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Bonding to Molar-Incisor Hypomineralization Affected Teeth: A Scoping Review of Adhesive Strategies, In Vitro Performance, and Clinical Outcomes

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ABSTRACT

Molar-incisor hypomineralization (MIH) poses major restorative challenges due to compromised enamel and its reduced bonding capacity. This scoping review evaluated treatment options for MIH-affected young permanent teeth following PRISMA-ScR guidelines. A systematic search in PubMed, Cochrane, Science Direct and gray literature identified 21 eligible studies published between 2013 and 2025, including in-vitro and clinical studies. Laboratory findings demonstrated lower bond strengths in MIH enamel compared with the sound enamel. Etch-and-rinse adhesives performed more reliably than that of self-etch systems, while pretreatment procedures improved adhesion in some settings. Clinical studies showed resin-based sealants and composites bonded with etch-and-rinse adhesives achieved higher retention. Glass ionomer and glass hybrid restorations offered mostly short-term success and are best used as an interim option. Investigated indirect restorations provided superior longevity in severe cases. Preventive adjuncts such as applying varnishes reduced hypersensitivity and caries risk. Finally, this review highlights the central role of adhesive performance in MIH management.

Keywords: Hypomineralization; Bonding; Composite Resins; Glass Ionomer; Dental Restoration

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INTRODUCTION

In the European Academy of Pediatric Dentistry (EAPD) congress meeting held in 2001, the term Molar-Incisor Hypomineralization (MIH) was introduced by Weerheijm et al. [1] to describe a systemic developmental dental defect that affects between one to four first permanent molars and is often also associated with permanent incisors [2]. The MIH prevalence varies by the region with some reports of it reaching more than 40%, while its global prevalence is around 14.2%. The high rates present the condition of significant public health concerns; and the differences of these reports in their research parameters, diagnostic criteria, study population and results, underscore the complexity of its identification and consistent management across various healthcare systems [3].

The MIH affected teeth face disrupted amelogenesis during their maturation that make their structure hypomineralized and porous. This results in teeth more prone to dental caries and hypersensitivity with higher probability of post-eruptive enamel breakdown (PEB) and opacities ranging in color from white to yellow or brown [4, 5]. In addition to the mentioned concerns, this condition creates significant challenges in the preventive and restorative management for the practitioner [6]. In comparison to sound enamel, MIH-affected enamel has lower mineral density, reduced hardness, increased porosity, and higher protein content. These structural changes in enamel explain its poor clinical prognosis [5, 6].

The clinical challenges in MIH-affected teeth include poor retention in sealants, marginal breakdown in restorations, and frequent restoration failures [7]. The children with MIH may require repeated interventions, which can impair their oral health-related quality of life [8]. Various adhesive strategies have been proposed to overcome these challenges. Conventional etch-and-rinse adhesives rely on phosphoric acid etching and their effectiveness is compromised in hypomineralized enamel. Self-etch and universal adhesives have been explored to improve bonding reliability. Pretreatment methods such as sodium hypochlorite deproteinization, casein phosphopeptide - amorphous calcium phosphate (CPP-ACP) application, bleaching, and microabrasion have been used to improve adhesion [9-11]. More recently, other materials such as papain-based gels and bioactive glasses have been investigated [12, 13].

Materials used to manage MIH range from the resin composites and sealants to the glass ionomer cements (GICs), giomers, and indirect restorations [9, 11]. Current evidence suggests that resin composites generally outperform GICs in survival rate and marginal adaptation [14], and indirect restorations can result in more predictable outcomes in severe affected teeth [11]. Preventive approaches such as sealants and varnishes are also critical in managing MIH, especially in its early stages [15].

The evidence base is highly diverse with limited consensus on various topics of MIH management [5, 6, 9, 10, 14, 16, 17]; particularly regarding bonding evaluation, with the last review published in 2016 [16, 17]. In vitro studies have assessed the shear and microtensile bond strengths, microleakage, and resin tag morphology using SEM [18-20]. Clinical studies have evaluated sealant retention, restoration survival, marginal adaptation, postoperative sensitivity, and failure rate [7, 21, 22]. The existing findings are heterogeneous as variations are present in study designs, adhesive protocols, and follow-up durations. Current reviews show a lack of consensus and the need for comprehensive mapping of available evidence [11, 14, 16, 17]. This complexity presents the need for a scoping review that focuses on the adhesive strategies and maps out the existing data.

Aim

This scoping review aims to map out the existing literature on adhesive strategies used for bonding to molar-incisor hypomineralization affected enamel.

Objectives

-To identify and evaluate the adhesive systems and pretreatment protocols investigated in MIH-related studies.

-To summarize the reported outcomes, including bond strength, retention, marginal integrity, and clinical survival.

-To highlight the methodological trends, limitations, and inconsistencies across studies.

-To identify gaps in the current evidence base and to suggest directions for future research and clinical practice.

METHODS

This scoping review was conducted in accordance to the framework presented in PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines [23]. A Population-Concept-Context (PCC) framework was created and implemented in the eligibility criteria to facilitate gathering of research materials. A systematic search was carried out across databases such as PubMed, Cochrane Library and ScienceDirect, and in gray literature using Google Scholar. This was done using the identified keywords and indexes presented in Table 1. The search was restricted to studies published from 2013 to 2025 and studies were eligible if they met the criteria presented in Table 2.

Table 1. Search keywords used

Databases	Search String Query
PubMed	("Molar Hypomineralization"[Mesh] OR "molar incisor hypomineralization"[tiab] OR "molar incisor hypomineralisation"[tiab] OR MIH[tiab]) AND (bond OR bonding OR "bond strength" OR adhesive OR "adhesive system" OR "etch and rinse" OR "self-etch" OR "universal adhesive" OR "glass ionomer" OR "resin infiltration" OR "surface pretreatment" OR microleakage OR "restorative performance" OR "restoration survival")
Cochrane Library	("molar incisor hypomineralization":ti,ab,kw OR "molar incisor hypomineralisation":ti,ab,kw OR "molar hypomineralization":ti,ab,kw OR MIH:ti,ab,kw) AND (bonding:ti,ab,kw OR "bond strength":ti,ab,kw OR adhesive:ti,ab,kw OR "adhesive system":ti,ab,kw OR "etch and rinse":ti,ab,kw OR "self etch":ti,ab,kw OR "universal adhesive":ti,ab,kw OR "glass ionomer":ti,ab,kw OR "resin infiltration":ti,ab,kw OR "surface pretreatment":ti,ab,kw OR microleakage:ti,ab,kw OR restoration:ti,ab,kw)
ScienceDirect	("molar incisor hypomineralization" OR "molar incisor hypomineralisation" OR MIH) AND (bond OR bonding OR adhesive OR "glass ionomer" OR "resin infiltration" OR restoration)
Google Scholar	(intitle:"molar incisor hypomineralization" OR intitle:"molar incisor hypomineralisation") AND (bonding OR "bond strength" OR adhesive OR "glass ionomer" OR "resin infiltration" OR restoration OR "composite resin" OR "sealant" OR "surface pretreatment" OR "etch and rinse" OR "self etch" OR "universal adhesive")

Table 2. Inclusion and exclusion criteria

Eligibility Criteria	Inclusion Criteria	Exclusion Criteria
Study Type	Laboratory studies, clinical trials and cohort studies	Case Reports, case series, editorial and commentary texts, research protocols and review studies
Publication Type	Scientific published journal	Conference abstracts, article in press
Languages	English	-
Year Range	2013 - 2025	-
Data Collection	Primary research	-
Study Population	MIH-affected permanent teeth (molars ± incisors)	-
Concept	Evaluation of bonding performances, adhesive strategies, restorative outcomes	Lack of sufficient and effective adhesive performance evaluation
Context	In-vitro or clinical studies with inclusion of any adhesive system.	-

Two phases of screening were conducted. In first phase, the titles and abstracts of all retrieved records were screened to identify potentially relevant studies for full-text review. In second phase, the full texts of these articles were assessed against the eligibility criteria to determine the final set of studies included in this review. After screening of a few articles by two reviewers (FM, SM) and then discussing about their selection in-person for calibration, the two reviewers screened all the articles independently. The study selection process is illustrated through the PRISMA-ScR flow diagram in Figure 1. Any discrepancies were resolved by discussion between the two reviewers. Endnote (Clarivate, 2025) was used for the bibliography management, screening, and selection process in this study.

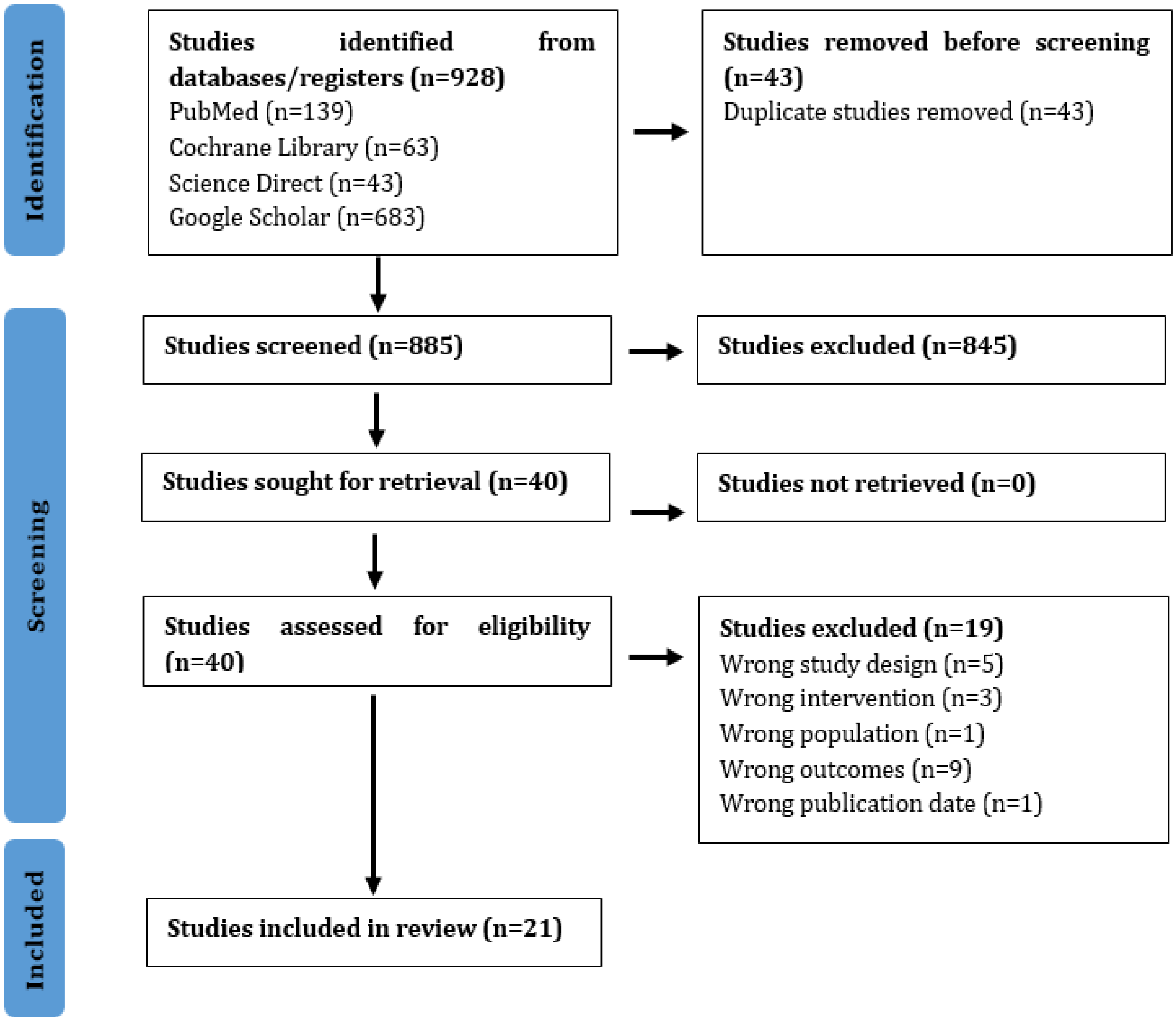

Fig 1. PRISMA-ScR flow diagram.

Data were extracted by the two reviewers (FM, SM) into an Excel spreadsheet. The extraction included author(s), publication year and the database, country, title, study design, sample size and description, surface pretreatments, adhesive system, restorative materials, and key findings.

The systematic search resulted in 928 studies but 885 ones remained after removing duplicated studies. First phase of screening was initiated and 40 studies were deemed suitable for full-text screening. Second phase of screening eliminated 19 out of the 40 studies. The 21 remaining studies met the eligibility criteria and their data were extracted. They were comprised of randomized clinical trials, prospective and retrospective cohorts, pilot, and in-vitro studies. The investigations were conducted mostly in Brazil and Turkey. The population of clinical studies mostly ranged from 6 to 12 years of age and involved up to 281 cases. The majority of studies implemented EAPD criteria [24] or MIH-Treatment need index (MIH-TNI) [25] for MIH assessment. The severity of MIH lesions including the presence of post-eruptive enamel breakdown, is known to influence bonding performance. However, severity was inconsistently reported across studies, limiting the ability to stratify outcomes by lesion severity. This variability should be considered when interpreting the findings. The studies are contained and presented in Table 3.

Table 3. Literature presentation data

Author(s) (Year)	Country	Study Design	Sample Size and Description	Surface Pretreatments	Adhesive Systems	Restoration Material	Key Findings
Özgür et al. [27] (2022)	Turkey	Randomized controlled clinical trial	39 children (13 female, 26 male), aged 6–12 years. 100 first permanent molars with MIH (50 per group)	Group 1 (Resin sealant): 37% phosphoric acid etching (etch-and-rinse) Group 2 (Giomer sealant): Self-etch primer (BeautiSealant Primer)	Group 1: Conventional resin sealant (Conceal F, SDI) with etch-and-rinse technique Group 2: Giomer sealant (BeautiSealant, Shofu) with self-etch primer	Group 1: Resin-based fissure sealant Group 2: Giomer-based fissure sealant	Resin sealants showed markedly higher retention and survival than giomer sealants; giomer failures were frequent, though neither group developed secondary caries.
Reham et al. [35] (2025)	Egypt	Randomized controlled clinical trial	88 hypomineralized permanent first molars in children aged 7–10 years (one molar per patient)	ART protocol (selective caries removal with hand instruments; margins placed in sound enamel); no acid etching or adhesive pretreatment (chemical adhesion only)	Test: Zirconia-reinforced GIC (Zirconomer® Improved, Shofu) Control: Glass-hybrid GIC (Equia Forte®, GC)	ZrGI / GhGI	Both glass ionomer materials achieved similar short-term success and pain reduction, with no significant difference in survival
Krämer et al. [19] (2017)	Germany	In vitro study	94 extracted human teeth (53 MIH, 41 sound); molars and incisors; enamel and dentin substrates tested	Phosphoric acid etching (OptiBond FL, Scotchbond Universal) Self-etch primer (Clearfil SE Bond) NaOCl pretreatment (protein removal) NaOCl + Icon infiltration pretreatment	OptiBond FL (3-step etch-and-rinse) Scotchbond Universal (2-step etch-and-rinse) Clearfil SE Bond (2-step self-etch	Resin composite (Z250, 3M ESPE)	Bond strength was consistently lower in MIH enamel due to poor etching patterns; self-etch adhesives performed weakest, while OptiBond FL showed comparatively better results. Pretreatments offered limited benefit, and MIH

Table 3 cont'd

							dentin bonded similarly to sound dentin.
Fragelli et al. [15] (2015)	Brazil	Prospective cohort study, 12 month follow up	21 children (6–9 years old); 48 first permanent molars affected by MIH	Weekly fluoride varnish (Duraphat®) for 1 month; absolute isolation during restoration; no removal of MIH-affected tissue unless carious	High-viscosity glass ionomer cement (Ketac Molar Easymix, 3M ESPE)	GIC protective restorations	GIC restorations showed moderate 12-month survival, with failures largely linked to enamel breakdown; greater MIH severity correlated with more extensive lesions and baseline caries.
Rolim et al. [30] (2020)	Brazil	Randomized controlled clinical trial	35 patients (7–16 years old); 64 first permanent molars with MIH randomized (TE = 33; SE = 31)	TE group: 35% phosphoric acid etching (30 s enamel, 15 s dentin) SE group: no prior etching	Ambar Universal adhesive (FGM, Brazil)	Bulk-fill resin composite (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent)	TE showed higher survival than SE, though both reduced pain and anxiety; SE produced earlier symptom relief.
Durmuş et al. [32] (2021)	Turkey	Prospective clinical study, 2 year follow up	58 children (8–11 years old); 134 first permanent molars with MIH	Selective carious tissue removal (SCR) - peripheral hard dentin left, pulpo-axial soft dentin preserved	High-viscosity glass ionomer (Equia Forte®, GC) with Equia Coat resin surface protection	HVGI (capsulated, injected)	High short-term survival with gradual decline by 24 months; failures mainly due to secondary caries and postoperative sensitivity.
Saad et al. [36] (2024)	Egypt	Randomized controlled clinical trial	28 children (20 girls, 8 boys; aged 6–9 years); 56 hypomineralized first permanent molars (moderate and severe MIH)	SMART group: 38% silver diamine fluoride (SDF) applied for 1 min, followed by HVGI restoration Conventional group: HVGI restoration +	High-viscosity glass ionomer (Equia Forte HT, GC)	HVGI (capsulated, injected)	SMART and conventional GIC performed similarly early on, but SMART showed better 12-month integrity and less occlusal wear,

Table 3 cont'd

				fluoride varnish application			with all groups showing reduced hypersensitivity.
Sezer et al. [34] (2025)	Turkey	Prospective cohort study, 6-year follow-up	58 children (30 girls, 28 boys; mean age 8.94 years); 134 MIH-affected first permanent molars	Selective caries removal (SCR); peripheral hard dentin left, pulpo-axial leathery dentin preserved	Glass hybrid restorative material (Equia Forte®, GC) with Equia Coat resin surface protection	Glass hybrid (capsulated, injected)	Restorations performed well for 2–3 years but deteriorated markedly by 6 years, especially in severe MIH; failures involved retention loss and secondary caries.
Arab et al. [26] (2018)	Kuwait	In vitro pilot study	11 extracted MIH-affected first permanent molars (22 enamel surface)	RBC group: 35% phosphoric acid etching (15 s), Adper Single Bond 2 adhesive, light curing RMGIC group: 20% polyacrylic acid conditioning (10 s), Fuji II LC placement	Etch-and-rinse adhesive (Adper Single Bond 2, 3M ESPE) RMGIC bonding via polyacrylic acid conditioning	Resin composite (Filtek Z350XT, 3M ESPE) Resin-modified glass ionomer (Fuji II LC, GC)	Resin composite demonstrated substantially higher bond strength to MIH enamel than RMGIC.
Hakmi and Dashash [38] (2023)	Syria	Randomized controlled clinical trial	20 children (7–10 years old); 40 mandibular first permanent molars with severe MIH	Sodium hypochlorite wipe (5.25%) before etching	DCRR: 37% phosphoric acid etch (15 s), Single Bond (3M ESPE), layered Filtek 350 composite ICRR: Indirect composite fabricated extraorally, bonded with self-adhesive dual-cure resin cement (Breeze,	Resin composite (Filtek 350, 3M ESPE); self-adhesive resin cement (Breeze, Pentron)	ICRR and DCRR showed comparable survival, though ICRR produced less postoperative sensitivity and higher patient satisfaction.

Table 3 cont'd

					Pentron), silane + sandblasting pretreatment of restoration		
Linner et al. [41] (2020)	Germany	Retrospective cohort study	52 children; 127 MIH teeth; 204 restorations (posterior = 184, anterior = 20)	Non-invasive GIC/composite: no cavity prep, cotton roll isolation. Conventional composite: removal of MIH tissue, cavity prep, etch-and-rinse adhesive. Ceramic crowns: removal of MIH tissue, intraoral scan, dual-cure composite cement.	Self-etch adhesive (Adper Prompt L-Pop, Scotchbond Universal L-Pop). Etch-and-rinse adhesive (Syntac Classic). Dual-cure composite cement for ceramics.	GIC (Ketac Molar, 3M). Flowable composite (Tetric EvoFlow, Ivoclar). Conventional composite (Tetric EvoCeram, Ivoclar). CAD/CAM ceramic crowns (Celtra Duo, Dentsply Sirona).	Non-invasive restorations showed poor durability, whereas conventional composite and ceramic options achieved superior survival.
Solanke et al. [20] (2025)	Austria	In vitro study	53 extracted teeth (36 MIH-affected first permanent molars, 17 sound third molars)	35% phosphoric acid (PA) 5% sodium hypochlorite (NaOCl) ICON® resin infiltration Combinations (PA + NaOCl, NaOCl + ICON, etc.)	Etch-and-rinse: Adper Scotchbond 1XT (3M ESPE) Universal adhesive (self-etch mode): Scotchbond Universal Plus (3M ESPE)	Resin composite (Filtek Universal Restorative, 3M ESPE)	Bond strength was significantly lower in MIH enamel, but pretreatment with NaOCl plus resin infiltration improved performance; MIH dentin bonded similarly to sound dentin.
Grossi et al. [33] (2018)	Brazil	Prospective clinical study	44 children (mean age 10.55 years); 60 teeth with severe MIH	Cavity Conditioner (GC, 10 s), cotton roll isolation, Equia Forte placement, resin coat (Equia Coat)	Glass hybrid restorative system (Equia Forte, GC) with resin surface sealant	Glass hybrid (capsulated, injected)	Very high short-term success with minimal failures, mainly in teeth with extensive breakdown.

Table 3 cont'd

Souza et al. (2016) [29]	Brazil	Randomized controlled clinical trial	18 children (6–8 years old); 41 first permanent molars with MIH	Conservative cavity preparation; provisional GIC restoration before definitive composite	Self-etch adhesive (Clearfil SE Bond, Kuraray) Total-etch adhesive (Adper Scotchbond Multi-Purpose, 3M ESPE)	Resin composite (Filtek Z350 XT, 3M ESPE)	SEA and TEA showed comparable survival, with failures mainly related to marginal adaptation and retention.
Ozsoy and Gungor [13] (2024)	Turkey	Randomized controlled clinical trial	90 children (8–15 years old); 189 first permanent molars with MIH randomly assigned to 4 groups	Group 1, 2 and 3: - Group 4: Papacarie Duo gel (deproteinization, 60 s)	Clearfil SE Bond (self-etch) for composite groups Equia Forte HT with Equia Coat for glass hybrid group	Group 1: Equia Forte HT (glass hybrid) Group 2: Fuji IX base + G-eanial composite Group 3: EverX Posterior fiber-reinforced base + G-eanial composite Group 4: Papacarie deproteinization + EverX Posterior base + G-eanial composite	Composite-based restorations outperformed GIC, with EverX-based approaches showing the best marginal adaptation; Papacarie pretreatment performed similarly to composite bases and better than GIC.
Gaardmand et al. [40] (2013)	Denmark	Pilot clinical study	33 children (mean age 12.1 years); 57 first permanent molars with severe MIH	Preparation borders placed in sound enamel	Dual composite resin cement (Twinlook, Heraeus Kulzer) used to bond cast gold copings	Cast adhesive gold copings (CAC)	Stainless steel copings demonstrated excellent long-term survival with minimal failures and no pulpal complications.

Table 3 cont'd

Sönmez and Saat [31] (2017)	Turkey	Prospective clinical study	30 children (mean age 8.9 years); 95 MIH-affected PFMs + 31 non-MIH carious PFMs (control)	Group I: Invasive cavity prep; all hypomineralized tissue removed Group II: Non-invasive cavity prep; caries + cheesy enamel removed Group III: Same as Group II + deproteinization with 5% NaOCl (60 s). Group IV (control): Non-MIH carious PFMs; conventional cavity prep.	Futurabond NR (self-etch, VOCO) after 37% phosphoric acid etching.	Grandio nano-hybrid composite (VOCO).	Most restorative approaches showed high retention, except one group with marginal and esthetic failures; postoperative sensitivity resolved over time.
Fragelli et al. [28] (2017)	Brazil	Prospective clinical study	21 children (6–8 years old); 41 first permanent molars (25 MIH-affected, 16 sound controls)	Four weekly fluoride varnish applications (Duraphat) before sealant placement 35% phosphoric acid etching (30 s) before sealant	Etch-and-rinse protocol (phosphoric acid)	Resin sealant (FluroShield, Dentsply/Caulk)	Sealant survival was similar between MIH and sound molars, with failures primarily due to retention loss.
Gatón-Hernandez et al. [43] (2020)	Spain	Prospective longitudinal clinical study	281 children (6–8 years old); one immature permanent molar per patient with severe MIH and open apex	Selective caries removal Cavity cleansing with 3% sodium hypochlorite Preventive protocol: diet counselling, oral hygiene instruction, plaque control, fluoride varnish with CPP-ACP	Interim: Glass ionomer cement (EQUIA, GC) Definitive: Etch-and-rinse adhesive (Scotchbond Multipurpose, 3M/ESPE) + resin composite (Filtek Supreme XTE)	Glass ionomer cement (interim), resin composite (definitive)	High 24-month success, with preventive measures such as CPP-ACP and fluoride contributing to improved enamel stability.

Table 3 cont'd

Dhareula et al. [39] (2019)	India	Randomized controlled clinical trial	30 children (8–13 years old); 42 permanent first molars with severe MIH randomly allocated (21 cast metal onlays, 21 indirect composite onlays)	5.2% NaOCl deproteinization, 37% phosphoric acid etching, Adper Single Bond Plus adhesive	Dual-cure resin cement (RelyX Unicem 2, 3M ESPE)	Cast metal onlays (cobalt-chromium alloy) Indirect composite onlays (SR Adoro, Ivoclar Vivadent)	Metal and resin restorations showed similarly high survival and retention, with resolution of sensitivity in all cases.
Unverdi et al. [37] (2024)	Turkey	Randomized controlled clinical trial	48 children; 112 hypomineralized permanent molars	Group 1: SDF + KI application only Group 2 (SMART): SDF + KI pretreatment + GIC sealant	Glass Ionomer Cement (SMART group)	GIC sealant (SMART); SDF + KI (preventive agent)	SMART demonstrated superior survival and caries prevention compared with SDF + KI, with both treatments reducing hypersensitivity.

RESULTS AND DISCUSSION

Given the heterogeneity of study designs and outcomes, the Results and Discussion parts were combined to provide an integrated and coherent synthesis consistent with scoping review methodology. In addition, the severity of MIH lesions, including the presence of post-eruptive enamel breakdown, is known to influence bonding performance. However, severity was inconsistently reported across studies, which limited the ability to stratify outcomes by lesion severity.

Bonding to MIH-affected teeth remains one of the challenging aspects of pediatric dentistry. The evidence synthesized in this scoping review illustrates both made progress and current limitations in adhesive strategies. Wide range of adhesive systems, pretreatment protocols, and restorative materials were investigated across the 21 included studies. This shows the heterogeneity of clinical presentation and the lack of consensus on optimal management. The in-vitro studies and clinical trials were reviewed, analyzed, and discussed separately to strengthen the clarity and credibility of this review.

In Vitro Studies

In vitro studies consistently demonstrated significant lower bond strengths in MIH enamel compared to the sound enamel. Krämer et al. showed that irregular etching patterns and porous structures were seen in MIH enamel, which resulted in weaker resin-enamel bonds and frequent pre-test failures; while dentin bonding remained comparable to sound dentin [19]. Arab et al. confirmed that resin composites bonded with etch-and-rinse adhesives achieved higher microshear bond strengths (≈30MPa) than that of resin-modified glass ionomers (≈11MPa) [26]. Solanke et al. further demonstrated that MIH enamel bonded with Scotchbond Universal Plus achieved significantly lower shear bond strengths than that of sound enamel [20]. However, oxidative pretreatment with sodium hypochlorite combined with resin infiltration improved bonding to near sound enamel. These findings suggest that while MIH enamel's composition compromises adhesion, targeted pretreatments may partially restore the bond strength.

The incorporation of bioactive additives such as 45S5 bioactive glass into self-etch adhesives also demonstrated improved bond strengths and stable resin-enamel interfaces over time. This improvement is attributed to the material's innate ability to release calcium and phosphate ions, which in turn can promote the formation of a hydroxyapatite-like layer. This leads to the adhesive layer becoming more chemically integrated with the enamel which reduces microleakage, improves bond durability, and maintains bond strength [12] which highlights a potential approach for durable adhesion. Collectively, the laboratory evidence highlights that the primary challenge in MIH bonding lies in achieving durable adhesion to the hypomineralized enamel rather than dentin, which generally bonds reliably [19, 20].

Clinical Trials

Clinical trials on sealants revealed similar trends. Özgür et al. compared the resin-based fissure sealants applied with etch-and-rinse adhesives against giomer sealants placed with self-etch primers. At 12 months, the retention rate was 68% for resin sealants versus only 8% for giomer sealants, underscoring the inadequacy of mild self-etch systems in MIH enamel [27]. Fragelli et al. also reported that sealants in MIH molars showed survival rates comparable to sound molars over 18 months, suggesting that etch-and-rinse resin sealants remain a reliable preventive option [28].

Composite restorations bonded with different adhesives showed variable outcomes. Souza et al. found no significant difference between the self-etch and total-etch adhesives in MIH molars [29]. Although, the survival rates declined to ~60–70% at 18 months, with failures mainly due to marginal adaptation and retention [29]. Rolim et al. reported the survival rates of 80.8% for total-etch versus 62.3% for self-etch at 12 months, again favoring the etch-and-rinse protocols [30]. Sönmez & Saat demonstrated that leaving the hypomineralized tissue without pretreatment compromised restoration survival, while deproteinization with NaOCl improved retention to levels comparable with invasive cavity preparation [31]. Ozsoy & Gungor showed that Papacarie deproteinization combined with fiber-reinforced composite bases achieved survival rates above 97% at 9 months, highlighting the potential of biologically oriented pretreatments [13].

Glass ionomer and glass hybrid restorations were widely tested as minimally invasive options. Fragelli et al. reported 78% survival rate at 12 months for high-viscosity GIC restorations, which failures associated with tooth breakdown [15]. Durmuş et al. found the survival probabilities of 87.5% at 24 months for Equia Forte restorations after selective caries removal, although, failures were mainly due to the secondary caries and sensitivity [32]. Grossi et al. demonstrated high short-term success (98% at 12 months) for glass hybrid restorations in field conditions [33]. On the other hand, Sezer et al. showed that the survival declined markedly over six years, with only 24% of mild lesions and 11% of severe lesions surviving [34]. Mahfouz et al. compared the zirconia-reinforced GIC with glass hybrids and found no significant differences, both achieving ~85% success rate at 12 months [35]. These findings suggest that GICs and glass hybrids are useful interim solutions, but their long-term survival is limited.

Preventive adjuncts such as SMART (silver diamine fluoride + KI + GIC) were evaluated by Saad et al. who found that the SMART restorations maintained integrity and reduced hypersensitivity in moderate and severe MIH molars up to one year. This was with less occlusal surface change compared to the conventional HVGI + varnish [36]. Importantly, a longer-term trial by Unverdi et al. compared SDF + KI alone with SMART sealants over three years [37]. Both groups reduced hypersensitivity, but SMART offered significantly better caries prevention (≈95% survival at 36 months vs ≈65% for SDF + KI) despite gradual retention loss. This reinforces the role of SMART as a superior preventive strategy compared to the SDF + KI alone, particularly for long-term caries control in MIH molars. CPP-ACP varnishes were also used in several protocols [15], showing benefits in remineralization and sensitivity reduction.

Indirect restorations consistently outperformed direct approaches in severe MIH. Hakmi & Dashash found the survival rates of 90% for indirect composites versus 85% for direct composites at 12 months, while, indirect restorations associated with lower sensitivity and higher child satisfaction [38]. Dhareula et al. reported cumulative survival rates of 95–100% for the cast metal and indirect composite onlays at 36 months with no significant differences between materials [39]. Gaardmand et al. demonstrated that cast adhesive gold copings achieved >98% survival at nearly four years [40]. In addition, Linner et al. showed that the ceramic crowns had 100% survival at three years mark, which far exceeded the conventional composites (76%) and GICs (7%) [41]. These data highlight that even though indirect restorations are more invasive and costly, they provide highly durable solutions for severely affected molars.

Methodologically, the evidence base is characterized by heterogeneity in diagnostic criteria (EAPD, MIH-TNI), variability in outcome measures (U.S. Public Health Service (USPHS), Atraumatic restorative treatment (ART) codes, survival analysis), and generally short follow-up periods. Many clinical trials that evaluated bonding had small sample size and thus, with limiting statistical power. In vitro studies often used extracted teeth with variable severity may not replicate clinical conditions. Few randomized controlled trials directly compared adhesive systems head-to-head, and long-term data beyond two years remain scarce, except for studies done by Sezer et al. [34] and Gaardmand et al. [40]. Patient-centered outcomes such as pain reduction, hypersensitivity, and satisfaction were assessed in some studies, including studies done by Rolim et al. [30] and Hakmi & Dashash [38].

Taken together, the evidence indicates that while the restorative material choice (composites, GICs, glass hybrids, indirect restorations) influences the survival, it is the adhesive strategy that emerges as a consistent determinant of success in MIH teeth. Failures across both in vitro and clinical studies were most often related to loss of adhesion, since the failures happened mostly through poor retention, marginal breakdown, or compromised bond strength and not intrinsic material fracture. Even though, etch-and-rinse adhesives did demonstrate superior performance in comparison to the self-etch systems in some cases [26, 27, 29, 30], other reviews did not find significant differences [10, 42]. This implies that both are viable options; but as the data were heterogenous in the reviews, the total-etch systems can be a safer choice. Universal adhesives showed variable outcomes depending on whether they were applied in the etch-and-rinse or self-etch mode [20, 30]. Pretreatment protocols such as sodium hypochlorite deproteinization [20, 31], Papacarie gel [13], resin infiltration [20], and bioactive glass incorporation into adhesives [12] were all targeted on the adhesive interface and showed potential to improve bonding, although, results remain inconsistent. Importantly, dentin bonding was generally reliable in MIH teeth [19, 20]. This indicates that the main challenge lies in achieving durable adhesion to hypomineralized enamel.

Consolidation

Across both laboratory and clinical evidence, findings suggest that while restorative materials provide the framework for treatment, optimization of adhesive systems, the pretreatment protocols can ultimately affect the restoration longevity and clinical success in MIH management. This shows the central role of bonding in MIH management and highlights the need for further investigations to systematically evaluate and enhance long-term bonding related to the properties in MIH-affected teeth through in-vitro studies and clinical trials. This can result in a universal criterion for MIH determination and classification, and also investigation of emerging new approaches.

CONCLUSION

This scoping review demonstrates that MIH enamel presents unique bonding challenges, with adhesion consistently weaker than in sound enamel. Etch-and-rinse adhesives remain the most reliable, while, the self-etch and universal systems may require adjunctive pretreatments to improve outcomes. Strategies such as sodium hypochlorite deproteinization, Papacarie gel, resin infiltration, and bioactive glass incorporation demonstrate promising results but need further validation. The glass ionomer and glass hybrid restorations provide short-term solutions and are better to be used as an interim option or to be minimally invasive. Indirect restorations are more invasive than other options but they offer significant superior longevity, especially in severe cases. New approaches such as bioactive glass incorporation have been emerging which need further research. Overall, ideal management of MIH primarily is patient-oriented and its durability depends on optimizing the adhesive protocols. Future research should focus on standardizing diagnostic criteria to improve comparability and long-term trials to strengthen evidence for clinical practice are needed.

CONFLICT OF INTEREST STATEMENT

None declared.

GENERATIVE AI IN SCIENTIFIC WRITING

None declared.

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