Description and Durability of the Various Direct Restoration Techniques in Molar-Incisor Hypomineralization: A Systematic Review

Keywords

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ABSTRACT

Introduction: Molar-incisor hypomineralization (MIH) is a qualitative defect of the enamel structure affecting at least one of the first permanent molars. Treatment will depend on its severity, the stage of dental development and the cooperation of the young patient. The aim of this study is to compare the different materials used for direct restorations on teeth with MIH. Methods: A systematic review was conducted on May 2024 and is described according to the PRISMA criteria. It was performed on three databases (PubMed, Science Direct, and Google Scholar). Twenty-nine articles were included. Results: 14 studies (48.3%) described the use of glass-ionomer cement (GIC), among which 12 concluded that its use could be recommended as a temporary material in the presence of MIH, protecting the tooth while awaiting a definitive restoration. Composite resins were described in 21 studies (72.4%), in association with both etch-and-rinse and self-etch adhesive systems. Conclusions: For direct tooth restoration in case of MIH, GIC seem to meet the objective of preserving the child's quality of life by protecting teeth during their eruption with an acceptable survival rate. The use of dental composite resins is more restrictive and will be optimal with complete removal of hypomineralized tissue.

INTRODUCTION

Molar-incisor hypomineralization (MIH) is a qualitative defect of the enamel structure affecting at least one of the first permanent molars, frequently associated with damage to the upper incisors[1,2]. MIH constitutes an important social issue as it affects approximately 14% of the children in the world[3] and its etiology is still poorly understood[4]. It seems to be the result of exposure to several risk factors[5] during pregnancy and after birth during the first four years of the child's life when amelogenesis occurs[6,7]. In the past 10 years, researches performed by Jedeon, Babajko *et al*. have highlighted a causal link between MIH occurrence and exposure to endocrine disruptors, especially bisphenol A[8,9]. Other factors also seem to be implicated in the syndrome development with a lower importance, for example respiratory diseases[10], otorhinolaryngology diseases[11], prematurity at birth[12], or even vitamin deficiencies[13,14]. The diagnostic criteria for MIH have been defined by the European Academy for Pediatric in 2003 and are still in use in 2024. They bring together during a clinical examination on dry molars and incisors: well delimitated enamel opacities, creamy

white (or even yellow-brown) discolorations, possible enamel fractures, presence of atypical restorations, tooth hypersensitivity and eventually a history of early tooth loss[15]. Recently, Altner *et al*. have once again shown that the occurrence of lesions was mainly located on molars[16].

The choice of treatment for teeth affected by MIH is difficult. There is no consensus and many factors come into play to choose the most appropriate treatment for the situation. Treatment will depend on the severity and involvement of the MIH, the stage of dental development as well as the cooperation of the young patient[17]. The difficulties encountered by patients with MIH are dental hypersensitivity, leading to an avoidance strategy when brushing, plaque build-up and therefore greater susceptibility to caries. In addition, since enamel is porous and fragile, it can fracture more easily. Anesthesia can also be complicated, as the pulp is chronically inflamed[18]. Finally, aesthetic damage is significant, especially when MIH affects the incisors[19]. According to Schwendicke *et al*., approximately 25% of the patients presenting an MIH need tooth restorative procedures to recover the shape, function, and aesthetics of the affected teeth[3]. The patient's age has an impact on his management, as children can become anxious about coming to the dentist. It has been shown that children with MIH undergo 10 times more dental treatment than children without MIH[20]. This is why studying materials and their survival on teeth affected by MIH seems essential in order to choose the most durable restoration possible, limiting the number of appointments required. It is also important to design permanent restorations as early as possible, either direct or indirect[7].

The aim of this study is to compare the different materials used for direct restorations on teeth with MIH through a systematic review of the literature.

METHODS

A systematic review was conducted on May 24th, 2024 and is described below according to the PRISMA criteria[21,22].

ELIGIBILITY CRITERIA

All articles that aimed to study or describe, clinically, the adhesion of direct restorations on permanent molars affected by MIH were included in this study. On the contrary, were excluded all the *in vitro* and *in vivo* studies, the publications dealing with enamel anomalies other than MIH, and those in which none of the studied groups refered to direct restorations. Articles not in English, French nor Spanish were also excluded from this study.

SCIENTIFICS SOURCES

The systematic review was performed on three databases (PubMed, Science Direct and Google Scholar), according to the recommendations to bring together the maximum of data[23,24].

SEARCH

The procedure was different between PubMed and the two others, with an advanced search in several steps on PubMed (*Supplementary Data 1*) and a one-step request on Science Direct and Google Scholar: ((composite resin) OR (glass ionomer) OR (GIC) OR (direct restorations)) AND ((MIH) OR (hypomineralization) OR (hypomineralisation)).

STUDY SELECTION

A first screening of the articles was performed by two trained investigators (RD and TC) after reading Titles and Abstract. Articles that did not meet our eligibility criteria were excluded and a second selection was then performed by reading the pre-selected articles in their entirety.

DATA COLLECTION PROCESS

Once the selection of the publications was completed, a database was created on Microsoft Excel 2016® software and implemented as the articles were read. The same two investigators who had determined the eligibility of the articles for inclusion in the study performed the data collection process.

DATA ITEMS

The following data were collected in the articles: date and country of publication, authors' names, type of study/publication, number of patients, their gender and age, treatments performed, teeth that were treated, biomaterials used, follow-up modalities and results.

RISK OF BIAS

The included studies are both well designed clinical trials and case reports, with the lowest level of scientific evidence. We performed a bias assessment for all these publications by using checklists from Joanna Briggs Institute (JBI) specifically designed for clinical trials[25], cohort studies[26] and case reports[27]. The evaluation considered aspects such as study design, data collection, and reporting transparency. Studies were not excluded based on the bias assessment to ensure a comprehensive review of the available literature.

SYNTHESIS OF RESULTS

In view of the high variability in the type of publications and their protocols, no statistical analysis could be performed. A complete table has been built to compile the main data obtained.

RESULTS

STUDY SELECTION

At the end of the selection process, 29 fully met the inclusion criteria to be considered in our systematic literature review *(Figure 1*).

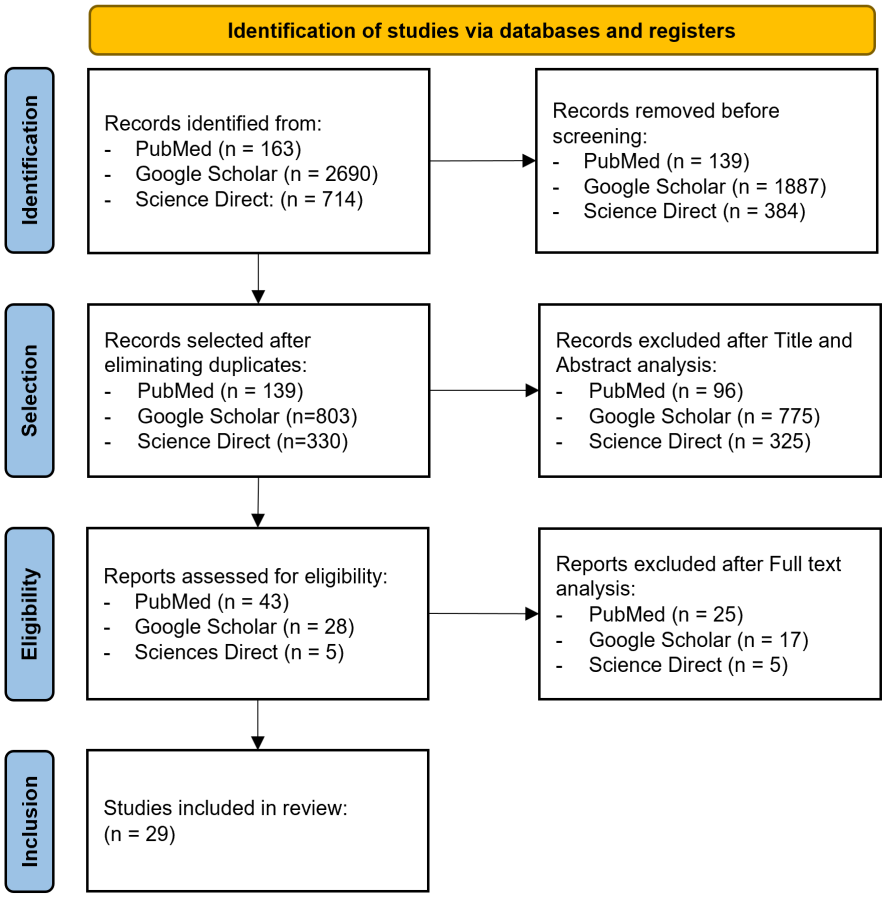

Figure 1: PRISMA flowchart of the study.

STUDY CHARACTERISTICS

The articles included in this study were published between 2013 and 2024, 6 of them (20.7%) in 2020 and 5 (17.2%) in 2018. Eleven articles (37.9%) were published by Brazilian authors, and 4 (13.8%) by Turkish which are the two most represented origins (*Figure 2*). This can be explained by a high prevalence of MIH in Brazil, around 29% according to the results presented by Reis *et al.* in 2021[28].

Fifteen publications (51.7%) are considered as case reports (and case series), 7 (24.1%) are clinical trials, 4 (13.8%) are prospective studies and 2 (6.9%) are retrospective analyses.

RESULTS

A total of 896 patients took part in the studies, with almost equal numbers of males and females. The youngest patient was 5 years old and the oldest 18 years old at time of their

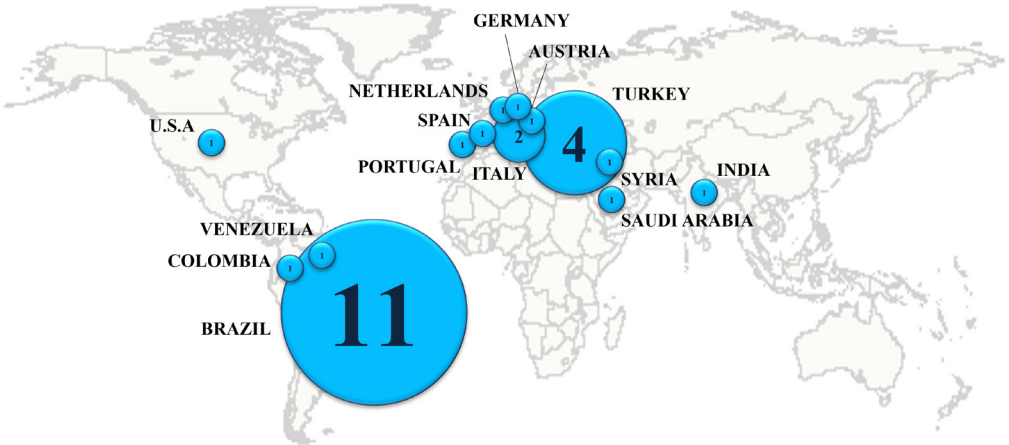

Figure 2: Schematic representation of the geographical places where studies included in this review have been performed worldwide. The size of the circles associated with each country, as well as the number inscribed inside, indicate the number of articles published in that country.

inclusion. Concerning the biomaterials used to treat hypomineralized teeth, 14 studies (48.3%) described the use of glass-ionomer cement and more than 80% of them concluded that it was an interesting temporary material in the presence of MIH, protecting the tooth while awaiting a definitive restoration. We have also included 21 studies (72.4%) in which tooth restorations are described with composite resins (as full restoration or infiltrated material). In these articles, both etch-and-rinse and self-etch protocols during bonding procedures are described. On this point, it would appear that the use of self-etching adhesive systems may be preferable, with a survival rate of 97% at one year[29] vs. 83% at one year for etch-and-rinse[30] and even less than 50% at 2 years[31]. Precise and detailed results are presented in Table 1.

Thirteen of the 29 studies (44.8%) recommended, not selective[32], but total removal of hypomineralized enamel as it can be observed a survival rate more than doubled for composite resins made when these tissues were removed[33]. This principle for tooth preparation also applies to GIC placement (resin-reinforced or not), with indicated survival rates of 98.3% at 1 year[34] and 96.8% at 24 months[35]. When isolation from oral fluids was needed, less than half of the studies used the rubber dam, otherwise, isolation was carried out using saliva swabs. The results do not allow us to conclude whether the use of a dam was more effective or not.

The important quantity of case reports that have been included in this review does not allow to conclude on the exact survival rate of GIC and composite resin restorations. Results obtained from clinical trials and cohorts indicate that GIC restorations have almost the same success rate as full composite resin restorations in the first year[36] and that removing all the hypomineralized enamel increases resin survival rate in the next years. In a general way, it appears that tissue conditioning before the application of filling material was very different between the publications, with no clear consensus on the necessity of performing tooth preparation or chemical treatment.

Depending on the authors and the articles, the follow-up period extended from 12 weeks to 14 years. Most of the studies described regular appointments at the dental office every 6 months or every year. Radiological controls were not described at each appointment.

RISK OF BIAS

Bias assessment is available for all the included publications in Table 2. Among them, 8 (27.59%) presented a low risk of bias, 14 (48.28%) a moderate risk of bias and 7 (24.14%) a high risk of bias. The inclusion of publications with a high level of bias was decided to present a complete overview of the articles published on the topic. The publication of Rolim *et al.*[37] was the most qualitative, covering over 96% of the prerequisites, whereas the weakest scored just 12.5%[38].

DISCUSSION

This literature review identified 29 publications studying and describing the treatment of MIH teeth with direct restorations. These restorations were mainly intended as a temporary solution until long-term restorations such as onlays could be performed. Glass-ionomer cement, with its tolerance to humidity and its fluoride content[58,59], appears to be indicated in order to preserve the tooth on the arch, particularly in the absence of rubber dam and until indirect restorations can be bonded. The advantages of direct restorations are ease of application and reduced clinical time. They provide rapid and effective relief for the patient.

The application of silver diamine fluoride (SDF) in conjunction with GICs can provide additional antibacterial protection[60], thereby enhancing the effectiveness of the restoration without compromising the capacity of GIC to adhere to the dentin[61]. Indeed, one of the most practical aspects of Class Ionomer Cements is their ability to interact with natural tissues even under relatively moist conditions. This characteristic greatly simplifies the clinical process, especially for young patients or those with cooperation difficulties. Conversely, for restorations of incisors affected by MIH, composite resin is generally preferred, especially in the case of minor damage to only one side of the tooth. This material offers superior aesthetics, which is crucial for visible anterior teeth. Additionally, it allows for more precise finishing and better integration with the surrounding dental tissues.

The main question concerning the efficacy of direct restorations is whether they can establish mechanical and/or chemical anchors on a tooth surface affected by MIH. On the one hand, GIC offer relatively moderate mechanical retention, but above all establish strong chemical bonds with hydroxyapatite thanks to the action of the polyalkenoic acid they contain[62]. The principle of these ionic bonds is based on the interaction between cations on the tooth surface and anions in the biomaterial[63]. Thus, chemical bonding may not be as qualitative on altered crystals. On the other hand, composite resins don't adhere to tissues on their own, and require the action of an adhesive that penetrates the dentinal tubules, mixes with the surface collagen and eventually, for universal adhesive, establishes chemical bonds thanks to the functional monomers it contains (mainly 10-methacryloyloxydecyl-dihydrogen phosphate also known as 10-MDP)[64]. The issue is therefore the same as for GIC, i.e. the lower effectiveness of these anchoring mechanisms on surfaces altered by MIH, and especially for dentists who use universal adhesives. Indeed, despite similar performance during placement, the resistance of these systems appears to be weaker over time than that of conventional adhesives[65]. Whatever the distribution of universal adhesives in collagen and tubules, the interaction between 10-MDP and dentin is mandatory to their success[66].

Table 1. Main results extracted from the studies included in the systematic review.

Authors	Sen Yavuz et al.[10]	Özsoy et al.[11]	Hakmi et al.[12]
Country	Turkey	Turkey	Syria
Year of publication	2024	2024	2023
Type of study	Randomized trial	Randomized trial	Randomized trial
Main topic of the study	Use of short fiber reinforced composite resin covered by micro-hybrid composite resin vs. glass hybrid material on MIH teeth	Treatment of severe MIH lesions with 4 different protocols	Effectiveness of direct vs. indirect composites on teeth with MIH
Number of patients	31	90	20
Sex	♀ (18) and ♂ (13)	♀ (58,8%) and ♂ (41.9%)	♂ and ♀ (50%)
Age (Years)	7.5±7.69	8-15	7 to 11
Follow-up	36 months	9 months	12 months
Follow-up frequency	Every 6 months	3, 6, 9 months	3, 6, 12 month
Follow-up modalities	Clinical	Clinical	Clinical
Teeth treated	First permanent molars	189 permanent molars	40 first permanent molars
Materials	**Glass hybrid or fiber reinforced composite resin covered by micro-hybrid composite resin**	**GIC & composite resin**	**Direct composite resin and onlays**
Tissue preparation	Removal of affected dentin	**Groupe 1*** GIC **Groupe 2*** GIC + composite resin **Groupe 3*** Fiber -reinforced composite resin + composite resin **Groupe 4*** Pre-treatment then fiber-reinforced composite resin + composite resin	Removal of decayed tissue and hypomineralized enamel
Etching	No	No No No No Yes	
Bonding	Yes (G premio bond)	No Yes (Clearfilbond) Yes (Clearfilbond) Yes (Clearfilbond) Yes (SimpleBond)	
Rubber Dam	No	No Yes Yes Yes Yes	
Pre-treatment	-	No No Papacarie application Application of 5,25%-NaOCl	
Results	Failure of 8 GH and 4 composite resins restorations.	Survival rate : 87,6% Survival rate : 97,6% Survival rate : 97,7% Survival rate : 97,3%	Direct composite resin survival rate = 83% Onlay survival rate = 90%
Conclusion	No statistically significant difference in clinical success between materials	GIC restorations have almost the same success rate as full composite resin restorations. Using dentin substitutes such as specific fiber-reinforced composite resin instead of GIC as a base in composite restorations gives better results. Papacarie deproteination showed similar success with the other composite groups.	No significant difference

Authors	Vieira et al.[13]	Iraida et al.[14]	Temudo et al.[15]	Alfarraj et al.[16]	
Country	Brazil	Venezuela	Portugal	Saudi Arabia	
Year of publication	2023	2023	2022	2022	
Type of study	Case report	Case Report	Case Report	Case report	
Main topic of the study	GIC and composite resins for treatment of teeth with MIH	Treatment of MIH teeth in a patient with distal renal tubular acidosis	Conservative approach for teeth with MIH	Treatment of teeth affected by MIH	
Number of patients	1	1	1	1	
Sex	♂	♂	♂	♀	
Age (Years)	6	7	9	8	
Follow-up	11 years	14 years	1 year	24 months	
Follow-up frequency	6 months, 1 year, 18 months then every year	Every 6 months for 3 years then every year	-	6 months then 24 months	
Follow-up modalities	Clinical & radiological	Clinical	Clinical	Clinical & radiological	
Teeth treated	First permanent molars and permanent central incisors	First permanent molars	4 first permanent molars + 4 permanent mandibular incisors	2 first permanent molars (46 & 36)	
Materials	**GIC / composite resin**	**GIC & composite resin**	**Composite resin**	**Composite resin & pre-formed pediatric crown**	
Tissue preparation	Removal of carious tissue	Elimination of hypomineralized tissue	Removal of carious tissue and hypomineralized enamel	Apexification with MTA then fitting of crown with GIC	
Etching	No	Yes	Yes for composite resin		
Bonding	No	Yes (Scotchbond)	Yes for composite resin (Scotchbond)		
Rubber Dam	No	Yes Yes No			
Pre-treatment	Application of fluoride varnish	Fluoride varnish	Application of 5.25% NaOCl	Application of 5.25%- NaOCl for composite resins	
Results				Short-term success: apical closure, no consequences on periodontal tissues	
Conclusion	GIC reduces sensitivities and should be used as a temporary material while awaiting definitive restorations.	A preventive approach is essential from the onset of clinical signs	Considered as first-line conservative treatment	Low level of evidence	

Authors	Bagattoni et al.[17]	Bekes et al.[18]	Schraverus et al.[19]	de Farias et al.[20]
Country	Italy	Austria	Netherlands	Colombia
Year of publication	2021	2021	2021	2021
Type of study	Case report	Prospective study	Randomized trial	Retrospective study
Main topic of the study	Preventing post-eruptive fractures of MIH teeth	Relief of hypersensitive MIH teeth with 2 fissure sealing techniques	Assess the preventive effect of sealing fissures with GIC on the occurrence of caries and post-eruptive fractures on teeth affected by MIH	Assess the survival rate of preformed pediatric crown vs. composite resins on teeth with MIH
Number of patients	1	39	77	Unclear
Sex	♂	♀ (46%) and ♂ (54%)	♀ (48%) and ♂ (52%)	♀ (48.3%) and ♂ (51.7%)
Age (Years)	6	6 to 10	5 to 9	7 to 10
Follow-up	36 months	12 weeks	12 months	24 months
Follow-up frequency	Every month	1, 4, 8, 12 weeks	6, 12 months	1, 6, 12, 24 months
Follow-up modalities	Clinical	Clinical & radiological	Clinical	Clinical, radiological & photographical
Teeth treated	First permanent molars	146 first permanent molars	228 first permanent molars	115 first permanent molars
Materials	**GIC**	**Composite resin / GIC**	**GIC**	**Preformed metal. crown / Composite resin**
Tissue preparation	No preparation	No preparation	No preparation	Removal of carious tissues and selective removal of hypomineralized enamel.
Etching	No	No	Yes	Yes
Bonding	No	Yes for composite resin (Scotchbond)	No	Yes (Adper SingleBond)
Rubber Dam	No	No	No	Yes
Pre-treatment	No	Cleaning with ClinPro Prophy Paste	No	No
Results	-	Composite resins: SCASS score: 2.3 WBFS score:7.0 The GIC group had a lower chance of developing caries compared to the control group (OR = 0.23, 95% CI 0.06-0.9). However, the GIC group was not associated with the prevention of post-eruptive fractures (p = 0.313). GIC: SCASS score: 2.4 WBFS score: 7.0	**PMC** Survival rate at 24 months = 94.4% **Comp. resin** Survival rate at 24 months = 49.2%
Conclusion	GIC is a good material to use on partially erupted MIH teeth while awaiting definitive restorations.	No significant difference Sealing fissures with GIC helps preventing the onset of caries but not post-eruptive fractures	PMC have a better survival rate than composite resins at 24 months

Authors	Hahn et al.[21]	Mendonça et al.[22]	Sundfeld et al.[23]	Linner et al.[24]			
Country	Germany	Brazil	Brazil	Germany			
Year of publication	2020	2020	2020	2020			
Type of study	Case report	Case report	Case report	Retrospective study			
Main topic of the study	Treatment of a MIH patient with mixed to permanent dentition	Adapted technique for simplified occlusal replication with GIC on molars with MIH	Causes, clinical aspects and restorative treatment of teeth with MIH	Comparison of 4 treatment strategies on teeth affected by MIH			
Number of patients	1	1	1	52			
Sex	♂	♀	♀	♂ and ♀ (50%)			
Age (Years)	11	11	17	6 to 18			
Follow-up	6 years	18 months	18 month	Variable			
Follow-up frequency	1, 3, 6 years	Every 3 months	1 month then 18 months	1 year, 2 years, 3 years			
Follow-up modalities	Clinical	Clinical	Clinical	Clinical & photographical			
Teeth treated	First permanent molars	First permanent molars	11 & 21	184 posterior teeth, 20 anterior teeth			
Materials	**Direct and indirect composite resin**	**GIC**	**Composite resin**	**GIC, conventional composite resin (non-invasive and invasive) and ceramic restorations**			
Tissue preparation	Removal of carious tissue and hypomineralized enamel	Removal of old restorations and carious tissue	At-home bleaching for 20 days then removal of hypomineralized enamel	GIC None Non-invasive c. None Conventional c. Removal of carious tissues and hypomineralized enamel. Ceramic Removal of carious tissues and hypomineralized enamel.			
Etching	Yes	Yes	Yes	No No Yes Yes			
Bonding	Yes (unknown for direct restoration)	No	Yes (Scotchbond)	No Yes (Scotchbond) Yes (Syntac classic)			
Rubber Dam	No	No	Yes	No No No No			
Pre-treatment	No	Application of fluoride varnish	External dental brightening	No			
Results	-	Survival rate at 18 months = 100%.		**GIC** 7% 6-months survival rate **Non-invasive c.** 29.9% **Conventional c.** 76.2% **Ceramic** 100%			
Conclusion	Direct or indirect restorations depend on the extent of MIH damage.	Good alternative, reduced procedure time, good survival rate but low level of evidence	Satisfactory results with etch & rinse adhesive application	Indirect restorations and conventional composite resins have better survival rates, but GIC protect teeth and increase the child's cooperation until they are more mature for definitive restorations.			

Authors	Rolim et al.[25]	Durmus et al.[26]	Gaton-Hernandéz et al.[27]	Pereira et al.[28]	Bhandari et al.[29]
Country	Brazil	Turkey	Spain	Brazil	India
Year of publication	2020	2020	2019	2019	2018
Type of study	Randomized trial	Prospective study	Prospective Study	Case Report	Case series
Main topic of the study	Study the survival rate of composite resins on teeth affected by MIH with various adhesive systems.	Assess the survival rate of resin modified-GIC on MIH teeth with selective caries removal	Minimally invasive treatment of teeth with MIH	Aesthetic approach to the treatment of MIH teeth	Evaluating the aesthetic results of resin infiltration on MIH-affected incisors
Number of patients	35	58	326	1	Unclear
Sex	♀ (45.7%) and ♂ (54.3%)	♀ (51.7%) and ♂ (48.3%)	♀ (47,3%) and ♂ (52,7%)	♂	♂ and ♀ (50%)
Age (Years)	7 to 16	8 to 12	6-8	13	7 to 16
Follow-up	12 months	24 months	24 month		6 months
Follow-up frequency	1, 6, 12 months	6, 12, 18, 24 months	6, 12, 18, 24 months		6 months
Follow-up modalities	Clinical, photographical and radiological	Clinical	Clinical & radiological		Photographical
Teeth treated	first permanent molars	134 first permanent molars	First permanent molars	Permanent maxillary central incisor	22 incisors
Materials	**Composite resin**	**Resin modified-GIC**	**GIC & composite resin**	**Composite resin**	**ICON® Resin**
Tissue preparation	Removal of carious tissues and selective removal of hypomineralized enamel.	Removal of carious tissues and selective removal of hypomineralized enamel.	Selective removal of decayed tissue	Abrade the stain 2-3 mm then bevel 2 mm	No preparation
Etching	**Self-etch** No	No -	Yes	Yes	From ICON package
Bonding	Yes (Universal Ambar)	No -	Yes (Adper SingleBond)		No
Rubber Dam	Yes	No	Yes	Yes	Yes
Pre-treatment	No	No	Application of fluoride varnish		Cleaning with prophylactic paste
Results	Self-etch Survival rate at 12 months = 62.3%	Survival rate at 24 months = 87.5% Survival rate at 24 month = 96,8%		ΔE3 = 13.3±6.8 ΔE3 At Day 0 = ΔE3 at 6 months (CIELAB Score)	Immediate esthetic results confirmed in Grade 1 MIH-affected incisors
Conclusion	Non-significant differences	Moderate survival rate; Selective removal of hypomineralized tissue is efficient	Selective removal of decayed tissue ensures restoration integrity. Temporization with GIC to manage sensitivity	Composite resins = treatment of choice. But no control group.	Effective and minimally invasive treatment for reducing white spots

Authors	Grossi et al.[30]	Gianetti et al.[31]	Pessôa et al.[32]	MacLean et al.[33]	Sönmez et al.[34]			
Country	Brazil	Italy	Brazil	USA	Turkey			
Year of publication	2018	2018	2018	2018	2017			
Type of study	Randomized trial	Case report	Case report	Case Report	Clinical trial			
Main topic of the study	Study of GIC restorations to restore teeth affected by MIH	ICON® procedure on teeth with MIH	Conservative treatment of teeth with MIH	Minimally invasive treatment of teeth with MIH	Study of deproteinization and cavity shapes for direct composite resins on teeth with MIH			
Number of patients	44	1	1	1	70			
Sex	♀ (54.54%) ♂ (45.45%)	Unknown	♀	♂	♀ and ♂ (unknown %)			
Age (Years)	7 to 13	Unknown	7	7	8 to 12			
Follow-up	12 months	1 month	7 years	10 months	2 years			
Follow-up frequency	6, 12 months	1 month	1, 3, 4, 5, 6, 7 years	-	Every 3 months			
Follow-up modalities	Clinical	Unclear	Clinical	Clinical	Clinical			
Teeth treated	59 first permanent molars + 1 permanent central incisor	Upper central incisors	First permanent molars	4 First permanent molars	First permanent molars			
Materials	**GIC**	**ICON® resin**	**Resin modified-GIC**	**GIC**	**Composite resin**			
Tissue preparation	Removal of carious tissues and hypomineralized enamel.	No preparation	Removal of carious tissue	Removal of decayed tissue and hypomineralized enamel	**Group 1** Removal of carious tissue and all hypomineralized enamel (HE) **Group 2** Removal of carious tissue and selective removal of HE **Group 3** Removal of carious tissue and selective removal of HE **Group 4** Removal of carious tissue from non-MIH teeth			
Etching	Yes	Yes	No	20% polyacrylic acid	Yes			
Bonding	No	Yes (Optibond FL)	No	Yes	Yes (FuturaBond)			
Rubber Dam	No	Yes	No	Yes	Unknown			
Pre-treatment	No	No	No	Application of SDF 2 to 4 weeks before	NaOCl only in Group 3			
Results	Survival rate at 12 months: 98.3%	-	-	Survival rate Group 1 = 81.25%	Survival rate Group 2 = 58.06% Survival rate Group 3 = 78.12% Survival rate Group 4 = 87.09%			
Conclusion	Efficient approach to preserve permanent first molars, good survival rate for 1-sided restorations.	Very conservative and aesthetic treatment. But very low level of evidence.	Resin modified-GIC is a good temporary treatment option for mixed-dentition while awaiting a definitive restoration.	Effective temporary restoration	Removing all the hypomineralized enamel increases resin survival rate. Application of NaOCl increases resin survival rate			

Authors	De Souza et al.[35]		Fragelli et al.[36]	de Oliveira et al.[37]	De Souza et al.[37]
Country	Brazil		Brazil	Brazil	Brazil
Year of publication	2016		2015	2015	2013
Type of study	Randomized trial		Prospective study	Case Report	Case Report
Main topic of the study	Different adhesive systems on MIH molars: self-etch and etch-and-rinse		Study of GIC restorations on teeth affected by MIH	GIC for restoration of teeth with MIH	Aesthetic treatment of teeth with MIH
Number of patients	18		21	1	2
Sex	♂ and ♀ (50%)		♀ (43.9%) ♂ (57.1%)	♂	♀ and ♂
Age (Years)	6 to 8		6 to 9	7	11 (girl) and 12 (boy)
Follow-up	18 months		12 months	6 years	
Follow-up frequency	1, 6, 12, 18 months		6, 12 months	Unclear	-
Follow-up modalities	Clinical, radiological & photographical		Clinical & photographical	Clinical & photographical	-
Teeth treated	41 first permanent molars		48 first permanent molars	First permanent molars	Permanent incisors
Materials	**Composite resin**		**GIC**	**GIC**	**Composite resin**
Tissue preparation	Removal of carious tissue		Removal of carious tissues	No preparation	Removal of surface opacity
Etching	Yes for etch-and-rinse		No	No	Yes
Bonding	Yes (Clearfil SE vs. Scotchbond)		No	No	Yes (Optibond)
Rubber Dam	Yes		No	No	Yes
Pre-treatment	No		Application of fluoride varnish	Application of fluoride varnish	-
Results	Self-etch: Survival rate 18 months = 68%	E&R: Survival rate 18 months = 55%	Failure rate 50% at 12 months	Survival rate at 6 years = 0%	E&R: Survival rate 18 months = 54%
Conclusion	No significant difference between self&-etch and etch-and-rinse systems		Good survival rate, especially for 1-sided restorations	Only one case, difficult to draw a conclusion	Aesthetic treatments must be carried out quickly to avoid harmful psychological effects.

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Table 2. Bias assessment by checklists from Joanna Briggs Institute's (JBI) Critical Appraisal Tools. The colors are related to the bias assessment (green means low risk of bias).

Articles (sorted by publication date)	Type of study	Bias assessment (%)	Bias assessment color
Sen Yavuz et al.[30]	Randomized trial	75	
Özsoy et al.[31]	Randomized trial	68.8	
Hakmi et al.[32]	Randomized trial	85.7	
Vieira et al.[33]	Case report	62.5	
Iraida et al.[34]	Case report	75	
Temudo et al.[35]	Case report	62.5	
Alfarraj et al.[36]	Case report	50	
Bagattoni et al.[37]	Case report	87.5	
Bekes et al.[38]	Prospective study	44.4	
Schraverus et al.[39]	Randomized trial	76.9	
de Farias et al.[40]	Retrospective study	66.7	
Hahn et al.[41]	Case report	75	
Mendonça et al.[42]	Case report	50	
Sundfeld et al.[43]	Case report	50	
Linner et al.[44]	Retrospective study	55.6	
Rolim et al.[45]	Randomized trial	96.8	
Durmus et al.[46]	Prospective study	66.7	
Gaton-Hernandéz et al.[47]	Prospective study	55.6	
Pereira et al.[48]	Case report	50	
Bhandari et al.[49]	Case series	40	
Grossi et al.[50]	Randomized trial	41.9	
Gianetti et al.[51]	Case report	37.5	
Pessôa et al.[52]	Case report	50	
MacLean et al.[53]	Case report	37.5	
Sönmez et al.[29]	Clinical trial	50	
De Souza et al.[54]	Randomized trial	84.2	
Fragelli et al.[55]	Prospective study	55.6	
de Oliveira et al.[56]	Case Report	12.5	
De Souza et al.[57]	Case Report	25	

Among the publications described in this review, 60% of those which described the use of composite resins have associated the biomaterial with an etch-and-rinse adhesive system. This may be explained by the well described efficiency of these products when the bonding procedure is performed mainly on enamel[67]. It however can be discussed that etch-and-rinse systems necessitate more clinical steps than self-etch and can thus be less easily used in a poorly cooperative patient.

Five studies have described the usefulness of deproteinizing enamel with sodium hypochlorite in order to improve bonding[29,30,32,41,42]. An enamel affected with MIH presents an obstruction of the dentinal tubules due to protein accumulation, which negatively affects the adhesive from penetrating[68]. It is still unknown, and thus interesting to investigate, the amount of deproteinization on teeth affected by MIH[69].

Of course, the results must be balanced depending on the degree of severity of the MIH and the number of faces involved on the treated teeth. These parameters are not always described in the studies. Clinically, the design of indirect restorations, such as inlays-onlays has shown a high success rate in MIH patient and must fully take part in the current therapeutic gradient[7]. They are biocompatible and aesthetic. However, the financial aspect of these restorations must be taken into account[7]. The use of preformed stainless steel crowns[42] appears as intermediary solutions as they are considered as direct restorations but they have an excellent survival rate more similar to bonded inlays. They are also easy to seal on a tooth. However, a significant drawback is their poor esthetics, which can be a concern for both patients and clinicians. To address these esthetic concerns, preformed zirconia crowns for first permanent molars are emerging on the market. Zirconia crowns offer superior esthetics compared to stainless steel, closely mimicking the natural appearance of teeth. Despite their potential, there is currently a lack of studies evaluating their long-term effectiveness and clinical performance for MIH-affected teeth.

This review shows that the follow-up periods are highly variable between the publications. Some months or even one year can be considered as too short to really study the adhesion of direct restorations and thus to validate or not their success rate. Truly, it is of high interest in the case of erupting teeth and pediatric dentistry. Treating MIH as early as possible increases the chances of the tooth surviving. A large number of patients are still left without treatment and do not have the chance to be diagnosed as soon as the first molars have erupted, thereby seriously compromising the future of the teeth affected. Preventive therapies are thus of prime interest in case of MIH and that is why 5 studies included in our systematic review have described the application of fluoride varnish as a pre-treatment before the restoration implementation[38,47,49,56,70].

One of the lessons to be learned from this study is that various techniques can be used in conjunction and in combination, depending on the clinical situation. The therapeutic gradient should begin with preventive therapies, such as fluoridation, or even the use of silver diamine fluoride. Immediately above these options are direct restorations, for long-term or temporary use. The choice of material, based on its biological and mechanical qualities, must take into account the severity of the MIH. But this choice also depends on the patient's own situation, such as sensitivities and difficulties in achieving local anaesthesia. Similarly, the choice of restorative materials will be guided in part by the young patient's ability to accept treatment. For example, the use of Glass Ionomer Cement, which is simpler and quicker to apply, is more suitable for younger children who are more reluctant to undergo treatment.

Further studies need to be carried out in countries where the prevalence of MIH is regularly revised upwards. In our review, over a third of the articles included were published by Brazilian authors, which is consistent with the large number of articles in the literature that evaluated, specifically in this country, the evolution of MIH prevalence[4]. However, other nations (Germany, Saudi Arabia, India) are also major providers of prevalence indicators for this pathology, but few studies have been found on the clinical management of patients. In the future, trials should also been conducted on a wider samples with also regular recall during a longer period, especially as MIH is highly diagnosed and has many consequences on children quality of life[19]. The aesthetic and psychological repercussions are higher when the incisors are affected[71]. In a society where physical injunctions are predominant, the presence of stains on the incisors can decrease the self-image and expose to teasing[72]. Despite the efforts made to improve oral hygiene, the stain will not disappear of its own. This can lead to a drop in motivation, with patients withdrawing into themselves and losing themselves in a vicious circle.

CONCLUSION

The management of patients with MIH is complex and must be considered on a case-by-case basis. The treatment decision will depend on many factors, such as age, compliance, severity of enamel breakdown, dental development and many others. The first essential step is to establish a proper diagnosis so that these young patients can be treated as early as possible in order to limit hypersensitivity and egression of the antagonist tooth after enamel breakdown. For erupting molars, GIC seems to give the best results in limited defects, until a resin composite can be applied under good sealing conditions. They can be placed into the cavity as dentin substitutes or as temporary materials until the tooth has fully erupted and the child is willing to cooperate in the creation of a permanent indirect restoration. Preformed metal crowns, although less aesthetic, represent a sustainable alternative for severe defect in erupting molars.

In conclusion, GIC seems to meet the objective of preserving the child's quality of life by protecting teeth during their eruption with an acceptable survival rate, while pending the replacement with indirect reconstructions.

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SUPPLEMENTARY DATA 1

Advanced search submitted on PubMed database on May 24th, 2024	
#1: ((((((((((((composite)[Title/Abstract])) OR (composite resin[Title/Abstract])) OR (dental composite[Title/Abstract])) OR (glass[Title/Abstract])) OR (glass ionomer[Title/Abstract])) OR (glass-ionomer[Title/Abstract])) OR (GIC[Title/Abstract])) OR (restorative dentistry[Title/Abstract])) OR (conservative[Title/Abstract])) OR (restorative[Title/Abstract])) OR (direct restoration[Title/Abstract])) OR (tooth restoration[Title/Abstract])) OR (conservative dentistry[Title/Abstract])	**1,157,301**
#2 : ((((((((((((((((((((((((((((((MIH[Title/Abstract])) OR (molar incisor[Title/Abstract])) OR (molar-incisor[Title/Abstract])) OR (molar incisor hypomineralisation[Title/Abstract])) OR (molar incisor hypomineralization[Title/Abstract])) OR (molar-incisor hypomineralisation[Title/Abstract])) OR (molar incisor-hypomineralisation[Title/Abstract])) OR (molar-incisor-hypomineralisation[Title/Abstract])) OR (molar-incisor hypomineralization[Title/Abstract])) OR (molar-incisor-hypomineralization[Title/Abstract])) OR (molar incisor-hypomineralization[Title/Abstract])) OR (tooth hypomineralisation[Title/Abstract])) OR (tooth hypomineralization[Title/Abstract])) OR (teeth hypomineralisation[Title/Abstract])) OR (teeth hypomineralization[Title/Abstract])) OR (hypomineralisation defect*[Title/Abstract])) OR (hypomineralization defect*[Title/Abstract])) OR (tooth enamel hypomineralisation[Title/Abstract])) OR (teeth enamel hypomineralisation[Title/Abstract])) OR (tooth enamel hypomineralization[Title/Abstract])) OR (teeth enamel hypomineralization[Title/Abstract])) OR (molar enamel hypomineralisation[Title/Abstract])) OR (incisor enamel hypomineralisation[Title/Abstract])) OR (molar incisor enamel hypomineralisation[Title/Abstract])) OR (molar-incisor enamel hypomineralisation[Title/Abstract])) OR (molar enamel hypomineralization[Title/Abstract])) OR (molar incisor enamel hypomineralization[Title/Abstract])) OR (molar incisor-enamel hypomineralization[Title/Abstract])) OR (incisor enamel hypomineralization[Title/Abstract])) OR (hspm[Title/Abstract])) OR (second primary molar hypomineralisation[Title/Abstract])) OR (second primary molar hypomineralization[Title/Abstract])	**1,569**
#3: ((((((Chinese[Language]) OR Polish[Language]) OR Japanese[Language]) OR German[Language]) OR Portuguese[Language]) OR Russian[Language]) OR Review[Publication Type])	**5,791,404**
#4: #1 AND #2	**182**
#5: #4 NOT #3	**163**