SIOI Policy on Direct Restorative Materials in Paediatric Dentistry

Context

Modern dental caries management is moving away from traditional surgical interventions toward a more preventive and patient-centered approach. This shift prioritises controlling disease progression rather than merely addressing its consequences, aligning with the principles of minimally invasive dentistry. The focus is on preserving healthy dental tissue while incorporating materials and techniques that support long-term oral health.

Briefly

Modern Restorative Approach: Beyond traditional fillings, focusing on adhesive and bioactive materials.
Key Materials: Resin composites, glass ionomers, compomers, and bioactive options, each with specific indications.
Amalgam Phase-Out: EU regulations limiting its use, shifting towards safer alternatives.
Adhesion & Longevity: Potential risks, like BPA exposure, are discussed, and mitigation strategies are offered.
Clinical Recommendations: Material choice based on isolation, caries risk, and tooth type.

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PURPOSE The Italian Society of Paediatric Dentistry (SIOI) is committed to encourage all dental practitioners to provide safe and updated prevention and treatment strategies for oral diseases in paediatric patients. SIOI promotes quality communication and information to parents and caregivers for prevention and awareness of oral diseases in the paediatric population. The purpose of this SIOI Policy is to provide dental professionals with comprehensive guidance on paediatric restorative materials, ensuring that treatment decisions are based on the latest and highest-quality scientific evidence.

METHODS This Policy is based on a review of the most recent and highest-quality dental literature i.e. reviews, systematic reviews, meta-analyses, recommendations and Best Practices from professional organisations over the last 10 years. An extensive electronic bibliographic search was conducted using PubMed®/MEDLINE with the following keywords: paediatric restorative dentistry, dental materials, dental restorations, dental caries, dental caries therapy, dental amalgam, composite resins, adhesive systems, glass ionomer cements, compomers, and bioactive materials. The following additional filters were applied: publication date (10 years), text availability (full text), article type (review, systematic review, and meta-analysis), species (humans), age (child: birth-18 years), and article language (English). One hundred forty-three articles met these criteria. Articles were screened by reading titles and abstracts.

Introduction

SIOI recognizes and supports the contemporary approach to managing dental caries, which emphasises that surgical intervention or restorative treatment alone does not halt the progression of the disease, as it addresses its effects rather than its causes. The goals of restorative therapy are as follows: repairing or limiting the damage caused by the carious process, protecting the remaining healthy dental structure, preserving pulp vitality, reducing the risk of secondary caries development, restoring adequate function and aesthetics, preventing tooth displacement due to the loss of dental structure, and facilitating the maintenance of proper home oral hygiene. In addition, restorative treatment of primary teeth allows for their retention in the dental arch and the proper natural management of space for the development of permanent dentition.The characteristics of the ideal paedodontic restorative material include: biocompatibility, adhesion to dental tissues, good mechanical and aesthetic properties, antimicrobial properties, ease of handling and simplicity of use, low sensitivity to moisture, fluoride release, longevity, and adaptability to growth and development [Colombo and Paglia, 2018; IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Discussion

The field of dental materials and restorative care for children and adolescents is continuously evolving [Dhar et al., 2015; Pilcher et al., 2023]. Scientific evidence both in support and against the use of the most common paedodontic conservative materials is presented in this Policy. The advantages and disadvantages of the materials described, along with the level of evidence regarding their indications for use, are summarised in Table 1. Adhesive systems and bioactive materials are discussed. Moreover, the Bisphenol A (BPA) issue is addressed.

Dental amalgam

General considerations

Historically, amalgam has been used to restore posterior teeth and continues to be the preferred choice in certain low- and middle-income countries due to its proven cost-efficiency [IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023]. The evidence on the longevity of amalgam restorations is inconsistent [Dhar et al., 2015]. In European countries, the use of dental amalgam is disciplined by Regulation (EU) 2017/852 of the European Parliament and the Council of 17 May 2017 on mercury. According to Article 10, "From 1 July 2018, dental amalgam shall not be used to restore primary teeth, in minors under the age of 15, or in pregnant or breastfeeding women, except in cases deemed strictly necessary by the clinician based on the patient's medical needs". However, a recent update to the general EU regulation (2024/1849) on the import, export, and production of mercury-containing products has been issued. This new regulation establishes the goal of phasing out the conventional use of dental amalgam by 1 January 2025, with exceptions for countries where it remains the only reimbursable material (covering at least 90% of the cost) for dental restorations in public health services or in specific cases determined by the clinician. This allows the use of dental amalgam in limited circumstances and specific countries until 31 December 2029 [Regulation (EU) 2024/1849].

Composition

Dental amalgam is a multiphase alloy formed by the reaction between liquid mercury and a powder containing several metals, including silver, copper, and tin. Once condensed and fitted into the cavity, the alloy hardens, forming a stable restoration.

Advantages and disadvantages

Dental amalgam is a cheap restorative material with excellent physical properties and simple use. Since it is not an adhesive material, its cavity design requires the removal of a large amount of healthy tissue to ensure adequate mechanical retentions. This is in contrast with the principle of "bio-economy" in dental tissue preservation, which represents the basis of modern adhesive dentistry. Moreover, dental amalgam is not an aesthetic material and is primarily used in posterior teeth. The main concern associated with its use, however, relates to its safety profile [Worthington et al., 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Resin composites

General considerations

Composite resins, also referred to as resin-based composites (along with photopolymerisation) have revolutionised clinical restorative dentistry since the late 1960s. In recent decades, their role in modern restorative dentistry has become central due to the increasing demand for aesthetics and the phase-down in the use of dental amalgam. Currently, they are the most widely used direct restorative material for treating carious lesions that cannot be arrested or remineralised [IAPD Restorative Dentistry in Children, 2021; Worthington et al., 2021; AAPD Best Practices: Restorative Dentistry, 2023]. Composite resins are highly technique-sensitive, and their longevity depends on several factors, including proper placement techniques, adequate photopolymerisation, the size of the restoration, and the tooth's position. The patient's lifestyle is also an essential factor influencing the longevity of these restorations and should not be overlooked. Annual failure rates of direct composite resin restorations range from 0% to 19.5% [Amend et al., 2022a; Amend et al., 2022b]. Composite resin restorations have a lower risk of bulk fracture compared to dental amalgam restorations but the overall risk of failure from secondary caries is higher than amalgam restorations [Splieth et al., 2020; Worthington et al., 2021]. Evidence is inconsistent regarding the longevity of restorations placed with or without cavity liners to reduce post-operative hypersensitivity [Schenkel et al., 2019]. Since the 1990s, there has been a trend toward simplifying and shortening the procedural steps for placing direct composite resin restorations, while enhancing gloss stability and polishability by reducing the size of filler particles, including those at the nanoscale [Heintze et al., 2022]. Among the different types of resin-based composites classified by their filler size, nanohybrids are the most commonly used due to their enhanced aesthetics, durability, and versatility. The development of flowable bulk-fill resin-based composites (BF-RBCs) has overcome the need for multiple incremental layers of ≤ 2mm each, simplifying restorative procedures which is particularly useful in paediatric restorative dentistry, and reducing the risk of errors for clinicians. These materials can be applied in 4–5mm layers, offering the advantages of shorter treatment times, reduced volumetric shrinkage stress, and enhanced curing depth, all while preserving micromechanical properties and exhibiting satisfactory clinical outcomes in posterior teeth [Delgado et al., 2021; de Menezes et al., 2024]. Furthermore, single-shade composite resins which can mimic the color of the surrounding tooth regardless of its shade, have considerably simplified color matching. However, evidence regarding the color match and stability of single-shade versus multi-shade composite resins after 12 months is considered low [Heintze et al., 2022; Leal et al., 2024].

Composition

Composite resins consist of a resin-based matrix made of an oligomer, such as bisphenol A-glycidyl methacrylate (Bis-GMA), mixed with low molecular weight diacrylate monomers such as ethylene glycol dimethacrylate (EGDMA) and triethylene glycol dimethacrylate, (TEGMA), along with inorganic particles such as silicon dioxide (silica) which serve as the filler. The matrix and the filler are chemically bonded thanks to a binding agent (silane). The size and type of filler, along with the quantitative ratio between the matrix and filler, influence the mechanical, aesthetic, and handling properties of composite resins, as well as the polymerisation depth and the extent of dimensional shrinkage. Larger filler particles contribute to greater strength, while smaller particles enhance the aesthetics and polishability of the material [IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

When it comes to resin-based materials, exposure to Bisphenol A (BPA), which is the starting monomer for bisphenol A-glycidyl methacrylate (Bis-GMA), has recently been questioned. BPA may be present in trace amounts in resin-based materials as an impurity resulting from the manufacturing process of its derivatives such as Bis-GMA and may be also released due to their incomplete polymerisation or enzymatic biodegradation in the oral cavity. Nowadays, there is inconsistent evidence that oral exposure to BPA via resin-based dental materials may represent a risk for human health. The following precautionary measures can still be adopted to reduce BPA exposure when performing resin-based restorations: ensure proper light-curing to maximise the material's monomer-to-polymer conversion (polymerisation time of at least 20 seconds, using LED-type polymerisation lamps and keeping the light-curing tip close to the restoration surface), use a rubber dam, apply glycerin gel to the superficial resin layer during polymerisation, rub pumice on a cotton roll or prophylaxis cup on the surface layer, and have patients rinse with water once light-curing is completed to minimise the risk of unpolymerised BPA residues on the material' surface. BPA-free resin-based materials such as composites and dental sealants are currently available [Colombo et al., 2018; AAPD Best Practices: Restorative Dentistry, 2023].

Advantages and disadvantages

Composite resins are biocompatible, adhesive, and aesthetic materials with good mechanical properties. However, the main challenges associated with direct composite resin restorations include polymerisation shrinkage and the resulting shrinkage stress, the extent of polymerisation conversion, and limited depth of cure [Heintze et al., 2022]. In addition, due to their high sensitivity to moisture, their use requires proper isolation of the operating field, preferably with the rubber dam. This, however, necessitates sufficient cooperation from the patient, which can be challenging, especially in preschool children [IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Adhesive systems

Over the years, adhesive systems have evolved considerably, marking significant advancements in contemporary restorative dentistry. Bonding to enamel has become a reliable and well-established technique while bonding to dentin remains more challenging due to its heterogeneous structure. Etch-and-rinse 3-step adhesives are considered the reference adhesive systems for permanent teeth, demonstrating generally high and stable bond strength over time [Bourgi et al., 2024]. As for decayed hypomineralised permanent teeth (MIH) [Villani et al., 2023], etch-and-rinse adhesive systems show better retention rates in mild-affected enamel, while self-etch systems are preferable for severe-affected enamel which structurally resembles the dentinal substrate where these systems show lower postoperative hypersensitivity [Lagarde et al., 2020]. Primary teeth have distinct chemical and morphological characteristics compared to permanent teeth, including lower mineral content, thinner enamel with higher prism density, and larger dentinal tubule diameter, which can interfere with the clinical performance of adhesive restorations. The evidence regarding which adhesive system leads to better clinical success rates is limited and should be interpreted with caution [Delgado et al., 2021]. Etch-and-rinse adhesives are generally preferable, and shortening the acid-etching time, especially for dentin which appears to be more reactive to acidic conditioning, seems to enhance long-term bond strength [Gindri et al., 2020]. As for universal adhesives, evidence is insufficient to determine the most effective etching strategy for bonding to primary teeth [Fröhlich et al., 2021].

Glass Ionomer Cements

General considerations

The development of Glass Ionomer Cements (GICs) since the 1970s has been a major advancement in paediatric restorative dentistry, thanks to their numerous properties that make them ideal for use in children, and especially in very young children when uncooperative for conventional treatments [Duangthip et al., 2016; Cianetti et al., 2017; IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023]. Improvements in the formulation of conventional GICs have enhanced their properties, leading to the development of resin-modified GICs (RM-GICs), which are preferable [Dhar et al., 2015; Yengopal et al., 2016; Colombo and Paglia, 2018].The longevity of GIC restorations is generally shorter compared to

Material	Advantages	Disadvantages	Evidence
Dental amalgam	- Ease and quick of use - Cost - Insensitive technique - Durable	- Not adhesive - Requires mechanical retention - Environmental/health concerns	- Permanent teeth: Class I and II (A)
Composite resins	- Adhesive - Aesthetic - Good mechanical properties	- Sensitive technique - Hydrophobic - Cost	- Primary teeth: Class I and II (A), Class V (B) - Permanent teeth: Class I (A), Class III and V (B)
Conventional GICs	- Adhesive - Fluoride release - Ease of use	- Sensitive Technique - Hydrophilic and highly soluble - Cost - Lower mechanical properties than composite resins	- Primary teeth: Class I[a] (A), Class III[b] (B) - Permanent teeth: Class I[a,c] (A), Class III[b,c] (B)
RM-GICs	- Adhesive - Fluoride release - Ease of use	- Limited aesthetics - Better mechanical properties than conventional GICs	- Primary teeth: Class I (A) - Permanent teeth: Class I[c] (A), Class V[c] (B)
Compomers	- Adhesive - Aesthetic - Fluoride release - Ease of use	- Sensitive technique - Lower mechanical properties than composite resins	- Primary teeth: Class I and II (B) - Permanent teeth: Class I[b] (B)
Bioactive materials	- Adhesive - Ion release (calcium, fluoride, or phosphate)	- Aesthetics ? - Mechanical properties ?	- Limited due to lack of long-term studies

TAB. 1 Advantages and disadvantages as well as evidence of use of paediatric restorative materials in primary and permanent teeth.

that of composite restorations. Annual failure rates of conventional GICs and RM-GICs range from 7.6% to 16.6% and 1.9% to 16.9%, respectively [Amend et al., 2022a; Amend et al., 2022b]. Overall, the clinical performance of GICs, particularly RM-GICs, appears to be superior to that of composite resins in preventing secondary caries in primary teeth. Moreover, being less sensitive to moisture in the operative site, their use is particularly indicated when moisture control is inadequate for composite resins restorations [Dias et al., 2018; Ortiz-Ruiz et al., 2020].

Conventional Glass Ionomer Cements

Composition

Conventional GICs consist of a basic powder (calcium fluoroaluminosilicate, barium glass, and zinc oxide) and an acidic aqueous liquid solution (polyacrylic acid and copolymers of itaconic acid, maleic acid, and tartaric acid), which react in an acid-base reaction.

Advantages and disadvantages

Conventional GICs are characterised by the following properties: biocompatibility, a thermal expansion coefficient similar to that of dental tissue, chemical adhesion to enamel and dentin, fluoride absorption and release in situ (acting as a fluoride reservoir), and lower sensitivity to moisture compared to composite resins. However, their mechanical properties i.e. compression and wear resistance are poor, and their aesthetic qualities are limited. The main disadvantage of these materials is their retention. Due to the high solubility of GICs in an aqueous environment, it is important to avoid contact with oral fluids during the early stages of the acid-base reaction to prevent deformation or detachment of the material. Complete hardening of the material occurs within 24 hours [Colombo and Beretta, 2018; Francois et al., 2020; IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Resin-modified Glass Ionomer Cements (RM-GICs)

Composition

Like conventional GICs, RM-GICs consist of a basic powder and an acidic liquid. However, these materials also include the addition of an acrylic monomer, such as hydroxyethyl methacrylate (HEMA), and a photoinitiator to the liquid. In their setting process, RM-GICs undergo a dual reaction: an acid-base reaction combined with a polymerisation process of the resin component, which can be either auto-activated or photo-activated.

Advantages and disadvantages

Thanks to their chemical composition, RM-GICs offer enhanced mechanical and aesthetic properties, along with lower solubility in the oral environment compared to conventional GICs. Additionally, the dual-setting reaction improves handling, which is particularly beneficial in paediatric restorative dentistry [Dias et al., 2018; Ortiz-Ruiz et al., 2020; IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Compomers

General considerations

Compomers are polyacid-modified composite resins introduced into dentistry in the 1990s and are mainly used to restore primary teeth [Dhar et al., 2015; Yengopal et al., 2016]. Annual failure rates of compomers range from 0% to 14.7% in primary teeth without pulp therapy [Amend at al., 2022b].

Composition

Compomers are composed of a resin matrix similar to that of composites with the addition of acidic acrylic monomers and a fluorosilicate glass filler containing calcium, strontium and aluminium.

Advantages and disadvantages

Compomers combine the advantages of composites and GICs, such as fluoride release, good aesthetics, and ease of use. They are available in various colors and harden through photopolymerisation. Compomers require an adhesive system like composites, thus moisture control in the operative site is mandatory [Dhar et al., 2015; Yengopal et al., 2016; IAPD Restorative Dentistry in Children, 2021; AAPD Best Practices: Restorative Dentistry, 2023].

Bioactive materials

Bioactive restorative materials are a recently introduced category of dental materials, defined by their dynamic behavior in the oral cavity, releasing ions (typically calcium, fluoride, or phosphate) as well as antibacterial monomers and other particles such as silver or strontium when salivary pH levels drop below the critical value of 5.5. This helps contrast the demineralisation process, stimulates the remineralisation of tissues, and controls the development of secondary caries, thereby prolonging the lifespan of restorations especially in individuals at high risk for caries [Melo et al., 2022; AAPD Best Practices: Restorative Dentistry, 2023]. Among restorative materials, bioactive composites, GICs, and adhesive agents are available. Bioactive restorative materials can be used for tissue remineralisation for both primary and permanent teeth. Bioactive composites are preferred for permanent teeth, while RM-GICs are more commonly used for primary teeth in controlling secondary caries [Pinto et al., 2023].

Recommendations

Oral health professionals must carefully choose the most appropriate restorative material for managing dental caries in children and adolescents. This decision is complex, as significant advancements in dental restorative materials over the past decades have resulted in a wide range of options, each promising superior performance in terms of longevity and aesthetics. In providing appropriate restorative treatment, clinicians must consider the following three key factors that can influence the outcomes:

1. The individual's caries risk, which influences the choice of restorative material;
2. The patient's age, which can affect cooperation and influence how long the restoration should remain in the oral cavity before tooth exfoliation;
3. Patient cooperation, which impacts both material selection and the choice of technique

Recommendations on the use of the restorative materials described in this Policy are summarised below.

Dental amalgam

- Dental amalgam shall not be used to restore primary teeth.
- Dental amalgam is not recommended in hypomineralised permanent molars (MH).
- The decision to use amalgam should be made on an individual patient basis.
- Amalgam restorations in good condition should not be replaced unless medically necessary.

Composite resins

- Composite resins can be used as long-term restorative materials in Class I and II cavities in primary and permanent teeth, as well as in Class III, IV and V cavities in anterior primary and permanent teeth.
- Composite resins should not be the material of choice in cases of inadequate isolation of the tooth to be restored, insufficient patient compliance, large restorations in posterior permanent teeth, and individuals with a high risk of caries and poor oral hygiene.
- The use of direct composite restorations is recommended in hypomineralised molars.
- Proper application of enamel-dentin adhesive systems reduces marginal staining and detachment of composite.
- The evidence on postoperative hypersensitivity following the placement of a dental cavity liner under Class I and Class II composite resin restorations is inconsistent. Furthermore, evidence is inconsistent regarding the longevity of restorations placed with or without cavity liners.

Glass Ionomer Cements

- Conventional GICs can be used for Class I restorations in primary teeth of high caries-risk individuals, thanks to their fluoride release.
- RM-GICs can be used for Class I and II restorations in posterior primary teeth, and for Class III, IV and V restorations in anterior primary teeth, in cases of inadequate isolation of the operative site in high caries-risk individuals, thanks to their fluoride release.
- High-viscosity GICs can also be used in the Atraumatic Restorative Treatment (ART) in primary teeth thanks to their superior mechanical properties (compressive and wear resistance) compared to other GICs.
- Evidence is insufficient to support the use of GICs as long-term restorations in permanent teeth in children.

Compomers

- Compomers can be used as an alternative restorative material for Class I and II restorations in primary teeth.
- Evidence is insufficient to support their use as restorative materials in permanent teeth in children.

Bioactive materials

- Potential for tissues' remineralisation and control of secondary caries development.
- Limited evidence about aesthetic and mechanical properties due to a lack of long-term studies.

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