ORIGINAL RESEARCH

1-year Results of Molar Incisor Hypomineralization-affected Cases Treated with Silver Modified Atraumatic Restorative Treatment: A Retrospective Study

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Abstract

Aim and background: Silver-modified atraumatic restorative treatment (SMART) can be an alternative method for molar incisor hypomineralization (MIH)-affected cases. The purpose of this study was to assess whether tooth location and cavity preparation affect the clinical success of MIH-affected permanent molars treated with the SMART technique.

Materials and methods: Modified United States Public Health Service criteria were utilized for the analyzes. The clinical records (3, 6, and 12 months) of 19 MIH-affected cases (6–12 years; no spontaneous pain and percussion/palpation sensitivity) treated with the SMART technique were assessed. The groups were allocated based on tooth location (mandibular-maxillary) and cavity preparation (class 1–2). The Fisher exact the Chi-squared test was utilized, and the *p*-value < 0.05 was accepted as statistically significant.

Results: Overall success rates were 94.7% at 3 and 6 months and 52.63% at 12 months. Clinical success did not differ statistically regarding location ($p > 0.05$). The class 1 cavity preparation group was found to be significantly more successful at the 12-month assessments ($p = 0.033$).

Conclusion: The class of cavity preparation may affect the success of the treatment in long-term assessments. The SMART technique, especially in class 1 occlusal restorations, can be recommended as a short-term alternative to traditional treatment methods for MIH-affected cases.

Keywords: Atraumatic restorative treatment, Hypomineralization, Silver diamine fluoride.

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Introduction

The condition where demarcated opacities ranging from white to yellow–brown appear in one to four permanent first molars and often in an incisor was defined as molar incisor hypomineralization (MIH) in 2001. Since that date, the etiology and treatment approaches have been studied and widely discussed.[1] Despite the past 22 years, no consensus has been reached on the etiology and treatment of MIH-affected cases. However, MIH is known as a congenital hypomineralization. The prevalence of MIH ranges between 20 and 40%, and this difference is usually attributed to geographic variations, changes in study populations, and the tools used to assess the disease.[2]

The severity of hypomineralization varies from white–yellow and yellow–brown discoloration to enamel breakdown due to quantitative deficiencies. The hypomineralized tissues are reported to contain less calcium and phosphate, have decreased hardness and elasticity, and exhibit increased porosity, making the surfaces predisposed to biofilm and caries formation.[3,4] The affected teeth are reported to require 5–10 times more dental treatment compared to the sound ones.[5]

The treatment procedure for a hypomineralized tooth may be challenging due to the sensitivity of the affected tissue, concerns about determining the extent of the cavity, and issues regarding adhesion. To overcome these problems, minimally invasive treatment (MIT) approaches can be recommended. MIT is a popular approach in current dental practices that aims to preserve tooth structure and tissues in their natural form. Atraumatic restorative treatment (ART), with less effect on enamel and dentin removal, is one of the most popular MIT approaches. This method is oriented toward removing the affected tissue using hand tools like excavators without drilling and restoring the tooth with glass ionomer cement (GIC) application.[6] During the COVID-19 pandemic, concerns about reducing aerosol dissemination and the need for treatment approaches that do not involve rotary instruments have come to the fore. Silver diamine fluoride (SDF) is a noninvasive caries-arresting agent that exerts its activity by releasing silver and fluoride ions when applied to the carious tissue.[7] SDF has various advantages, including eliminating the need for local anesthesia and instrumentation with rotary systems; hence, it can be

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considered a painless application and a safe technique that can even be used during pandemics. However, this technique still has the disadvantage of discoloration due to the blackening effect of silver ions.[8,9]

Silver diamine fluoride, known for its ability to promote fluorohydroxyapatite formation, is advocated for treating MIH-affected cases.[10,11] In the silver-modified atraumatic restorative treatment (SMART) technique, carious tissue is treated using SDF and subsequently restored with GIC.[5] Considering the adhesion problems between MIH-affected tissues and resin restorative materials, the choice of GIC application, which chemically adheres to enamel and dentin, seems to be a logical decision. GIC also provides the advantage of masking the blackening effect of SDF treatment. This approach, which includes caries arrest, fluoride release, and desensitizing properties, demonstrates beneficial effects on tissues affected by MIH. SMART can favorably be preferred in the treatment of these cases.[7] Although high-viscosity GIC is the choice of restorative material, conventional GIC also has the potential to be an alternative.[6]

Systematic reviews have highlighted SDF's success in caries arrest.[12] However, studies assessing the effectiveness of the SMART technique in treating MIH cases are limited.[9–12] In response to this gap in the literature, the current study aimed to assess whether tooth location and type of cavity preparation affect the clinical efficacy of the SMART technique in MIH-affected permanent molars.

Materials and Methods

Ethical Consideration

The study was approved by the Scientific Research Ethics Committee (2022-330, 11.22.2022) and conducted in line with the Helsinki Declaration with all revisions.

Case Selection and Sample Size Analyzes

Patients treated with the SMART technique at the pediatric dentistry clinics of the University of Health Sciences, Faculty of Dentistry between 1st September 2021 and 1st June 2022, had their records reviewed before analysis. According to the clinical records, the MIH-affected teeth (showing no spontaneous pain and sensitivity to percussion/palpation) treated with the SMART technique were included in the study. Patients with systemic diseases, teeth restored with the SMART technique but with <1-year follow-up period, records lacking information, or images with low resolution were excluded from the study. The treated molars had white–yellow and yellow–brown lesions.[1] The GIC (R&D Series Nova Glass F, Imicryl, Konya, Türkiye) was applied one week after the SDF (Kids-e-Dental, Mumbai, India) application to minimize the risk of discoloration.[6] The caries excavation was performed by rotary instruments for the enamel removal and selective caries excavation for the removal of dentinal caries. Considering the inclusion criteria, 19 MIH-affected molars of patients aged between 6 and 12 were included in the study. A power analysis (G*Power 3.1.9.4) was also performed regarding the previous literature, and this sample size was found acceptable with 90% power and 0.4 effect size.

Success Criteria

The analysis utilized the modified United States Public Health Service (USPHS) criteria scale[13], which is the established method for assessing the survival of dental restorations based on criteria such as retention, marginal adaptation, marginal discoloration, and the presence of secondary caries. Since this study was retrospective, evaluations of the restorations were conducted using recorded images. Initial images taken immediately after treatment and follow-up images at 3, 6, and 12 months were utilized for the analysis.

A pediatric dentist with >3 years of experience analyzed the images, and the scores were recorded. Another colleague with 10 years of experience was also recruited for the analyzes, and consensus was reached for each image.

The modified USPHS criteria were evaluated using the terms "Alpha," "Bravo," and "Charlie." The term "Alpha" represents the highest clinical level, while "Bravo" indicates clinical success with no need for any intervention, although deformities can be detected. The "Charlie" designation signifies clinical failure and indicates a need for replacement or repair of the restoration. The scoring of the modified USPHS criteria is as follows[10]:

- Retention: Each image was scored as either Alpha (restoration present), Bravo (partial loss of restoration, however, clinically acceptable), or Charlie (clinically unacceptable partial-total loss of restoration).
- Marginal adaptation: Teeth were scored as either Alpha (continuity at the margin), Bravo (slight discontinuity at the margin), or Charlie (marginal defects requiring replacement).
- Marginal discoloration: Images were scored as either Alpha (no discoloration), Bravo (superficial discoloration), or Charlie (extensive discoloration of the margins extending to the pulp).
- Seconder caries: The images were scored as either Alpha (caries absent) or Charlie (caries present).

The teeth labeled Alpha and Bravo are categorized as successful, whereas those labeled Charlie are placed in the unsuccessful cases group. The treated teeth were classified into groups according to their location (mandibular or maxillary) and the type of cavity (class 1/occlusal or class 2/proximal). Teeth scoring Charlie for any of the criteria were excluded from the study, and evaluations were performed on images of the remaining cases.

Statistical Analysis

The statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) (Version 20.0, Statistical Package for the Social Sciences, IBM Inc., Chicago, Illinois, United States of America). Demographic characteristics were presented in terms of counts and proportions. The Fisher Exact Chi-squared test was used to determine the association between the groups. The intraclass correlation coefficient (ICC) was computed to evaluate the reliability of both intra- and interexaminer measurements. A significance level of ($p < 0.05$) was used to determine statistical significance.

Results

A total of 19 patients, 11 (57.9%) boys and 8 (42.1%) girls, were included in the study. While 42.1% of the patients were 9 years old, the proportion of 7-year-old and 10-year-old patients was equal (21.1%). The number of teeth studied in the maxilla and the mandible was 14 (73.7%) and 5 (26.3%), respectively. Class 2 had the highest frequency with 14 (73.7%), while the frequency of class 1 was 5 (26.3%) (Table 1).

The clinical performance of the SMART technique and the clinical-radiographical images of selected cases are shown in Table 2 and Figure 1. Since the data on retention, marginal adaptation, marginal discoloration, and secondary caries were observed at the same frequencies according to the location and cavity preparation, Chi-squared tests for these variables resulted in the same outcomes. Therefore, these results are presented in the same tables for each parameter (Tables 3 and 4).

The interexaminer reliability for the modified USPHS criteria was high, with the intraclass ICC between the measurements being at least 0.965. The results of the Chi-squared test performed to examine whether the treatment success for retention, marginal adaptation, marginal discoloration, and secondary caries differed in terms of location (mandibular-maxillary) are given in Table 3. Accordingly, while the percentage of successful treatment was 94.7% at the 3- and 6-month assessments (n = 18), this rate was 52.6% (n = 10) at the 12-month assessment. At the assessments of 3, 6, and 12 months, the differences between the groups regarding the rate of successful treatment were not statistically significant ($p > 0.05$) (Figs 1 and 2).

The results of the Chi-squared test performed to examine whether the treatment success for retention, marginal adaptation, marginal discoloration, and secondary caries differed in terms of cavity preparation (class 1–2) are given in Table 4. At 3 and 6 months, there was no statistically significant relationship between treatment success and cavity preparation ($p > 0.05$). At the 12-month assessment, a statistically significant relationship was determined between the groups compared ($p = 0.033$) (Fig. 1).

Discussion

The outcomes indicated that while there was a high rate of clinical success in the initial 6-month follow-up, this level of performance was not sustained in subsequent periods. Nevertheless, the findings demonstrated an adequate level of treatment efficacy over the 12-month follow-up period. Statistically, class 1 occlusal restorations exhibited superior clinical outcomes compared to class 2 restorations. However, there was no significant difference in outcomes based on the location of the treated tooth.

In the literature, as mentioned before, there is no consensus on the appropriate treatment choices for MIH-affected cases. These patients usually have cooperation problems due to increased hypersensitivity, and concerns about adhesion to hypomineralized tissue are among the most mentioned drawbacks of the treatment process for MIH-affected teeth.[14] To overcome these problems, SMART, with the advantages of SDF and GIC applications, comes to the fore.[4] The literature review has uncovered an absence of data regarding the effect of the SMART approach on the lifespan of the cases.[15] In this context, this study aimed to evaluate the success rate of SMART-applied cases conducted in our clinics, particularly during the pandemic.

The study was performed on clinical records. The recorded images and anamnesis were analyzed by two specialists. The modified USPHS criteria were utilized for evaluations. USPHS is a tool developed to analyze restoration features such as color differences, secondary caries, adhesion properties, and marginal integrity and has been widely preferred in previous studies.[10,16] Various treatment protocols can be preferred for caries removal of MIH-affected teeth, and selective removal of soft dentin to avoid pulp perforation is one of the most recent approaches.[17] In the current study, following the removal of enamel by rotary instruments, carious dentin was removed by selective excavation, and affected dentin was left

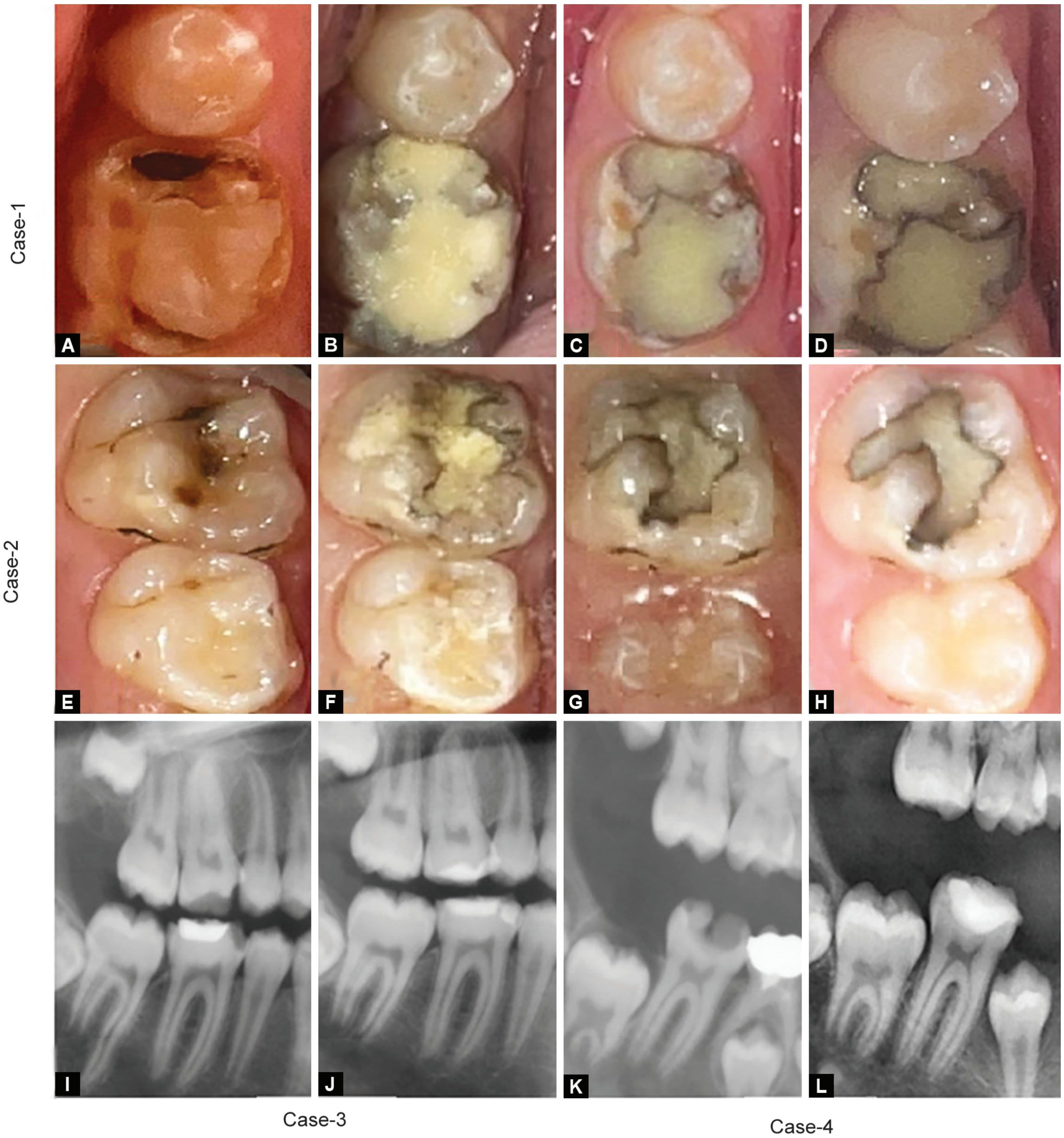
Table 2: Demographic values

	Category	*Frequency (n)*	*%*
Gender	Female	8	42.1
	Male	11	57.9
Age	7	4	21.1
	9	8	42.1
	10	4	21.1
	11	3	15.8
Tooth number	16	8	42.1
	26	6	31.6
	36	2	10.5
	46	3	15.8
Location	Mandibular	5	26.3
	Maxillary	14	73.7
Cavity class	Class 1	5	26.3
	Class 2	14	73.7

Table 1: Clinical performance of SMART technique according to the modified USPHS criteria

		Follow-up		
		3 months	*6 months*	*12 months*
Modified USPHS criteria	*USPHS scores*	*Total (n = 19) n (%)*	*Total (n = 18) n (%)*	*Total (n = 18) n (%)*
Retention	A	18 (94.7)	18 (100)	10 (55.6)
	B	–	–	–
	C	1 (5.3)	–	8 (44.4)
Marginal adaptation	A	17 (89.4)	9 (50)	5 (27.8)
	B	1 (5.3)	9 (50)	5 (27.8)
	C	1 (5.3)	–	8 (44.4)
Marginal discoloration	A	–	–	–
	B	18 (94.7)	18 (100)	10 (55.6)
	C	1 (5.3)	–	8 (44.4)
Secondary caries	A	18 (94.7)	18 (100)	10 (55.6)
	C	1 (5.3)	–	8 (44.4)

A, Alpha; B, Bravo; C, Charlie



Figs 1A to L: (A to D) Case 1, initial 3-, 6-, and 12-month follow-up images of an affected mandibular first molar with a cavity design of class 2; (E to H) Case 2, initial 3-, 6-, and 12-month follow-up images of an affected maxillary first molar with a cavity design of class 1; (I and J) Case 3, initial and 12-month follow-up radiographical images of a mandibular case; (K and L) Case 4, initial and 12-month follow-up radiographical images of a mandibular case

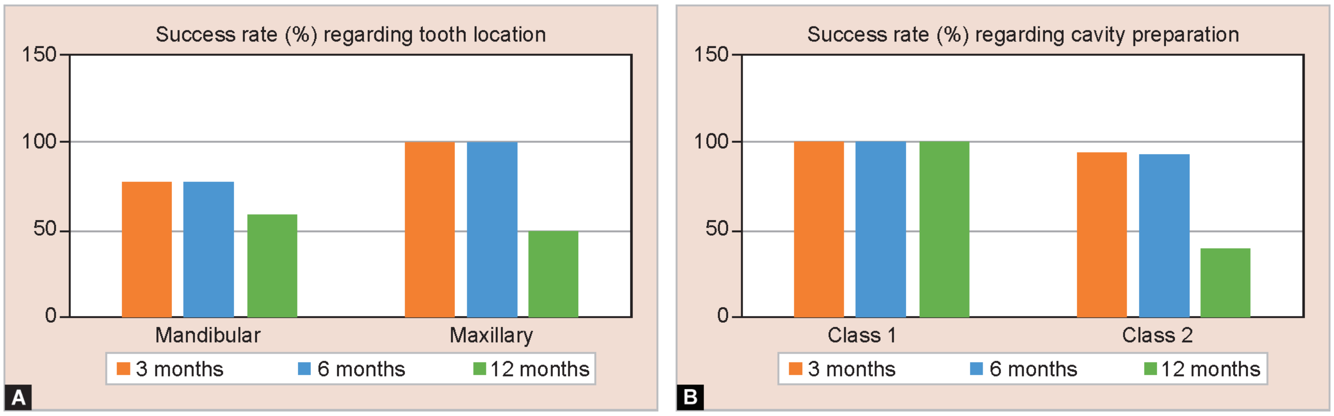
Table 3: Chi-squared test results of relation between retention, marginal adaptation, marginal discoloration, and secondary caries success and tooth location

		Month 3		*Month 6*		*Month 12*	
	Treatment	*n*	*%*	*n*	*%*	*n*	*%*
General	Successful	18	94.7	18	94.7	10	52.6
	Failed	1	5.3	1	5.3	9	47.4
Mandibular	Successful	4	80	4	80	3	60
	Failed	1	20	1	20	2	40
Maxillary	Successful	14	100	14	100	7	50
	Failed	0	0	0	0	7	50
p-value		0.263		0.263		1.00	

Table 4: Chi-squared test results of relation between retention, marginal adaptation, marginal discoloration, and secondary caries success and cavity preparation

		Month 3		*Month 6*		*Month 12*	
	Treatment	*n*	*%*	*n*	*%*	*n*	*%*
General	Successful	18	94.7	18	94.7	10	52.6
	Failed	1	5.3	1	5.3	9	47.4
Class 1	Successful	5	100	5	100	5	100
	Failed	0	0	0	0	0	0
Class 2	Successful	13	92.9	13	92.9	5	35.7
	Failed	1	7.1	1	7.1	9	64.3
p-value		1.00		1.00		0.033*	

*$p < 0.05$



Figs 2A and B: At 3, 6, and 12 months, the rates of treatment success regarding tooth location and cavity preparation

near the pulp considering the lesion depth and the degree of tooth hypersensitivity. In this technique, the elimination of local anesthesia is also an advantage, considering the possible chronic pulpal inflammation that complicates the anesthesia procedure.[17] Accordingly, the selective caries-removal technique was performed following the removal of enamel by rotary instruments, and the cavities were restored with conventional GIC subsequent to SDF application.

Different concentrations of SDF can be identified in the literature, with a 38% concentration being highly suggested. In a previous study, researchers reported that the solution with a concentration of 38% SDF was more efficacious in arresting caries compared to the solution with 12% SDF.[18] Hence, a 38% SDF solution was preferred in the current study without the addition of potassium iodide (KI), considering the inhibitory effect of KI on the antibacterial activity of the SDF solution.[19]

Adhesion of resin-containing restorative materials to hypomineralized enamel revealed lower bonding success compared to intact enamel.[20] de Souza et al. reported that the 18-month survival rates of resin restorations with self-etch and total-etch adhesives after conservative removal of hypomineralized enamel were 68.4 and 54.6%, respectively, in pediatric patients aged between 6 and 8 years.[21] Accordingly, GIC placement following SDF application is recommended in cases with severe MIH to enhance the caries-arresting effect of silver ions and mask the discoloration caused by SDF application.[15] GIC can be used in various forms, such as conventional powder-liquid and injectable high-viscosity GIC. In the current study, the analyzed cases were restored with conventional GIC that was mixed manually. Manual manipulation of GIC may cause pore formation, which can decrease the resistance of the material and shorten the restoration's life.[22] The failure rate of the long-term results in the current study might be related to this situation, and different results might be observed if a high-viscosity GIC cement had been preferred.

Ballıkaya et al. conducted a similar study wherein they compared the clinical success of SMART and SDF-only applications in MIH-affected molars over a period of 12 months. The effect of these treatments on reducing hypersensitivity was also analyzed. The outcomes of the study revealed that the survival rate at 12 months was 88.7% on occlusal surfaces and 58.8% on palatal surfaces. The researchers also concluded that SMART and SDF-only applications have similar effectiveness in caries prevention and reducing hypersensitivity.[10] The current study also shows similarity with the results of this previous study, with 100% success for class 1 occlusal restorations and 35.7% success for class 2 restorations over the 12-month period. This reveals the higher success rate of occlusal restorations compared to proximal or palatal surfaces.

Durmus et al. assessed the 2-year survival rate of high-viscosity GIC in MIH-affected teeth. The results of the study revealed that 14% of the cases showed secondary caries. The rates for Bravo scores regarding USPHS criteria were as follows—14% for marginal adaptation, 9% for retention, and 13% for marginal discoloration.[17] In the current study, as a result of a 1-year follow-up, 55.6% of the cases were considered successful with an Alpha score in terms of retention and a Bravo score in terms of marginal discoloration. However, it was determined that secondary caries developed in 44.4% of the cases. Differences in clinical success between the previous study and the current one can be attributed to the use of high-viscosity GIC in the previous study, while conventional GIC was used in the current one. Furthermore, in the current study, the percentage of cases with a Charlie score regarding marginal adaptation was 44.4%, which could also affect the development of secondary caries.

In a prospective cohort study, it was reported that ART restorations had the potential to enhance the short-term prognosis of teeth with MIH after 12 months of follow-up. GIC was declared a good option for these cases due to its features such as chemical adhesion, mineralization-enhancing capacity, and relief of hypersensitivity. In this study conducted by Fragelli et al., MIH-affected molars were restored with hand-mixed high-viscosity GIC. Accordingly, the survival rate of GIC restorations was reported to be 78.7% at 12 months and 91.7% at 6 months.[23] Grossi et al. presented a survival rate of 98.3% at the 12-month follow-up when the cases were treated with hybrid GIC.[24] Durmus et al. has declared the survival rate as 94%.[17] The rate of providing restoration integrity in molars restored with GIC was found to be higher in occlusal restorations, and these results support the outcomes of the current study.

Puwanawiroj et al. declared that SDF did not cause an adverse effect on the adhesion between GIC and carious primary dental tissues.[18] Schraverus et al. highlighted that glass ionomer sealants are able to prevent dental caries but are not successful in preventing post-eruptive breakdown.[25] According to the 12-month results of the current study, 52.6% of the cases were successful in terms of retention and marginal adaptation. These outcomes, with an acceptable success rate, are also consistent with the results of previous similar studies.

This was a retrospective archive study, and the treatment procedure was not planned. The analyzed cases were treated during the pandemic, with the main aim being to provide a solution for MIH-affected teeth under conditions that required minimal use of rotary instruments to reduce aerosol and decrease treatment sessions. The ideal restorative material choice for these cases was not provided due to clinical restrictions, and conventional GIC was used. The number of cases was also limited to patients who were admitted to our clinics with MIH-affected teeth during the pandemic. Studying with a larger population and using injectable GIC might yield different outcomes. Extending the follow-up period could also provide additional insights. These factors can be considered limitations of the current study.

Conclusion

Considering the constraints of the present study, it can be inferred that the SMART technique offers effective short-term outcomes and represents a nonaerosol treatment alternative for managing MIH-affected carious teeth, particularly in class 1 occlusal restorations. However, this treatment approach cannot be recommended for long-term class 2 restorations. Given the lack of consensus on treatment approaches and the difficulties encountered in caries removal and adhesion in MIH-affected cases, the SMART technique appears to be a preferable treatment choice for short-term applications. To evaluate the restoration success of the SMART technique and the long-term clinical survival of MIH-affected cases, randomized controlled clinical studies should be conducted.

Author Contributions

M A and C B provided the opinion; M A S and M B D S collected and analyzed the data; and C B and M B D S wrote the first draft. M A reviewed the manuscript.

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