



Non-invasive and Minimally Invasive Management of Carious Lesions in Children: A Scoping Review

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ABSTRACT

Background: Dental caries is a major health problem affecting children in all areas of the world. Less-invasive treatment modalities are gaining popularity to avoid the burden of more conventional treatments.

Aim: To provide a comprehensive and focused review of available evidence on non-invasive and minimally invasive caries management options in children.

Materials and Methods: Relevant scientific research papers were retrieved by searching numerous databases, including MEDLINE, EBASE, PubMed, and Cochrane Library. The search was conducted up to the end of December 2020 using both free text and controlled vocabulary (MeSH) terms. The following search terms were used "Non-Invasive Dentistry", "Minimally Invasive Dentistry", "Stepwise Caries Excavation", "Selective Caries Excavation", "Partial Caries Excavation", "Fluoride Varnish", "SDF", "Pit and Fissure Sealant", "Atraumatic Restorative Treatment", "Resin Infiltration", and "Hall Crowns". Studies published in English language in the period between 2000 and 2020 were considered for review. Systematic reviews with meta-analysis references' lists were searched manually for possible missed articles in the preliminary search. Studies in English, published in the period between 2000 and 2020 and investigating one or more of the non-invasive and minimally invasive carious management techniques in children in regard to its survival/success, cost-effectiveness, and acceptability were included.

Results: The preliminary search resulted in 225 articles with topics in the searched terms. The Second filtering of the articles revealed 73 papers meeting the pre-specified criteria.

Conclusion: Success, cost-effectiveness, and acceptability of both non-invasive and minimally invasive treatments for children are supported by considerable evidence from randomized trials. Trials on broader scales and considering more than one aspect of caries management modalities in children will inform decision-making in pediatric dentistry.

Key words: Non-invasive dentistry, Minimally-invasive dentistry, Children, Caries, Management, Biological, Pediatric, Dentistry

Abbreviations: SDF: Silver Diamine Fluoride; NaF: Sodium fluoride varnish; FiCTION: Filling children's teeth indicated or not?; HT: Hall Technique; PMC: Preformed Metal Crown; ART: Atraumatic Restorative Treatment; OHRQoL: Oral Health Related Quality of Life; mAART: modified Atraumatic Restorative Treatment

HOW TO CITE THIS ARTICLE: Latifa Alhawaish, Non-invasive and Minimally Invasive Management of Carious Lesions in Children: A Scoping Review, J Res Med Dent Sci, 2021, 9(S1): 1-9.

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Received: 01/03/2021

Accepted: 15/03/2021

INTRODUCTION

Dental caries is defined as a disease which requires the presence of biofilm and sugar, in an imbalanced ecological environment with frequent exposures to cariogenic attacks. This multifactorial disease remains very prevalent amongst children in diverse populations across the globe [1]. The management of children affected with dental caries is considered a challenge in the field of dentistry. The British dental journal published an interesting conference paper entitled (caring for children: little teeth, big challenges) [2]. In this paper

the author had a critical statement focusing on the fact that in the current era, restoring carious children's teeth remains a debatable and controversial issue [2]. The classical treatment for dental caries in children is mainly the so known "drill and fill" approach. The costs of this approach on both health systems economies and children's dental tissues are very high [1]. Several previous and ongoing studies have compared the biological approach versus the traditional approach in managing carious lesions on different levels and aspects including longevity, behavior, acceptance, and costs [3-6].

One major national multi-center trial is the (FiCTION trial) that was conducted in the UK and their findings presented in 2020. This trial had very noteworthy outcomes. The three caries management approaches used in this trial were prevention only approach, traditional treatment in combination with prevention,

and biological treatment with prevention. The summarized conclusion of the trial is surprising to the pediatric dentistry community. There were no statistical or clinical differences in the three arms of the trial in terms of dental pain and/or infection episodes [6].

Minimally Invasive (MI) treatment can be defined as a conservative approach to control carious lesions with the aim of preserving as much as possible of dental tissues [7]. The MI techniques range over a spectrum of options starting with prevention of the caries process through management of caries disease process to the actual intervention in the resulting carious lesion using both surgical and non-surgical procedures [8]. In a detailed document of experts' consensus statement, an excellent definition of various levels of invasiveness in the available carious lesions management options. Non-invasive, micro-invasive or minimally, and invasive strategies. The authors stated that all of the suggested caries categories can be managed in a minimally invasive manner [8].

The minimally invasive options of caries management are gaining popularity specifically in pediatric dentistry. The fact that this technique of management is less invasive when compared to conventional treatment, less costly, less time consuming, and maybe more appealing to children and easier to be accepted in pre cooperative and uncooperative groups of children, are the reasons behind the attention given lately to such techniques [4,9,10]. Agreement on terminology of carious tissue removal and management was published in 2016. The listed types of carious tissue removal are: Atraumatic Restorative Treatment (ART), fissure sealants (no tissue removal), Hall technique, prevention and non-restorative cavity control, selective removal of carious tissue, stepwise removal of carious tissues, and finally the complete caries removal which is not under the umbrella of minimally invasive dentistry category [11]. Given the tremendous increase in interest toward as well as the debate on minimally invasive pediatric dentistry, the aim of the present review is to search and examine the available scientific evidence on the several suggested techniques used in pediatric dentistry.

Research Question

What is the success, cost-effectiveness, and acceptability of different non-invasive and minimally-invasive carious lesion management techniques used on children?

Search Strategy

Relevant scientific research papers were retrieved by searching numerous databases, including MEDLINE, EMBASE, PubMed, and Cochrane Library. The search was conducted up to the end of December 2020 using both free text and controlled vocabulary (MeSH) terms. The following search terms were used "Non-Invasive Dentistry", "Minimally Invasive Dentistry", "Stepwise Caries Excavation", "Selective Caries Excavation", "Partial

Caries Excavation", "Fluoride Varnish", "SDF", "Pit and Fissure Sealant", "Atraumatic Restorative Treatment", "Resin Infiltration", and "Hall Crowns". Studies published in English language in the period between 2000 and 2020 were considered for review. Systematic reviews with meta-analysis references' lists were searched manually for probable missed articles in the preliminary search. Studies in English, published in the period between 2000 and 2020 and investigating one or more of the non-invasive and minimally invasive carious management techniques in children in regard to its survival/success, cost-effectiveness, and acceptability were included.

DISCUSSION

The preliminary search resulted in 225 articles with topics in the searched terms. Second filtering of the articles revealed 73 papers meeting the pre-specified criteria.

Non and minimally invasive techniques with current scientific evidence

When an active but non-cavitated carious lesions are diagnosed, the clinician must first determine the caries-risk of the child and the extension of the disease. This is then followed by developing a patient-tailored preventive plan that focuses on arresting caries and prevention of progression [1,2]. The dentist can, and based on each individual case needs, choose one of the non-invasive techniques such as, fluoride varnish, SDF, resin infiltration, and pit and fissure sealants. Minimally-invasive options might be required in cases of active cavitated lesions. The following section will discuss the evidence available for non-invasive and minimally-invasive caries management techniques in pediatric dentistry.

Fluoride varnish

Fluoride varnishes are topical clinician-applied materials. It has been expansively used all over the world for more than three decades [12]. The caries-inhibiting effects of fluoride varnish in both primary and permanent teeth have been proven in several trials [12]. Application of fluoride varnish is considered one of the non-invasive dental procedures that when applied regularly has the capability to prevent and/or arrest early childhood caries [13].

Recently, the advancement in fluoride products led to several comparisons between fluoride varnish (sodium fluoride), silver nitrate and silver diamine fluoride. The effectiveness of the use of each separately or in combination has been a major area of fluorides research. The use of 5% NaF showed higher efficacy when combined with silver nitrate or silver diamine fluoride [14]. One *in vitro* study showed that both SDF solution and fluoride varnish demonstrate similar efficacy in preventing the demineralization and enamel loss of primary anterior teeth. The authors stated that no statistical or clinical significance between the two treatments could be detected in the studied sample [15].

It has been shown in a randomized trial that over 30 months, annual 38% SDF application was more effective than three-weekly application of 5% NaF varnish. The conclusion of this trial must be interpreted with caution. It is true that SDF arrested caries sooner than fluoride varnish, however at 30 months the caries arrest was similar in both groups [16]. Fluoride varnish remains an excellent modality of treatment to manage early caries lesion in children. Given the fact that SDF is not without drawbacks, it is the author's opinion that fluoride varnish still has its uses in dentistry and distinct advantages.

Pit and fissure sealants

Pit and fissure sealant is an extensively used technique to prevent occlusal pits and fissure caries and arrest the non-cavitated occlusal lesions [17]. Different materials have been introduced for the use as sealants and they are broadly categorized into either resin-based sealants and glass-ionomer sealants. The selection of which material to be used depends on the primary goal of placing the sealant and the level of cooperation by the child. Resin-based sealants has shown higher retention rates while glass-ionomer has the advantage of lower technique sensitivity and fluoride release [18]. This micro-invasive dental procedure is simple and widely accepted by young patients [19].

Additionally, it has been shown through systematic review that pit and fissure sealants are more effective in preventing and/or reversing caries process when compared to no intervention or intervention with fluoride varnish only [20].

On the other hand, a recent Cochrane review stated that when clinical trials comparing pit and fissure sealant to fluoride varnish efficiency, none of them is shown to be superior. The authors also reported that with low certainty, the combination of fluoride varnish and resin-based sealants can give superior clinical effectiveness. Currently, 14 trials are going on which according to the review authors, will help determining which technique is better in preventing and arresting caries in occlusal surfaces of molars [21]. One study reported on the cost-effectiveness of sealing primary molars. The authors reported that although sealing of primary molars versus non-sealing has a higher initial cost, however the future dental treatment needs for the non-sealing group is very high and thus they recommended the sealing of primary molars to minimize the need for future costly dental procedures [22].

Silver Diamine Fluoride (SDF)

Silver Diamine Fluoride is one of the non-invasive treatment modalities that is gaining considerable attention at the current time. SDF is an odourless and clear liquid that was originally indicated for hypersensitive teeth. The American Academy of Pediatric Dentistry has introduced a policy document and clinical practice guidelines on the use of SDF in children [14,23].

38% SDF is the formulation mostly studied and recommended for the purpose of caries arrest in children

and special needs patients. The biannual use of 38% SDF has shown higher effectiveness when compared to 5% NaF varnish [23,24].

In the last two decades, a good number of clinical studies investigated the relatively new silver bullet (SDF) [24-26]. The effects of SDF have been studied either alone or in comparison to other treatment modalities. One randomized trial compared the outcomes of SDF and ART in terms of oral health related quality of life in pre-schoolers. The authors concluded that both SDF and ART equally and positively impacted the OHRQoL in the studied group of pre-schoolers [27].

Fluoride varnish is another treatment option that has been compared to 38% SDF in a clinical trial. The investigators reported higher effectiveness of 38% SDF in caries arrest compared to 5% NaF in high caries risk group of children in 12-months follow up when applied semi-annually [28]. Overall, 38% SDF when applied to arrest caries in primary teeth and when compared to fluoride varnish, placebo or no treatment is highly effective as reported in a meta-analysis [29].

A major drawback of the SDF is the unpleasant staining that is seen following its application [30]. Parents' views on the aesthetic and black staining following the use of SDF have been investigated and many authors concluded that it was acceptable for most of caregivers. The simple and non-invasive nature of the treatment could be the reason of its acceptance; however, the black staining was a concern in some cases of anterior teeth treatment.

It is important here to highlight that pre-treatment informed consent supplemented by photographs of how teeth might look like following treatment is very crucial [31,32].

It has been recently reported that the use of potassium iodide in combination with SDF has the advantage of minimizing the discolouration caused by SDF but unfortunately it has also reduced the caries arrest properties in the used silver diamine fluoride [33].

In addition to the anticaries effects of the SDF, it has been shown that it also contributes to reducing candida albicans adhesion to dentine and is therefore advocated to be used with the aim of inhibiting dental plaque caused by candida [34].

Dentists' opinions were also investigated with regard to SDF. It was reported that, despite the surveyed dentists' strong believes on the caries arresting potential of SDF and its practicality as well as cost-effectiveness, the discolouration drawback remains a major issue that needs to be resolved [35].

Cost-effectiveness is an important advantage of SDF. For any dental treatment modality, this feature has an influence on its acceptance among practitioners and patients. Providing SDF as a caries management strategy can reduce dental care expenditures by avoiding the costly caries treatments. The use of SDF might also minimize the need for the more invasive treatments that could require pharmacological management and general

anaesthesia in some cases. Given the many advantages of SDF, the use of 38% SDF should be considered by stakeholders and decision makers especially in high caries risk young children [36].

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Resin infiltration

Resin infiltration is relatively a new innovative minimally invasive approach to manage the non-cavitated interproximal carious lesion. It can be simply described as the use of low-viscosity resin to seal the lesions in a three-dimensional manner [37].

A Cochrane review assessed the efficacy of resin infiltration as one of the micro-invasive techniques in interproximal lesions for both primary and permanent teeth. The included trials involved lesions that radiographically are limited to the dentine outer third. The review concluded that resin infiltration is supported by good evidence to suggest that they are more effective than prevention (fluoride application or advice to floss) in arresting non-cavitated proximal lesions [38].

A recent two-year randomized split mouth design trial showed that resin infiltrated inter-proximal lesions in primary molars had lower progression (54%) than the progression seen in the control non-infiltrated lesions (79%) [39].

In another clinical study, the researchers reported that children in their sample found resin infiltration as enjoyable and acceptable as fluoride varnish application which according to the authors is an additional positive point that can be added to its higher efficacy [40].

The aspect of cost-effectiveness of resin infiltration of primary molars has not been adequately investigated. Generally, the available evidence that looked at its radiographic caries progression arrest is encouraging. It is a good technique to be mastered and included in the minimally-invasive restorative choices in pediatric dentistry.

Atraumatic Restorative Treatment

The atraumatic restorative treatment has been known for many decades as a means for dental treatment for people living in remote areas with no access to structured dental clinics and electricity [41]. The ART has also been endorsed by the World Health Organization in 1994 as a recognized approach for dental treatment in the underprivileged areas of the world [42,43]. The

technique requires no rotary instrumentation and relies only on hand excavation of soft carious lesion followed by glass ionomer cement restoration [41,44]. Later, the technique received some modification to reduce manual fatigue through using rotary high-speed handpieces in areas where access to dental units and electricity is not a problem and this is the modified ART (mART). The mART is also assumed to induce less patients' discomfort [45].

Several clinical studies and trials examined the success of ART and mART in primary dentition [9,41,42,44-48]. High success rates (around 93%) have been reported in ART when used in cases of occlusal class I carious lesions. These success rates considerably drop to almost 60% when it comes to multi-surface ART restoration [49,50]. The low success rates in class II ART have led researchers to further investigate other adhesive dental materials as well as different isolation options (rubber dam and cotton rolls) to improve the technique's survival [41,44]. High viscosity glass ionomer cements class II ART shows better survival than regular glass ionomer cements. Additionally, their survival is comparable to conventional approach utilizing composite resins or amalgam in primary molars [44,51,52]. The use of rubber dam did not improve the survival of ART restorations as compared to cotton roll isolation approach and is therefore not advisable [41].

In a randomized trial that followed up the recruited sample for 4 years, ART showed excellent clinical outcome for early childhood caries in infants with age range 18-36 months [46]. When the class II ART is confronted against another minimally invasive treatment such as the Hall technique, its success is inferior to those reported with the use of Hall crowns [44]. From the reviewed studies, it became obvious that class I ART is highly successful while Hall crown is preferred when it comes to multi-surface restorations.

Cost-effectiveness is essential aspect to be considered when deciding which of the available treatment approaches to be used. It has been shown that ART is cost-effective as it would help avoidance of the more expensive dental procedure such as sedation and general anaesthesia [4,53]. In another randomized clinical study, it was proven that ART is an efficient technique and would reduce the need for dental general anaesthesia in young children and thus reduce both the associated hazards and cost [3].

Furthermore, the oral health related quality of life has improved with the use of ART in school children [48]. Child patients present lower anxiety levels and low pain experience when treated using ART technique in comparison to conventional restorative procedures however, the difference was not statistically significant [54,55]. A meta-analysis had supported the above findings and concluded that ART does not significantly reduce the anxiety levels in pediatric dental patients [56].

To summarize, the literature has good evidence on both success rates and cost-effectiveness of class I occlusal

restoration in pediatric patients. Other minimally invasive treatment options might be more successful when considering multi-surface carious lesions in children.

Hall Technique

In Scotland, UK, a novel technique of placing preformed metal crowns had started more than three decades ago. The novelty in the technique was that it is different than what is being practiced and taught as conventional crowns placements in pediatric dentistry. Dr. Norna Hall was a general dental practitioner who started using preformed metal crown in the 1980s differently on primary molars. No local anaesthetic is given and no tooth preparation is made. The dentist would choose the appropriate size of the PMC and cement it using glass ionomer cement through finger pressure or the patients' biting force. Only while carrying out an audit, specialists noticed the technique being used by Dr. Norna Hall, which led them to further investigate the survival and clinical effectiveness of Hall crowns [57].

The main concept of Hall crowns is the use of Preformed Metal Crown (PMC) to seal over dental caries on primary molars and thus it is a minimally invasive and non-aerosol-generating treatment choice [58]. The online published manual on hall crowns states that teeth with no signs of irreversible pulpal involvement and with sufficient radiographic evidence of sound dentine separating the pulp from the carious lesion, can be crowned using this innovative technique [59]. In cases where tight inter-proximal contact might prevent sufficient seating of the PMC, placement of orthodontic separators is recommended for up to 5 days prior to the hall crown cementation [59].

The Hall technique has been widely studied over the last 20 years. Different aspects were looked at by investigators, namely its survival, cost, acceptability and any associated drawbacks such as occlusion discrepancies [4]. In a randomized parallel controlled clinical trial, Hall crowns showed very comparable outcomes to those obtained by standard PMCs. The authors concluded that in addition to its clinical effectiveness, the technique is simple, acceptable by caregivers and requires less time [44]. This trial had another significant finding indicating that Hall crowns have better clinical and radiographic outcomes when compared to atraumatic restorative treatment. Another 5-year randomized controlled trial proved that when general dental practitioners are the treatment providers, Hall crowns outperform the standard direct restoration in primary molars [60]. In another well-designed study, the longevity of Hall crowns was better than that of the intra-coronal conventional restoration. Furthermore, signs and symptoms of pulpal pathology were less in the Hall technique group as reported by the trial team [61]. An interesting study in New Zealand looked at the 2-year clinical outcome of HT.

The unique conclusion of this study is that Hall crowns can be as successful in the hand of therapist

when they get sufficient training [62]. A retrospective study investigated the outcomes of conventional dental treatment to the biological dental treatment (e.g., Hall crowns). The investigators concluded that both approached had equal success rates [5]. When performed in pediatric dentistry clinics, Hall crowns showed similar success to conventional PMCs however in a less invasive approach. In one study the investigators assessed the effect of modifying the Hall technique through the introduction of interproximal slicing prior to cementing a crown. The slicing technique did not have an influence on the success of the crown when compared to the standard Hall technique [63]. Several studies compared cost-effectiveness of Hall technique to other commonly used approaches [5,64,65] and all agreed that Hall crowns are very cost effective as they are retained longer and experience less complications at lower costs. In terms of Hall technique acceptability, both children and parents showed very high acceptance to this modality of treatment [66].

One of the most debatable aspects related to Hall crowns is the issue of possible occlusion discrepancy. It is claimed that the placement of PMCs without any tooth structure reduction will result in increased occlusal vertical dimension and negatively affects the muscular structures and can lead to Temporomandibular Disorders (TMD) [67,68]. A prospective clinical study found that any occlusion changes seen immediately following Hall crown placement will eventually normalize within 3-4 weeks without any extrusion of teeth [67]. Additionally, the Hall approach did not result in any TMD signs or symptoms in the studied group [67].

Selective Caries Excavation (SE) and Stepwise Caries Excavation (SW)

Another minimally invasive procedures that can be used in dentistry for children, are selective or partial caries excavation and the stepwise caries excavation. When a deep dentine carious is faced in primary teeth with no evidence of pulpal inflammation, these procedures can be used with the aim of minimizing the need for extensive, avoidable dental procedures such as pulp therapy, extractions and space maintainers [69,70]. In selective/partial caries removal, a layer of carious but firm dentine is left over the pulp and protected with a liner that is then covered by a final restorative material at the same treatment visit. It must be emphasized that lateral walls of the cavity must be completely caries-free [71,72]. The literature has reported success rates measured by caries arrestment of selective caries excavation reaching 78% in a 4-year follow-up in primary dentition [71].

On the other hand, stepwise excavation means the removal of carious tissue partially and over two steps. The caries is removed partially, soft carious dentin is left behind in deep parts of the pulpal floor to avoid pulp exposure. This is followed by a temporary restoration that is kept for a period up to 12 months. The aim of this procedure is to inactivate the soft dentine to become hard and inactive. The tooth is then re-visited

to remove the remanent caries in the pulpal floor and place a permanent restoration [73,74]. A randomized clinical trial has compared stepwise and selective caries removal in primary molars with a 2-year follow-up period. The authors reported that both techniques are equally successful, however, restorations in the selective excavation group showed more failures in respect to restoration integrity and staining. The researchers also highlighted that although stepwise excavation has similar success to selective excavation, it is less cost-effective due to the fact that treatment is not completed in one treatment visit [75]. For a clinician to be able to accurately evaluate both techniques and decide which one possess higher chances of success in a specific case, randomized clinical trials with longer follow-up periods are needed.

CONCLUSION

A large body of scientific evidence exists to support non and minimally invasive caries management options in children. The advantages of these reviewed techniques cannot be overlooked especially when access to advanced pediatric dental care and costs of extensive treatments are barriers.

CONFLICT OF INTERESTS

The author declares no conflict of interests.

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