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REVIEW

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Clinical interventions for caries management through minimal intervention procedures in young children: an updated evidence-based review

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Abstract

This review aimed to summarize the preventive, non-restorative and restorative minimal intervention dentistry (MID) interventions for managing dental caries during the primary dentition stage, after selecting the highest quality evidence. A comprehensive literature search for relevant studies was performed in PubMed (MEDLINE), Embase, Cochrane Library and Google Scholar, published between 2007 and 2022. Only clinical randomized controlled trials, clinical guidelines with literature review, systematic reviews and meta-analyses conducted in the primary dentition were included. One hundred fifty-three MID-associated references were found, and 63 of them were considered for the present review. Of these, 24 were clinical randomized controlled trials, 21 were systematic reviews, 3 umbrella reviews and 11 practice guidelines with a literature review. The retrieved evidence was divided into (and discussed) three general caries management strategies: (i) carious lesion diagnosis and individual risk assessment; (ii) preventive measurements and non-cavitated lesions management; and (iii) cavitated lesions management. MID is an attractive alternative management that promotes prevention rather than intervention to achieve a long-lasting oral health in young children through easy and cost-benefit preventive, non-invasive, minimally invasive or conservative invasive restorative measures. This philosophy of management is suitable for treating young children, considered friendlier and less anxiety-provoking than traditional methods.

Keywords

Minimally intervention dentistry; Young children; Conservative caries management

1. Introduction

Dental caries is recognized by the World Health Organization (WHO) as a disease that affects 60–90% of school children [1]. One type of destructive caries, early childhood caries (ECC), is defined as the presence of one or more decayed, missing or filled tooth surfaces in any primary tooth in a child at 71 months of age or younger [1, 2]. The condition is considered a major oral health problem worldwide carrying a significant health and economic impact and represents the main cause of tooth loss among young children [1]. ECC may cause oral pain, orthodontic abnormalities, enamel defects, eating and speaking difficulties, and an increased risk of caries development in permanent dentition [3]. Despite the progress made in caries prevention and control, oral hygiene and dietetic advice, dental caries currently remains the most chronic childhood disease [4]. Thus, this condition involves an important financial burden on society in many developing countries, where its prevalence is higher in vulnerable populations, such as low socioeconomic or ethnic minorities with limited accessibility to oral health care [4]. Nowadays, there are several methods and materials available for managing carious lesions in primary molars that usually require expensive electricity-based equipment or technology (including specialized maintenance) and highly trained personnel. On the other hand, recent dental literature has mentioned that there is a lack of reliable evidence on the appropriate and effective management of dental caries in primary teeth [5]. Previous studies have questioned the success of conventional restorative interventions under local anesthesia, including the removal of carious lesions and the placement of a restorative filling by primary dental care practitioners for preventing pain and infections in children, exhibiting an apparent lack of effective caries management [1]. One study [6] suggested that placing a restoration, compared with leaving the tooth untreated, did not improve the clinical outcome in terms of pain and infection. A second work [7] showed non-different levels of dental pain or infection between restored and unrestored primary teeth. A randomized clinical trial [8], exhibited similar results, in terms of failure rates, after two and five years of follow-up, respectively. These findings

have caused considerable uncertainty for pediatric dentistry professionals, patients and parents. Another confusing issue is the concept "Repeat Restoration Cycle" [9], which states that "eliminating" carious lesions based on Black's principles, does not keep teeth functional for life for all individuals.

The traditional caries management in primary dentition required, until recently, the removal of all the bacterial deposits or biofilm and affected structures before restoration under injected local anesthesia [1, 10]; thus, restorative interventions for grossly carious primary teeth are unpleasant in many young children, often triggering anxiety and a poor cooperation level on the dental chair [6]. However, comprehensive knowledge and understanding of the dental caries process in children and the contemporary restorative materials indicated for primary dentition have enabled pediatric dentists to provide less invasive and more conservative procedures when arising the first manifestations of the disease or when it is already present [11, 12]; in this regard, it should be taken on account that carious lesion progression can be early intercepted, controlled, slowed down or arrested [11]. Contemporary evidence has allowed the development of alternative treatment strategies, rather than the traditional complete surgical excision or drill-and-fill model [1]. This management philosophy of dental caries, in its initial stages, is known as Minimal Invasive Dentistry (MID), implemented in the '90s, which has the purpose of reducing the need for restorative therapy and placing an even greater emphasis on oral prevention. MID encompasses (i) reduction of cariogenic flora or biofilm removal using dental brushing and flossing; (ii) control of precipitating/risk factors through carbohydrate dietary restriction; (iii) enamel and dentin remineralization; (iv) sealing the affected tooth from the substrate; and (v) repairment rather than replacement of defective restorations [1, 9, 11]; according to Frencken *et al*. [9], some of these strategies should be performed throughout a person's life and only when oral care has failed and a carious cavity has developed. This management approach also involves an individual, early caries detection and risk assessment, in order to control or slow the disease progression [4, 13].

MID mainly comprises three aspects: optimal preventive measures, restorative (minimally invasive operative interventions), and non-invasive procedures targeting to maintain the affected primary teeth functional for a long time [10, 12]. For example, several conservative restorative modalities do not require dental drilling equipment, even local anesthesia; here, only the soft demineralized and grossly infected dentin is removed from the cavity floor using hand instruments, to preserve the sound structure [14]; and under the premise that 'smaller and less destructive cavity preparations mean smaller restorations', with more chance for preserving the tooth vitality and function [9]. Thus, the child's anxiety is reduced, and behavior management is enhanced [12]. Added to this selective carious tissue removal, the development of different adhesive systems and biomimetic restorative materials has contributed importantly to attaining the aims of MID [9].

This evidence-based review aimed to update and summarize the most recent available preventive, non-invasive and/or minimally invasive caries management strategies for primary teeth employed by pediatric dentists worldwide, to assist the practitioners' decision-making about diagnosing, preventing and controlling dental caries in young children, in order to minimize its detrimental effects.

2. Methods

The present critical/evidence-based review was conducted according to the methodology suggested by Giacaman *et al*. [15], Altoukhi and El-Housseiny [16], and Al-Halabi *et al*. [17]. The presented information is supported by an exhaustive examination of the available and relevant literature published during the last 15 years. Included were developed following methodological designs corresponding to the highest levels of the pyramid of evidence in oral clinical research.

2.1 Search strategy

An evidence-based literature search for the identification of relevant studies was performed in the following electronic databases: PubMed (MEDLINE), Embase, Cochrane Library and Google Scholar, in the period from 2007 to 2022. The search strategy used a combination of controlled vocabulary, keywords and free-text terms, and it was limited to English language references. A complimentary hand search was also carried out in the reference lists of those included relevant articles for additional studies. The following terms were used: "*minimal intervention dentistry*", "*non-invasive dentistry*", "*non-operative cavity control*", "*pediatric dentistry*", "*biological caries management*", "*primary/deciduous teeth*", "*early childhood caries*", "*fluoride toothpaste*", "*stepwise technique*", "*selective caries removal*", "*incomplete caries removal*", "*atraumatic restorative treatment*", "*proximal sealing*", "*indirect pulp treatment*", "*silver diamine fluoride*" and "*resin infiltration*".

2.2 Inclusion criteria

Clinical randomized (or non-randomized) trials (parallel-group, crossover or split-mouth designs), clinical guidelines with literature review, and systematic/umbrella reviews (with or without meta-analysis) were included. These studies must report clinical issues such as carious lesion progression, restoration survival, pulp exposure and signs/symptoms derived from caries activity in primary teeth. Articles that used placebo as the control group, that employed surrogate outcomes (*e.g.*, microbial counts or marginal staining), with follow-up of fewer than six months, *in vitro* studies, expert opinions, gray literature and case reports/series were excluded.

2.3 Study selection

The titles and abstracts of potential articles meeting the selection criteria were independently scanned and identified by three trained authors (PNP, DGU, GTD) for possible eligibility. Mendeley reference management program (v. 1.17.13, Elsevier, Amsterdam, Netherlands) was used to organize the potentially eligible studies and remove duplicates. The full report of these potential articles was obtained and rigorously assessed for representativeness or pertinence by the other three authors (AGR, SRR and APG), also in an independent way, to establish their definitive inclusion in the review. Agreements

were reached after careful discussion and consensus by all the authors. For this review, no critical review for assessing the risk of bias of included articles was performed due to the substantial methodological heterogeneity observed among the included studies. However, after a careful selection process by all authors, twenty-one systematic/umbrella/evidence-based reviews with a global low risk of bias were included for an additional detailed summarizing process, in which important methodological information and main findings were extracted (see **Supplemental Table 1**) [10, 18–39].

3. Results and discussion

A total of 153 references were found addressing the issues previously established, but only 63 of them fully met the selection criteria and were considered pertinent for the current review. Of these, 24 were clinical randomized controlled trials, 21 were systematic reviews, 3 umbrella reviews and 11 practice guidelines including a literature review. The present section was divided into three subsections for a better understanding of associated important subjects: (I) carious lesion diagnosis and individual risk assessment; (II) preventive measurements and non-cavitated lesions management; and (III) cavitated lesions management.

3.1 Carious lesion diagnosis and risk assessment

According to two recent umbrella/systematic reviews [40, 41], the most common caries-related risk factors in young children are: (i) enamel structural defects, (ii) presence of dentinal caries, (iii) high levels of *mutans streptococci*, (iv) increased consumption of soda and sugary snacks and obesity. In these ages, the oral microbiota and host defensive mechanisms are still in a developing stage. A personalized caries risk assessment establishes the probability of an individual child for the development of new carious lesions or the changes in the size or activity of already present cavities, over some time [42]. In young children, a correct clinical (visual appearance, lesion staging, tactile sensation and gingival health) and radiographic diagnosis in addition to a precise individual carious lesion detection, as early as possible, is crucial for an appropriate oral healthcare management plan [4] under the MID principle "minimal intervention and maximum preservation of sound tooth tissue" or "constriction with conviction" rather than "extension for prevention" [11]. During the caries-activity evaluation (past and present caries experience), the practitioner should consider the intricate dynamic interaction between biological (pathological), sociocultural, family and community variables [4, 12, 13]. Besides the radiograph, there are several electronic devices available for detecting approximal and proximal carious lesions [9]. For example, the Fiber-Optic Trans-Illumination (FOTI) device, the infrared laser-fluorescence device (DIAGNOdent®, KaVo, Biberach, Germany), the quantitative light-induced fluorescence (QLF), electrical impedance (CarieScan Pro®, CarieScan, LLC. Charlotte, NC, USA), and photothermal radiometry (Canary System®, Quantum Dental Technologies, Toronto, Canada).

Additionally, there are different specific tools designed for these purposes. The WHO method is based on a "yes" or "no" answer regarding clearly cavitated dentin lesions, without considering the assessment of less extensive lesions (*e.g.*, enamel lesions) [9, 15]. Three useful clinical indices that register enamel/dentin lesion activity are ICDAS/ICDAS II (International Caries Detection and Assessment System) [43], PUFA (Pulpal Involvement Ulcerations Fistula Abscess) and Nyvad [9]. Nyvad criteria is a visual-tactile caries classification according to the caries activity and severity. The caries process severity is classified into nine stages, from clinically sound surfaces/teeth, non-cavitated and micro-cavitated enamel caries lesions, to evident cavitation into the dentine; these categories can be subsequently classified as active or inactive [44]. ICDAS system detects and classifies the small variations in visual signs at the dental surface throughout the progression of the carious lesion [15]. The CAST (Caries Assessment Spectrum and System) tool is more suitable for epidemiological studies and fulfills all of the WHO criteria for caries diagnosis [12]; this index detects the entire dental caries spectrum, including sound, preventive and restorative management. CAST index criteria also describe the caries severity and the advanced stages of caries progression [45]. CAMBRA (Caries Management by Risk Assessment) involves evaluating and recording individual caries risk, followed by prevention-oriented treatment planning [13]. This tool takes those factors that contribute to caries progression or reversal over time. It provides a risk assessment form for the individual patient and uses the risk level as a basis for developing a caries management plan [46].

Likewise, the American Academy of Pediatric Dentistry (AAPD) provides different caries-risk assessment forms (comprising 13 items) and protocols for caries management. Further, there are available algorithm-based software programs, such as Cariogram and NUSCRA [42]. In general, three levels of caries risk are applied in children: "low risk" (absence of disease or risk factors and presence of protective factors), "moderate risk" and "high risk" [42].

3.2 Preventive measurements and non-cavitated lesion management

In cases of active non-cavitated lesions (ICDAS codes 1 and 2), different treatment options are available with the aim of arresting the carious lesion progression. These lesions preserve the enamel's surface integrity at the clinical level. Therefore, oral preventive measures and minimally invasive interventions are indicated [14, 15]. Preventive or non-invasive measures involve standard oral home care and regular oral hygiene (for disturbing the biofilm and dental plaque) with a toothbrush, dental floss and other devices; dietary counseling (including fermentable carbohydrates and sugar substitutes); proper exposure to fluorides; xylitol (with antimicrobial effects *vs. mutans streptococci*); chlorhexidine-containing agents (rinses, gels, and varnishes) applications; probiotics; and regular control dental visits [9, 11, 31, 47]. Non-invasive methods encourage an ecological change in the oral environment, favoring enamel remineralization [14, 15]. Remineralizing agents mainly include topical fluorides (toothpastes, mouthwashes, gels and varnishes). Fluorides are incorporated into the enamel's crys-

talline structure of the carbonated hydroxyapatite, decreasing enamel solubility and increasing the precipitation rate of minerals. Fluorides have been combined with antimicrobials (*e.g.*, stannous fluoride or silver diamine fluoride) [47] or with the peptide arginine [48].

- Fluoride dentifrices. Fluoride plays a significant role in the reduction of cariogenic activity through mineral deposition, especially during the first three years of life [49, 50]. Daily release of fluoride *via* dentifrices represents a crucial method for caries prevention and control, particularly in patients with high caries risk and those under orthodontic therapy, to avoid the appearance of white spot lesions [4, 25, 28, 29]. In general, once or twice daily manual tooth brushings with a fluoride dentifrice (grain of rice size) in concentrations of 1000 to 1500 ppm F, for at least one minute each, may promote a biofilm reduction of up to 42% and adequate control of pre-existing enamel, dentin and/or root caries lesions; however, patients must avoid rinsing with a lot of water after brushing [49, 51, 52]. On the other hand, Wong *et al.* [34], Pretty [66] and Toumba *et al.* [49] recommend toothpastes with less than 1000 ppm F for young children (less than 6 years of age) regularly exposed to other sources of fluoride, and when the risk of fluorosis is a concern. However, patients under four years of age may swallow some paste with the subsequent risk of fluorosis; thus, toothbrushing should be closely supervised or assisted during this life stage.

High-concentrated F pastes (1500 to 5000 ppm) are recommended for children >6 years old with special care needs and adolescents with high caries risk or with fixed orthodontic appliances [49, 53]. In young children (<6 years old) such products must be restricted to well-indicated cases in which the risk of severe morbidity due to caries is higher than that of esthetically objectionable fluorosis [53].

- CaP derivatives. Different topical calcium phosphate (CaP) derivatives, such as tricalcium phosphate (TCP), casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), functionalized β-tricalcium phosphate (fTPC), calcium sodium phosphosilicate, CPP-amorphous calcium F phosphate (CPP-ACFP) are commercially available, in chewing gums, toothpastes and drinks [37]. In general, these agents possess the ability to stabilize high concentrations of calcium and phosphate in order to bind and buffer the biofilm and the tooth surface; this creates an environment supersaturated with calcium and phosphate ions, thus inhibiting demineralization and promoting remineralization [9, 37, 54]. A systematic review with meta-analysis, including 26 randomized controlled trials (10 in the meta-analysis) by Singal *et al.* [37], demonstrated that topical application of CaP plus fluoride exhibited higher remineralization potential and antimicrobial effect on pediatric dental caries than no intervention, and/or placebo or topical fluoride; however, low methodological certainty was detected among the included studies due to high/unclear risk of bias, imprecision and indirectness.

- Minimally invasive restorative interventions. These procedures are indicated for carious lesions without clear cavitation [9, 15, 31]. These strategies comprise sealing, infiltration and ozone therapy, which modify the environment and the microbial composition, aiming to arrest the carious lesion [15, 31, 47]. Through their significant penetration inside the pit and fissure and the etching process, resin-based or glass ionomer (GI) sealants avoid acid diffusion and isolate cariogenic bacteria from external carbohydrates [14, 55, 56]. Although recent evidence [36, 57] recommend using dental sealants on non-cavitated lesions of primary molars, there is still insufficient evidence to support their use in those teeth, as their efficacy against caries has not yet been well established; however, sealants should be considered for children at high caries risk [56].

- Carious lesion infiltration. It is a micro-invasive restorative approach based on the penetration of low-viscosity or fluid resins into incipient enamel lesions on approximal and buccal surfaces, after removing and eroding the surface layer with etching with hydrochloric acid and drying with ethanol and air [9, 11, 14]. As a consequence, a diffusion barrier is formed within the enamel sub-surface, preventing acid diffusion (hydrogen ions) and mineral loss, inactivating the lesion [14]. The procedure also provides significant caries remineralization [11]. This method has been combined with fluoride varnish applications with excellent results after 3 years of follow-up [9]. According to four recent studies [31, 38, 58, 59], infiltration and sealing were more efficacious than non-invasive treatments for stopping non-cavitated proximal lesions of primary teeth.

- Ozone. Ozone, an unstable gas and a short-lived form of oxygen, is a powerful oxidizing agent, with the ability to temporarily arrest or reverse carious lesions, and remineralize the primary tooth's hard tissues; however, these findings are still controversial [9, 60]. Theoretically, ozone reduces the cariogenic microbial counts in active cavities, by oxidizing the bacterial cell wall, causing its lysis; also, ozone turns the pyruvic acid (produced by bacteria) into acetic acid and carbon dioxide [61]. Topical administration of the gas is performed through an open system or a suction sealing, as a requirement to avoid inhalation and adverse effects in the child [62]. Ozone has been combined with chlorhexidine, sodium fluoride, nanohydroxyapatite and glass-ionomer cements [61, 62]. It has also been reported that ozone possesses promissory beneficial clinical and microbiological effects when it is applied in the stepwise excavation technique in primary molars [63]. However, according to two systematic reviews by Rickard *et al.* [60] and Santos *et al.* [30] (this one with a meta-analysis), including three and twelve single randomized trials, respectively, no reliable or consistent (even statistical) evidence was found to support that ozone therapy is capable of arresting or reversing the progression of the dental caries process. The risk of bias in most of these studies was rated high, with diverse methodological concerns; so, pediatric dentists should interpret the "beneficial" effects of ozone very cautiously before accepting its use in their clinical practice for the management of dental caries.

3.3 Cavitated lesion management

In order to reduce the application of more complex restorative treatments or endodontic procedures in primary teeth (*e.g.*, pulpotomy or pulpectomy), great emphasis has been given to a recent concept known as minimally invasive therapy for

cavitated carious lesions (ICDAS 5 and 6) [15, 21]. In an effort to preserve as much tooth structure as possible, conservative approaches for carious dentin removal have been proposed, in which only a portion of deeply affected dentin is eliminated [21]. Stepwise and selective removal of carious tissues, intending to reduce the risk of pulp exposures, loss of vitality and their possible sequelae [21, 47]. In this same regard, diverse restorative procedures and chemical agents are available for caries control or removal indicated in the primary dentition, especially for anxious, uncooperative or medically compromised children, which can be treated in numerous instances with little discomfort, and without employing local anesthesia or the use of rotatory instruments [11]. So, this section will be divided into three parts: (i) chemomechanical caries removal; (ii) non-restorative cavity control, atraumatic restorative treatment (ART), and the Hall technique; and (iii) stepwise dentin removal and selective removal.

3.3.1 Chemomechanical caries removal (CMCR)

CMCR agents were introduced in the '70s with the purpose of dissolving carious softened tissues in order to facilitate their subsequent hand excavation [64]. This MID procedure preserves healthy structures, avoids pulp irritation and decreases child discomfort [65]. It is indicated in cases of cavitated buccal lesions, cervical/root caries and very deep lesions with potential pulp exposure in primary molars [11]. The following most commonly used chemical agents are reviewed:

- Carisolv. Carisolv is a viable alternative to the mechanical method in the management of dental caries, especially in children. This modified-gel agent contains three charged amino acids (lysine, leucine and glutamic acid, which react with different moieties of carious lesions), mixed with sodium hypochlorite [64]. The solution denatures the carious dentin collagen (present in the demineralized portion of a carious lesion) and disrupts its fiber structure, making it easier to scrape off; the healthy dentin remains unaffected [11, 64]. Carisolv lacks potential deleterious effects on the pulp, due to heat or pressure, compared with conventional mechanical methods. The softened carious dentin is then easily removed with slow-speed ceramic and polymer burs, thus avoiding over-excavation [65, 66].

- Papacarie. It is an enzyme-based gel consisting mainly of papain (a proteolytic enzyme with bactericidal, bacteriostatic and anti-inflammatory properties), chloramine and toluidine blue [9, 11, 64, 67]. Papacarie only acts on the infected/necrotic dentin, degrading the denatured collagen fibrils [39, 64]. The agent can be safely applied in combination with blunt spoon excavators for minimally invasive quick removal of carious tissue [39, 67, 68].

- Silver Diamine Fluoride (SDF). This topical alkaline solution (also named "silver fluoride bullet") is a combination of silver, nitrate and sodium fluoride ($Ag(NH_3)_2F$), used as a carious lesion inhibitor in non- and cavitated lesions, with a simple and inexpensive method [9, 21]. SDF reduces the growth of cariogenic bacteria, hinders the degradation of dentin collagen, reduces the demineralization rate, and promotes the remineralization of both enamel and dentin [22]. According to two recent systematic reviews/meta-analyses [22, 24] and an umbrella review [23], SDF inactivates and arrests the progression of caries lesions in children, being up to 90% clinically more effective than other active treatments, after two years of follow-up [21]; further, it prevents the formation of new carious cavities and avoids exposed dentin hypersensitivity (through developing a squamous layer and plugging dentin tubules) [69]. According to Crystal and Chaffee [70] and Vollú *et al*. [71], SDF requires much less chair time with similar clinical results in young children in comparison with the atraumatic restorative treatment and other therapies in arresting caries, anxiety and esthetic perception. The agent acts by combining sclerotic dentin formation, powerful antimicrobial effect and remineralization [24], without serious adverse effects [23]. The American Academy of Pediatric Dentistry recommends a 38% SDF application once a year; however, twice-yearly applications have also been suggested [9, 21, 55]. A great advantage of the therapy is that trained auxiliary personnel can apply the solution [9]. Its main and obvious drawback is the dark staining or blackening of the treated carious cavities, which may cause esthetic concerns [31, 72].

3.3.2 Non-restorative cavity control, atraumatic restorative treatment, and the hall technique

- Non-restorative cavity control (NRCC). Gruythuysen defines "non-restorative cavity control" as a concept that applies in primary teeth with the aim of reinstating the cleanability of cavitated carious lesions (ICDAS 3–5) by shaping, cutting or grinding away overhanging biofilm-trapping enamel or dentin [73]. It is considered a causal therapy (*i.e.*, fighting the cause of the disease and not its symptoms), and must be part of a comprehensive caries control program, including rigorous home care; thus, parents should be greatly involved in its success [74]. Examples of NRCC are (a) daily removal of cavity biofilm with toothbrush and fluoride toothpaste, supported by 3-monthly professional fluoride varnish application or placement of a glass-ionomer layer, or (b) professional application of SDF and daily biofilm removal with a toothbrush and fluoride toothpaste [75]. A randomized clinical trial in which the NRCC method was applied on occluso-proximal carious lesions reported that 70% of the carious lesions did not show any type of signs or symptoms of pulp irritation or damage after 2.5 years of follow-up; these results were similar to those of the conventional restorations group [76].

- Atraumatic restorative treatment ART. ART is a friendly two-step strategy for the management of occlusal and occluso-proximal carious cavities in primary teeth: (a) the restorative step, consisting of partial caries removal with hand excavators (with no local anesthesia, running or rotatory instruments) and the subsequent restoration with adhesive materials, such as high-viscosity GI cement or Intermediate Restorative Material (IRM), and (b) essential supportive oral educational-preventive strategies [15, 21, 77]. Reported restoration success rates range from 50 to 75% in the first 2 to 3 years, with reported survival rates after 3 years of evaluation even lower [21, 77, 78]. Further, the ART approach can be combined with previous topical applications of silver diamine fluoride with successful outcomes [72]. Two systematic reviews by Frencken *et al*. [33] and Chaudhari *et al*. [34] concluded that

the ART technique using high-viscosity glass ionomer cement might be considered a useful intervention to replace traditional restorative alternatives (composite resin or amalgam) in single- and multiple-surface carious cavitated lesions in primary molars, with up to 72% of survival rate after 6 years of follow-up.

- Hall technique. This MID-cost-effective intervention involves the sealing of deep carious cavities in primary molars by placing preformed metallic crowns, without local anesthesia and any type of caries removal, or coronal reduction [14, 32, 79]. Hall technique (HT) concept combines the biological management of carious lesions through both sealing pathogenic bacteria and depriving their nutrition sources. Furthermore, the molar structure loss is adequately restored [14, 21]. The crown is fitted and cemented with glass ionomer cement (which promotes lesion remineralization) [74], by either the clinician's finger pressure or the child's biting force, positioning it in an inevitable "high on the bite", above the occlusal plane [80]; however, an occlusion reestablishment will occur in 2 to 4 weeks.

Hu and co-workers [32] recently developed a systematic review with meta-analysis to assess the available evidence on HT for treating dentine caries in the primary dentition, in which 5 unique publications with low risk of bias were included in the statistical analysis. They concluded that HT crowns showed similar successful outcomes when compared to traditional preformed crowns and superior rates regarding direct restorations. In this same context, two randomized controlled trials were conducted in the primary dentition [77, 78]; it was concluded that HT is comparable with ART, in terms of clinical outcomes and acceptance by patients and parents, but ART causes less discomfort. Similar results were reported in a randomized controlled trial in primary molars by Ayedun *et al.* [80] when the HT was compared with conventional SSC-preformed crowns in clinical and radiographical outcomes. However, in another clinical trial, HT was significantly more successful clinically than NRCC after one year of follow-up [74]. This procedure has shown high success rates in the clinical setting as a restorative option for arresting caries and preserving the pulp vitality, with significant longevity until tooth shedding [16, 21, 32, 74]. However, poor esthetics is still a concern for clinicians and parents [32, 74].

3.3.3 Stepwise and selective dentin removal

During pediatric dentistry practice, it is frequent to treat deep carious lesions in vital and symptomless primary molars (ICDAS 6); in the last decades, the therapeutic possibilities for these lesions have evolved [19, 20]. According to different clinical trials performed in children and systematic reviews, in order to preserve dentin tissue on the cavity floor, clinicians and researchers have introduced contemporary concepts such as "selective" or "stepwise" (a two-stage excavation procedure) dentin removal as MID approaches for deep carious lesions [20, 47, 63, 81–83]. In the selective dentin removal (one-step dentin excavation or indirect pulp treatment/capping), the outer layers of carious dentin (infected, soft, irreversibly deteriorated and non-remineralizable) are completely removed [80]; the inner dentin layer (uninfected, hard, reversibly degenerated and physiologically remineralizable) is kept in place to avoid pulp exposures and complications [14, 20, 83]; this procedure stimulates dentin sclerosis, tertiary dentin formation and deepest carious dentin remineralization, without damaging the pulp tissue [21]. The dentin layer is then washed with a disinfecting solution (*e.g.*, chlorhexidine gluconate) and sealed beneath a long-lasting restoration [19, 63]. One-step partial removal of dentin carious has demonstrated similar clinical and radiographic success rates when compared to traditional total caries removal in primary teeth; this finding indicates that the procedure is a reliable, simple, inexpensive and quick MID strategy for applying in young children and that the maintenance of carious dentin does not interfere with pulp vitality [20, 21, 83]. Several studies have shown high clinical/radiographic success rates of the one-step dentin excavation technique in primary teeth, which are similar to those of pulpotomy. Further, an adequate cavity margin sealing, with a preformed metal crown, glass ionomer cement or resin composite, is a very important factor for the success of the procedure [18]. Diverse biocompatible capping materials have been studied for the technique in primary teeth, such as calcium hydroxide liner, dentin bonding agents, MTA (Mineral Trioxide Aggregate), glass ionomer cement, zinc oxide/eugenol, calcium silicate and Portland cement [18].

On the other hand, in the stepwise carious dentin removal method, a provisional restoration (*e.g.*, glass ionomer) is placed. Two-six months later, the restoration is detached and carious dentin is re-excavated until firm/leathery dentin remains in proximity to the pulp chamber [83, 84]; however, this management strategy is little recommended nowadays [20, 84]. Currently, available adhesive systems with suitable clinical, biological and mechanical properties, allow conservative restorations of cavitated lesions; these materials provide adequate sealing while conserving healthy remineralizable dentinal tissue, and also pulp vitality [81, 84].

3.4 Study limitations

The present evidence-based review presents the weakness that a critical methodological quality and the risk of bias assessment of each selected article were not assessed. However, we justify the validity of the current review through the inclusion of only high-quality methodological designs (controlled and randomized trials, systematic/umbrella reviews, meta-analysis and well-sustained clinical guidelines) because they are less prone to bias and confounding. On the other hand, even though the authors intended to gather the best available and reliable evidence, by restricting the literature search to only articles published in the English language, some relevant studies could be missed. Despite these limitations, we are confident that sufficient reliable and useful information on MID in primary dentition could be collected and synthesized.

As a summary, the authors propose a sequential MID plan for the primary dentition, according to the initial individual caries risk and ICDAS assessments; this plan is detailed in Fig. 1.

4. Conclusions

The MID treatment philosophy is not just a technique, but it should be considered as a conjunction of clinical preven-

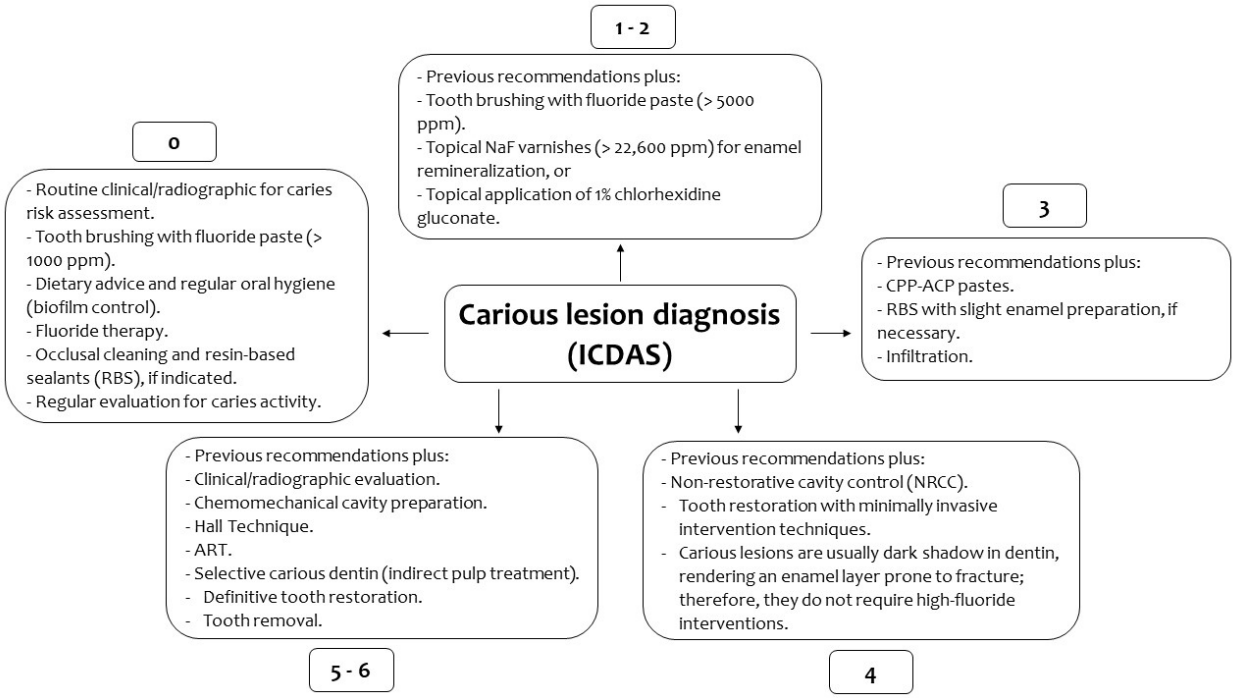

FIGURE 1. Decision-making flowchart for applying the MID method in young children (primary dentition). Complementary to this decision process, the clinician must perform a comprehensive individual risk caries assessment [40, 42]. CPP-ACP: casein phosphopeptide-amorphous calcium phosphate; ART: Atraumatic Restorative Treatment.

tive strategies and restorative therapies aiming to facilitate caries management in young children, with little discomfort and to increase the useful survival lifespan of primary teeth. This philosophy impacts the child's behavior management on the dental chair positively because many treatments can be carried out without local anesthesia, rubber-dam isolation or high-speed rotatory instruments, which reduce fear and anxiety in the patients. MID represents an attractive, cost-effective alternative for improving dental care coverage and enhancing the quality of life of pediatric patients, both at the individual and the community level, particularly in vulnerable or underserved populations. Because of its several advantages, in comparison with traditional caries management, MID should be encouraged and implemented among the pediatric dentistry community, despite the still existing resistance of many dental professionals. Through MID, caries disease is initially treated bearing in mind the purpose of controlling the biofilm, halting the carious lesion progression, preserving of tooth's structures, and reducing the risk of pulp exposures. Thus, the pulp vitality is maintained, avoiding radical invasive pulp procedures. Thereby, functional and esthetic needs are accomplished in the primary dentition. Before deciding the best MID approach treatment for non-cavitated or cavitated carious lesions or for preventing the development of new lesions in young children, the practitioner has to consider numerous clinical and socio-economic aspects, such as the patient's age, behavior or maturity level, caries risk, family expectations, treatment costs and professional expertise. When it is correctly applied in the family, MID philosophy is capable to increase the conditions for a better oral health status among infants and young children.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article (and supplementary material).

AUTHOR CONTRIBUTIONS

PNP, DGU and GTD—conceived the presented idea and designed the research study. SRR, AGR and APG—supervised the implementation of the electronic/manual search. AGR and APG—drafted the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Amaury Pozos-Guillén is serving as one of the Editorial Board members of

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SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1720309782439444480/attachment/Supplementary%20material.docx.

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