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Comparison of four different treatment strategies in teeth with molar-incisor hypomineralization-related enamel breakdown—A retrospective cohort study

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[Correction added on 01 March 2021, after first online publication: Copyright line is corrected.]

Abstract

Background: There is little information available on the longevity of non-invasive glass ionomer cement (GIC) and composite restorations as well as conventional composite and ceramic restorations placed on permanent teeth with enamel breakdowns due to molar-incisor hypomineralization (MIH).

Aim: To compare the longevity of the abovementioned treatment procedures.

Design: Of 377 identified MIH patients, 118 individuals received restorative treatment and were invited for clinical examination, including caries and MIH status. Finally, survival data from 204 MIH-related restorations placed on 127 teeth were retrospectively collected from 52 children, monitored between 2010 and 2018. Descriptive and explorative analyses were performed, including Kaplan-Meier estimators and the Cox regression model.

Results: The mean patient observation time was 42.9 months (SD = 35.1). The cumulative survival probabilities after 36 months—7.0% (GIC, N = 28), 29.9% (non-invasive composite restoration, N = 126), 76.2% (conventional composite restoration, N = 27) and 100.0% (ceramic restoration, N = 23)—differed significantly in the regression analysis.

Conclusions: Conventional restorations were associated with moderate-to-high survival rates in MIH teeth. In contrast, non-invasive composite restorations, which were predominately used in younger or less cooperative children, were linked to lower survival rates.

KEYWORDS

disturbances in dental development, molar-incisor hypomineralization, restorative dentistry/dental materials

1 | INTRODUCTION

Molar-incisor hypomineralization (MIH) is a prevalent dental developmental disorder, and ~10%-20% of children and adolescents are affected,[1-3] with a varying degree of severity, ranging from mainly mild opacities to severe enamel breakdowns, mostly in occlusion-bearing areas, shortly after tooth eruption.[4] From the patients' viewpoint, first permanent molars (FPMs), with extensive enamel breakdowns, are especially hypersensitive and limited in functionality as well as difficult to clean, which is finally associated with an increased caries risk.[5-9] Therefore, dental anxiety and lack of cooperation are frequent co-variables in children affected by MIH.[10]

Considering structural specifications of MIH lesions, including reduced mineral content, increased porosity, and protein concentration, the inferior mechanical properties show reduced hardness and modulus of elasticity compared with normal enamel.[3,11] Furthermore, conventional conditioning of the hypomineralized enamel with phosphoric acid produces a much less pronounced etching pattern and, therefore, limits the adhesive bond of restorations.[12,13] Adhesion on hypomineralized enamel still works with limitations but can be increased after removal of MIH tissue and placing cavity margins in sound enamel, bringing the retention to similar rates compared with caries-related restorations.[14,15]

From the dental practitioner´s perspective, restoring the form, function and aesthetics of MIH teeth with multi-surface hard tissue defects seem mandatory. Knowing well the possibly indicated spectrum of treatment options, for example direct or indirect restorations (Table 1), their applicability in young patients is frequently limited mostly due to the invasiveness of cavity preparation and the need for local anaesthesia. Therefore, non-invasive restorative procedures are necessary to meet patient demands and to cover hypersensitive hard tissue defects, aiming at reducing hypersensitivities, protecting hypomineralized tissue, ensuring children´s cooperation, and improving oral health-related quality of life. For this aim, direct restorative materials, for example glass ionomer cements (GICs) or adhesively bonded composites, are used clinically to simply cover disintegrated hypomineralized enamel.[16,17] Considering the limitations of such non-invasive clinical treatment options on occlusion-bearing surfaces, this approach might be child-oriented and fulfil several of the abovementioned dental requirements in young children but will probably be linked to reduced survival rates. Later, in life, when full cooperation is warranted, local anaesthesia, optimal cavity preparation, and restoration of the tooth can be achieved by the use of conventional composite restorations[18-20] or indirect restorations.[21-26] Nevertheless, both treatment options can also be conducted under general anaesthesia in case that dental rehabilitation is indicated in young, but uncooperative children. Interestingly, few clinical data[17] have been published about non-invasive clinical procedures in comparison with conventional restorations so far. Therefore, this retrospective cohort study aimed, first, to analyse the survival probability of non-invasive composite restorations on MIH-affected permanent teeth and, second, to investigate applied operative treatment options (Table 1) in children and adolescents exhibiting MIH-related hard tissue breakdowns. The null hypothesis to be tested was that all procedures would have the same success rates.

Why this paper is important for paediatric dentists

- MIH-related hard tissue breakdowns, which can occur shortly after tooth eruption, need to be restored on an individual basis to protect the exposed dentin and maintain vitality, form, function, and aesthetics. Frequently, hypersensitivity and a lack of cooperation, however, complicate conventional treatment. Therefore, non-invasive composite restorations seem to be a possible treatment strategy to bridge the time until definitive conventional restorative procedures can be implemented.
- The data provide evidence for the longevity of conventional composite and CAD/CAM-fabricated ceramic restorations in MIH teeth with multi-surface hard tissue breakdowns.
- This study introduces the paediatric dentists to non-invasive treatment alternatives and documented satisfactory survival rates for such procedures

2 | MATERIAL AND METHODS

This retrospective cohort study was conducted in adherence to the Declaration of Helsinki. The reporting followed the STROBE guidelines for observational studies.[27] Ethical approval of the Human Ethics Committee of the medical faculty of the Ludwig Maximilians University, Munich, was obtained (Project no. 18-249).

2.1 | Patient sample and standardized review of dental records

The digital patient documentation system (Highdent Plus, version 5.57, CompuGroup Medical Dentalsysteme GmbH) at the Department of Conservative Dentistry and Periodontology at the Ludwig Maximilians University of Munich, Germany, was systematically screened for subjects who visited the department for examination and/or treatment of MIH during the interval from February 2010 to December 2018. Patients with caries, periodontal diseases, trauma, or other diagnoses were not considered. A total of 377 MIH patients were primarily identified, of whom 259 had to be excluded due to receiving no dental treatment or having developmental defects other than MIH. All remaining 118 patients with MIH-associated restorations were invited for a clinical examination. The present study finally comprised 52 individuals who were treated at the Department of Conservative Dentistry and Periodontology due to MIH. Detailed information about the stepwise patient selection is presented in Figure 1. From each patient's documentation, the

TABLE 1 Indications and treatment protocols of the four analysed restorative procedures

	Non-invasive restorations		**Conventional restorations**	
	Glass ionomer cement	**Composite**	**Composite**	**CAD/CAM ceramics**
				
Tooth-related indication	Disintegration of hard tissue with small- to medium-sized defects	Disintegration of hard tissue with small- to medium-sized defects	Disintegration of hard tissue with small- to large-sized defects	Extensive disintegration of hard tissue with dentine exposure at multiple surfaces, repetitive failure of direct restorations
Type of anaesthesia	No local or general anaesthesia	No local or general anaesthesia	No, local or general anaesthesia in relation to patients cooperation and treatment needs	Local or general anaesthesia in relation to cooperation status and treatment needs
Treatment protocol	Tooth cleaning, no cavity preparation, cotton roll isolation, application of GIC, and occlusion control	Tooth cleaning, no cavity preparation, cotton roll isolation, self-etching adhesive, application and light polymerization of flowable composite and occlusion control	Tooth cleaning, removal of MIH tissue, preparation of cavity margins, cotton roll isolation, total etch and total bond, composite application, light polymerization, and occlusion control	Tooth cleaning, mostly removal of all MIH tissue, preparation of cavity margins, intraoral scan, fabrication of CAD/CAM ceramic crown, cotton roll isolation, total etch and total bond, insertion with dual-cure composite cement, and occlusion control

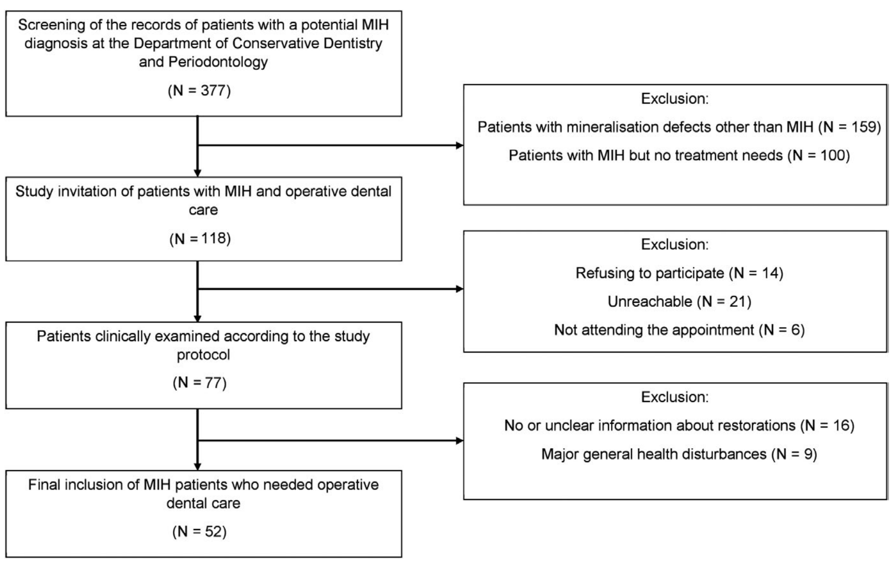

FIGURE 1 Patient flow chart

therapy was assessed by recording the treatments for every affected tooth separately with the date of therapy, type of anaesthesia, endodontic treatment, and restorative procedure. When a tooth received more than one restoration, the previous one was scored as repaired/replaced because of clinical insufficiency and the retreatment was added as new sample.

2.2 | Clinical examination

The standardized examination was performed in a professional setting using a dental unit with an operation light and a dental syringe. At the beginning of each clinical examination, professional tooth cleaning, using a rotary brush and polishing paste, was performed. Subsequently, a trained and calibrated dentist (TL) conducted all examinations of each tooth and surface by using standard conditions with a plane dental mirror and a blunt CPI-probe (CP-11.5B6, Hu-Friedy).

The plaque index was assessed by a visual and tactile examination of each tooth after air drying and judging the presence of plaque as 'yes' or 'no'. Caries status was determined using the dmf/DMF index in the primary and permanent dentition.[28] A caries lesion was recorded when the surface had an unmistakable cavity, undermined enamel, or a detectably softened floor or wall. First visible signs established carious lesions and microcavities without dentin exposure were recorded as non-cavitated carious lesions (nccls/NCCLs) for both dentitions according to the International Caries Detection and Assessment System (ICDAS) and Universal Visual Scoring System (UniViSS).[29,30] No bitewing radiographs were performed or involved. MIH-related demarcated opacities, surface breakdowns of hypomineralized enamel, MIH-related restorations, and extractions were diagnosed according to EAPD criteria on all permanent teeth and surfaces.[31] Hypomineralized lesions with a diameter <1 mm were not registered. Individuals with other enamel defects, for example hypoplasia, fluorosis, amelogenesis imperfecta, and dentinogenesis imperfecta, were excluded from this investigation. MIH-associated defects or restorations were not scored in the dmf/DMF index. In the case of multiple findings on a tooth or surface, caries and MIH were recorded separately.

2.3 | Treatment strategies in MIH patients

In the patients included in the study, two non-invasive and two definitive conventional treatment strategies (Table 1) had been applied clinically in a university-based setting. Patients with less sufficient cooperation and small- to medium-sized defects received non-invasive restorations, either with GIC (Ketac Molar, 3M Deutschland GmbH) or with an adhesive bonding agent (Adper Prompt L-Pop or Scotchbond Universal L-Pop, 3M Deutschland GmbH) and composite material (Tetric EvoFlow, Ivoclar Vivadent AG, Schaan, Liechtenstein) to cover disintegrated hard tissue without any cavity preparation. Patients with sufficient cooperation or who were treated under general anaesthesia received a definitive conventional restoration to reconstruct the tooth anatomy. Composite restorations (Tetric EvoCeram, Ivoclar Vivadent AG, Schaan, Liechtenstein) were placed on teeth with small- to large-sized defects after cavity preparation with the removal of unstable hypomineralized enamel, etching, and application of an adhesive bonding agent (Syntac Classic, Ivoclar Vivadent AG, Schaan, Liechtenstein). If the tooth had a multi-surface lesion, the hypomineralized enamel was completely removed to place chairside-fabricated CAD/CAM ceramic restorations (Celtra Duo, Dentsply Sirona) strictly in healthy hard tissue. The allocation of the teeth was mainly determined by the treatment needs and cooperation status of the patients under consideration of their age and preferences of the operator and parents. Further information on indication, treatment protocol, and allocation of the restorations is presented in Table 1.

2.4 | Quality assessment of MIH-related restorations

For the quality assessment of restorations on MIH teeth, the FDI criteria[32] for fracture of material and retention, marginal adaptation and tooth integrity were used. For a final dichotomization, each restoration rated exclusively as clinically sufficient/satisfactory or better was scored as 'sufficient', and if a restoration was judged clinically unsatisfactory or worse, it was rated as 'insufficient'. For insufficient restorations, the observation period was defined as the period between the placement of the restoration and the date of repair or renewal. Teeth that underwent extraction were excluded from the survival analysis. All restorations were photographed with a professional single-lens reflex camera (Nikon D7100/D7200 with AF-S Micro Nikkor 105 mm 1:2.8G IF-ED, Nikon; EM-140 DG macro flash, Sigma) immediately after clinical assessment, to enable subsequent consensus diagnoses.

2.5 | Calibration before examination

Before the study, a two-day theoretical and practical calibration training, focussed on the scoring of cavitated caries lesions, NCCLs, and MIH, was undertaken with the examiner (TL) by an experienced clinician and epidemiologist (JK). The theoretical training provided information about study design, indices, and diagnostic principles. The practical component included analysis and discussion of numerous high-quality photographs of single tooth surfaces illustrating carious and MIH lesions as well as lesions with possible differential diagnoses. At the end of the calibration training, the examiner evaluated one hundred and twenty unknown, high-quality photographs from occlusal and smooth surfaces, respectively, for the detection of cavitated carious lesions and caries-associated restorations (DMF index and NCCLs) and MIH. The inter- and intra-examiner kappa values of the examiner were found to be higher than 0.80 in all cases.

2.6 | Data management and statistics

An electronic case report form (EpiData, EpiData Association, version V4.4.1.0) was designed to allow structured data entry of relevant information about patient characteristics, caries and MIH status as well as MIH-related restorations. In the next step, the compiled EpiData database was exported to an Excel sheet (Office 2016 Excel, Microsoft Corporation) for further processing. Statistical analysis was undertaken using R software (version 3.6.0, R Development Core Team). The significance level was set at $\alpha = 0.05$, with a 95% confidence interval. Kaplan-Meier estimators were conducted to generate survival curves, survival probability, and median survival time.[33] Differences in the survival rate were assessed by applying the log-rank test. Cox proportional hazard regression analysis was carried out to investigate the influence of the variables of interest (restorative procedure, defect size, age, gender, (re-) treatment, and anaesthesia) on restoration survival.

3 | RESULTS

The mean age of the study population (N = 52; 26 females/ 26 males) was 11.2 years (SD = 2.9, min = 6.6, max = 18.2) at the time point of clinical evaluation, and the included individuals were monitored for a mean of 42.9 months (SD = 35.1). The mean plaque index in the primary and permanent dentition was 20.3% (SD = 33.3%) and 28.9% (SD = 31.9%), respectively. A total of 59.6% of the study population were found to be free of decayed, extracted, or filled teeth in their primary and permanent dentition (dmf/DMF = 0). Taking NCCLs additionally into account, 36.5% of the individuals were caries free (nccl/NCCL/dmf/DMF = 0). The mean caries experience amounted to 1.4 dmf (SD = 2.3) and 0.1 DMF (SD = 0.4); the mean number of permanent MIH teeth per patient was 6.8 (SD = 4.0), and the mean number of restored teeth due to MIH was 2.2 (SD = 2.9). More details about the caries and MIH status can be taken from Table 2.

In the study group, 204 MIH-related restorations (posterior teeth = 184/ anterior teeth = 20) were placed, consisting of 28 (13.7%) GIC restorations, 126 (61.8%) non-invasive composite restorations, 27 (13.2%) conventional composite restorations, and 23 (11.3%) CAD/CAM-fabricated ceramic restorations. A total of 127 teeth (62.3%) received a primary restoration, and 77 teeth (37.7%) needed a retreatment, with 70.6% (60/85) of the retreatments occurring in 20.8% (10/48) of the patients.

When comparing the survival data descriptively and exploratively, it was found that both non-invasive treatment procedures showed the highest failure rates in comparison with conventional restorations, and interestingly, failure rates were higher in teeth with retreatments (Table 3). The Kaplan-Meier curves (Figure 2) revealed that the cumulative survival probability after 36 months was highest in the CAD/CAM group (100.0%), followed by conventional composite

TABLE 2 Characterization of permanent and *primary* dentition in the study population (N = 52/*36*)

	Tooth level		Surface level			Tooth level		Surface level	
Caries	**Mean (SD)**	**%**	**Mean (SD)**	**%**	**MIH**	**Mean (SD)**	**%**	**Mean (SD)**	**%**
Non-cavitated caries lesions					Demarcated opacities				
NCCLs	1.1 (2.4)	91.7	1.3 (3.0)	86.6	Perm.	3.3 (2.2)	48.5	6.6 (4.3)	39.5
nccls	*1.0 (1.3)*	*41.6*	*1.3 (1.8)*	*29.6*	*Prim.*	*0.2 (0.8)*	*66.7*	*0.5 (1.9)*	*83.3*
Cavitated caries lesions					Enamel breakdowns				
D	0.0 (0.1)	0	0.1 (0.4)	6.7	Perm.	1.0 (1.2)	14.7	1.3 (1.6)	7.8
d	*0.1 (0.3)*	*4.2*	*0.2 (0.7)*	*4.5*	*Prim.*	*0.1 (0.5)*	*33.3*	*0.1 (0.7)*	*16.7*
Restorations due to caries					Restorations due to MIH				
F	0.1 (0.4)	8.3	0.1 (0.4)	6.7	Perm.	2.2 (2.9)	32.4	7.6 (10.2)	45.5
f	*1.2 (1.9)*	*50*	*2.2 (3.8)*	*50.0*	*Prim.*	*0.0 (0.0)*	*0*	*0.0 (0.0)*	*0.0*
Extractions due to caries					Extractions due to MIH				
M	0.0 (0.0)	0	0.0 (0.0)	0.0	Perm.	0.3 (1.1)	4.4	1.2 (5.5)	7.2
m	*0.1 (0.7)*	*4.2*	*0.7 (3.4)*	*15.9*	*Prim.*	*0.0 (0.0)*	*0.0*	*0.0 (0.0)*	*0.0*
Total					Total				
DMF/NCCLs	1.2 (2.6)	100	1.5 (3.4)	100.0	Perm.	6.8 (4.0)	100	16.7 (14.5)	100.0
dmf/nccls	*2.4 (3.2)*	*100*	*4.4 (6.9)*	*100.0*	*Prim.*	*0.3 (1.1)*	*100*	*0.6 (2.6)*	*100.0*

Abbreviations: D, decayed; F, filled; M, missing; NCCLs, non-cavitated caries lesions; Perm, permanent dentition; Prim, primary dentition; SD, standard deviation (Abbreviations in capital letters present the permanent dentition, lower-case letters present the primary dentition).

TABLE 3 Detailed presentation of the number of restorations, the mean patient age, and type of anaesthesia applied, when placing the different restorations (N = 204)

	Non-invasive restorations				Conventional restorations			
	GIC (N = 28)		Composite (N = 126)		Composite (N = 27)		CAD/CAM ceramics (N = 23)	
	Primary treatment	Retreatment	Primary treatment	Retreatment	Primary treatment	Retreatment	Primary treatment	Retreatment
N treatments (%)	18 (8.8)	10 (4.9)	73 (35.8)	53 (26.0)	23 (11.3)	4 (1.9)	13 (6.4)	10 (4.9)
Mean patient age in years (SD)	7.7 (0.7)	6.9 (0.7)	8.9 (2.2)	9.9 (2.0)	10.1 (2.3)	9.0 (1.4)	9.7 (1.2)	8.4 (0.5)
No/ local/ general anaesthesia	17/ 1/ 0	10/ 0/ 0	62/ 11/ 0	48/ 5/ 0	15/ 1/ 7	3/ 0/ 1	0/ 1/ 12	0/ 0/ 10
Failure rate in the 1st year (%)	61.1	90.0	28.8	41.5	0.0	25.0	0.0	0.0
Failure rate in the 2nd year (%)	25.0	100.0	20.5	45.0	0.0	33.3	0.0	0.0
Failure rate in the 3rd year (%)	0.0	-	23.8	0.0	16.7	-	0.0	0.0
Mean observation time in days (SD)	242 (260)	123 (87)	561 (517)	402 (392)	1203 (835)	403 (250)	1186 (963)	750 (246)
Median survival time in days (95% CI)	240 (91-/)	91 (75-/)	742 (555-1408)	379 (273-637)	-	547 (114-/)	-	-

Note: The failure rates in the first three years, mean observation time and median survival time are presented for primary treatments and retreatments separately with standard deviation (SD) and 95% confidence intervals (CI).

(76.2%) and non-invasive composite restorations (29.9%) and lowest in GIC restorations (7.0%). Using the log-rank test, the four restorative procedures ($P < .001$), local anaesthesia ($P < .05$), and the type of treatment ($P < .05$) presented a significant effect on the survival. Detailed information on the influence of the investigated variables is presented in the Cox proportional hazard regression analysis (Table 4).

4 | DISCUSSION

This retrospectively designed cohort study analysed different non-invasive and conventional restorative procedures, which were mostly used in children severely affected by MIH in the Department of Conservative Dentistry at the LMU. The study population presented a low caries risk and good oral hygiene, which is in line with previously published reports conducted in Munich[2,34] or Germany.[7] Contrarily to the low caries risk, the study population was characterized by a high MIH burden (Table 1) which is nearly three to five times higher than the population-based average in Munich adolescents.[2,34] Therefore, the data support the assumption that MIH children who are severely affected and need restorative dental treatment may accumulate the MIH burden. This theory is underlined by the findings in this study revealing that every patient was restoratively treated on average once a year. This result is in line with those of other studies describing an increased treatment frequency in MIH children compared to unaffected controls.[10,20,35,36]

When comparing data on restoration survival (Table 3, Figure 2), it must be considered that the initially formulated null hypothesis must be rejected because the investigated treatment strategies were linked to significantly different survival rates (Table 3, Figure 2). This can be explained by the different treatment procedures and indications, which in turn were mainly influenced by the children's cooperative capability, the defect characteristics and the informed consent between the dentist and parents. GIC restorations, which were predominately placed in posterior teeth of less cooperative patients, without cavity preparation, had the lowest cumulative survival probability (Figure 2). This finding is supported by previous studies indicating that GIC can be easily and non-invasively applied but shows a high likelihood to fail in stress-bearing areas of FPMs and should, therefore, only be considered as an intermediate approach.[16,19] Contrary to this Fragelli et al[16] showed that the likelihood of a restored tooth remaining unchanged at the end of 12 months was 78%, but restorations in this trial were placed under absolute isolation, which may probably enhance the longevity and is, furthermore, an indicator for the good cooperation of the 6- to 9-year-old patients. Aiming to achieve better longevity results, adhesively bonded composite materials were frequently used to cover MIH defects non-invasively without

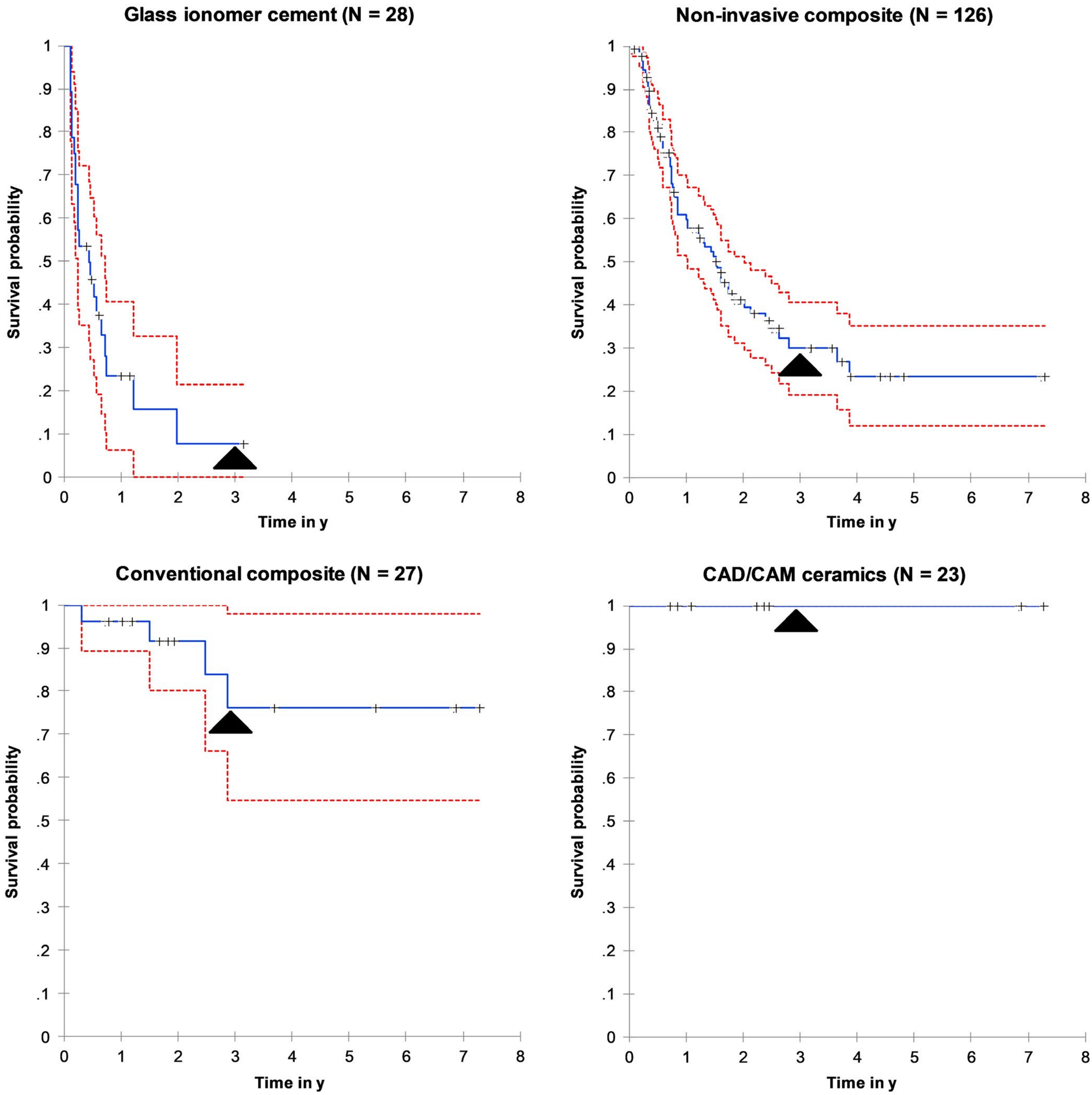

FIGURE 2 Kaplan-Meier survival curves (blue) with 95% confidence intervals (red), censored restorations (+), and 36-month (▲) survival probability

cavity preparation in our department. The corresponding cumulative survival probability (Figure 2) was found to be significantly higher in comparison with GIC. Therefore, this procedure seems to be an appealing alternative for quick and satisfactory treatment. Nevertheless, it must be considered that some teeth were treated non-invasively, although a conventional restoration would have been indicated, since an invasive procedure was not feasible and, therefore, a higher failure rate and risk for early retreatment was accepted.

It must be, however, noted, on the basis of our results (Table 3 and 4, Figure 2), that definitive conventional restorative care increases the restoration longevity and may positively affect the quality of life in MIH children.[37] For conventional composite restorations with cavity preparation and removal of unstable hypomineralized enamel, the present study registered a high cumulative survival probability (Figure 2), which is comparable to previously published data.[19,20,38] CAD/CAM ceramic restorations, which were applied on teeth with multi-surface lesions, did not fail within the first three years after complete removal of hypomineralized enamel and placing the restoration margin in sound enamel. This finding is in line with retention rates

TABLE 4 Results of Cox proportional hazard regression analysis on the effect of potential influencing variables

	Hazard ratio (95% CI)	*P*-value
Age	0.92 (0.81-1.04)	.1844
Gender		
Male	1.00	
Female	0.72 (0.47-1.10)	.1307
Defect size		
1-2 surfaces	1.00	
3-5 surfaces	1.97 (0.87-4.46)	.1039
Treatment		
Primary treatment	1.00	
Retreatment	1.94 (1.24-3.04)	**.0037**
Anaesthesia		
None	1.00	
Local anaesthesia	0.49 (0.25-0.97)	**.0393**
General anaesthesia	1.85 (0.26-13.25)	.5409
Restorative procedure		
GIC	1.00	
Non-invasive composite	0.33 (0.20-0.56)	**<.0001**
Conventional composite	0.06 (0.01-0.28)	**.0003**
CAD/CAM ceramic	0.00 (0.00-inf)	**<.0001**

Note: Bold printed *p*-values indicate a significant influence of the factor in the model.

of other clinical studies, which investigated the survival of indirect restorations in MIH teeth.[21-26] The given outcomes support that long-lasting restorations on hypomineralized teeth can be achieved with conventional direct composite restorations[17,18] and indirect ceramic restorations.[21,39,40] It is important to note, however, that these treatment options can only be carried out in cooperative individuals or under general anaesthesia and in combination with removal of most of the clinically hypomineralized hard tissue and placement of the restoration margins, preferably on sound enamel.[14,15]

Beside the before-mentioned significant differences between the investigated materials, the Cox regression model documented, furthermore, that local anaesthesia and retreatments were found to be significant variables (Table 4). This finding might be discussed in close relation to the cooperation of the children, due to the fact that less cooperative children do prefer simplified dental procedures which result in a less frequent use of local anaesthesia. Contrary to this, simplified dental procedures might be associated with an increased probability for a retreatment. Larger restorations with a defect size of 3-5 MIH surfaces showed a higher probability to fail. But this association was found not to be significant (Table 4).

The major strength of this study lies, first, in the presentation of the first data on non-invasive composite restorations on disintegrated hard tissue of MIH-affected teeth, in which a cavity preparation was completely omitted. Second, to the best of our knowledge, no clinical and survival data have been published on chairside-fabricated CAD/CAM ceramic restorations in severely affected MIH teeth either. As a possible limitation of the study, the sample size, which seems to be small, can be discussed. When considering the overall MIH prevalence of ~10% in the Munich area and the fact that fewer than 10% of all MIH-affected teeth exhibit enamel breakdown or MIH-related restorations,[2,34] it becomes obvious that the number of eligible subjects with severely affected MIH teeth is small. In addition, the retrospective study design has limitations as well. First, relevant information, for example patient cooperation, was not documented in the patient records consistently well and, therefore, could not be used for analysis, even though it is probably one of the influential variables for the type of restorative procedure applied. Furthermore, other variables, for example regular recalls, a constant operator and more predefined selection criteria for each restorative procedure, which typically will be controlled within a prospectively designed clinical study, could not be considered. In addition, details of the baseline dental status or specific information of each treatment, for example number of surfaces, could not be reconstructed retrospectively, which is resulting in a lack of information. Furthermore, treatment decisions were made individually on the basis of defect size, cooperation, compliance, patients' needs as well as parental consent and, therefore, did not follow a strict and standardized protocol. Due to these individually varying aspects, the heterogeneity of the groups might be high and, therefore, the generalizability of the results is limited. Apart from that, our range of restorative procedures is limited, and other institutions or dentists may prefer different treatment strategies. Nevertheless, its practice-based design could help paediatric dentists, who are involved in the dental care of MIH patients, to identify adequate treatment procedures for managing MIH-related hard tissue breakdowns.

5 | CONCLUSION

Conventional composite restorations and CAD/CAM ceramic restorations placed on MIH-affected teeth after cavity preparation were associated with moderate-to-high survival rates. In contrast, non-invasive composite and, especially, GIC restorations without preparation, which were predominately used in less cooperative children, were linked to lower survival rates but may help to protect disintegrated hard tissue and increase cooperativeness of the patients until they are mature enough to cope with the implementation of more invasive but long-lasting treatment options.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest with respect to the authorship or publication of this article.

AUTHOR CONTRIBUTIONS

RH and JK developed the study design; KB and JP contributed to the data acquisition; YK and TL analysed the data; RH, JK, and TL interpreted the data and led the writing of the manuscript. All authors approved the manuscript.

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