapatite [24].

Minimally invasive cavity preparation techniques

The quest for an inoffensive, painless and ultraconservative approach to caries removal has resulted in the evolution of procedures that focus exclusively on removing only the carious dentin tissue that has been infected by the bacteria and irrevocably demineralized. Unfortunately, there are still issues with determining the caries eradication target, as it is unlikely to be clinically attainable [19]. During the cavity preparation, these principles should be followed to match the MID philosophy: Entrance to the carious lesion with less devastation, excavation of the dental tissues that have been damaged and are not capable of rejuvenation, preserving and supporting the intact enamel structure that has been undermined, minimizing the restoration boundary and occlusal stress reduction on the ultimate restoration [32].

The following techniques are used in minimally invasive cavity preparation.

1) Mechanical high/low speed rotary systems.
   a) Fissurotomy burs.
   b) Polymer burs as (smart burs).
2) Chemomechanical cavity preparation systems.
   a) Application of carisolv agent.
   b) Application of papacarie agent.
3) Air abrasion.
4) Ultrasonics and sono abrasion.
5) Atraumatic Restorative Treatment (ART).
6) Ozone therapy.
7) Laser application.
8) Antibacterial Photodynamic Therapy (APDT).

Mechanical high/low speed rotary systems

For the purpose of cavity preparation, two types of bur will be discussed in this section.

Fissurotomy burs: They are used particularly for pit and fissure dental caries treatment. The head length of these burs is 2.5 mm, which allows the dental practitioners to remove dental tissues just below the Dentino Enamel Junction (DEJ) and no more. Hence, their use is confined to the enamel structure. The tapered shape of these burs permits the cutting tip to confront fewer dentinal tubules. The flowable composite is considered a suitable restorative material to fill this type of cavity preparation [33]. The burs tips are tiny and more conservative than those of a ¼ round bur. The head length of fissurotomy original and fissurotomy micro NTF is 2.5 mm, whereas the head length of fissurotomy micro STF is 1.5 mm. The fissurotomy original and micro NTF burs can be used to remove caries conservatively and ultra-conservatively, respectively, from molar pits and fissures, while the fissurotomy micro STF can be used for deciduous teeth, permanent premolars and enameloplasty [34].

Advantages

Fissurotomy burs have many advantages including the following:
Often time without local anesthesia, low heat generation and vibration, fast treatment procedures associated with using these burs, familiar instruments to dental practitioners that do not demand the incorporation of a new device and enhancement of patient comfort [33,34].

Disadvantages

Fissurotomy burs have a few disadvantages including the following:
Exorbitant price must be used in conjunction with proper restorative materials [34].

Polymer burs as (SmartPrep)

The development of a specific form of bur employing amedical grade poly ether ketone-ketone has resulted in the emergence of this bur, which is a rotary instrument designed for minimally invasive cavity preparation. Which excavate carious dentin in selective manner without removing intact dentin tissues? [19,35].

This feature is based on the differential hardness of this bur being lower than intact dental tissues [19,35]. The hardness of intact dentin varies from (51-65) Knoop Hardness (KHN). Deeper dentin is softer than superficial dentin. The active carious lesion has an average of 6.7 KHN, while the arrested carious lesion has an average of 39.2 KHN. Consequently, a dentin caries removal instrument with 50 KHN had to be developed. Based on the aforementioned findings, polymer burs (SmartPrep) was synthesized and introduced in 2003 with 50 KHN, which is between the hardness of intact and carious dentin, as a result, the cutting edges become blunt when they encounter intact dentin and only the diseased dentin is removed [19].

Advantages

The use of polymer bur in cavity preparation offers the clinician several advantages including the following: This bur removes just the decayed dental structures thus lowering the risk of exposing the pulp tissue and thereby reducing the pain and/or irritation intra-operatively and/or postoperatively, it is disposable bur thus lowering the possibility of "cross infection in dentistry" [34].

Disadvantages

The use of polymer bur has fewer disadvantages including the following: Costly instrument, technique sensitive and if the bur encounters the enamel or intact dentin throughout the operative procedure, the risks of bur destruction are higher [34].

Chemo mechanical cavity preparation systems

In this section, we will discuss two types of chemical systems and their methods for cavity preparation.

Application of Carisolv agent

Original Carisolv red color gel comes in two syringes. One of them contains three amino acids; they are (glutamic, leucine and lysine) and carboxy methylcellulose based gel and the other syringe contains sodium hypochlorite. In contrast to the original agent, the new Carisolv gel is a colorless agent and it contains half the concentration of the amino acids and two fold the concentration of sodium hypochlorite [16,17]. The "new carisolv twin multi mix syringe dispenser" is the name given to the delivery method which equilibrates the two components, resulting in the emergence of the active gel from the tip of the syringe. The carisolv acts by dissolving the external layer of the carious lesion, which is contaminated and irrevocably demineralized and does not have the ability to be remineralized again, thus preserving the internal layer, which is incompletely demineralized [36].

The clinical procedure of the Carisolv agent

After the preparation of the Carisolv gel, it was then applied by covering the carious lesion for 30 to 60 seconds and then an appropriate hand instrument was used to excavate the soft carious tissue. The gel was clear, but when applied to a carious lesion it became cloudy from the debris. This technique was continued until the gel was not cloudy anymore, the cavity should be checked to be hard with the excavator and caries free using the explorer, then the cavity was restored with an appropriate restoration [36,37].

Advantages

The use of Carisolv offers several advantages including the following: It is a painless procedure, without local anesthetic, no noxious effect on the pulpal tissue, it can be used with the anxious patient, excavation of the infected dentin tissue only, preservation of the affected dentin and no smear layer production [16,36–38].

Disadvantages

When considering the Carisolv agent for cavity preparation the following disadvantages will be presented: The need for significant training and specialized instruments, expensive agent, it takes more time to complete the procedures, it has an unpalatable taste and unappealing odor [16,18].

Application of Papacarie agent

To address the shortcomings of the Carisolv, the Papacarie, which translates as "caries eater," was launched onto the market in 2003. Papacarie is composed of the papain enzyme, which is derived from the papaya tree's leaf and fruit, toluidine blue, chloramine, salts and thickening agent. All the above mentioned components are contained in the form of a syringe with a 3 ml volume and they work together to provide the Papacarie with its bacteriostatic, bactericidal and anti-inflammatory properties [16,18,39].

The clinical procedure of the Papacarie agent

Using radiographic assessment to evaluate the selected tooth, prophylaxis is performed with a rubber cup and pumice, followed by washing with air/water spray and tooth isolation, allowing the chemical process to act for thirty to forty seconds after applying the Papacarie. Using the other side of the excavator, clear out the soft, carious dentin. Softened tissue should be scraped, reapplication of the gel, if necessary. When the cavity is caries free, then the cavity is washed with water and dried and filled with appropriate restoration [18].

Advantages

The use of Papacarie offers several advantages including the following: It is a biocompatible agent, low cost, there is no need for a local anesthetic, it preserves the integrity of the healthy tissue, aids in the excavation of the infected dentin only and no smear layer formation [18,38,39].

Air abrasion

Air abrasion is a pseudo mechanical, non-rotatable system that utilizes kinetic energy, which has the ability to remove both intact dental tissues and carious lesions depending on many variables, including the types of the abrasive particles. A strong tight flow of dynamic abrasive particles such as aluminum oxide particles is oriented toward the cavity damaged area. The damaged tissues are quickly removed with this method. An important note that should be considered regarding the use of aluminum oxide particles is that they remove the intact dentin and enamel more effectively compared to softened, infected carious lesions. Because their hardness is higher than carious lesions [6,10]. The use of softer abrasive particles such as polycarbonate resin has been indicated to remove the carious dentin selectively.

Advantages

The use of the air abrasion system offers many advantages including the following: Often time no local anesthesia is required, it is a painless, fast and simple procedure, no heat generation and vibration [6,10,40].

Disadvantages

When the air abrasion is considered for the cavity preparation the following disadvantages will be presented: It cannot be utilized in deep caries removal because of the increased risk of pulp exposure, the isolation with a rubber dam is mandatory to prevent the complications associated with its use, such as abrasive powder inhalation and it should not be used in patients with pulmonary diseases [40].

Ultrasonics and Sonoabrasion

Ultrasonic instruments employ energy at a frequency of 20 kHz above the range of human hearing. They can be used to eliminate carious lesions by abrading the dental tissue with "oscillating diamond coated tips". Due to the particular angulation forms of the oscillating tips, which produce oscillations that enable less invasive cavity preparation and efficient removal of caries found in difficult locations, such as the proximal area of both anterior and posterior teeth [41]. Sono-abrasion represents the modern version of the ultrasonic system. It employs "high frequency, sonic, air scalars with modified abrasive tips." The oscillation of this system is in a sonic range lower than 6500 Hz. The oscillating tip of this system moves longitudinally between (0.055-0.135) mm and transversally between (0.08-0.15) mm [6]. The system is utilized in cavity preparation because it aids in the removal of dental carious lesions preferentially and provides the maximum conservation of dental structures. It should be a part of dental instruments, especially for dental practitioners who are concerned with the preservation of natural dental tissues [42].

Advantages

The use of ultrasonic and Sono-abrasion systems offers many advantages including the following: Minimal demand for local anesthetic, a good field of view during the treatment session, decreased risk of causing damage to adjacent dental structures, minimal noise, minimal thermal changes [11,41].

Disadvantages

The use of ultrasonic and a sono abrasion system have some disadvantages including the following: Minimal abrasiveness, the enamel rods become weakened near the prepared area, which leads to the development of "Cracks" [24].

Atraumatic Restorative Treatment (ART

Atraumatic Restorative Treatment (ART) represents one of the minimally invasive methods of preparing carious cavities. The aim of developing this approach was to treat dental caries in countries and regions with low services, where there are insufficiencies in dental practice and general services, including the lack of electrical power and water pipe systems, which are considered essential for dental equipment. This method relies on the simplest instruments used routinely in dental clinics. Hand instruments are used to excavate the cariously infected dental tissues in a selective manner [43]. After minimally preparing the cavity with the (ART) method, it is then filled with glass ionomer. The glass ionomer leaches fluoride ions, which help in the remineralization of the affected, demineralized dentin tissue [44]. The glass ionomer has many advantages, including the following: It is a biocompatible material, cheap, reduces the possibility of recurrent caries, usability and has a fine sealing property [15].

Advantages

The atraumatic restorative treatment approach provides the following: It is an affordable treatment, there is no need for local anesthesia, it does not produce dental anxiety, it is a painless procedure and it aids in the preservation of natural dental tissues [15,43,45].

Ozone therapy: Because bacteria are the sources of many dental issues, potent therapy is required to effectively eliminate these causative organisms. Ozone therapy has been introduced as a new approach for treating caries in recent years. The antimicrobial impact of ozone is owing to the fact that it damages cells' cytoplasmic membranes by "ozonolysis of dual bonds" and also modifies intracellular contents due to "secondary oxidants" actions. The traditional treatment of dental caries by "drilling and filling" can be replaced with the use of ozone treatment because it has been proposed that cariously infected lesions can be halted or reversed [46,47]. Individuals with a higher risk of getting caries may benefit from having ozone gas applied to non-activated carious lesions of the occlusal fissures. It has been proposed to use ozone as a new treatment method to treat early fissure caries lesions that have not yet cativated.

Advantages

The use of ozone therapy in minimally invasive dentistry offers several advantages, including the following: It is a painless, quick and simple procedure, there is no need for local anesthetic, it reduces dental anxiety and there is no need for drilling and filling [46].

Contraindication: Although ozone therapy has many advantages, there are contraindications to its use, especially in these cases: It should not be used during pregnancy, hyperthyroidism disease, G6PD deficiency and ozone allergy [12].

Laser application

The word laser represents the abbreviation for "light amplification by stimulated emission of radiation". Laser light can take many forms if directed at a particular tissue. These forms are absorption, reflection, transmission and scattering. However, there are three main ways that lasers interact with the tooth components (enamel and dentin): With inorganic substances, with water and with organic substances including lipids and proteins. The dentin contains more water and proteins than enamel this highlight the importance of them in light absorption [48]. The following laser are currently being tested for their potential to ablate hard tissues more selectively: Er: YAG (Erbium: Yttrium Aluminum Garnet), Nd: YAG (Neodymium: YAG) mid infrared–(IR) to IR emission, Excimer laser (AF (Argon: Freon) and XeCl (Xenon: Chlorine)–UV emission and Holmium lasers [6,32]. The Er: YAG represents one of the dental lasers that have been utilized to ablate carious lesions whenever its wavelength of 2.94 um matches the maximum water absorption in the tissue. The mechanism of action for efficient caries removal happens by the micro explosion of the evaporated water. Hence, Er: YAG offers conservative cavity preparation with the preservation of intact tissues. It also provides a thermic impact which leads to the crumbling of the microbial cell, followed by micro explosion, which reduces the number of them [49].

Advantages

The use of laser in minimal invasive cavity preparations offers the following advantages: It is a painless procedure, no or minimal use of local anesthetic, it does not produce noise and vibration, it prevents the iatrogenic pulp exposure and it has a bactericidal effect [13,20,49].

Disadvantages

When the use of a laser is considered for minimal cavity preparation, the following disadvantages will be encountered: There is difficulty in using it, especially in posterior teeth; it cannot remove the carious tissues completely from cavity walls, so the use of curettes is required [49].

Antibacterial Photodynamic Therapy (aPDT)

Antibacterial Photodynamic Therapy (aPDT) represents a perfect option for treating caries lesions in the deep dentin. The implementation of (aPDT) deactivates the carious lesions and decreases the level of the cariogenic bacteria in the dentin tissue and simultaneously lowers the possibility of iatrogenic pulp exposure, thus prohibiting the advancement of the bacterial activity, thereby promoting dental tissue mend. The outer layer and soft dentin tissues are excavated, thus preserving tooth structures. Generally, aPDT can help treat dental caries in a way that is not very invasive [50,51].

Antibacterial photodynamic therapy mechanism of action

The mechanism of action is achieved by a combination of non-poisonous Photo Sensitizer (PS) with an accurate light wavelength. The photosensitizer then gets activated and leads to phototoxic action in the presence of oxygen at a sufficient level. This process produces Reactive Oxygen Species (ROS), which destroy the biomolecules and oxidize the cytological components, ultimately killing the microorganisms. Each of these variables "PS, light, oxygen" is safe on its own, but when they interact, they can produce fatal cytotoxic ROS capable of selectively destroying microorganisms. aPDT can be performed multiple times due to its non-invasive nature and lack of cumulative toxicity effect. Additionally, due to its minimal danger, it's safe to be used on old and compromised individuals [52].

The photosensitizers used in aPDT

Photo Sensitizers (PS) are substances that can induce chemical alterations in other substances via a photochemical reaction. The appropriate PS should have a particular impact on the prokaryotic cells. The efficacy of aPDT relies on several factors, including the PS concentration, contact duration and the concerned microorganisms' species [53]. The photosensitizers can be classified according to their charges depending on their pH in the solution as either anionic PS, which are negatively charged such as aluminum disulphonated phthalocyanine, rose bengal, erythrosin and porphyrin derivatives (photosan TM, photogemTM, photofrinTM) or as cationic PS, which are positively charged such as methylene blue, toluidine blue O, and pyridinium Zn (II) phthalocyanine. Another classification of photosensitizers is based on the hydrophilicity and hydrophobicity properties. The methylene blue, toluidine blue O, and erythrosin have a hydrophilic property while phthalocyanine and porphyrin derivatives have a hydrophobic property [54].

The light sources used in aPDT

The fundamental prerequisite of the light sources should match the activation range of the PS that is utilized in aPDT. They should generate sufficient light intensity at the correct wavelengths. The effectiveness of the aPDT is correlated to output power, the quantity of illumination dosage and exposure period [55]. Traditional lamps with incoherent, polychromatic light and a high heat property were used as primary light sources in the past. Laser advancement with unique properties such as mono chromaticity, coherence and collimation made the laser more efficacious in the aPDT. The diode laser has a resonant wavelength absorption band of the majority of dyes used in the aPDT, it's a cheap device. Moreover, Light Emitting Diode (LED) sources that are already incorporated in the dental practice can be employed in the a PDT without the use of additional devices, they are cheap, with small sizes and with minimal heat production [53,55]. Halogen light source has the property to be spectrally filtered to coincide with all photosensitizers but it causes a thermal effect. Gram positive bacteria have cell walls that are composed of a porous layer of peptidoglycan and lipoteichoic acid, so they have great sensitivity to both anionic and cationic photosensitizers because these PS can permeate through the cell walls and get access to the cytoplasmic membrane. On the other hand, gram negative bacteria are comprised of multilayers that act as permeation barricades. There is an extra membrane with asymmetrical lipid structures external to the peptidoglycan layer, which consists of Lipo Poly Saccharides (LPS) with a strong negative charge, lipoprotein and porin functioning protein. The abovementioned components decrease the permeation and increase the impedance to aPDT [52,56]. In order for photosensitizers to get into bacterial cells, the dyes should be water soluble. Because hydrophilic photosensitizers have a greater permeation into gram positive bacteria. On the other hand, hydrophobic photosensitizers have a greater permeation into gram negative bacteria [54]. A critical factor that should be considered in the aPDT is the PS concentration because the "self-quenching" phenomena happen with a higher PS concentration, which decreases the quantity of light that is intended to approach the bacterial cells and the generated ROS, which in turn affects the aPDT efficacy. Thus, a minimal concentration of PS is required to produce good results [51].

The clinical procedure of the aPDT

A study conducted by Guglielmi C de AB, et al. [57] described the clinical procedure for aPDT. The local anesthetic solution was injected, then tooth isolation with a rubber dam, the carious tissues were excavated from the lateral walls, the caries lesions were kept over the pulpal wall of the cavity and then were gathered with a 1 mm diameter sterilized micro punch, then the methylene blue PS of 0.01% concentration and 3 ml volume was applied to the carious lesions and kept for 5 minutes in what is called a pre irradiation period followed by irradiation with (InGaAlP) diode laser with 660 nm wavelength for ninety seconds, after the completion of irradiation other specimens were gathered near the baseline specimens site, both pre-aPDT and post-aPDT specimens that obtained were placed in a transport media and the cavities were cleaned and rinsed with water till the elimination of all photosensitizers and finally, the cavities were restored with glass ionomer cement. The study concluded that there was a substantial decrease in the *S. mutans* and *lactobacillus* species level thus this therapy may be a suitable option for the treatment of deep carious lesions utilizing minimally invasive techniques.

Advantages

The use of antibacterial photodynamic therapy in minimally invasive cavity preparations offers the following advantages: It is a painless, quick, easy and affordable procedure. It eradicates the micro organisms that are present in dentin tissue and preserves the adjacent tissues, no bacterial resistance will develop to this treatment and the PS is precisely designed to destroy microorganisms without affecting human cells [51,55,56].

DISCUSSION

Repair rather than replacement of the defective restoration

The goal of minimally invasive dentistry is to reduce the unessential removal of intact tissues and one of its pillars is the repair of faulty restorations. This treatment approach is not commonly considered by dentists for the management of defective fillings [21]. Every general dentist around the globe spends between 50–71% of his/her work replacing old fillings. Constantly consideringthe patient's risk of caries development, the dentist's appraisal of the advantages restoration's and dangers and conservative cavity preparation guidelines are essential when deciding whether to repair a present restoration or to replace it [20,45]. When the amalgam and resin based restorations need to be replaced, a large and short lasting restoration will be the result of this intervention. There are several causes behind the replacement of the defective fillings, which are the bond strength of the present fillings, the remaining residual caries and recurrent caries on the restoration margins, which indicate the increasing likelihood of caries development at other sites, even beneath the present restoration, furthermore, dental caries does not advance beneath good sealed fillings and has a slow advance in the majority of people. Therefore, the repair of faulty fillings represents a feasible and ultraconservative treatment approach [20]. It is also an effective and useful approach because the defective fillings are repaired in less time and at a lower cost, making it an affordable option that increases the number of people who get dental care [21].

CONCLUSION

The application of the minimally invasive dentistry principles outlined above will result in significant changes in how dental practitioners deal with the caries process. The advancement of adhesive systems and the development of bioactive materials, as well as the increased understanding in the field of preventive and conservative dentistry, should encourage dental practitioners to adopt this new approach in their practices. However, some of the minimally invasive cavity preparation techniques have a few disadvantages, which are either the cost or the effectiveness of these techniques. Further research is needed to overcome the drawbacks, upgrade the available techniques and develop a new approach to caries management.

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