Pediatric Restorative Dentistry

Latest Revision

2019

How to Cite: American Academy of Pediatric Dentistry. Pediatric restorative dentistry. The Reference Manual of Pediatric Dentistry. Chicago, Ill.: American Academy of Pediatric Dentistry; 2020:371-83.

Purpose

The American Academy of Pediatric Dentistry (**AAPD**) intends these recommendations to help practitioners make decisions regarding restorative dentistry, including when it is necessary to treat and what the appropriate materials and techniques are for restorative dentistry in children and adolescents.

Methods

These recommendations originally were developed by the Restorative Dentistry Subcommittee of the Clinical Affairs Committee and adopted in 1991.[1] The last comprehensive revision by the Council of Clinical Affairs of this document was in 2014,[2] and an addition regarding the Hall technique (**HT**) for preformed metal crowns was added in 2016.[3] A thorough review of the scientific literature in the English language pertaining to restorative dentistry in primary and permanent teeth was completed to revise the previous guideline. Electronic database and hand searches, for the most part between the years 2000-2019, were conducted using the terms: dental caries, intra-coronal restorations, restorative treatment decisions, caries diagnosis, caries excavation, dental amalgam, glass ionomers, resin modified glass ionomers, conventional glass ionomers, atraumatic/alternative restorative technique (**ART**), interim therapeutic restoration (**ITR**), resin infiltrations, resin based composite, dental composites, compomers, full coverage dental restorations, stainless steel crowns (**SSC**), Hall technique, primary molars, preformed metal crowns, strip crowns, pre-veneered crowns, zirconia crowns, esthetic restorations; parameters: clinical trials, randomized controlled clinical trials (**RCTs**).

Full evaluation and abstraction included examination of the clinical efficacy on specific restorative dentistry topics, research methods, and potential for study bias (e.g., patient recruitment, randomization, blinding, subject loss, sample size estimates, conflicts of interest, statistics). Research that was considered deficient or had high bias was eliminated. In those topic areas for which there were rigorous meta-analyses or systematic reviews available, only those clinical trial articles that were not covered by the reviews were subjected to full evaluation and abstraction.

The assessment of evidence for each topic was based on a modification of the American Dental Association's grading of recommendations: strong evidence (based on well-executed RCTs, meta-analyses, or systematic reviews); evidence in favor (based on weaker evidence from clinical trials).[4]

When to restore

Historically, the management of dental caries was based on the belief that caries was a progressive disease that eventually destroyed the tooth unless there was surgical and restorative intervention.[5] It is now recognized that restorative treatment of dental caries alone does not stop the disease process,[6] and restorations have a finite lifespan. Conversely, some caries lesions may not progress and, therefore, may not need restoration. Contemporary management of dental caries includes identification of an individual's risk for caries progression, understanding of the disease process for that individual, and active surveillance to assess disease progression and manage with appropriate preventive services, supplemented by restorative therapy when indicated.[7,8]

With the exception of reports of dental examiners in clinical trials, studies of reliability and reproducibility of detecting dental caries are not conclusive.[9] There also is minimal information regarding validity of caries diagnosis in primary teeth,[5] as primary teeth may require different criteria due to thinner enamel and dentin and broader proximal contacts.[10]

Furthermore, indications for restorative therapy only have been examined superficially because such decisions generally have been regarded as a function of clinical judgment.[11] Decisions for when to restore caries lesions should include at least clinical criteria of visual detection of enamel cavitations, visual identification of shadowing of the enamel, and/or radiographic recognition of enlargement of lesions over time.[7,12,13]

The benefits of restorative therapy include: removing cavitations or defects to eliminate areas that are susceptible to caries; stopping the progression of tooth demineralization; restoring the integrity of tooth structure; preventing the spread of infection into the dental pulp; and preventing the shifting of teeth due to loss of tooth structure. The risks of restorative therapy include reducing the longevity of teeth by making them more susceptible to fracture, recurrent lesions, restoration failure, pulp exposure during caries excavation, future pulpal complications, and iatrogenic damage to adjacent teeth.[14,15]

ABBREVIATIONS

AAPD: American Academy of Pediatric Dentistry. **ART:** Alternative restorative technique. **BPA:** Bisphenol A. **FDA:** Food and Drug Administration. **GIC:** Glass ionomer cement. **HT:** Hall technique. **ITR:** Interim therapeutic restoration. **RCTs:** Randomized controlled trials. **RMGIC:** Resin modified glass ionomer cements. **SSC:** Stainless steel crowns. **UK:** United Kingdom.

Primary teeth may be more susceptible to restoration failures than permanent teeth.[16] Additionally, before restoration of primary teeth, one needs to consider the length of time remaining prior to tooth exfoliation.

Recommendations:

1. Management of dental caries includes identification of an individual's risk for caries progression, understanding of the disease process for that individual, and active surveillance to assess disease progression and manage with appropriate preventive services, supplemented by restorative therapy when indicated.
2. Decisions for when to restore carious lesions should include at least clinical criteria of visual detection of enamel cavitation, visual identification of shadowing of the enamel, and/or radiographic recognition of progression of lesions.

Deep caries excavation and restoration

Among the objectives of restorative treatment are to repair or limit the damage from caries, protect and preserve the tooth structure, and maintain pulp vitality whenever possible. The AAPD's *Use of Vital Pulp Therapies in Primary Teeth with Deep Caries Lesions*[17] and *Pulp Therapy for Primary and Immature Permanent Teeth*[18] state the treatment objective for a tooth affected by caries is to maintain pulpal vitality, especially in immature permanent teeth for continued apexogenesis.[19]

With regard to the treatment of deep caries, three methods of caries removal have been compared to complete excavation, where all carious dentin is removed. Stepwise excavation is a two-step caries removal process in which carious dentin is partially removed at the first appointment, leaving caries over the pulp, with placement of a temporary filling. At the second appointment, all remaining carious dentin is removed and a final restoration placed.[19] Partial, or one-step, caries excavation removes part of the carious dentin, but leaves caries over the pulp, and subsequently places a base and final restoration.[20,21] No removal of caries before restoration of primary molars in children aged three to 10 years also has been reported.[22]

Evidence from RCTs and a systematic review shows that pulp exposures in primary and permanent teeth are significantly reduced using incomplete caries excavation compared to complete excavation in teeth with a normal pulp or reversible pulpitis. Two trials and a Cochrane review found that partial excavation resulted in significantly fewer pulp exposures compared to complete excavation.[23-25] Two trials of step-wise excavation showed that pulp exposure occurred more frequently from complete excavation compared to stepwise excavation.[19,24] There also is evidence of a decrease in pulpal complications and post-operative pain after incomplete caries excavation compared to complete excavation in clinical trials, summarized in a meta-analysis.[28]

Additionally, a meta-analysis found the risk for permanent restoration failure was similar for incompletely and completely excavated teeth.[28] With regard to the need to reopen a tooth with partial excavation of caries, one RCT that compared partial (one-step) to stepwise excavation in permanent molars found higher rates of success in maintaining pulp vitality with partial excavation, suggesting there is no need to reopen the cavity and perform a second excavation.[20] Interestingly, two RCTs suggest that restoration without excavation can arrest dental caries so long as a good seal of the final restoration is maintained.[22,29]

Recommendations:

1. There is evidence from RCTs and systematic reviews that incomplete caries excavation in primary and permanent teeth with normal pulps or reversible pulpitis, either partial (one-step) or stepwise (two-step) excavation, results in fewer pulp exposures and fewer signs and symptoms of pulpal disease than complete excavation.
2. There is evidence from two systematic reviews that the rate of restoration failure in permanent teeth is no higher after incomplete rather than complete caries excavation.
3. There is evidence that partial (one-step) excavation followed by placement of final restoration leads to higher success in maintaining pulp vitality in permanent teeth than stepwise (two-step) excavation.

Resin infiltration

Resin infiltration is used primarily to arrest the progression of non-cavitated interproximal caries lesions.[30,31] The aim of the resin infiltration technique is to allow penetration of a low viscosity resin into the porous lesion body of enamel caries.[30] Once polymerized, this resin serves as a barrier to acids and theoretically prevents lesion progression.[32]

A systematic review and meta-analysis evaluated the effectiveness of enamel infiltration in preventing initial caries progression in proximal surfaces of primary and permanent teeth. This review identified eight studies for inclusion for quantitative analysis.[33] Seven of the eight studies found that infiltration was significantly more effective than placebo treatment. The meta-analysis compared 470 teeth in the resin infiltration group and 473 in the control group. Caries progression was seen in 61 of the infiltration group and 185 of the control group. Current American Dental Association clinical practice guidelines for non-restorative treatment for non-cavitated interproximal caries lesions conditionally recommends enamel infiltration for treatment of these lesions, (low to very low certainty).[34] Few RCTs evaluate the long-term effectiveness of resin infiltration, and further research is recommended. An additional use of resin infiltration has been suggested to restore white spot lesions formed during orthodontic treatment. Based on a RCT, resin infiltration significantly improved the clinical appearance of such white spot lesions and visually reduced their size.[35,36]

Recommendation:

1. There is low to moderate evidence in favor of resin infiltration as a treatment option for small, non-cavitated interproximal caries lesions in primary and permanent teeth.
2. Further research regarding long-term effectiveness of resin infiltration is needed.

Dental amalgam

Dental amalgam has been the most commonly used restorative material in posterior teeth for over 150 years.[37] Amalgam contains a mixture of metals such as silver, copper, and tin, in addition to approximately 50 percent mercury.[38] Dental amalgam has declined in use over the past decade,[37] perhaps due to the controversy surrounding perceived health effects of mercury vapor, environmental concerns from its mercury content, and increased demand for esthetic alternatives.

With regard to safety of dental amalgam, a comprehensive literature review of dental studies published between 2004 and 2008 found insufficient evidence of associations between mercury release from dental amalgam and the various medical complaints.[39] Two independent RCTs in children have examined the effects of mercury release from amalgam restorations and found no effect on the central and peripheral nervous systems and kidney function.[40,41] However, on July 28, 2009, the U.S. Food and Drug Administration (**FDA**) issued a final rule that reclassified dental amalgam to a Class II device (having some risk) and designated guidance that included warning labels regarding: (1) possible harm of mercury vapors; (2) disclosure of mercury content; and (3) contraindications for persons with known mercury sensitivity. Also in this final rule, the FDA noted that there is limited information regarding dental amalgam and the long-term health outcomes in pregnant women, developing fetuses, and children under the age of six.[38]

With regard to clinical efficacy of dental amalgam, results comparing longevity of amalgam to other restorative materials are inconsistent. The majority of meta-analyses, evidence-based reviews, and RCTs report comparable durability of dental amalgam to other restorative materials,[42-47] while others show greater longevity for amalgam.[48,49] The comparability appears to be especially true when the restorations are placed in controlled environments such as university settings.[42]

Class I amalgam restorations in primary teeth have shown in a systematic review and two RCTs to have a success rate of 85 to 96 percent for up to seven years, with an average annual failure rate of 3.2 percent[16,46,49] Efficacy of Class I amalgam restorations in permanent teeth of children has been shown in two independent randomized controlled studies to range from 89.8 to 98.8 percent for up to seven years.[46,48]

With regard to Class II restorations in primary molars, a 2007 systematic review concluded that amalgam should be expected to survive a minimum of 3.5 years and potentially in excess of seven years.[50] For Class II restorations in permanent teeth, one meta-analysis and one evidence-based review conclude that the mean annual failure rates of amalgam and composite are equal at 2.3 percent.[42,45] The meta-analysis comparing amalgam and composite Class II restorations in permanent teeth suggests that higher replacement rates of composite in general practice settings can be attributed partly to general practitioners' confusion of marginal staining for marginal caries and their subsequent premature replacements. Otherwise, this meta-analysis concludes that the median success rate of composite and amalgam are statistically equivalent after ten years, at 92 percent and 94 percent respectively.[42]

The limitation of many of the clinical trials that compare dental amalgam to other restorative materials is that the study period often is short (24 to 36 months), at which time interval all materials reportedly perform similarly.[51-55] Some of these studies also may be at risk for bias, due to lack of true randomization, inability of blinding of investigators, and, in some cases, financial support by the manufacturers of the dental materials being studied.

Recommendation:

There is strong evidence that dental amalgam is efficacious in the restoration of Class I and Class II cavity restorations in primary and permanent teeth.

Composites

Resin-based composite restorations were introduced in dentistry about a half century ago as an esthetic restorative material[56,57], and composites increasingly are used in place of amalgam for the restoration of carious lesions.[58] Composites consist of a resin matrix and chemically bonded fillers.[42] They are classified according to their filler size, because filler size affects polishability/esthetics, polymerization depth, polymerization shrinkage, and physical properties. Hybrid resins combine a mixture of particle sizes for improved strength while retaining esthetics.[59] The smaller filler particle size allows greater polishability and esthetics, while larger size provides strength. Flowable resins have a lower volumetric filler percentage than hybrid resins.[60]

Several factors contribute to the longevity of resin composites, including operator experience, restoration size, and tooth position.[48] Resins are more technique sensitive than amalgams and require longer placement time. In cases where isolation or patient cooperation is in question, resin-based composite may not be the restorative material of choice.[61]

Bisphenol A (**BPA**) and its derivatives are components of resin-based dental sealants and composites. Trace amounts of BPA derivatives are released from dental resins through salivary enzymatic hydrolysis and may be detectable in saliva up to three hours after resin placement.[62] Evidence is accumulating that certain BPA derivatives may pose health risks attributable to their estrogenic properties. BPA exposure reduction is achieved by cleaning filling surfaces with pumice and cotton roll and rinsing. Additionally, potential exposure can be reduced by using a rubber dam.[62] Considering the proven benefits of resin based dental materials and minimal exposure to BPA and its derivatives, it is recommended to continue using these products while taking precautions to minimize exposure.[62]

There is strong evidence from a meta-analysis of 59 RCTs of Class I and II composite and amalgam restorations showing an overall success rate about 90 percent after 10 years for both materials, with rubber dam use significantly increasing restoration longevity.[42] Other isolation techniques (e.g., dental isolation suction systems) may be used. Strong evidence from RCTs comparing composite restorations to amalgam restorations showed that the main reason for restoration failure in both materials was recurrent caries.[46,48,63]

In primary teeth, there is strong evidence that composite restorations for Class I restorations are successful.[16,46] There is only one RCT showing success in Class II composite restorations in primary teeth that were expected to exfoliate within two years.[53] In permanent molars, composite replacement after 3.4 years was no different than amalgam,[46] but after seven to 10 years the replacement rate was higher for composite.[61] Secondary caries rate was reported as 3.5 times greater for composite versus amalgam.[48] There is evidence from a meta-analysis showing that etching and bonding of enamel and dentin significantly decreases marginal staining and detectable margins in composite restorations.[42] Regarding different types of composites (packable, hybrid, nanofilled, macrofilled, and microfilled) there is strong evidence showing similar overall clinical performance for these materials.[64-67]

Recommendations:

1. In primary molars, there is strong evidence from RCTs that composite resins are successful when used in Class I restorations. For Class II lesions in primary teeth, there is one RCT showing success of composite resin restorations for two years.
2. In permanent molars, there is strong evidence from meta-analyses that composite resins can be used successfully for Class I and II restorations.
3. Evidence from a meta-analysis shows enamel and dentin bonding agents decrease marginal staining and detectable margins for the different types of composites.

Glass-ionomer cements (GIC)

Glass-ionomers cements have been used in dentistry as restorative cements, cavity liner/base, and luting cement since the early 1970s.[68] Originally, glass ionomer materials were difficult to handle, exhibited poor wear resistance, and were brittle. Advancements in conventional glass ionomer formulation led to better properties, including the formation of resin-modified glass ionomers. These products showed improvement in handling characteristics, decreased setting time, increased strength, and improved wear resistance.[69,70] All glass ionomers have several properties that make them favorable for use in children including: chemical bonding to both enamel and dentin; thermal expansion similar to that of tooth structure; biocompatibility; uptake and release of fluoride; and decreased moisture sensitivity when compared to resins.

Fluoride is released from glass ionomer and taken up by the surrounding enamel and dentin, resulting in teeth that are less susceptible to acid challenge.[71,72] One study has shown that fluoride release can occur for at least one year.[73] Glass ionomers can act as a reservoir of fluoride, as uptake can occur from dentifrices, mouth rinses, and topical fluoride applications.[74,75] This fluoride protection, useful in patients at high risk for caries, has led to the use of glass ionomers as luting cement for SSCs, space maintainers, and orthodontic bands.[76]

Regarding use of conventional glass ionomers in primary teeth, one RCT showed the overall median time from treatment to failure of glass ionomer restored teeth was 1.2 years.[49] Based on findings of a systematic review and meta-analysis, conventional glass ionomers are not recommended for Class II restorations in primary molars.[77,78] Conventional glass ionomer restorations have other drawbacks such as poor anatomical form and marginal integrity.[79,80] Composite restorations were more successful than GICs where moisture control was not a problem.[78]

Resin-modified glass-ionomer cements (**RMGICs**), with the acid-base polymerization supplemented by a second resin light cure polymerization, have been shown to be efficacious in primary teeth. Based on a meta-analysis, RMGIC is more successful than conventional glass ionomer as a restorative material.[78] A systematic review supports the use of RMGIC in small to moderate sized Class II cavities.[77] Class II RMGIC restorations are able to withstand occlusal forces on primary molars for at least one year.[78] Because of fluoride release, RMGIC may be considered for Class I and Class II restorations of primary molars in a high caries risk population.[80] There is also some evidence that conditioning dentin improves the success rate of RMGIC.[77] According to one RCT, cavosurface beveling leads to high marginal failure in RMGIC restorations and is not recommended.[63]

With regard to permanent teeth, a meta-analysis review reported significantly fewer carious lesions on single-surface glass ionomer restorations in permanent teeth after six years as compared to restorations with amalgam.[80] Data from a meta-analysis shows that RMGIC is more caries preventive than composite resin with or without fluoride.[81] Another meta-analysis showed that cervical restorations (Class V) with glass ionomers may have a good retention rate, but poor esthetics.[82] For Class II restorations in permanent teeth, one RCT showed unacceptable high failure rates of conventional glass ionomers, irrespective of cavity size. However, a high dropout rate was observed in this study limiting its significance.[83] In general, there is insufficient evidence to support the use of RMGIC as long-term restorations in permanent teeth.

Other applications of glass ionomers where fluoride release has advantages are for **ITR** and **ART**. These procedures have similar techniques but different therapeutic goals. ITR may be used in very young patients,[84] uncooperative patients, or patients with special health care needs[47] for whom traditional cavity preparation and/or placement of traditional dental restorations are not feasible or need to be postponed. Additionally, ITR may be used for caries control in children with multiple open carious lesions, prior to definitive restoration of the teeth.[85] In-vitro, leaving caries-affected dentin does not jeopardize the bonding of glass ionomer cements to the primary tooth dentin.[86] ART, endorsed by the World Health Organization and the International Association for Dental Research, is a means of restoring and preventing caries in populations that have little access to traditional dental care and functions as definitive treatment.

According to a meta-analysis, single surface ART restorations showed high survival rates in both primary and permanent teeth.[87] One RCT supported single surface restorations irrespective of the cavity size and also reported higher success in non-occlusal posterior ART compared to occlusal posterior ART.[88] With regard to multi-surface ART restorations, there is conflicting evidence. Based on a meta-analysis, ART restorations presented similar survival rates to conventional approaches using composite or amalgam for Class II restorations in primary teeth.[89] However, another meta-analysis showed that multi-surface ART restorations in primary teeth exhibited high failure rates.[87]

Recommendations:

1. There is evidence in favor of GICs for Class I restorations in primary teeth.
2. From a systematic review, there is strong evidence that RMGICs for Class I restorations are efficacious, and expert opinion supports Class II restorations in primary teeth.
3. There is insufficient evidence to support the use of conventional or RMGICs as long-term restorative material in permanent teeth.
4. From a meta-analysis, there is strong evidence that ITR/ART using high viscosity glass ionomer cements has value as single surface temporary restoration for both primary and permanent teeth. Additionally, ITR may be used for caries control in children with multiple open carious lesions, prior to definitive restoration of the teeth.

Compomers

Polyacid-modified resin-based composites, or compomers, were introduced into dentistry in the mid-1990s. They contain 72 percent (by weight) strontium fluorosilicate glass and the average particle size is 2.5 micrometers.[90] Moisture is attracted to both acid functional monomer and basic ionomer-type in the material. This moisture can trigger a reaction that releases fluoride and buffers acidic environments.[91,92] Considering the ability to release fluoride, esthetic value, and simple handling properties of compomer, it can be useful in pediatric dentistry.[90]

Based on a recent RCT, the longevity of Class I compomer restorations in primary teeth was not statistically different compared to amalgam, but compomers were found to need replacement more frequently due to recurrent caries.[46] In Class II compomer restorations in primary teeth, the risk of developing secondary caries and failure did not increase over a two-year period in primary molars.[54,93] Compomers also have reported comparable clinical performance to composite with respect to color matching, cavo-surface discoloration, anatomical form, and marginal integrity and secondary caries.[94,95] Most RCTs showed that compomer tends to have better physical properties compared to glass ionomer and resin modified glass ionomer cements and in primary teeth, but no significant difference was found in cariostatic effects of compomer compared to these materials.[49,93,96]

Recommendations:

1. Compomers can be an alternative to other restorative materials in the primary dentition in Class I and Class II restorations.
2. There is not enough data comparing compomers to other restorative materials in permanent teeth of children.

Preformed metal crowns

Preformed metal crowns also known as SSCs are prefabricated crown forms that are adapted to individual teeth and cemented with a biocompatible luting agent. Preformed metal crowns have been indicated for the restoration of primary and permanent teeth with extensive caries, cervical decalcification, and/or developmental defects (e.g., hypoplasia, hypocalcification), when failure of other available restorative materials is likely (e.g., interproximal caries extending beyond line angles, patients with bruxism), following pulpotomy or pulpectomy, for restoring a primary tooth that is to be used as an abutment for a space maintainer, for the intermediate restoration of fractured teeth, and for definitive restorative treatment for high caries-risk children. They are used more frequently in patients whose treatment is performed under sedation or general anesthesia.[97-99]

There are very few prospective RCTs comparing outcomes for preformed metal crowns to intra-coronal restorations.[100,101] A Cochrane review and two systematic reviews conclude that the majority of clinical evidence for the use of preformed metal crowns has come from nonrandomized and retrospective studies.[16,97-99] However, this evidence suggests that preformed metal crowns showed greater longevity than amalgam restorations,[16] despite possible study bias of placing SSCs on teeth more damaged by caries.[98,99,102] Five studies which retrospectively compared Class II amalgam to preformed metal crowns showed an average five year failure rate of 26 percent for amalgam and seven percent for preformed metal crowns.[98]

A two-year RCT regarding restoration of primary teeth that had undergone a pulpotomy procedure found a non-significant difference in survival rate for teeth restored with preformed metal crowns (95 percent) versus resin modified glass ionomer/composite restoration (92.5 percent).[100] In another prospective study, significantly fewer restoration failures and improved calcium hydroxide pulpotomy success were found with preformed metal crowns (79.7 percent) versus amalgam restorations (60 percent) after one year.[103] However, a systematic review did not show strong evidence that preformed metal crowns were superior over other restorations for pulpotomized teeth.[104]

With regards to gingival health adjacent to preformed metal crowns, a one year RCT showed no difference in gingival inflammation between preformed metal crowns and composite restorations after pulpotomy.[99] Yet, a two-year randomized clinical study showed more gingival bleeding for preformed metal crowns vs. composite/glass ionomer restorations.[100] Inadequately contoured crown and residues of set cement remaining in contact with the gingival sulcus are suggested as reasons for gingivitis associated with preformed metal crowns, and a preventive regime including oral hygiene instruction is recommended to be incorporated into the treatment plan.[98]

There is one RCT on preformed metal crowns versus cast crowns placed on permanent teeth,[105] and this report found no difference between the two restoration types for quality and longevity after 24 months. The remaining evidence is case reports and expert opinion concerning indications for use of preformed metal crowns on permanent molars. The indications include teeth with severe genetic/developmental defects, grossly carious teeth, and traumatized teeth, along with tooth developmental stage or financial considerations that require semi-permanent restoration instead of a permanent cast restoration.[97,102,105] The main reasons for preformed metal crown failure reportedly are crown loss[16,103,106] and perforation[106].

One method of providing preformed metal crowns is known as HT.[107] This method calls for cementation of a SSC over a caries-affected primary molar without local anesthetic, caries removal, or tooth preparation. It is a less invasive caries management procedure for treating carious primary teeth and involves the concept of caries control by managing the activity of the biofilm.[108] This technique was developed for use when delivery of ideal treatment was not feasible. Using the HT may reduce discomfort from local anesthetic and caries removal at the time of treatment compared to fillings,[107] but it may add the discomfort of placement of separator bands prior to the SSC, as well as the pain from biting the crown into place.[109] The HT has gained some popularity in the United Kingdom (**UK**),[107] primarily from use by general dentists (who provide the majority of care for young children).[110] All prospective investigations on the effectiveness of HT have been by general dentists in UK, and comparison groups include restorative treatment as traditionally provided in those settings, where traditional use of SSCs to restore caries in primary teeth has not been a popular or a frequently used technique.[111-114] This is in spite of the existence of guidelines and policy statements from the British Society of Paediatric Dentistry that SSCs are the restoration of choice for primary molars with multi-surface lesions or extensive caries or when pulp treatment has been performed.[115,116]

Results of a 2003 repeat questionnaire of general dentists in the UK showed that the use of amalgam had declined with an increase in the use of GIC and very little change in the use of SSCs.[111] Placement of GIC restorations or observation without treatment was the management approach of choice, and the use of local anesthesia to provide dental care to children was infrequent.[112] Given the differences in treatment approaches in health care settings and system between countries, the HT has not been widely adopted in the U.S., and it usually is limited to individual situations where proven methods of caries management cannot be used.[117] Studies that compare this technique to traditionally placed preformed metal crowns using radiographic assessment and caries removal are needed.[117]

Recent retrospective studies[118,119] for cost-effectiveness combined with a cross-sectional evaluation of patient acceptance showed that 95.8 percent of primary teeth restored using the HT remained asymptomatic after a follow-up period of up to 77 months, compared to 95.3 percent in the conventional methods (caries removal with placement of SSC or other restoration); they did not, however, report a breakdown by follow-up time. Although HT and conventional restorative methods had similar successful outcomes, using the HT was associated with reduced treatment costs if general anesthesia or sedation is considered. Both approaches were accepted favorably by the children and care providers.[119]

SSCs continue to offer the advantage of full coverage to combat recurrent caries and provide strength as well as long-term durability with minimal maintenance, which are desirable outcomes for caries management for high-risk children.

The interest in esthetic options for full coverage restoration of primary posterior teeth is increasing by clinicians and patients.[120,121] Scientific studies that evaluate esthetic options for restoring teeth with large caries lesions are not widely reported in the literature. The most popular options are opened-face SSCs, pre-veneered SSCs, and zirconia crowns.[122] There are several preformed pediatric zirconia crowns available on the market, and each brand has different material composition, fabrication, surface treatment, retentive feature, and cementation method. The amount of tooth reduction and technique for tooth preparation varies significantly.[123] There is need for more circumferential tooth reduction requirements for proper fit and placement for zirconia crowns compared to SSCs. The indications for the preformed esthetic crowns are generally the same as those of the preformed SSCs but with consideration of esthetics.[124] SSCs have comparatively better retention, but recent studies demonstrate that the gingival health and plaque accumulation around zirconia crowns are better than SSCs.[124,125]

Recommendations:

1. There is evidence from retrospective studies showing greater longevity of preformed metal crown restorations compared to amalgam or resin-based restorations for the treatment of caries lesions in primary teeth. Therefore, use of SSCs is supported on high-risk children with large or multi-surface cavitated or non-cavitated lesions on primary molars, especially when children require advanced behavioral guidance techniques[126] including general anesthesia for the provision of restorative dental care.
2. There is evidence from case reports and one RCT supporting the use of preformed metal crowns in permanent teeth as a semi-permanent restoration for the treatment of severe enamel defects or grossly carious teeth.

Anterior esthetic restorations in primary teeth

Despite the continuing prevalence of dental caries in primary maxillary anterior teeth in children, the esthetic management of these teeth remains problematic.[127] Esthetic restoration of primary anterior teeth can be especially challenging due to: the small size of the teeth; close proximity of the pulp to the tooth surface; relatively thin enamel; lack of surface area for bonding; and issues related to child behavior.[128]

There is little scientific support for any of the clinical techniques that clinicians have utilized for many years to restore primary anterior teeth, and most of the evidence is regarded as expert opinion. While a lack of strong clinical data does not preclude the use of these techniques, it points out the strong need for well designed, prospective clinical studies to validate the use of these techniques.[129] Additionally, there is limited information on the potential psychosocial impact of anterior caries or unaesthetic restorations in primary teeth.[127]

Class III (interproximal) restorations of primary incisors can be prepared with labial or lingual dovetails to incorporate a large surface area for bonding to enhance retention.[129] Resin-based restorations are appropriate for anterior teeth that can be adequately isolated from saliva and blood. Resin-modified glass ionomer cements have been suggested for this category, especially when adequate isolation is not possible.[130,131] It has been suggested that patients considered at high-risk for future caries may be better served with placement of full tooth coverage restorations.[131]

Class V (cervical) cavity preparations for primary incisors are similar to those in permanent teeth. Due to the young age of children treated and associated behavior guidance difficulty, it is sometimes impossible to isolate teeth for the placement of composite restorations. In these cases, GIC or RMGIC is suggested.[130,131]

Table 1. EVIDENCE OF EFFICACY OF VARIOUS DENTAL MATERIALS/TECHNIQUES IN PRIMARY TEETH WITH REGARD TO CARIES LESION CLASSIFICATIONS

Strong evidence – based on well executed randomized control trials, meta-analyses, or systematic reviews; **Evidence in favor** – based on weaker evidence from clinical trials; **Expert opinion** – based on retrospective trials, case reports, in vitro studies and opinions from clinical researchers; **Evidence against** – based on randomized control trials, meta-analysis, systematic reviews.

	Class I	Class II	Class III	Class IV	Class V
Amalgam	Strong evidence	Strong evidence	No data	No data	Expert opinion
Composite	Strong evidence	Strong evidence	Expert opinion	No data	Evidence in favor
Glass ionomer	Strong evidence $^{\alpha}$	Evidence against $^{\beta}$	Evidence in favor $^{\gamma}$	No data	Expert opinion $^{\gamma}$
RMGIC	Strong evidence	Expert opinion $^{\delta}$	Expert opinion	No data	Expert opinion
Compomers	Evidence in favor	Evidence in favor	No data	No data	Expert opinion
SSC	Evidence in favor $^{\varepsilon}$	Evidence in favor $^{\varepsilon}$	No data	No data	No data
Anterior $^{\phi}$ crowns	N/A	N/A	Expert opinion	Expert opinion	Expert opinion

RMGIC = resin modified glass ionomer cement.
α Evidence from ART trials.
β Conflicting evidence for multisurface ART restorations.
γ Preference when moisture control is an issue.
SSC = stainless steel crown.
δ Small restorations; life span 1-2 years.
ε Large lesions.
ϕ Strip crowns, stainless steel crowns with/without facings, zirconia crowns.

Table 2. EVIDENCE OF EFFICACY OF VARIOUS DENTAL MATERIALS/TECHNIQUES IN PERMANENT TEETH WITH REGARD TO CARIES LESION CLASSIFICATIONS

	Class I	Class II	Class III	Class IV	Class V
Amalgam	Strong evidence	Strong evidence	No data	No data	No data
Composite	Strong evidence	Evidence in favor	Expert opinion	No data	Evidence in favor
Glass ionomer	Strong evidence $^{\alpha}$	Evidence against	Evidence in favor $^{\beta}$	No data	Expert opinion $^{\beta}$
RMGIC	Strong evidence	No data	Expert opinion	No data	Evidence in favor
Compomers	Evidence in favor $^{\gamma}$	No data	Expert opinion	No data	Expert opinion
SSC	Evidence in favor $^{\delta}$	Evidence in favor $^{\delta}$	No data	No data	No data
Anterior $^{\phi}$ crowns	N/A	N/A	No data	No data	No data

RMGIC = resin modified glass ionomer cement.
α Evidence from ART trials.
β Preference when moisture control is an issue.
ϕ Strip crowns, stainless steel crowns with/without facings.
SSC = stainless steel crown.
γ Evidence from studies in adults.
δ For children and adolescents with gross caries or severely hypoplastic teeth.

Full coronal restoration of carious primary incisors may be indicated when: (1) caries is present on multiple surfaces, (2) the incisal edge is involved, (3) there is extensive cervical decalcification, (4) pulpal therapy is indicated, (5) caries may be minor, but oral hygiene is very poor, or (6) the child's behavior makes moisture control very difficult.[129] Successful full-coronal restorations of extensively decayed primary anterior teeth have been reported; however, due to the lack of available clinical studies, it is difficult to determine whether certain techniques of restoring carious primary anterior teeth are effective.[128,132] A retrospective study showed that 80 percent of strip crowns were completely retained after three years, and 20 percent were partially retained, with none being completely lost.[133] Another retrospective study, with 24-74 months follow-up, reported 80 percent retention of strip crowns.[134]

Preveneered SSCs also are among the options of restoring primary anterior teeth with full coronal coverage. Three retrospective studies report excellent clinical retention of these types of crowns, yet with a high incidence of partial or complete loss of the resin facings.[127,135,136] Preveneered SSCs have the concerns of color stability and surface roughness changes,[137] so long term clinical studies are required to establish their comparative effectiveness. Preformed SSCs and opened-face stainless steel crowns are still options for treatment on primary anterior teeth, but published studies reporting their effectiveness and use are sparse[111] given the availability of more esthetic and easier-to-use alternatives.

Preformed pediatric zirconia crowns are another option for esthetic full coronal coverage restoration.[122] As they require a passive fit, the amount of tooth reduction is greater than that required for SSC (minimum of 1.5-2.0 mm), and technique for tooth preparation does vary significantly among different brands.[123] Although a RCT with a follow-up of only six months suggests that zirconia crowns gave significantly better results than the others with regard to gingival health and crown fractures[124], a systematic review on the topic[125] concluded that due to the small number of RCTs on this topic and their risk of bias, future RCTs with better study design are required to compare differences between the different types of pediatric preformed zirconia crowns and between other esthetic treatment options.

Recommendations:

1. There is expert opinion that suggests the use of resin-based composites as a treatment option for Class III and Class V restorations in the primary and permanent dentition.
2. There is expert opinion that suggests the use of RMGIC as a treatment option for Class III and Class V restorations for primary teeth, particularly in circumstances where adequate isolation of the tooth to be restored is difficult.
3. There is expert opinion that suggests that strip crowns, pre-veneered SSCs, preformed SSCs, and opened-face SSCs are a treatment option for full coronal coverage restorations in primary anterior teeth.

References

1. American Academy of Pediatric Dentistry. Guidelines for pediatric restorative dentistry 1991. In: American Academy of Pediatric Dentistry Reference Manual 1991-1992. Chicago, Ill.: American Academy of Pediatric Dentistry; 1991:57-9.
2. American Academy of Pediatric Dentistry. Guideline on restorative dentistry. Pediatr Dent 2014;36(special issue): 230-41.
3. American Academy of Pediatric Dentistry. Guideline on restorative dentistry. Pediatr Dent 2016;38(special issue): 250-62.
4. American Dental Association Center for Evidence-Based Dentistry. ADA Clinical Practice Guidelines Handbook, Update 2013. American Dental Association, Chicago, Ill. November 2013. Available at: "http://ebd.ada.org/~/media/EBD/Files/ADA_Clinical_Practice_Guidelines_Handbook-2013.ashx". Accessed June 18, 2019.
5. Tinanoff N, Douglass JM. Clinical decision-making for caries management of primary teeth. J Dent Ed 2001;65 (10):1133-42.
6. Sheiham A. Impact of dental treatment on the incidence of dental caries in children and adults. Community Dent Oral Epidemiol 1997;25(1):104-12.
7. American Academy of Pediatric Dentistry. Caries-risk assessment and management for infants, children, and adolescents. The Reference Manual of Pediatric Dentistry. Chicago, Ill.: American Academy of Pediatric Dentistry; 2019:221-6.
8. Urquhart O, Tampi MP, Pilcher L, et al. Nonrestorative treatments for caries: Systematic review and network meta-analysis. J Dent Res 2019;98(1):14-26.
9. National Institute of Health. Consensus Development Statement: Diagnosis and management of dental caries throughout life. NIH Consensus Statement. J Am Dent Assoc 2001;132(8):1153-61.
10. Nelson SJ. Wheeler's Dental Anatomy, Physiology, and Occlusion. 9th ed. Philadelphia, Pa.: WB Saunders; 2010.
11. Bader JD, Shugars DA. Understfanding dentists' restorative treatment decisions. J Pub Health Dent 1992;52(2): 102-11.
12. Ismail AI, Sohn W, Tellez M, et al. The international caries detection and assessment system (ICDAS): An integrated system for measuring dental caries. Community Dent Oral Epidemiol 2007;35(3):170-8.
13. Beauchamp J, Caufield PW, Crall JJ, et al. Evidence-based clinical recommendations for the use of pit-and-fissure sealants: A report of the American Dental Association Council on Scientific Affairs. J Am Dent Assoc 2008; 139(3):257-68.
14. Downer MC, Azli NA, Bedi R, Moles DR, Setchell DJ. How long do routine dental restorations last? A systematic review. Brit Dent J 1999;187(8):432-9.

15. Lenters M, van Amerongen WE, Mandari GJ. Iatrogenic damage to the adjacent surface of primary molars in three different ways of cavity preparation. Eur Archives Paed Dent 2006;1(1):6-10.
16. Hickel R, Kaaden C, Paschos E, Buerkle V, García-Godoy F, Manhart J. Longevity of occlusally-stressed restorations in posterior primary teeth. Am J Dent 2005;18(3):198-211.
17. Dhar V, Marghalani AA, Crystal YO, et al. Use of vital pulp therapies in primary teeth with deep caries lesions. Pediatr Dent 2017;39(5):E146-E159.
18. American Academy of Pediatric Dentistry. Pulp therapy for primary and immature permanent teeth. Pediatr Dent 2018;40(6):343-51.
19. Bjørndal L, Reit C, Bruun G, et al. Treatment of deep caries lesions in adults: Randomized clinical trials comparing stepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy. Eur J Oral Sci 2010;118(3):290-7.
20. Maltz M, Garcia R, Jardim JJ, et al. Randomized trial of partial vs. stepwise caries removal: 3-year follow-up. J Dent Res 2012;91(11):1026-31.
21. Maltz M, Jardim JJ, Mestrinho HD, et al. Partial removal of carious dentine: A multicenter randomized controlled trial and 18-month follow-up results. Caries Res 2013;47(2):103-9.
22. Innes NP, Evans DJ, Stirrups DR. Sealing caries in primary molars: Randomized control trial, 5-year results. J Dent Res 2011;90(12):1405-10.
23. Lula EC, Monteiro-Neto V, Alves CM, Ribeiro CC. Microbiological analysis after complete or partial removal of carious dentin in primary teeth: A randomized clinical trial. Caries Res 2009;43(5):354-8.
24. Orhan AI, Oz FT, Orhan K. Pulp exposure occurrence and outcomes after 1- or 2-visit indirect pulp therapy vs. complete caries removal in primary and permanent molars. Pediatr Dent 2010;32(4):347-55.
25. Ricketts D, Lamont T, Innes NPT, Kidd E, Clarkson JE. Operative caries management in adults and children (Review). Cochrane Database Syst Rev 2013;3:54.
26. Foley J, Evans D, Blackwell A. Partial caries removal and cariostatic materials in carious primary molar teeth: A randomised controlled clinical trial. Br Dent J 2004;197(11):697-701.
27. Phonghanyudh A, Phantumvanit P, Songpaisan Y, Petersen PE. Clinical evaluation of three caries removal approaches in primary teeth: A randomised controlled trial. Community Dent Health 2012;29(2):173-8.
28. Schwendicke F, Dorfer CE, Paris S. Incomplete caries removal: A systematic review and meta-analysis. J Dent Res 2013;92(4):306-14.
29. Mertz-Fairhurst EJ, Curtis JW Jr, Ergle JW, Rueggeberg FA, Adair SM. Ultraconservative and cariostatic sealed restorations: Results at year 10. J Am Dent Assoc 1998;129(1):55-66.
30. Paris S, Hopfenmuller W, Meyer-Lueckel H. Resin infiltration of caries lesions: An efficacy randomized trial. J Dent Res 2010;89(8):823-6.
31. Meyer-Lueckel H, Bitter, K, Paris S. Randomized controlled clinical trial on proximal caries infiltration: Three-year follow-up. Caries Res 2012;46(6):544-8.
32. Dorri M, Dunne SM, Walsh T, Schwendicke F. Micro-invasive interventions for managing proximal dental decay in primary and permanent teeth. Cochrane Database Syst Rev 2015;(11):CD010431.
33. Faghihian R, Shirani M, Tarrahi M, Zakizade M. Efficacy of the resin infiltration technique in preventing initial caries: A systemic review and meta-analysis. Pediatr Dent 2019;49(2):88-94.
34. Slayton RL, Urquhart O, Araujo M, et al. Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions. J Am Dent Assoc 2018;149(10):837-49.
35. Tellez M, Gomez J, Kaur S, Pretty IA, Ellwood R, Ismail AI. Non-surgical management methods of noncavitated carious lesions. Community Dent Oral Epidemiol 2013;41(1):79-96.
36. Senestraro SV, Crowe JJ, Wang M, et al. Minimally invasive resin infiltration of arrested white-spot lesions. J Am Dent Assoc 2013;144(9):997-1005.
37. Beazoglou T, Eklund S, Heffley D, Meiers, J, Brown LJ, Bailit H. Economic impact of regulating the use of amalgam restorations. Public Health Rep 2007;122(5):657-63.
38. U.S. Department of Health and Human Services. Final Rule. Federal Register 75: Issue 112 (Friday, June 11, 2010). Available at: "https://www.fda.gov/media/77127/download". Accessed July 24, 2019.
39. American Dental Association Council on Scientific Affairs. Statement on Dental Amalgam, Revised 2009. Chicago, Ill.; 2009. Available at: "https://www.ada.org/en/about-the-ada/ada-positions-policies-and-statements/statement-on-dental-amalgam". Accessed July 24, 2019.
40. Belliger DC, Trachtenberg F, Barregard L, et al. Neuropsychological and renal effects of dental amalgam in children: A randomized clinical trial. J Am Med Assoc 2006;295(15):1775-83.
41. DeRouen TA, Martin MD, Leroux BG, et al. Neurobehavioral effects of dental amalgam in children: A randomized clinical trial. J Am Med Assoc 2006;295(15):1784-92.
42. Heintze SD, Rousson V. Clinical effectiveness of direct Class II restorations–A meta-analysis. J Adhes Dent 2012;14(5):407-31.
43. Mickenautsch S, Yengopal V. Failure rate of high-viscosity GIC based ART compared with that of conventional amalgam restorations–Evidence from an update of a systematic review. J South African Dent Assoc 2012;67(7):329-31.

References continued on the next page.

44. Yengopal V, Harnekar SY, Patel N, Siegfried N. Dental fillings for the treatment of caries in the primary dentition (Review). Cochrane Database of Syst Rev 2009;(2): CD004483.
45. Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. Oper Dent 2004;29(5):481-508.
46. Soncini JA, Meserejian NN, Trachtenberg F, Tavares M, Hayes C. The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: Findings from the New England Children's Amalgam Trial. J Am Dent Assoc 2007;138(6):763-72.
47. Mandari GJ, Frencken JE, van't Hof MA. Six-year success rates of occlusal amalgam and glass-ionomer restorations placed using three minimal intervention approaches. Caries Res 2003;37(4):246-53.
48. Bernardo M, Luis H, Martin MD, et al. Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial. J Am Dent Assoc 2007;138(6):775-83.
49. Qvist V, Laurberg L, Poulsen A, Teglers PT. Eight-year study on conventional glass ionomer and amalgam restorations in primary teeth. Acta Odontol Scand 2004; 62(1):37-45.
50. Kilpatrick NM, Neumann A. Durability of amalgam in the restoration of Class II cavities in primary molars: A systematic review of the literature. Eur Arch Paediatr Dent 2007;8(1):5-13.
51. de Amorim RG, Leal SC, Mulder J, Creugers NH, Frencken JE. Amalgam and ART restorations in children: A controlled clinical trial. Clin Oral Investig 2014;18(1): 117-24.
52. Kavvadia K, Kakaboura A, Vanderas AP, Papagiannoulis L. Clinical evaluation of a compomer and an amalgam primary teeth class II restorations: A 2-year comparative study. Pediatr Dent 2004;26(3):245-50.
53. Fuks AB, Araujo FB, Osorio LB, Hadani PE, Pinto AS. Clinical and radiographic assessment of Class II esthetic restorations in primary molars. Pediatr Dent 2000;22(5): 479-85.
54. Duggal MS, Toumba KJ, Sharma NK. Clinical performance of a compomer and amalgam for the interproximal restoration of primary molars: A 24 month evaluation. Brit Dent J 2002;193(6):339-42.
55. Donly KJ, Segura A, Kanellis M, Erickson RL. Clinical performance and caries inhibition of resin-modified glass ionomer cement and amalgam restorations. J Am Dent Assoc 1999;130(10):1459-66.
56. Leinfelder KF. Posterior composite resins. J Am Dent Assoc 1988;117(4):21E-26E.
57. Minguez N, Ellacuria J, Soler JI, Triana R, Ibaseta G. Advances in the history of composite resins. J Hist Dent 2003;51(3):103-5.
58. Opdam NJM, Bronkhorst EMB, Loomans BAC, Huysmans MC. 12-year survival of composite vs. amalgam restorations. J Dent Res 2010;89(10):1063-7.
59. Burgess JO, Walker R, Davidson JM. Posterior resin-based composite: Review of the literature. Pediatr Dent 2002;24(5):465-79.
60. Pallav P, De Gee AJ, Davidson CL, Erickson RL, Glasspoole EA. The influence of admixing microfiller to small-particle composite resins on wear, tensile strength, hardness and surface roughness. J Dent Res 1989;68(3):489-90.
61. Antony K, Genser D, Hiebinger C, Windisch F. Longevity of dental amalgam in comparison to composite materials. GMS Health Technol Assess 2008;13(4):Doc12.
62. Fleisch AF, Sheffield PE, Chinn C, Edelstein BL, Landrigan PJ. Bisphenol A and related compounds in dental materials. Pediatrics 2010;126(4):760-8.
63. Alves dos Santos MP, Luiz RR, Maia LC. Randomised trial of resin-based restorations in Class I and Class II beveled preparations in primary molars: 48-month results. J Dent 2010;38(6):451-9.
64. Dijken JW, Pallesen U. A six-year prospective randomized study of a nano-hybrid and a conventional hybrid resin composite in Class II restorations. Dent Mater 2013;29 (2):191-8.
65. Krämer N, García-Godoy F, Reinelt C, Feilzer AJ, Frankenberger R. Nanohybrid vs. fine hybrid composite in extended Class II cavities after six years. Dent Mater 2011;27(5):455-64.
66. Shi L, Wang X, Zhao Q, et al. Evaluation of packable and conventional hybrid resin composites in Class I restorations: Three-year results of a randomized, double-blind and controlled clinical trial. Oper Dent 2010;35 (1):11-9.
67. Ernst CP, Brandenbusch M, Meyer G, Canbek K, Gottschalk F, Willershausen B. Two-year clinical performance of a nanofiller vs a fine-particle hybrid resin composite. Clin Oral Investig 2006;10(2):119-25.
68. Wilson AD, Kent BE. A new translucent cement for dentistry. The glass ionomer cement. Br Dent J 1972;132 (4):33-5.
69. Mitra SB, Kedrowski BL. Long-term mechanical properties of glass ionomers. Dent Mater 1994;10(2):78-82.
70. Douglas WH, Lin CP. Strength of the new systems. In: Hunt PR, ed. Glass Ionomers: The Next Generation. Philadelphia, Pa.: International Symposia in Dentistry, PC; 1994:209-16.
71. Tam LE, Chan GP, Yim D. In vitro caries inhibition effects by conventional and resin-modified glass ionomer restorations. Oper Dent 1997;22(1):4-14.
72. Tyas MJ. Cariostatic effect of glass ionomer cements: A 5-year clinical study. Aust Dent J 1991;36(3):236-9.
73. Swartz ML, Phillips RW, Clark HE. Long-term fluoride release from glass ionomer cements. J Dent Res 1984;63 (2):158-60.

74. Forsten L. Fluoride release and uptake by glass ionomers and related materials and its clinical effect. Biomaterials 1998;19(6):503-8.
75. Donly KJ, Nelson JJ. Fluoride release of restorative materials exposed to a fluoridated dentifrice. ASDC J Dent Child 1997;64(4):249-50.
76. Donly KJ, Istre S, Istre T. In vitro enamel remineralization at orthodontic band margins cemented with glass ionomer cement. Am J Orthod Dentofacial Orthop 1995;107(5):461-4.
77. Chadwick BL, Evans DJ. Restoration of Class II cavities in primary molar teeth with conventional and resin modified glass ionomer cements: A systematic review of the literature. Eur Arch Paediatr Dent 2007;8(1):14-21.
78. Toh SL, Messer LB. Evidence-based assessment of tooth-colored restorations in proximal lesions of primary molars. Pediatr Dent 2007;29(1):8-15.
79. Daou MH, Tavernier B, Meyer JM. Two-year clinical evaluation of three restorative materials in primary molars. J Clin Pediatr Dent 2009;34(1):53-8.
80. Mickenautsch S, Yengopal V, Leal SC, Oliveira LB, Bezerra AC, Bonecker M. Absence of carious lesions at margins of glass-ionomer and amalgam restorations: A meta-analysis. Eur J Paediatr Dent 2009;10(1):41-6.
81. Yengopal V, Mickenautsch S. Caries-preventive effect of resin-modified glass-ionomer cement (RM-GIC) versus composite resin: A quantitative systematic review. Eur Arch Paediatr Dent 2011;12(1):5-14.
82. Heintze SD, Ruffieux C, Rousson V. Clinical performance of cervical restorations–A meta-analysis. Dent Mater 2010;26(10):993-1000.
83. Frankenberger R, García-Godoy F, Kramer N. Clinical performance of viscous glass ionomer cement in posterior cavities over two years. Int J Dent 2009;2009:781462.
84. Wambier DS, dos Santos FA, Guedes-Pinto AC, Jaeger RG, Simionato MR. Ultrastructural and microbiological analysis of the dentin layers affected by caries lesions in primary molars treated by minimal intervention. Pediatr Dent 2007;29(3):228-34.
85. Dulgergil DT, Soyman M, Civelek A. Atraumatic restorative treatment with resin-modified glass ionomer material: Short-term results of a pilot study. Med Princ Pract 2005;14(3):277-80.
86. Alves FB, Lenzi TL, Guglielmi Cde A, et al. The bonding of glass ionomer cements to caries-affected primary tooth dentin. Pediatr Dent 2013;35(4):320-4.
87. van't Hof MA, Frenecken JE, van Palenstein Helderman WH, Holmgren CJ. The Atraumatic Restorative Treatment (ART) approach for managing dental caries: A meta-analysis. Int Dent J 2006;56(6):345-51.
88. Frenecken JE, van't Hof MA, Taifour D, Al-Zaher I. Effectiveness of ART and traditional amalgam approach in restoring single surface cavities in posterior teeth of permanent dentitions in school children after 6.3 years. Community Dent Oral Epidemiol 2007;35(3):207-14.
89. Raggio DP, Hesse D, Lenzi TL, Guglielmi CAB, Braga MM. Is atraumatic restorative treatment an option for restoring occluso-proximal caries lesions in primary teeth? A systematic review and meta-analysis. Int J Paediatr Dent 2013;23(6):435-43.
90. Nicholson JW. Polyacid-modified composite resins ('compomers') and their use in clinical dentistry. Dent Mater 2007;23(5):615-22.
91. Cildir SK, Sandalli N. Fluoride release/uptake of glass-ionomer cements and polyacid-modified composite resins. Dent Mater J 2005;24(1):92-7.
92. Peng D, Smales RJ, Yip HK, Shu M. In vitro fluoride release from aesthetic restorative materials following recharging with APF gel. Aust Dent J 2000;45(3):198-203.
93. Daou MH, Attin T, Göhring TN. Clinical success of compomer and amalgam restorations in primary molars: Follow up in 36 months. Schweiz Monatsschr Zahnmed 2009;119(11):1082-8.
94. Attin T, Opatowski A, Meyer C, Zingg-Meyer B, Mönting JS. Class II restorations with a polyacid-modified composite resin in primary molars placed in a dental practice: Results of a two-year clinical evaluation. Oper Dent 2000;25(4):259-64.
95. Attin T, Opatowski A, Meyer C, Zingg-Meyer B, Buchalla W, Mönting JS. Three-year follow up assessment of Class II restorations in primary molars with a polyacid-modified composite resin and a hybrid composite. Am J Dent 2001;4(3):148-52.
96. Welbury RR, Shaw AJ, Murray JJ, Gordon PH, McCabe JF. Clinical evaluation of paired compomer and glass ionomer restorations in primary molars: Final results after 42 months. Br Dent J 2000;189(2):93-7.
97. Attari N, Roberts JF. Restoration of primary teeth with crowns: A systematic review of the literature. Eur Arch Paediatr Dent 2006;7(2):58-62.
98. Randall RC. Preformed metal crowns for primary and permanent molar teeth: Review of the literature. Pediatr Dent 2002;24(5):489-500.
99. Innes NP, Ricketts D, Evans DJ. Preformed metal crowns for decayed primary molar teeth. Cochrane Database Syst Rev 2007;(1):CD005512.
100. Atieh M. Stainless steel crown versus modified open-sandwich restorations for primary molars: A 2-year randomized clinical trial. Int J Paediatr Dent 2008;18(5):325-32.
101. Hutcheson C, Seale NS, McWhorter A, Kerins C, Wright J. Multi-surface composite vs stainless steel crown restorations after mineral trioxide aggregate pulpotomy: A randomized controlled trial. Pediatr Dent 2012;34(7):460-7.
102. Randall RC, Vrijhoef MM, Wilson NH. Efficacy of preformed metal crowns vs. amalgam restorations in primary molars: A systematic review. J Am Dent Assoc 2000;131(3):337-43.

103. Sonmez D, Duruturk L. Success rate of calcium hydroxide pulpotomy in primary molars restored with amalgam and stainless steel crowns. Br Dent J 2010;208(9):E18.
104. Bazargan H, Chopra S, Gatonye L, Jones H, Kaur T. Permanent restorations on pulpotomized primary molars: An evidence-based review of the literature. 2007. Available at: "http://www.dentistry.utoronto.ca/system/files/pulpotomizedprimarymolars.pdf". Accessed October 17, 2013.
105. Zagdwon AM, Fayle SA, Pollard MA. A prospective clinical trial comparing preformed metal crowns and cast restorations for defective first permanent molars. Eur J Paediatr Dent 2003;4(3):138-42.
106. Roberts JF, Attari N, Sherriff M. The survival of resin modified glass ionomer and stainless steel crown restorations in primary molars, placed in a specialist paediatric dental practice. Br Dent J 2005;198(7):427-31.
107. Innes NP, Stirrups DR, Evans DJ, Hall N, Leggate M. A novel technique using preformed metal crowns for managing carious primary molars in general practice – A retrospective analysis. Br Dent J 2006;200(8):451-4; discussion 444.
108. Santamaria RM, Innes NPT, Machiulskiene V, et al. Alternative caries management options for primary molars: 2.5-year outcomes of a randomised clinical trial. Caries Res 2018;51(6):605-14.
109. Page LA, Boyd DH, Davidson SE, et al. Acceptability of the Hall Technique to parents and children. N Z Dent J 2014;110(1):12-7.
110. Roberts A, McKay A, Albadri S. The use of Hall technique preformed metal crowns by specialist paediatric dentists in the UK. Br Dent J 2018;224(1):48-52.
111. Roshan D, Curzon MEJ, Fairpo CG. Changes in dentists' attitudes and practice in paediatric dentistry. Eur J Paediatr Dent 2003;4(1):21-7.
112. Threlfall AG, Pilkington L, Milsom KM, Blinkhorn AS, Tickle M. General dental practitioners' views on the use of stainless steel crowns to restore primary molars. Br Dent J 2005;199(7):435-5.
113. Blinkhorn A, Zadeh-Kabir R. Dental care of a child in pain: A comparison of treatment planning options offered by GDPs in California and Northwest of England. Int J Paediatr Dent 2003;13(3):165-71.
114. Maggs-Rapport FL, Treasure ET, Chadwick BL. Community dental officers' use and knowledge of restorative techniques for primary molars: An audit of two trusts in Wales. Int J Paediatr Dent 2000;10(2):133-9.
115. Kindelan SA, Day P, Nichol R., Willmott N, Fayle SA. UK National Clinical Guidelines in Paediatric Dentistry: Stainless steel preformed crowns for primary molars. Int J Paediatr Dent 2008;18(Suppl. 1):20-8.
116. Fayle SA, Welbury RR, Roberts JF, British Society of Paediatric Dentistry. British Society of Paediatric Dentistry: A policy document on management of caries in the primary dentition. Int J Paediatr Dent 2001;11(2):153-7.
117. Fontana M, Gooch BF, Junger ML. The Hall technique may be an effective treatment modality for caries in primary molars. J Evid Based Dent Pract 2012;12(2):110-2.
118. BaniHani A, Duggal M, Toumba J, Deery C. Outcomes of the conventional and biological treatment approaches for the management of caries in the primary dentition. Int J Paediatr Dent 2018;28(1):12-22.
119. BaniHani A, Deery C, Toumba J, Duggal M. Effectiveness, costs, and patient acceptance of a conventional and a biological treatment approach for carious primary teeth in children. Caries Res 2018;53(1):65-75.
120. Holsinger DM, Wells MH, Scarbecz M, Donaldson M. Clinical evaluation and parental satisfaction with pediatric zirconia anterior crowns. Pediatr Dent 2016; 38(3):192-7.
121. Davette J, Brett C, Catherine F, Gary B, Gary F. Wear of primary tooth enamel by ceramic materials. Pediatr Dent 2016;38(7):519-22.
122. Planells DP, Fuks AB. Zirconia crowns–An esthetic and resistant restorative alternative for ECC affected primary teeth. J Clin Pediatr Dent 2014;38(3):193-5.
123. Clark L, Wells MH, Harris EF, Lou J. Comparison of amount of primary tooth reduction required for anterior and posterior zirconia and stainless steel crowns. Pediatr Dent 2016;38(1):42-6.
124. Donly KJ, Sasa I, Contreras CI, Mendez MJC. Prospective randomized clinical trial of primary molar crowns: 24-month results. Pediatr Dent 2018;40(4):253-8.
125. Taran PK, Kaya MS. A comparison of periododontal health in primary molars restored with prefabricated stainless steel and zirconia crowns. Pediatr Dent 2018; 40(5):334-9.
126. American Academy of Pediatric Dentistry. Behavior guidance of the pediatric dental patient. Pediatr Dent 2018;40(6):254-67.
127. Shah PV, Lee JY, Wright JT. Clinical success and parental satisfaction with anterior preveneered primary stainless steel crowns. Pediatr Dent 2004;26(5):391-5.
128. Waggoner WF. Anterior crowns for primary anterior teeth: An evidence-based assessment of the literature. Eur Arch Paediatr Dent 2006;7(2):53-7.
129. Waggoner WF. Restoring primary anterior teeth. Pediatr Dent 2002;24(5):511-6.
130. Croll TP, Bar-Zion Y, Segura A, Donly KJ. Clinical performance of resin-modified glass ionomer cement restorations in primary teeth. A retrospective evaluation. J Am Dent Assoc 2001;132(8):1110-6.
131. Donly KJ. Restorative dentistry for children. Dent Clin North Am 2013;57(1):75-82.
132. Lee JK. Restoration of primary anterior teeth: Review of the literature. Pediatr Dent 2002;24(5):506-10.
133. Kupietzky A, Waggoner WE, Galea J. Long-term photographic and radiographic assessment of bonded resin composite strip crowns for primary incisors: Results after 3 years. Pediatr Dent 2005;27(3):221-5.

134. Ram D, Fuks AB. Clinical performance of resin-bonded composite strip crowns in primary incisors: A retrospective study. Int J Paediatr Dent 2006;16(1):49-54.
135. Roberts C, Lee JY, Wright JT. Clinical evaluation of and parental satisfaction with resin-faced stainless-steel crowns. Pediatr Dent 2001;23(1):28-31.
136. MacLean J, Champagne C, Waggoner W, Ditmyer M, Casamassimo P. Clinical outcomes for primary anterior teeth treated with preveneered stainless steel crowns. Pediatr Dent 2007;29(5):377-82.
137. Truong K, Chen JW, Lee S, Riter H. Changes of surface properties of composite preveneered stainless steel crowns after prophy polishing to remove stains. Pediatr Dent 2017;39(2):17-24.