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Minimally Invasive Approaches in Pediatric Dentistry

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Abstract

The aim of this work was to assess the efficacy, affordability, and acceptability of various "non-invasive and minimally invasive techniques" that are used in treatment of carious lesion in children. Minimally invasive techniques represent a paradigm shift in pediatric dentistry, emphasizing patient-centered care and preserving healthy tooth structure. Considering continuing technological development these techniques will become even more crucial in providing safe, effective, and comfortable dental experiences for children allowing pediatric dentists to foster a positive and e stress-free environment for children, establishing the foundation for long-term dental health.

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Introduction

Dental caries can be defined as a complex, dynamic, sugar-driven, biofilm-mediated, and multifactorial disease that results in phasic demineralization and remineralization of the tooth structure. Caries occurs any time in life, in both sets of dentitions. It is an unevenly distributed, preventable disease that has significant negative effects on quality of life and economy [1]. Preservation of each patient's natural teeth should be the objective of all dentists [2]. During the diagnosis of an active, non-cavitated lesion, the dentist must firstly assess the extension of the disease and the caries risk of the child. After that, a preventive plan is made that focuses on arresting and preventing caries progression [3]. Later, based on each case's needs, the dentist will select one of the minimally invasive methods like varnish, SDF, fissure sealant, and resin infiltration [4]. Minimal Invasive Dentistry (MID) has developed a conservative philosophy that addresses dental caries through MID techniques and preserves tooth structure. It provides a new approach to reduce pain, stress, and the time of restorative procedure, resulting in decreasing patient anxiety [5].

Fluoride Varnishes (FVs)

Fluoride varnish is a professionally applied fluoride that can stick to the tooth surfaces and release fluoride in an effective way for a relatively long time. In the past, the main disadvantage of the previous topical fluoride systems (fluoridated mouth rinse and gels) was the short duration of fluoride exposure. Therefore, there was a need to develop a material that could overcome this problem by increasing the adherence of fluoride to the tooth surface [6]. 5% NaF varnish was used for this purpose. In fact, the combination of 5% NaF with silver nitrate or SDF have showed higher efficacy [7]. FV remains an excellent modality in caries prevention, White Spot Lesions (WSLs) management, reduction of hypersensitivity, supporting enamel development in children and protecting against ECC (Early Childhood Caries) [8]. The frequency of FVs application can be two to four times a year depending on the child's caries risk level [9].

Pit and Fissure Sealant

A preventative procedure used to stop dental caries before they progress to the final stage, known as a "hole" or cavity [10,11]. It works by blocking the tooth's pits and fissures, which prevents bacteria from adhering to them [12,13]. Many sealant materials had been developed and they were mostly classified into glass-ionomer, polyacid-modified resin based sealants and resin-based sealants [14-16]. As the glass-ionomer type had the advantage of less technique sensitivity with fluoride release, the resin sealant had shown better retention [15]. Although resin-based pit and fissure sealants are most used, they still experience abrasive wear [17]. Moreover, a systematic review had shown that using sealants were more

effective in preventing or reversing the process of dental caries in comparison with no intervention or when applying only fluoride varnishes [18]. Authors suggested that pit and fissure sealants are a good intervention in preventing and arresting dental caries lesions in primary and permanent teeth [19].

Silver Diamine Fluoride (SDF)

Since 1969, SDF had been referred to the literature by several names, like silver diamine fluoride, silver fluoride diamine, ammoniated silver fluoride and diamine silver fluoride [20]. SDF had the potential to encourage dentin formation by using silver salt to become calcified, with the germicidal activity of silver nitrate and the power of fluoride to stop deterioration [21]. The presumptive features of SDF that are particularly noteworthy are: control of inflammation and irritation; ease of use and pain relief; cost-effectiveness; material affordability; shorter duration and controllability of use; in addition to the non-invasiveness [22,23]. The term "silver-fluoride bullet" was applied to SDF since it had the ability to stop and delay the caries process [24]. The mostly studied formulation was 38% SDF and it was recommended for caries arrestment in both children and patients with special needs. When compared to 5% NaF varnish, the biannual application of 38% SDF had demonstrated more efficacy [25,26]. The major disadvantage of SDF is the metallic taste with black staining that is experienced during its application [27], an in vitro study showed that SDF/KI (silver diamine fluoride/Potassium Iodide) has the potential to reduce the black staining effect of SDF, though not entirely [28] . However, Newer silver compounds like NanoSilverFlouride (NSF) did not demonstrate tissue discoloration resulted from the oxidation of silver ion. Additionally, following one to three months of applying NSF in saliva or plaque a significant decrease in the number Streptococcus mutans was reported in vivo [29,30]. Besides, a clinical trial suggested that compared to SDF, NSF was more successful in arresting dental decay in preschoolers without causing black discoloration on their teeth and with higher parental satisfaction [31]. The combination of Nano silver particles and fluoride results in a synergistic effect that promotes enamel remineralization and combats cariogenic bacteria more effectively [32]. NSF not only ensures an aesthetically pleasing outcome but also avoids the drawbacks associated with SDF also it is viable option for both pediatric and adult. The remarkable advantages of NSF make it highly applicable for inclusion in public health initiatives [33]. The long-term effectiveness of this substance needs more thorough study with bigger sample size is necessary.

Resin Infiltration

Another MID technique was resin infiltration, which is used for treating mild hypomineralized lesions by sealing enamel porosities and strengthening enamel defects and thus improving esthetics [34]. Using this technique, non-cavitated lesions on the proximal and smooth surfaces of the teeth can be treated [35]. A one-year follow-up clinical study showed that resin infiltration had the ability for instant diffusion into the WSLs, resulting in improvement in the aesthetic outcome [36]. A Cochrane review concluded that when it came to preventing proximal non-cavitated lesions, resin infiltration worked better than preventative measures like applying fluoride or encouraging flossing [37]. In addition, it provided acceptable results in treating MIH lesions [38]. In pediatric dentistry, resin infiltration is a useful method to be used for treating WSLs in both primary and permanent teeth. However, there is a little data on the microleakage, color stability, and long-term durability of resin infiltration. These are the material limitations that need more studies.

Atraumatic Restorative Treatment (ART)

Dr. Frencken created a concept of ART for decay management, which uses simply hand instruments to remove tooth decay. The World Health Organization accepted his idea, which is now used all over the world [39, 40]. ART had become an extremely important dental technique, especially for those patients who face obstacles utilizing conventional dental interventions as well as areas with limited resources. This entails utilizing hand instruments to carefully remove decay and employing glass ionomer cement to restore cavities [41]. The modified ART is a modification that uses high-speed handpieces to alleviate hand fatigue in places where access to dental equipment and power is not an issue [42]. Later, the SMART approach (Silver Modified Atraumatic Restorative Technique) was developed, which used SDF to eliminate the bacteria then glass ionomer to seal the tooth to deny any nutrition that bacteria need to thrive [43]. A comprehensive review to highlight the effectiveness of SMART revealed that SDF made a beneficial addition to enhance the effectiveness of ART in primary dentition [44].

Hall's Technique (HT)

Hall's technique is one of the approaches used to biologically seal the decayed tooth in deciduous molars. No need for any intervention like using low speed or high-speed hand piece for cavity preparation or no anesthetizing the tooth and the procedure depends on separating or sealing the bacteria from the oral cavity and the decay will be inactive [45,46]. Even the bacteria will be present after placing the SS crown it will be unviable [47]. The name derived from a Scottish dentist Dr Norna Hall, who established and utilized the procedure with good achievement [48]. Valentim *et al*. found that HT is greater to other restoration procedures concerning its reception by children and their guardian in relation to of painful, non-comfortable procedures, fear, and crown preference and fulfillment. HT seems to be with greater cost to the dentists, regarding the success over time, the minor need for consultations and decay removal interventions verifies improved cost-benefit than other restorative procedures [49]. However, most pedodontics considered HT one of the therapy methods considered to halt the decayed primary molar rather than a therapy method. [50,51] One of the more recent and advantageous materials in pediatric dentistry that is utilized with HT is SDF. [52,53]

HT technique is favorable to teeth with no history of pain and used to children with anxiety [54-58]. applying HT has an obvious effect on child cooperation inside the clinic [59]. However, Poludasu *et al*. compared between M T A pulpotomy and HT he found no significant difference [60]. It seems to affect the masseter muscle activity (MMA) in children treated with a unilateral HTC in which Clench MMA was reduced immediately post-treatment [61].

Air Abrasion (Aab)

New machines and materials have been invented to treat the child with less discomfort almost with no or less pain, fast, easy, less destructive tooth structure; one of them is the air abrasion system. The action principal of AAb depends on using nontoxic particles submitted to excessive pressure and high velocity to quite eliminate decayed areas in the tooth. This method gives the dentist the advantage of lower the surface heat, less vibration, less noise also eliminating the anesthesia leading to child cooperation [62], AAb could be useful for anxious, fearful, uncooperative or even autistic children [63-64] This method aims to preserve as much as possible the tooth structure. This technique used in cavity preparation as well as for sealants, preventive resin restorations and removal of previous fillings [62]. Regarding the cavity preparation and material adherence to enamel and dentin concerning its effect on the surface roughness researchers found that air abrasion has equivalent effect to the conventional cavity preparation [65-66].

Other found combining acid etching and AAb have greater effect on adherence [67].

Chemo Mechanical Caries Removal CMCR

CMCR offers an alternative to the conventional drilling for caries removal [68] as many dentists focus on measuring the technique time, patient comfort, caries removal efficacy, pain assessment, dentist manipulation and the cost of the procedure. Most of the authors reached mostly to a comparable conclusion regarding great patient acceptance to the procedure with less fear, but time-consuming procedure [68-71]. Many commercial materials that are widely used are Carie-Care™ [68], RT + CMCRA (CMCRA, Papacárie Duo Gel® seems to be less efficient than using drilling burs [70]. Smart prep bur II (polymer bur) or Brix 3000 (caries dissolving enzymes) [70].

Concerning the caries removal using smart burs was better than CMCRA [72]. Studies concerning the composite adhesion to enamel and dentin, A S Coelho *et al.* found that the application of Brix 3000™ decreased adhesion power while Papacárie Duo® had no effect on the dentin adhesion to composite in the teeth [73]. The same material found to be efficient in minimally invasive caries excavation and was more comfortable for children [74,75] comparing the application of brix 3000 and the drilling procedure, brix 3000 remove the affected decayed area while the drilling method doesn't specify the decayed area only so taking more tooth structure, also less pain and sensitivity to the child but longer time than drilling method [76]. More advantages to the previously mentioned considering brix 3000 as a non-toxic, nonirritant to the oral cavity material also has an easily applicable no need for complicated instruments [77]. Also, Papa-Carie displayed hopeful outcomes in terms of bond intensity to dentin caries [78,79]. Application of Papacarie lead to a conclusion that mostly the same time and less pain also its effect on the child was better than the drilling procedure [80]. In 2025 Gupta *et al.* found that as all the CMCR agents share the same advantages like less pain same time with conventional method.

Ozone (O3)

Ozone is one of the natural compounds, consist of triple oxygen, the ultraviolet radiation affects and convert the oxygen to ozone. Which considered an effective disinfectant against microbes [81,82]. As a therapeutic agent increased in researches recently regarding its effect on bacteria, on inflammation, and in pain relief effect in all the fields of dentistry such as operative, endodontic, periodontology, surgery and other fields [83]. Bin Hassan S. A. in 2024. Found that ozonated water decrease the sensitivity after bleaching the teeth with Hydrogen Peroxide [84] furthermore its useful if it is mixed with toothpaste resulting in temporary remineralization especially when applied after bleaching [85]. The disinfection properties of ozonated water were obvious and comparable to 0.1% octenidine dihydrochloride [86]. Also, its positive effect in comparison to NaOCl/conventional irrigation [87]. In future it can be utilized in remineralization of the enamel and dentine layers by destroying the biological molecules of decayed part and eliminating proteins from the decayed area, leading to a porous and ensuring increased mineral ion and remineralizing agent perfusion [88].

In endodontic treatment, zinc oxide-ozonated oil reveal most desirable effect in deciduous endodontically obturated teeth [89]. With high concentration and long treatment intervals, it is efficiently eliminating *S. mutans* biofilms not only by oxidizing EPS, furthermore destruct the plasma membrane, leading to content outflow, lowering ATP levels, and final inactivation of cells which Increases the viability of the usage of ozonated water in the treatment of decayed teeth [90,91]. In the recent studies disinfecting the cavity with ozonated water increase its durability of the filling material and decrease or eliminate the recurrence of caries with no effect on bonding strength [92]. Dähnhardt et al. experimented the effect of Ozone and tool excavating method in pulpotomy procedure to children which are fearful, uncooperative, and young [88,93]. Ozone treatment procedures need to be expanded with further studies for more evaluation of results, effect, methods [91].

Laser

The development of dental laser technology has made it possible to perform several therapeutic procedures, "pulpotomy and pulpectomy", oral tissue, trauma management to permanent teeth, and the removal decayed spots in all types of teeth, typically without anesthesia usage [94].

Although their implementation is restricted by high charges and training necessities [95]. laser technology has significantly impacted modern dentistry by enabling initial finding, MITs and accurate operative procedures, eventually enlightening patient consequences and growing the choice of dental treatment [96]. A key factor in preventing caries is the tooth surface's resistance to cariogenic agent penetration. It is possible to successfully strengthen the freshly emerged permanent tooth resistance against acid corrosion by using erbium and CO2 lasers [97,98]. Before applying pit and fissure sealants, the tooth surface can also be prepared using a laser. Pits and fissures can also be cleaned, disinfected, and conditioned using laser [99]. Declared laser benefits pain reduction, fast tissue heals and limiting anesthesia usage. Erbium and diode lasers are the most used kinds for teeth and mouth soft tissue [100], in pediatric dentistry focusing on the cavity preparation, pulpotomies, soft-tissue management, in cavity preparation and root access [101,102]. Children can withstand laser treatment since it involves little contact. Parents, dentists, and the kids themselves are all more satisfied when patients cooperate better. For many traditional pediatric dentistry procedures, lasers can be a good substitute. pulp therapy, caries diagnosis and removal, minimizing the possibility of contamination, edema, and irritation, minimizing blood oozing, improving soft tissues repair, alleviating discomfort, also lessening the gag reaction [103].

Limitations

Employing MID allows pediatric dentists to ensure a positive and stress-free experience for young children and consequently good dental habits for life. On the other hand, some limitations might reduce its widespread application in pediatric dental care. High costs (laser system), technique sensitivity and moisture control (resin infiltration), and periodic recalls (fissure sealant and SDF). Besides, improving accessibility and achieving better clinical results in pediatric dentistry need to address issues like cost reduction, improved training programs, and ongoing studies into bioactive materials and technology.

Conclusion

Minimally invasive procedures represent a paradigm shift in pediatric dentistry that emphasize natural tooth structure preservation. It is undoubtedly that future development of bioactive materials will provide synergic effect to MIT in preserving tooth structure, promoting remineralization, tissue regeneration and minimizing the need for extensive restorative procedures. Future studies should concentrate on developing reasonably priced materials, enhancing durability, incorporating artificial intelligence and computer-aided technologies. With ongoing innovations, minimally invasive procedures will be the gold standard in pediatric dentistry, improving childrens' oral health care globally.

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