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Restorative approaches to treat dentin caries in preschool children: systematic review

ABSTRACT

Aim Dental restorations have long been used for the management of early childhood caries, but there is a need to have an evidence based approach when selecting the most appropriate restorative intervention to treat dentin caries in preschool children. This systematic review aimed to assess the effectiveness of restorative treatments of dentin caries in primary teeth in preschool children.

Materials and methods Design: A systematic search of the main electronic databases (Pubmed, Cochrane Collaboration, EMBASE) was conducted to identify peer reviewed papers published in English in the years 1947-2014. Search keywords and MeSH headings were "dental caries", "primary dentition" and "dental restoration". The inclusion criteria were clinical studies conducted in children under 6 years old, and reported findings on the longevity or failure of restorations in primary teeth. Retrieved papers were read by two reviewers independently to assess suitability for inclusion, and the final decision was made by consensus. The quality of the included studies was assessed and data were extracted for analysis.

Results The search identified 348 papers for screening. Among these, 218 papers did not satisfy the study inclusion criteria. Consequently, 130 full papers were retrieved and reviewed. Finally, 9 papers were included. Most of the trials were assessed as having high risk of bias. Five included studies that compared the success rates of restorations with different filling materials and liner materials. Two studies showed clinical advantages of using minimally invasive approaches in caries removal and cavity preparation. The other two trials showed

low success rates of interim GI restorations done in a field setting, compared to the high caries arrest rates of silver diammine fluoride application.

Conclusion Within the limitation of this systematic review, there is insufficient evidence to make recommendations regarding which material and technique is the most appropriate for restorative treatment in young children. Minimally invasive approaches are advantageous in operative caries management in primary teeth in preschool children. More well-designed randomised controlled trials are required to confirm these findings.

Keywords Dental caries; Dental restorations; Preschool children; Primary teeth.

Introduction

Early childhood caries (ECC) is a global oral health problem, particularly in disadvantaged communities in both developed and developing countries [Satcher, 2000]. ECC has implications for both the general and the dental health of affected children. Dental fillings or restorations have long been used for the management of ECC [Yengopal et al., 2009]. Materials used include amalgam, composite resins, glass ionomer cements and compomers, all of which performed well in one- or two-surface restorations [Qvist et al., 2010]. Prefabricated metal crowns are usually suitable for multi-surface lesions or extensive caries. The longevity of dental restorative materials used in the primary dentition was reviewed and great variations in the success rates were reported [Kilpatrick, 1993]. A recent Cochrane systematic review by Yengopal et al. [2009] concluded that there was insufficient evidence to recommend the best filling material for use in primary dentition. Therefore, there is still debate regarding the survival rates of different restorative materials in primary teeth.

Recently, new alternative techniques of cavity preparation/caries excavation have been introduced. These techniques include atraumatic restorative treatment (ART); tunnel preparation; air abrasion; sono-abrasion and chemo-mechanical caries removal. They all aim to remove or help remove caries-infected tissue as selectively as possible, while being minimally invasive through maximum preservation of caries-affected tissue [de Almeida Neves et al., 2011]. ART using high-viscosity glass ionomer cement has become an essential element in public oral health care systems, particularly in those with inadequate resources [Frencken, 2010]. In addition, it is considered as a good therapeutic option, especially in children, anxious patients and those with special needs [Holmgren et

al., 2013]. Despite its success for school children and adolescents, no systematic review of the effectiveness of ART for preschool children was published. Theoretically, caries lesions are arrested if they remain completely sealed. Partial or non-mechanical removal of carious tissue has been found to favour the arrest of dental caries [Ferreira et al., 2012]. Much of the evidence on the effectiveness of restorative treatment in primary teeth has been derived from cross-sectional and longitudinal retrospective studies which may have significant bias. Prior studies have noted that the longevity of restorations placed in younger children was lower [Wong and Day, 1990]. Results of clinical trials in schoolchildren are likely to differ from those of preschool children. The generalisability of using these restorative approaches in very young children has been questioned. Oral health professionals need to make astute decisions about the type of restorative materials and techniques chosen to manage patients with early childhood caries. To date, there is a lack of scientific evidence for clinically-effective restorative approach in dental caries management in preschool children. This systematic review aimed to assess the effectiveness of restorative treatments of dentin caries in primary teeth in preschool children.

Materials and Methods

Study design and follow-up period

Clinical studies of randomised controlled trial or controlled trial with a minimum follow-up period of 6 months were included. Studies on children aged below 6 years who had at least one dentin carious lesion in the primary dentition at the start of the study were considered for inclusion in this review.

Interventions

This review was concerned with comparisons of outcomes of different restorative approaches. Outcomes of restorative approaches were also compared with those of non-restorative approaches.

Various restorative treatments using different filling materials and different techniques for caries removal or cavity preparation in primary teeth were investigated. Different types of dental restorative materials that are used in the primary dentition such as amalgam, glass-ionomer, composite resin, polyacid-modified resin composite and crown were included. The various degrees of caries removal included no caries removal, incomplete caries removal and complete caries removal. Comparisons of outcomes between various techniques of caries removal (caries removal with rotary burs or spoon excavators with or without the chemo-mechanical method) were made. In addition, different techniques of cavity preparation, i.e. tunnel restoration, bevel preparation were evaluated.

Outcomes

The outcomes of the included studies were survival rates, failure rates or longevity of restorations. The treatment could have been performed by dentists or dental auxiliaries. The location of treatment could be in any place such as in kindergarten, hospital or dental clinic.

Exclusion criteria for studies for this review

Papers were excluded if they were in one or more of the following categories.

1. Incomplete description of sample selection and outcomes or poor study design.
2. Early reports of studies, *in vitro* or animal studies, narrative reviews or systematic reviews.

Where doubt existed over the exclusion of a study based on the title or abstract, the full paper was retrieved. For example, if the abstract reported a wide range of participants' age overlapping the preschool period (<6 years), the full text of the article was retrieved and then checked if there were available data for preschool subgroup analysis. Personal communication via email was established with some authors whose papers were identified for possible inclusion with the aim of obtaining information on additional studies which might be eligible for this review.

Search strategy

Identification of studies to be considered for inclusion was based on a systematic search of the popular electronic databases such as Pubmed, Cochrane collaboration and EMBASE. The search was restricted to reports written in English. Reports in the grey literature such as dissertations, theses, unpublished studies, product reports were not included in this study. Inclusion and exclusion criteria were applied by examining the title and abstract. Title and abstract of identified studies were independently reviewed by two reviewers for eligibility.

The keywords and MeSH headings were combined using four main concepts:

1. Dental caries [MeSH Terms] OR tooth demineralisation [MeSH Terms.]
2. Primary dentition [MeSH Terms] OR ("deciduous teeth") OR ("deciduous tooth") OR ("milk teeth") OR ("milk tooth") OR ("primary dentition") OR ("primary teeth") OR ("primary tooth") OR child [MeSH Terms].
3. Dental Restoration, Permanent [MeSH Terms] OR Dental Restoration, Temporary [MeSH Terms] OR Dental Amalgam [MeSH Terms] OR glass ionomer cement [MeSH Terms] OR composite resins [MeSH Terms] OR "stainless steel crown".
4. Survival rate [MeSH Terms] OR longevity [MeSH Terms] OR dental restoration failure [MeSH Terms].

Assessment criteria

Assessment of the risk of bias in the included studies

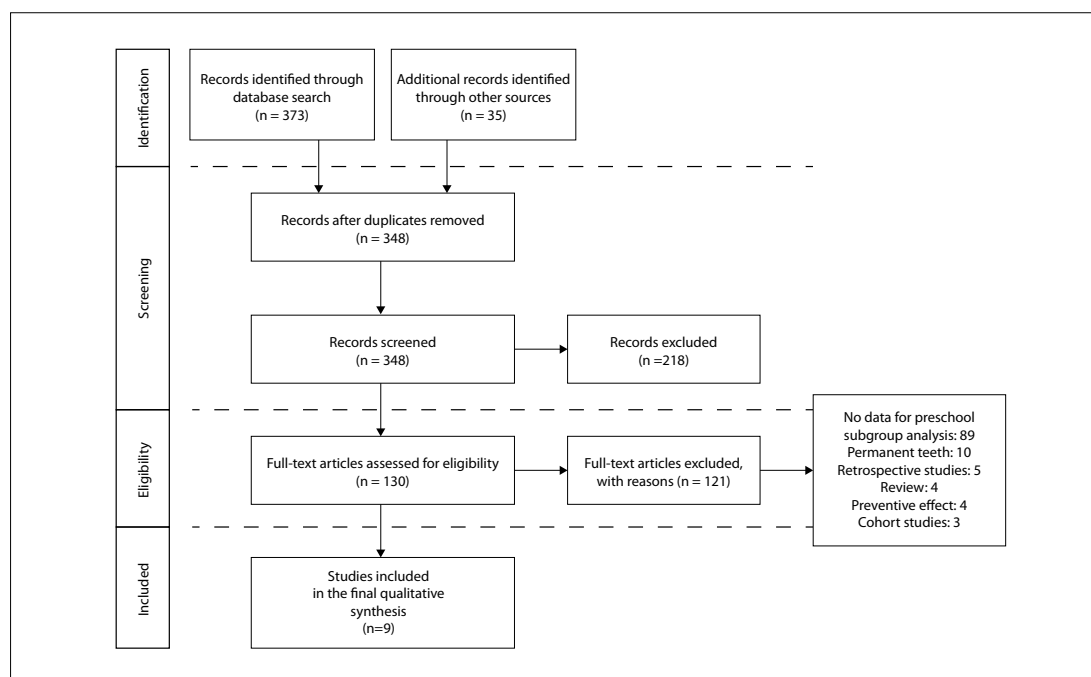


FIG 1 Flow diagram of identification and study selection for qualitative synthesis.

was conducted by using The Cochrane Collaboration's tool for assessing risk of bias [The Cochrane Collaboration, 2011]. Six domains were assessed for each included study: selection bias, performance bias, detection bias, attrition bias, reporting bias and other bias. Within each domain, a judgement of 'low', 'high' or 'unclear' risk of bias was made. An overall risk of bias was also made as follows.

- Low risk of bias (plausible bias unlikely to seriously alter the results) where all key domains were assessed at low risk of bias.
- Unclear risk of bias (plausible bias that raises some doubt about the results) where one or more of the domains was assessed unclear.
- High risk of bias (plausible bias that seriously weakens confidence in the results) where one or more domains was assessed at high risk of bias.

The quality of the studies was assessed using the criteria reported in the ADA Clinical Recommendations Handbook as follows [Center for Evidence-Based Dentistry, 2011].

- Initial assembly of comparable groups.
- Consideration of potential confounders with either restriction or measurement for adjustment in the analysis; consideration of inception cohorts.
- Maintenance of comparable groups (includes attrition, crossovers, adherence, contamination).
- Important differential loss to follow-up or overall high loss to follow-up.
- Measurements: equal, reliable, and valid (includes masking of outcome assessment).
- Clear definition of interventions.
- All important outcomes considered.
- Analysis: adjustment for potential confounders for

cohort studies, or intention to treat analysis for RCTs.

The studies were then graded as good, fair, or poor based on the ADA's criteria.

Results

Results of the search

From the search in PubMed, Cochrane and EMBASE databases, a total of 373 records was initially found. In addition, 35 further studies were retrieved by cross-referencing and screened for eligibility. Then, the 348 de-duplicated records were checked on the basis of the title, keywords, and abstract. From these records, 218 records were clearly irrelevant for this review due mainly to exclusion criteria such as reporting on permanent teeth, review papers or *in vitro* studies. The full text of the remaining 130 studies was investigated. Four authors of 4 studies were contacted for further information, and three of them replied. A total of 121 papers were excluded due to the following reasons: no data of preschool subgroup analysis (73.6%), conducted on permanent teeth (8.3%), retrospective studies (4.1%), review (3.3%), prevention only (3.3%), cohort studies (2.5%) and other reasons (5.0%). Finally, 8 trials reported in 9 articles were found eligible for this review (Fig. 1).

Included studies

Approximately 500 patients were involved in the included studies. Eight trials published in 9 publications were conducted in different countries (Table 1-3). The number of participants in each trial varied significantly

(from 21 to over 200 children). Trials were reported between 1990 and 2012 with follow-up period ranging from 1 to 5 years. Most trials recruited only preschool children, except two studies investigating both preschool and school children [Hickel and Voss, 1990, Barr-Agholme et al., 1991].

Outcomes of using different materials (liner and filling material) and techniques (caries removal and cavity preparation) were evaluated. The interventions were mostly carried out in a dental clinic. No paper reported on the fluoride background of the children. Evaluation of the restorations was mainly based on visuo-tactile clinical examination (6/9 articles) with a variety of assessment criteria. Half of the included articles (5/9) were graded as 'poor' and with 'high risk

of bias'. Random allocation and concealment allocation were unclear in most studies. The maintenance of comparable groups during the study period was only reported in one trial. Potential confounders were less considered in most studies. Due to the heterogeneity of outcomes with different therapeutic interventions, data were not pooled for meta-analysis.

Summary of findings

The 8 trials in the 9 articles could be divided into two different types of comparisons.

1. Comparisons between restorative approaches with different materials and techniques used (Table 1-2).
2. Comparisons between restorative and non-restorative approaches (Table 3).

Author (year)	Duration Study type	Participants	Intervention	Outcome Assessment	Results/Conclusion	Comment/Quality Assessment
Barr-Agholme et al. [1991]	2 years RCT	43 children* (mean age 6.4 years) who had proximal caries lesions in primary molars on both right and left sides	In every child, one composite and one amalgam restorations were placed randomly by two dentists. Group 1: 55 amalgam restorations Group 2: 64 composite restorations	Clinical exam (USPHS guidelines) and bitewing radiograph at 1- and 2-year follow up.	For children aged 4-6 years, 80% of composite restorations and 63% of amalgam restorations were classified as satisfactory. However, in all age groups, more composite restorations (88%) were classified as satisfactory compared to amalgam restorations (68%).	Random allocation was unclear. No sample size calculation was reported. Blinding of outcome assessment was impossible since the two materials looked totally different. In addition, the operator and investigator were the same person. Mistyping was found in Table 3. High risk of bias Study quality (ADA): poor
Hickel et al. [1990]	3.5 years controlled trial	74 children* (aged 4-10 years) having caries lesions in primary molars	215 restorations were placed using glass cermet cements (GCC) and amalgam.	Clinical exam using scores 1-4 following Ryge 's criteria score 1-2: acceptable score 3-4: need replacement	For children aged below 6, GCC showed slightly better results. At 2-year, survival rates of GCC and amalgam were 64% and 56%, respectively.	Random allocation and sample size calculation was not reported. Blinding of outcome assessment was impossible. High risk of bias Study quality (ADA): poor
Menezes et al. [2006]	1 year RCT	110 children (4-6 years) who had at least one dentin caries lesion in primary molars.	245 simplified restorations in primary molars using glass ionomer cements (Vidrion R and Ketac-Molar).	Clinical examination using the 0-4 scale as follows: 0= satisfactory with little wear and gap 1= satisfactory 2= unsatisfactory, needing repair 3= unsatisfactory, total loss 4= missing and replace	Success rate of teeth restored with Vidrion R on a single tooth surface was 63%, while the teeth restored with Ketac-Molar achieved a success rate of 82%. Regarding 2-surface restorations, the success rates of Vidrion R and Ketac Molar were 18% and 31%, respectively. High failure rates of multi-surface restorations were found.	The duration of follow up was short. Dropout rate (19%) was quite high for the 12-month follow-up. Moderate risk of bias Study quality (ADA): fair

TABLE 1 Details of included studies showing the success rates of restorations using different materials (n=5 articles).

Author (year)	Duration Study type	Participants	Intervention	Outcome Assessment	Results/Conclusion	Comment/Quality Assessment
Kirzioglu et al. [2007]	1 year RCT	28 children (4-6 years) with contralateral occlusal caries in primary molar teeth; size of lesions should be equal and open access (no access drilling)	56 occlusal caries were treated with two methods of caries removal in primary molars as follows: 1. Carisolv trade mark system 2. Hand excavation After caries removal, non rinse conditioner with bonding agent was applied and Dyract was used in both groups	Clinical follow-up was made every 3 months. Clinical evaluations of restorations were carried out in accordance with criteria with 5 categories: color match, marginal discoloration, anatomic form, marginal adaptation and secondary caries.	Regarding the overall clinical quality of restorations, the success rate of Carisolv ranged between 86-96%, while those of hand excavation were 78-93%. Marginal adaptation and secondary caries were found to be statistically insignificant (P>0.05) between groups. Carisolv system was effective in the removal of caries and caused minimum pain.	Strong design (Split mouth RCT) with low drop outs. However, sample size was small. The duration of 12-month follow-up was short. Reporting bias was found in favor of Carisolv, although no differences in success rates of restorations were found between two caries removal techniques. Moderate risk of bias Study quality (ADA): fair
Trairatvo-rakul and Piwat [2004]	2 years RCT	36 children aged 2years 6months-5 years 3months	36 matched pairs of Class III composite restorations in primary anterior teeth with the following designs: 1. Slot design 2. Dovetail design	Clinical exam: › marginal adaptation, › anatomic form, › secondary caries, › marginal discoloration	After 2 years, success rates of the slot and dovetail Class III restorations were 91% and 86%, respectively. There were no statistically significant differences in clinical characteristics between the two designs (p > 0.05).	Random allocation was unclear. No sample size calculation was reported. Blinding of outcome assessment was impossible. Loss to follow up was high (39%). High risk of bias Study quality (ADA): poor

TABLE 2 The details of included studies with the success rates of restorations using different operative techniques (n=2 articles).

Comparison between restorative approaches with different materials and techniques used (n= 7 articles).

Restorative materials (n=3)

Class II amalgam and composite restorations in primary molars by Barr-Agholme et al. [1991]

This trial recruited both preschool and school children, but the surface-level data of preschool children group were presented. From this part of the results, no significant differences were found between the success rates of composite (P30, 3M, St. Paul, MN, USA) and amalgam restorations (Dispers alloy, Lee Pharmaceuticals Corp, South El Monte, CA). The success rates of composite and amalgam restorations were 80% and 63%, respectively, at the 2-year recall evaluation. Due to high risk of bias, this study was graded as ‘poor’.

Class I and II glass cermet cement and amalgam restorations in primary molars by Hickel et al. [1990]

Children aged 4-10 years were recruited and 215 restorations were placed using Ketac-Silver (ESPE, Seefeld, West, Germany) and Amalcap SAS (Vivadent, Schaan, Liechtenstein). In the age-group 4-5.9 years, glass cermet cement restorations showed higher survival rates (64%)

compared with amalgam restorations (56%) at the 2-year recall. Both materials showed significantly poorer results in younger children compared with restorations in older children (p<0.0001). Due to high risk of bias, this study was graded as ‘poor’.

Different GI materials (Vidrion R and Ketac-Molar) in different classes of restorations by Menezes et al. [2006]

The atraumatic technique was performed without local anaesthesia in both groups. Overall, restorations with Ketac-Molar (3M ESPE, Seefeld, Germany) had a better clinical performance than those with Vidrion R (SS White, Senador Alencar, Rio de Janeiro, Brazil). The two-surface GI restorations of both materials yielded lower success rates (18%-31%) compared to the single-surface GI restorations (63%-82%). The study was rated as ‘fair’ with moderate risk of bias.

Liner materials (n=2)

The effect of adhesive system and Dycal (Dentsply, Milford, DE) over incomplete dentin caries removal were evaluated in Class I composite restorations in primary molars. The 2- and 5-year follow up results were published

by Falster et al. [2002] and Casagrande et al. [2009], respectively. Composite resin (Z100) (3M ESPE, Seefeld, Germany) was used as a filling material in both groups. The clinical and radiographic success rates of the two materials used were very high (over 80%) at the 2- and 5-year recall evaluation. No significant differences were found in success rates between different liner materials used in Class I composite restorations. The quality of this trial was rated as 'poor' with high risk of bias due to high dropout (over 40% at 5-year recall) and small sample size. These plausible biases could weaken the confidence of the results.

Caries removal (n=1)

The clinical efficacy of Carisolv (MediTeam Dental AB, Gothenburg, Sweden) and the hand excavation method in removing occlusal dentin caries of primary molars was evaluated [Kirzioglu et al., 2007]. Dyract AP (Dentsply/De Trey, Konstanz, Germany) was used to restore the teeth in both groups. Differences between Carisolv and hand excavation groups in terms of marginal adaptation and secondary caries were not statistically significant.

Overall, success rates of both groups were high, ranged from 78%-96% at the end of 1 year. Chemo-mechanical treatment with Carisolv caused less pain, but it was more time consuming than hand excavation. This study was found to have a moderate risk of bias with the quality of study as 'fair'.

Cavity preparation (n=1)

The clinical characteristics between slot and dovetail Class III preparation of primary anterior teeth were compared [Trairatvorakul and Piwat, 2004]. At 2 years, overall high success rates (86%-91%) of Class III composite restoration with two types of cavity preparation were found. No significant differences in clinical characteristics were found between the slot and the dovetail preparations. Due to high risk of bias (small sample size with high dropout rates), this study was graded as 'poor'.

Comparison between the restorative and non-restorative approaches (n=2)

Two studies compared the results of GI restorations and silver diammine fluoride (SDF) application [dos Santos et

Author (year)	Duration Study type	Participants	Intervention	Outcome Assessment	Results/Conclusion	Comment/Quality Assessment
Zhi et al. [2012]	2 years RCT	212 children aged 3-4 years with active caries in primary teeth	1. 38% SDF once a year 2. 38% SDF twice a year 3. Flowable GI filling (Fuji VII) once a year	Clinical examination criteria used: Active: lesions were easily penetrated by probe Arrested: smooth, hard surfaces when probed, but for Group 3 also lesions totally covered with GI.	After 24 months, only 3.5% full retention of GI material found. Caries arrest rates in Groups 1-3 found at the 24 - month examination were 79%, 91% and 82%, respectively. Although retention of restorations was low, the caries arrest rate of Group 3 was high, 82%. Effect of annual SDF and GI application on arresting caries did not differ significantly.	Well- planned study design (random allocation, adequate sample size) Dropout rate was not high (15%). Confounding factors were taken into consideration. However, blinding of outcome assessment (between group 3 and groups 1,2) is impossible. Low risk of bias Study quality (ADA): good
dos Santos et al. [2012]	1 year RCT	91 children aged 5-6 years	1. interim restorative treatment with GI filling (Fuji IX) without caries removal 2. 30% SDF	Clinical examination criteria used: Group 1: arrested if restorative materials was present Group2 Active caries: lesions were easily penetrated by probes Arrested caries: smooth hard surfaces when probed	At 12 months, the success rate of SDF (67%) was higher than interim restoration with GI filling (39%). There was a higher rate of failure when GIC filling involved multiple surfaces (52%) relative to a single surface (48%). SDF was more effective than interim restoration with GI for arresting caries in primary teeth.	No details about the random allocation and attrition rate. Non blinded study and duration of study was short. High risk of bias Study quality (ADA):poor

TABLE 3 The details of included studies with the success rates of restorative and non-restorative approaches (n=2 articles).

al., 2012; Zhi et al., 2012]. The quality of one of these two trials was graded following ADA criteria as "good" and the other one as "poor" as seen in Table 3. The therapeutic interventions of both trials were somewhat similar, using either silver diammine fluoride or GI restorations under field settings. However, no caries removal was done prior to restoration placement (interim therapeutic restoration) in the study by dos Santos [2012], while the other trial removed soft caries using hand excavation and restored with flowable glass ionomer cements. Low success rates (29%-39%) of restorations were found in both studies at the 12-month follow up.

Actually, caries arrest rate was the main outcome of these trials comparing restorative and non-restorative approach. Zhi et al. [2012] found that annual and semi-annual application of SDF solution arrested active dentin caries with success rates of 79% and 91%, respectively, while the annual paint-on of flowable glass ionomer arrested active dentine caries (82%). Similarly, the trial by dos Santos et al. [2012] reported that success rate of SDF (67%) was higher than that of interim restoration with GI filling (39%) at 12 months. However, detection bias could easily occur since fillings and fluoride treatment were totally different.

Discussion

Restorative approaches are the mainstream to treat tooth decay in children by involving caries removal and placement of restorations. New restorative materials and alternative techniques have been developed. Much effort has been made to improve the quality of conducting and reporting clinical studies such as the SPIRIT 2013 statement [Chan et al., 2013], and the CONSORT 2010 statement [Schulz et al., 2010]. There is a need for the dental professionals in this era to use an evidence-based approach when selecting materials and techniques for treating the decayed teeth in their young patients. However, it was somewhat disappointing that there is insufficient scientific evidence to support the materials and techniques commonly used for the management of carious primary teeth. At the full text stage, over 120 relevant studies were retrieved. However, most of these studies had inadequate information to support further preschool children subgroup analysis. As a result, only 8 trials (9 publications) were suitable for this review, although the inclusion criteria of different types of intervention were as broad as possible. In addition, the majority of the included studies showed a high risk of bias. The lack of quality studies has also been found in other systematic reviews concerning primary teeth [Yengopal et al., 2009].

Shortcomings of the included studies include deficiencies in study design or insufficient reporting regarding the randomisation procedures and allocation concealment. Other confounding factors such as caries risk and habits of subjects were seldom considered. Unlike the studies in

preventive dentistry, most included trials did not adequately describe the details of subjects such as dmft score, behaviour and socioeconomic background. Therefore, there is a lack of certainty that the different groups were initially comparable. Furthermore, the external validity of the study results is unclear. The conclusions would have been more useful, if these confounding variables had been taken into account. In addition, sample size calculation and statistical power analysis were not presented in most trials. High loss to follow up was commonly found in the included studies and drop-out rates in the different study groups were seldom reported.

Regarding the outcome measurement, the US Public Health Service (USPHS) criteria with five categories (color match, marginal discolouration, anatomic form, marginal adaptation and secondary caries) or the Ryge criteria were commonly used and adapted to evaluate the quality of restorations. The overall criteria to judge restorations as acceptable or failure was somewhat different among the included studies. One trial focused only on a specific aspect, and it was unclear how many restorations failed in total [Kirzioglu et al., 2007]. Recommendations for conducting controlled clinical studies of dental restorative materials have been published [Hickel et al., 2007]. The assessment of dental restorations should be based on three main clinical criteria as follows: aesthetic properties (roughness, staining, colour match, anatomic form), functional properties (fracture, marginal adaptation, wear, proximal contact, patient's perception) and biological properties (post-operative sensitivity, recurrence of caries, periodontal and mucosal response, oral and general health). However, questions remain if it is practical and valuable to adopt all criteria in assessments to judge the quality of restoration in primary teeth. Improved dental health rather than achievement in operative caries therapy will be of great benefit for both patients and care-providers. Oral health related quality of life, acceptability of treatment and dentist's preferences should also be evaluated to provide information for decision making by policy makers, clinicians and patients. Continuing research to develop a standard and appropriate assessment of restorative approaches in primary teeth is required.

Regarding the limitation of this review, language bias could occur since we focused on papers published in English, leading to possibly erroneous conclusions. Nevertheless, it was found that excluding trials published in languages other than English has generally little effect on summary treatment effect estimates [Juni et al., 2002]. Another possible limitation of this review was the lack of meta-analysis results which may restrict the interpretation of findings. However, due to the heterogeneity of the included studies such as clinical and methodological diversity, the meta-analysis results would not be appropriate and true differences would be obscured.

Amalgam has been the material of choice for restoring the primary and permanent posterior teeth for years. Surprisingly, only three trials which compared different

restorative materials were found to be eligible for inclusion in this review. The success rate of Class II amalgam restorations found in this review was lower than that of composite restorations [Barr-Agholme et al., 1991]. In contrast to an earlier systematic review [Kilpatrick and Neumann, 2007], it was reported that failure rates of Class II amalgam restorations were low under more controlled conditions. However, that study was graded as 'poor' due to the deficiency in study design and poor internal validity.

Glass ionomer cements have an important place in restorative dentistry for children because of their fluoride releasing property and chemical adhesion. The present review found that different brands of GI restorative materials had significant differences in failure rates. Glass ionomers are usually brittle and have lower flexural and compressive strength than amalgam. Metal-reinforced glass ionomers (glass cermet cements) have been proposed for primary molars with better properties such as less occlusal wear and greater flexural strength [Hickel and Voss, 1990]. However, the 2-year results of the included study showed high failure rates (over 40%) of both amalgam and glass cermet cement restorations in young children.

Using the atraumatic restorative treatment [Menezes et al., 2006], GI Class I restorations showed higher success rates (63%-82%) than GI multiple-surface restorations (18%-31%). These results are consistent with those of another review which found that failure rates of glass ionomer cements with conventional Class II cavities varied from 7% to 60% [Chadwick and Evans, 2007]. Similarly, a recent review of ART restorations showed higher failure rates of multiple-surface ART restorations compared to those of single-surface ART restorations [de Amorim et al., 2012]. Based on the present review, the use of GI with ART technique is successful in Class I cavities in preschool children. Placement of GI in multiple-surface carious primary teeth should be done with greater caution.

In general, stainless steel crowns (SSC) or composite strip crowns are indicated to restore primary teeth with multiple carious surfaces. It was reported that failure rates of preformed metal crowns varied between 2%-30% and were lower than those of comparable restorations [Attari and Roberts, 2006]. Due to the specific research question, focusing on caries into dentin level without symptoms, studies in non-vital teeth were excluded since it is difficult to judge if the cause of clinical failures occurred as a result of restoration leakage or recurrent of pulp inflammation. Within the limitation of this study, no conclusion could be made regarding the clinical success of stainless steel crowns or strip crowns for the treatment of decayed vital teeth in preschool children.

Regarding the different liner materials for indirect pulp capping, the success rates of Class I composite restorations of both groups (Dycal and adhesive system) were high (over 80%) at the 2- and 5-year follow up [Casagrande et al., 2009; Falster et al., 2002]. No significant differences between liners were found in the success rate of restorations. These findings seem to support the

observations of a previous review, which found that partial removal of carious tissues favours the arrest of dental caries lesions in primary teeth [Ferreira et al., 2012]. However, with a small sample size (only 21 children involved in the included study) caution is required as the findings might not be transferable to all preschool children. More research in this topic needs to be undertaken before a conclusion can be drawn.

Despite Carisolv has been used to remove carious dentin for some time, questions remain regarding its effectiveness and efficacy. A previous systematic review found that, compared with rotary instruments, Carisolv did not increase complete caries removal rates and the treatment time of Carisolv group was significantly longer than that of the group using local anaesthesia [Li et al., 2014]. Similarly, the included study in this review reported that Carisolv system caused minimum level of pain. However, the use of Carisolv for caries removal did not enhance the success rates of restorations, compared to the use of hand excavation alone [Kirzioglu et al., 2007]. From this point, the future use of Carisolv is likely to be influenced not by the evidence of the longevity of restorations or the efficacy of caries removal but rather by less pain occurrence in young children.

Nowadays, caries management is being modified to less 'surgical' by preserving the tooth structure in combination with good sealing restorations. This concept was supported by Trairatvorakul and Piwat [2004] who found that the additional dovetail preparation did not result in better clinical characteristics, nor more durability than the slot preparation in Class III composite restorations. Nevertheless, it was somewhat surprising that the placement of composite in young children exhibited relatively high success rates (86%-91%) in overall clinical quality of restorations. There are several possible explanations for these results. This trial was conducted by a specialist with very specific inclusion criteria. In addition, all restorations were placed using rubber dam and local anaesthesia. These results may not be transferable to the restorative treatment by general dental practitioners in a primary care setting.

Use of non-restorative approach by topical application of silver diammine fluoride (SDF) solution has better results on caries arrest, compared to the restorative approach with interim GI restorations under field settings [dos Santos et al., 2012, Zhi et al., 2012]. The high failure rates of restorations done in a field setting might be explained as follows. Firstly, operative techniques such as 'no caries removal' might affect the longevity of restorations [dos Santos et al., 2012]. Secondly, the type of materials used such as flowable GI restorative material which usually have lower strength than the conventional GI material might also lower the retention rates of fillings [Zhi et al., 2012]. In light of the results of two included studies, instead of GI restorations, the application of SDF solution may be a better alternative as it is less-invasive and more cost-effective in young children. Result of this review supports

that of a previous systematic review [Rosenblatt et al., 2009] which concluded that SDF is an effective therapeutic agent for treating dentin caries. However, black staining on caries lesions after SDF application is common. Prior to using this agent, adverse effects should be clearly explained and caution should be exercised when applying high concentrated fluoride agents to young children.

Despite the high prevalence of ECC and the variability of treatment, results of this systematic review are insufficient to make decisions on the most appropriate choice of materials and techniques for placing dental restorations in young children. There is great variation in the success rate of restorations, depending on the type of cavities, materials and operative techniques. In controlled clinical trials in preschool children, the single-surface composite or compomer restorations such as Class I and III in primary teeth are effective with favourable success rates regardless of the operative techniques used. The two-surface restorations have highly variable success rates. Regarding the operative techniques, the use of minimally invasive approaches (indirect pulp capping, ART, hand excavation, slot preparation) to preserve more tooth structure seems to be beneficial for preschool children. Provisional or interim GI restoration performed in a field setting is less effective on caries arrest compared to non-surgical approach using SDF solution. However, due to the risk of bias within included studies, further well-designed randomised clinical trials are required to compare different caries management strategies in preschool children.

Conclusion

Within the limitation of this systematic review, it is found that there is insufficient evidence to make any recommendations on which material and technique is the most appropriate for a restorative treatment in young children. Minimally invasive approaches are advantageous in treating dentin caries in primary teeth in preschool children.

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