Pediatric Restorative Dentistry

Latest Revision
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Abstract
This best practice provides clinicians with guidance to form decisions about restorative dentistry, including when treatment is necessary and which techniques and materials are appropriate for restorative dentistry in pediatric patients. Not every caries lesion requires restoration, and restorative treatment of caries alone does not stop the disease process. Further, restorations have finite lifespans. Restorative approaches and supporting evidence for the excavation and restoration of deep caries lesions, including complete excavation, stepwise (i.e., two-step) excavation, partial (i.e., one-step) excavation, and no removal of caries prior to restoration, are discussed. Further research on long-term effectiveness of resin infiltration for small, noncavitated interproximal lesions is recommended. The evidence for and against the use of amalgam, composite, glass ionomer and resin-modified glass ionomer cements, compomers, stainless steel crowns, and anterior crowns has been summarized. Practitioners should familiarize themselves with such evidence to inform their clinical decisions regarding pediatric restorative dentistry.

This document was developed through a collaborative effort of the American Academy of Pediatric Dentistry Councils on Clinical Affairs and Scientific Affairs to offer updated information and guidance regarding restorative dental care for children.

KEYWORDS: DENTISTRY, OPERATIVE, DENTAL MATERIALS, DENTAL RESTORATION, PERMANENT, DENTAL RESTORATION, TEMPORARY, EVIDENCE-BASED DENTISTRY

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 revision by the Council on Clinical Affairs occurred in 2019.[2] 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 version. Electronic database searches using PubMed®/MEDLINE, for the most part between the years 2012-2022, were conducted using the terms: dental caries, intracoronal restorations, restorative treatment decisions, caries diagnosis, caries excavation, dental amalgam, glass ionomers, resin-modified glass ionomers, conventional glass ionomers, glass ionomer cements, atraumatic/alternative restorative technique (ART), interim therapeutic restoration (ITR), resin infiltration, resin-based composite, dental composites, compomers, full coverage dental restorations, stainless steel crowns (SSC), Hall technique, primary molars, preformed metal crowns (PMC), strip crowns, preveneered crowns, zirconia crowns, esthetic restorations; parameters: humans, English, birth through age 18, clinical trials, randomized controlled clinical trials (RCTs). This search yielded 1,671 articles. Articles were screened by viewing titles and abstracts. Articles were chosen for review from these searches and from the references within selected articles. When data did not appear sufficient or were inconclusive, recommendations were based upon expert and/or consensus opinion by experienced researchers and clinicians.

Background
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 or restorative intervention.[3] It is now recognized that restorative treatment of dental caries alone does not stop the disease process and that restorations have a finite lifespan.[3] 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.[3] Management with targeted preventive services and therapy such as silver

ABBREVIATIONS

AAPD: American Academy of Pediatric Dentistry. **ADA:** American Dental Association. **ART:** Alternative restorative technique. **BPA:** Bisphenol A. **FDA:** United States Food and Drug Administration. **GIC:** Glass ionomer cement. **HT:** Hall technique. **ITR:** Interim therapeutic restoration. **MIH:** Molar-incisor hypomineralization. **MTA:** Mineral trioxide aggregate. **PMC:** Preformed metal crown(s). **RCTs:** Randomized controlled trials. **RMGIC:** Resin-modified glass ionomer cement(s). **SSC:** Stainless steel crowns. **UK:** United Kingdom.

diamine fluoride is supplemented by restorative therapy when indicated.[3-5]

Molar-incisor hypomineralization (**MIH**) is a developmental defect involving any number of the permanent first molars and possibly the permanent incisors as well. This condition presents esthetic and restorative challenges due to the range of clinical variation, including hypersensitivity, altered resin bond strength, potential for tooth structure loss, and a caries presentation that can be unusual.[6,7] Restorative treatment options and overall management of MIH depend on the degree of affected teeth, potential for breakdown of tooth structure, sensitivity, severity and quality of the dental defect in addition to patient preferences and behavior.[7,8]

Recommendations

When to restore

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. AAPD's *Use of Vital Pulp Therapies in Primary Teeth with Deep Caries Lesions*[9] and *Pulp Therapy for Primary and Immature Permanent Teeth*[10] state the treatment objective for a tooth affected by caries is to maintain pulpal vitality, especially in immature permanent teeth for continued apexogenesis.

Indications for restorative therapy have been examined only 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 the least: clinical criteria of visual detection of enamel cavitations, visual identification of shadowing of the enamel, or radiographic recognition of enlargement of lesions over time.[3,12,13]

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 tooth structure and function, 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, and future pulpal complications, in addition to the risk of iatrogenic damage to adjacent teeth.[14-16]

Primary teeth may be more susceptible to restoration failures than permanent teeth.[17] Additionally, before restoration of primary teeth, one needs to consider the length of time until tooth exfoliation.

Recommendations:

1. Management of dental caries should include 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 intervention with appropriate preventive services, supplemented by restorative therapy when indicated.
2. Decisions for when to restore caries lesions should include at the least: clinical criteria of visual detection of enamel cavitation, visual identification of shadowing of the enamel, or radiographic recognition of progression of lesions.

Deep caries excavation and restoration

Regarding 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.[18] 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.[19,20] No removal of caries before restoration of primary molars in children aged three to 10 years also has been reported.[21]

Evidence from multiple studies shows that frequency of pulp exposures in primary and permanent teeth is significantly reduced when 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.[22-24] One five-year RCT evaluated the pulpal vitality of teeth treated with partial excavation compared to stepwise excavation and found that the success rate was significantly higher in partial excavation (80 percent) versus stepwise excavation (56 percent).[25] Two trials of stepwise excavation showed that pulp exposure occurred more frequently from complete excavation compared to stepwise excavation.[18,23] Evidence of a decrease in pulpal complications and postoperative pain after incomplete caries excavation compared to complete excavation in clinical trials is summarized in a meta-analysis.[26]

Additionally, a meta-analysis found the risk for permanent restoration failure was similar for incompletely and completely excavated teeth.[26] 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.[19] Interestingly, two RCTs suggest that restoration without excavation can arrest dental caries as long as a good seal of the final restoration is maintained.[21,27]

Recommendations:

1. Multiple RCTs and systematic reviews determined that incomplete caries excavation, either partial (one-step) or stepwise (two-step) excavation, in primary and permanent teeth with normal pulps or reversible pulpitis results in fewer pulp exposures and fewer signs and symptoms of pulpal disease than complete excavation. Incomplete caries removal should be considered in primary and

permanent teeth with deep caries and normal pulp status or reversible pulpitis when complete caries removal is likely to result in pulp exposure.
2. Two systematic reviews reported that the rate of restoration failure in permanent teeth is no higher after incomplete rather than complete caries excavation.
3. Numerous studies concluded 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 noncavitated interproximal caries lesions.[28,29] The aim of the resin infiltration technique is to allow penetration of a low viscosity resin into the porous lesion body of enamel caries.[28] Once polymerized, this resin serves as a barrier to acids and theoretically prevents lesion progression.[30,31]

A systematic review and meta-analysis that evaluated the effectiveness of enamel infiltration in preventing initial caries progression in proximal surfaces of primary and permanent teeth found infiltration was significantly more effective than placebo treatment.[32] In randomized clinical trials, resin infiltration, when used as an adjunct to preventive measures, was found to be more effective in reducing the radiographic progression of early or incipient proximal lesions on primary molars than preventive measures alone over a 24 month period.[33-36] Current ADA clinical practice guidelines for non-restorative treatment for noncavitated interproximal caries lesions conditionally recommends enamel infiltration for treatment of these lesions, (low to very low certainty).[37] Few RCTs evaluate the long-term effectiveness of resin infiltration. An additional use of resin infiltration has been suggested to restore white-spot lesions. Based on a RCT, resin infiltration significantly improved the clinical appearance of such white-spot lesions and visually reduced their size.[38]

Recommendations:
1. Resin infiltration is indicated as an adjunct to preventive measures for primary and permanent teeth with small, noncavitated interproximal caries lesions to reduce lesion progression and for white-spot lesions to improve their clinical appearance.
2. Further research regarding long-term effectiveness of resin infiltration is needed.

Dental amalgam

Dental amalgam contains a mixture of metals such as silver, copper, and tin, in addition to approximately 50 percent mercury.[39] Use of dental amalgam has declined, perhaps due to the controversy surrounding perceived health effects of mercury vapor, environmental concerns from its mercury content, and increased demand for esthetic alternatives.[40]

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.[41,42] However, in 2009, the United States 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.[39] Also in this final rule, the FDA noted information regarding dental amalgam and the long-term health outcomes in pregnant women, developing fetuses, and children under the age of six is limited.[39]

In 2020, the FDA published recommendations on the use of dental amalgam in certain populations considered high-risk, such as pregnant women, women planning to become pregnant, nursing women, children under six years old, and people with pre-existing neurological disease.[43] The FDA recommended providers avoid the use of dental amalgam in these high-risk populations and consider alternative restorative materials.[43] However, the ADA immediately reaffirmed that amalgam is a durable, safe, and effective restorative option and that the FDA's recommendations did not cite any new scientific evidence.[44] The ADA encourages providers to review all options for restorations with their patients and review the risks and benefits of amalgam.[44] Both organizations recommend that existing amalgam fillings in good condition should not be removed or replaced unless medically necessary.[43,44]

With regard to clinical efficacy of dental amalgam, results comparing longevity of amalgam to other restorative materials are inconsistent. Most meta-analyses, evidence-based reviews, and RCTs report comparable durability of dental amalgam to other restorative materials,[45-50] yet others show greater longevity for amalgam.[51,52] The comparability appears to be especially true when the restorations are placed in controlled environments such as university settings.[45]

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.[17,49,52] Efficacy of Class I amalgam restorations in permanent teeth of children has been shown in two independent RCTs to range from 89.8 to 98.8 percent for up to seven years.[49,51]

With regard to Class II restorations in primary molars, a 2015 systematic review recommended that amalgam could be utilized in preparations that do not extend beyond proximal line angles.[53] 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.[45,48] 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.[45] 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.[45]

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.[54-58] 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.

Recommendations:

1. Dental amalgam may be used to restore Class I and Class II cavity restorations in primary and permanent teeth.
2. Providers should review the risks and benefits of amalgam restorations with patients.

Composites

Resin-based composite restorations were introduced in dentistry about a half century ago as an esthetic restorative material[59,60], and composites increasingly are used in place of amalgam for the restoration of caries lesions.[45,61] Composites consist of a resin matrix and chemically-bonded fillers.[45] They are classified according to their filler size, because filler size affects physical properties, polishability/esthetics, polymerization depth, and polymerization shrinkage.[62] Hybrid resins combine a mixture of particle sizes for improved strength while retaining esthetics. [63] 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.[64]

Several factors contribute to the longevity of resin composites, including operator experience, restoration size, and tooth position.[51] Resins are technique sensitive and require longer placement time than amalgams.[65] In cases where isolation or patient cooperation is in question, resin-based composite may not be the restorative material of choice.[65,66] Additionally, composite may not be the ideal restorative material for primary posterior teeth requiring large multisurface restorations or high-risk patients with poor oral hygiene, numerous carious teeth, and demineralization.[65]

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 increase from baseline at 24 hours posttreatment but return to baseline by 14 days and remain at baseline six months after treatment.[67] Evidence is accumulating that certain BPA derivatives may pose health risks attributable to their endocrine-disrupting properties, but no established thresholds for safety and exposure have been determined.[67] 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.[68] Considering the proven benefits of resin-based dental materials and minimal exposure to BPA and its derivatives, continued use of these products, while taking precautions to minimize BPA exposure, has been recommended.[69]

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.[45] Strong evidence from RCTs comparing composite restorations to amalgam restorations showed the main reason for restoration failure in both materials was recurrent caries.[49,51,68]

In primary teeth, there is strong evidence that composite materials for Class I restorations are successful.[17,49] One RCT showed success of Class II composite restorations in primary teeth that were expected to exfoliate within two years.[56] Another RCT comparing total caries removal versus selective caries removal with composite restorations showed a statistically significant higher survival rate with total caries removal after 36 months (81 percent to 57 percent).[70] In permanent molars, composite replacement after 3.4 years was no different than amalgam,[49] but after seven to 10 years the replacement rate was higher for composite.[66] Secondary caries rate was reported as 3.5 times greater for composite versus amalgam.[51] A meta-analysis concluded that etching and bonding of enamel and dentin significantly decreases marginal staining and detectable margins in composite restorations.[45] Regarding different types of composites (i.e., packable, hybrid, nanofilled, macrofilled, microfilled), evidence showing similar overall clinical performance for these is strong.[71-74]

Recommendations:

1. Resin-based composites can be used as Class I and Class II restorations in primary and permanent molars.
2. Evidence from a meta-analysis shows enamel and dentin bonding agents decrease marginal staining and detectable margins for the different types of composites.
3. Precautions should be used in conjunction with placement of resin-based composites to help minimize BPA exposure.

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.[75] Originally, glass-ionomer materials had long setting times and low fracture strength and exhibited poor wear resistance.[76] 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.[77,78] 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.[76]

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.[79,80] Glass ionomers can act as a reservoir of fluoride, as uptake can occur from dentifrices, mouth rinses, and topical fluoride applications.[81,82] 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.[83]

One RCT showed the overall median time from treatment to failure of conventional glass-ionomer restored primary teeth was 1.2 years.[52] Based on findings of a systematic review and meta-analysis, conventional glass ionomers have not been recommended for Class II restorations in primary molars.[84,85] Conventional glass-ionomer restorations have other drawbacks such as poor anatomical form and marginal integrity.[86,87] Composite restorations were more successful than GICs where moisture control was not a problem.[85]

Resin-modified glass-ionomer cements (**RMGIC**), with the acid-base polymerization supplemented by a second, light-cure polymerization, have been shown to be efficacious in primary teeth.[88] Based on a meta-analysis, RMGIC is more successful than conventional glass ionomer as a restorative material.[85] A systematic review supports the use of RMGIC in small to moderate sized Class II cavities.[84] Class II RMGIC restorations are able to withstand occlusal forces on primary molars for at least one year.[85] Because of fluoride release, RMGIC may be considered for Class I and Class II restorations of primary molars in a high caries risk population.[87] Conditioning dentin improves the success rate of RMGIC.[84] According to one RCT, cavosurface beveling leads to high marginal failure in RMGIC restorations and is not recommended.[68]

With regard to permanent teeth, a meta-analysis review reported significantly fewer caries lesions on single-surface glass ionomer restorations in permanent teeth after six years as compared to restorations with amalgam.[87] Data from a meta-analysis show that RMGIC is more caries preventive than composite resin with or without fluoride.[89] Another meta-analysis showed that cervical restorations (Class V) with glass ionomers may have a good retention rate but poor esthetics.[45] For Class II restorations in permanent teeth, one RCT showed unacceptable high failure rates of conventional glass ionomers, irrespective of cavity size.[91] However, a high dropout rate in this study limits significance.[91]

Silver diamine fluoride (**SDF**) application has been used prior to or in conjunction with GIC and RMGIC restorations in primary and permanent teeth. A systematic review and meta-analysis that evaluated the influence of SDF on the dentin bonding of adhesive materials included eleven and ten studies, respectively.[92] The systematic review found that prior application of SDF does not have a negative effect on the bond strength between glass ionomer cement and dentin.[92] Another systematic review of thirteen studies that examined the effect of SDF application on the bond strength between dentin and adhesives and dentin and glass-ionomer cements was inconclusive due to the inconsistent results from the included studies.[93] Further research examining the effect of SDF application to the bond strength of glass ionomers, as well as the advantages of its use prior to the application of glass ionomers, is needed.

Glass ionomers can be utilized for caries control in patients with high caries risk and for restoration repair.[76] Other applications of glass ionomers in which 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,[94] uncooperative patients, or patients with special health care needs[50] for whom traditional cavity preparation or placement of traditional dental restorations is not feasible or needs to be postponed. Additionally, ITR may be used for caries control in children with multiple open caries lesions, prior to definitive restoration of the teeth.[95] In-vitro, leaving caries-affected dentin does not jeopardize the bonding of glass ionomercements to the primary tooth dentin.[96] 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.[97]

According to a meta-analysis, single-surface ART restorations had a high survival percentage over the first three years in primary teeth and over the first five years in permanent teeth.[98] 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.[99] With regard to multisurface 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.[100,101]Multisurface ART restorations in primary teeth exhibited a medium survival percentage over two years.[98] A recent RCT that compared modified ART to preformed metal crowns on primary teeth reported major failures on 21 percent of modified ART restorations at six months and 34 percent at twelve months.[102] More research is needed on the survival percentage of multisurface ART restorations in permanent teeth.

Recommendations:

1. GICs may be used for Class I restorations in primary teeth.
2. RMGICs may be used for Class I restorations, and expert opinion supports Class II restorations in primary teeth.
3. Evidence is insufficient to support the use of conventional or RMGICs as long-term restorative material in permanent teeth.
4. ITR/ART using high-viscosity glass-ionomer cements may be used as single surface temporary restoration for both primary and permanent teeth. Additionally, ITR may be used for caries control in children with multiple open caries lesions, prior to definitive restoration of the teeth.
5. Further research examining the effect of SDF application on the bond strength of glass ionomers to dentin is needed.

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.[103] 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.[104,105] Considering the ability to release fluoride, esthetic value, and simple handling properties, compomer can be useful in pediatric dentistry.[103]

Based on a 2007 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.[49] 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.[57,106] Compomers also have reported comparable clinical performance to composite with respect to color matching, cavosurface discoloration, anatomical form, and marginal integrity and secondary caries.[107,108] Compomers are available in a variety of nonconventional colors which, when polymerized, can cause varying pulp chamber temperatures.[109,110] Most RCTs showed that compomer tends to have better physical properties compared to GIC and RMGIC in primary teeth, but no significant difference was found in cariostatic effects of compomer compared to these materials.[52,106,111-114]

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.

Bioactive materials

A recently recognized category of materials is termed bioactive. Bioactive restorative materials release ions (typically calcium, fluoride, or phosphate[115]) yet, at times, antibacterial monomers, silver particles, or strontium particles.[116] The materials also can absorb ions at their surface. Although they may not meet true ionic equilibrium, the ion exchange still can help prevent adjacent tooth demineralization and enhance remineralization.[117,118]

Bioactive dental restorative materials are available for sealants, adhesive bonding agents, cements, resin-based restorations, GIC and RMGIC restorations, as well as pulp capping agents. Since each bioactive material interacts with hard tissue differently, a modified surface treatment may be required.[119]

Recommendations:

1. Bioactive materials can be used for remineralization and pulp capping.
2. Further research examining the basic properties and long-term effect of bioactive materials and comparing bioactive materials to other restorative materials is needed.

Preformed metal crowns

Preformed metal crowns (**PMC**), also known as SSC, are prefabricated crown forms that are adapted to individual teeth and cemented with a biocompatible luting agent. PMC have been indicated for the restoration of primary and permanent teeth with extensive caries, cervical decalcification, 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.[120] They are used more frequently in patients who exhibit high caries risk and whose treatment is performed under sedation or general anesthesia.[121-123]

Very few prospective RCTs compare outcomes for PMC to intracoronal restorations.[124,125] A Cochrane review and additional studies, including two systematic reviews, concluded that the majority of clinical evidence for the use of PMC has come from nonrandomized and retrospective studies.[17,121-123] However, this evidence suggests that PMC showed greater longevity than amalgam restorations,[17] despite possible study bias of placing SSCs on teeth more damaged by caries.[122,123,126] Five studies which retrospectively compared Class II amalgams to PMC showed an average five-year failure rate of 26 percent for amalgam and seven percent for PMC.[122] SSC were shown in a recent retrospective study to have a higher survival rate compared to multisurface restorations and may be considered when treating multisurface caries in children younger than four years old in order to avoid possible retreatment.[127]

A two-year RCT regarding restoration of primary teeth that had undergone a pulpotomy procedure found a nonsignificant difference in survival rate for teeth restored with PMC (95 percent) versus RMGIC/composite restoration (92.5 percent).[124] A one-year RCT comparing primary molars treated with mineral trioxide aggregate (**MTA**) pulpotomies and restored with either multisurface composite restorations or PMC showed no difference in radiographic success over a 12-month follow-up period.[125] However, the pulpotomized teeth with multisurface composite restorations had more marginal change and required more maintenance than those with PMC, and a majority turned gray up to 12 months later even with the use of white MTA.[125] A systematic review on the use of SSC determined that the reported outcomes of primary teeth with pulpal therapy are best in teeth treated with SSC.[120]

With regards to gingival health adjacent to PMC, a one-year RCT showed no difference in gingival inflammation between PMC and composite restorations after pulpotomy.[123] Yet, a two-year randomized clinical study showed more gingival bleeding for PMC versus composite/glass ionomer restorations.[124] Inadequately contoured crown and residues of set cement remaining in contact with the gingival sulcus have been suggested as reasons for gingivitis associated with PMC, and a preventive regime including oral hygiene instruction has been recommended for incorporation into the treatment plan.[122]

The one RCT on PMC versus cast crowns placed on permanent teeth[128] found no difference between the two restoration types for quality and longevity after 24 months. A recent retrospective cohort study that focused on long-term clinical outcomes of SSCs compared to amalgam and composite restorations in permanent teeth on special needs populations concluded that posterior permanent teeth restored with SSCs can be expected to last for 10 years and represent a viable treatment option for severely carious or fractured posterior permanent teeth.[129] The remaining evidence is case reports and expert opinion concerning indications for use of PMC 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.[121,126,128] The main reasons for PMC failure reportedly are crown loss[17,130,131] and perforation[131].

A recent method of providing PMC is known as the Hall technique (**HT**).[132] The HT calls for cementation of an SSC over a caries-affected primary molar without local anesthetic, caries removal, or tooth preparation. A less invasive management procedure for treating carious primary teeth,

Table 1. EVIDENCE OF EFFICACY OF VARIOUS DENTAL MATERIALS/TECHNIQUES IN PRIMARY 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	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

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.

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.
N/A = not available.

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

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.

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.
N/A = not available.

HT involves caries control by managing the activity of the biofilm.[133] In essence, bacteria sealed into the tooth and denied of substrate will die rather than result in caries progression, and the best way of producing an effective marginal seal is with a crown.[134]

Using HT may reduce discomfort from local anesthetic and caries removal at the time of treatment compared to fillings,[132] 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.[135] In a randomized split mouth clinical trial with general dentists as providers, sealing in caries by using HT significantly outperformed the general dentists' standard restorations to restore caries interproximally and was more effective in the long term.[136] HT may be considered a treatment modality for carious primary molars when traditional SSC technique is not feasible due to limitations such as poor cooperation or barriers to care.[102] Additional studies that compare this technique to traditionally-placed PMC using long-term follow-ups, radiographic assessment, and caries removal are needed.[102,137]

SSC 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.[120]

Recommendations:

1. Retrospective studies reported greater longevity of PMC restorations compared to amalgam or resin-based restorations for the treatment of caries lesions in primary teeth. Therefore, use of SSC is indicated for high-risk children with large or multi-surface cavitated or non-cavitated lesions on primary molars, especially when children require advanced behavioral guidance techniques[138] including general anesthesia for the provision of restorative dental care.
2. PMC may be indicated in permanent teeth as a semi-permanent restoration for the treatment of severe enamel defects or grossly carious teeth.
3. Further research comparing HT to traditionally-placed PMC is needed.

Posterior esthetic crowns in primary teeth

The interest by clinicians and patients in esthetic options for full coverage restoration of primary posterior teeth is increasing.[139,140] Scientific studies that evaluate esthetic options for restoring posterior primary teeth with large caries lesions are not widely reported in the literature. While opened-faced SSC or preveneered SSC are not ideal based on minimum evidence, zirconia crowns are an option that has been used by pediatric dentists. Several preformed pediatric zirconia crowns are available on the market, and brands differ in material composition, fabrication, surface treatment, retentive feature, and cementation method.[141] More circumferential tooth reduction is needed for proper fit and placement of zirconia crowns compared to SSC[142] and, for proper retention, the minimum abutment height is two millimeters[143]. The indications for the preformed esthetic crowns are generally the same as those of the preformed SSCs but with consideration of esthetics.[144] Clinical parameters between zirconia crowns and SSC are similar except for retention and gingival health; SSC have comparatively better retention and zirconia crowns have relatively better gingival health.[144,145]

Recommendation:

1. Evidence is limited on the use of zirconia crowns as esthetic crowns for primary posterior teeth. When SSC would otherwise be indicated, zirconia crowns may be considered in lieu of SSC to due to esthetic considerations.

Anterior esthetic restorations in primary teeth

With increasing demand for esthetic considerations for children by their parents, treatment of dental caries of primary anterior teeth remains one of the biggest challenges in pediatric dentistry.[146] 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.[147]

Most evidence for the clinical techniques utilized to restore primary anterior teeth 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 their use.[147]

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.[147] Resin-based restorations are appropriate for anterior teeth that can be adequately isolated from saliva and blood. RMGIC have been suggested for this category, especially when adequate isolation is not possible.[76,148,149] Patients considered at high risk for caries may be better served with placement of full tooth coverage restorations.[147,149]

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 cooperation difficulty, it is sometimes impossible to isolate teeth for the placement of composite restorations. In these cases, GIC or RMGIC is suggested.[148,149]

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) cervical decalcification is extensive, (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.[147] Currently, full coronal restorations of primary teeth are bonded to existing tooth structure or cemented in place.[147] Resin strip crowns are bonded to the tooth, and two retrospective studies show that 80 percent are retained after three years.[150,151] Resin strip crowns are esthetic, and parental satisfaction is high. They are technique sensitive and require sufficient tooth structure to provide surface area for bonding. Hemorrhage or saliva can interfere with bonding of the materials, and hemorrhage can affect the color of the crown.[141,147]

Preveneered SSC also are among the options of restoring primary anterior teeth with full coronal coverage. Three retrospective studies report excellent clinical retention of this type of crowns, yet a high incidence of partial or complete loss of the resin facings.[152,153] The crimping of preveneered SSC on the metal side does not affect the fracture resistance.[154] Preveneered SSC have the concerns of color stability and surface roughness changes,[155] so long-term clinical studies are required to establish their comparative effectiveness. Preformed SSC and opened-faced SSC are still options for treatment on primary anterior teeth, but published studies reporting their effectiveness and use are sparse[156] given the availability of more esthetic and easier-to-use alternatives.

Preformed zirconia crowns have been available in pediatric dentistry since 2010.[147] Zirconia crowns are strong, esthetic, and biocompatable.[147,157] Zirconia crowns placed in a university clinic displayed survival probability at 12, 24 and 36 months of 93, 85, and 76 percent respectively.[158] Parental esthetic satisfaction has been shown to be higher for zirconia crowns than resin strip crowns or preveneered SSC.[157] Disadvantages of zirconia crowns include a steep learning curve for dentists and, since the crowns cannot be adjusted, the tooth must be reduced in order to fit the crown. The amount of tooth reduction is greater than that required for an SSC and reduction of 1.5 to two millimeters with a feather margin is required to passively seat the zirconia crown.[142]

Recommendations:

1. Resin-based composites may be used as a treatment option for Class III and Class V restorations in the primary and permanent dentition.
2. Expert opinion finds 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. Expert opinion suggests that strip crowns, preveneered SSC, preformed SSC, opened-faced SSC, and zirconia crowns are treatment options for full coronal coverage restorations in primary anterior teeth.

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