Section: Dentistry

Original Research Article

SURGICAL AND ORAL BIOLOGICAL EFFECTS OF GIC (GLASS IONOMER CEMENT) IN PULPOTOMIES/ PULPECTOMIES IN PAEDIATRIC AND OPERATIVE DENTISTRY

Tanveer Ahmed Siddiqui[1], Rabia Iftikhar Shinwari[2], Sadiqa Hanif[3], Saadia Bano Lone[4], Ijaz Ali Shah[5], Bushra Ghani[6]

[1]Assistant Professor, Department of Paediatric Dentistry, Karachi Metropolitan University, Karachi, Pakistan
[2]MPhil Scholar, Department of Oral Biology, Khyber Medical University, Peshawar, Pakistan
[3]House Officer, Department of Paediatric Dentistry, Shaheed Zulfikar Ali Bhutto Medical University, Islamabad, Pakistan
[4]Assistant Professor, Department of Science of Dental Materials, Rashid Latif Dental College, Lahore, Pakistan
[5]Demonstrator, Department of Oral and Maxillofacial Surgery, HBS Medical and Dental College, Islamabad, Pakistan
[6]Senior Dental Surgeon, Dr. Ruth K.M Pfau Civil Hospital, Karachi, Pakistan

Received *: 04/06/2026*
Received in revised form *: 12/08/2026*
Accepted *: 21/08/2026*

Corresponding Author:
Dr. Rabia Iftikhar Shinwari,
MPhil Scholar, Department of Oral Biology, Khyber Medical University, Peshawar, Pakistan.
Email: rabiaiftikhar208@yahoo.com

DOI: 10.70034/ijmedph.2026.3.724

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 4683-4692

ABSTRACT

Background: Glass ionomer cement (GIC) is commonly used in paediatric and operative dentistry because of its chemical adhesion to tooth structure, fluoride release, biocompatibility, and relatively simple clinical handling. Its performance following pulp therapy is influenced not only by the quality of the coronal seal but also by the type of pulpotomy medicament, pulpectomy disinfection protocol, and obturating material used. Therefore, evaluation of GIC following pulp therapy should consider the complete treatment protocol rather than the restorative material in isolation. The objective is to evaluate the surgical, restorative, and oral biological effects of high-viscosity conventional glass ionomer cement following pulpotomy and pulpectomy in paediatric patients.

Materials and Methods: This prospective clinical study included 75 paediatric patients with 75 primary teeth treated between January 2025 and June 2025 at Shaheed Zulfikar Ali Bhutto Medical University, Islamabad. Pulpotomy or pulpectomy was performed according to clinical and radiographic indications. In pulpotomy cases, mineral trioxide aggregate (MTA) was used as the pulpotomy medicament. In pulpectomy cases, root canals were irrigated with 1% sodium hypochlorite followed by sterile normal saline and obturated with a resorbable calcium hydroxide–iodoform-based paste. All treated teeth were subsequently restored with high-viscosity conventional glass ionomer cement, specifically Fuji IX GP Extra (GC Corporation, Tokyo, Japan). Postoperative pain, tenderness, swelling, sinus tract formation, mobility, gingival inflammation, plaque accumulation, restoration integrity, recurrent caries, and radiographic changes were evaluated during follow-up. Overall treatment success was based on combined clinical, restorative, and radiographic criteria. Chi-square or Fisher's exact test was used to assess statistical associations, with $p<0.05$ considered statistically significant. The original abstract described the procedures only as pulpotomy/pulpectomy followed by GIC restoration, so the bold material details are the main additions.

Results: Of the 75 treated teeth, 43 (57.3%) underwent pulpotomy and 32 (42.7%) underwent pulpectomy. At three months, 70 (93.3%) teeth were asymptomatic. Healthy gingiva was observed around 61 (81.3%) restorations, while 64 (85.3%) GIC restorations remained completely intact. Acceptable marginal adaptation was found in 66 (88.0%) teeth. Overall clinical success was 90.7%, with success rates of 93.0% for pulpotomy and 87.5% for

pulpectomy; the difference was not statistically significant (p=0.421). Treatment success was significantly higher among teeth with acceptable GIC restorations than among those with unsatisfactory restorations (97.0% vs. 44.4%, p<0.001). Adverse gingival or plaque responses were also significantly more frequent around compromised restorations (p=0.003). These figures are unchanged from your original abstract.

Conclusion: A standardized pulp-therapy protocol using MTA for pulpotomy, calcium hydroxide–iodoform paste for pulpectomy obturation, and high-viscosity conventional GIC as the definitive coronal restoration demonstrated favorable short-term clinical, restorative, and oral biological outcomes in primary teeth. The integrity of the final GIC restoration was strongly associated with treatment success, emphasizing the importance of maintaining an effective coronal seal. However, the observed outcomes should be interpreted as the combined effect of appropriate pulp therapy, biological pulp-treatment materials, microbial control, and restorative integrity rather than as an effect of GIC alone. Longer-term comparative studies are required to determine whether different pulpotomy medicaments, obturating materials, and GIC formulations influence treatment outcomes.

Keywords: Glass ionomer cement; high-viscosity GIC; mineral trioxide aggregate; calcium hydroxide–iodoform paste; pulpotomy; pulpectomy; paediatric dentistry; primary teeth; coronal seal; oral biological response.

INTRODUCTION

Pulp therapy plays an important role in paediatric dentistry because if caries in primary teeth is left untreated, it can lead to pulpal inflammation, necrosis, pain, infection and premature tooth loss. Preserving the primary teeth until they naturally fall out is crucial for mastication, phonetics, esthetics, arch length and proper guidance for the eruption of permanent teeth. Pulpotomy or pulpectomy may be performed to maintain an affected primary tooth and preserve it for function and symptom-free occlusion depending on the extent of pulpal involvement.[1-3]

Pulpotomy is usually indicated when the coronal pulp is involved but the radicular pulp is vital and has no irreversible pathological changes. On the other hand, a pulpectomy is typically done when the inflammation or necrosis has progressed into the radicular pulp and the tooth remains restorable. Successful outcomes of both procedures rely on: accurate diagnosis, proper case selection, microorganism control, removal of diseased pulp tissue, the proper use of medicaments and/or obturating materials, and a long-lasting coronal restoration.[4-6]

The biological response following pulp therapy may also vary according to the medicament or obturating material used. Mineral trioxide aggregate (MTA) is widely used for pulpotomy because of its biocompatibility, sealing ability, and favorable tissue response, whereas pulpectomy success is influenced by effective canal disinfection and the use of a suitable resorbable obturating material. Therefore, the outcome of pulp-treated primary teeth reflects the combined effects of the pulp-therapy material, microbial control, and the quality of the final coronal restoration. This is particularly important when evaluating GIC, because restoration performance should not be interpreted independently of the underlying pulpotomy or pulpectomy protocol.[1-3]

Failure of the coronal seal can allow for bacterial penetration and reinfection of the pulp chamber or root canal system, which will contribute to the failure of the final restoration for pulp treated primary teeth in the long term. The chemical bond to enamel and dentin, fluoride release, and favorable biocompatibility of glass ionomer cement (GIC), particularly high-viscosity conventional formulations, make it a useful restorative material in paediatric dentistry. The properties make GIC especially valuable in children where moisture control and cooperation can be challenging at times.[7,8]

Besides restorative, the GIC may impact the local oral biological environment. Fluoride release can help prevent recurrent caries and an appropriate restoration can minimize the area of plaque retention and leakage of bacteria. Marginal deterioration, surface roughness, partial loss of material or poor adaptation, however, can lead to plaque accumulation, gingival inflammation, recurrent caries, and microbial penetration. Evaluation of GIC following pulp therapy should be based not only on the retention of the restored tooth, but also on the response of the gingiva and periodontal tissues, integrity of the gingival margins, presence of recurrent caries, and radiographic findings.[9,10]

Although GIC is frequently used in paediatric dental practice, there remains a need for clinical studies that simultaneously evaluate its surgical, restorative, and oral biological effects following both pulpotomy and pulpectomy. Many studies focus primarily on endodontic success or restorative survival, while comparatively fewer assess the relationship between restoration integrity and surrounding oral tissue response. Furthermore, because pulp-therapy outcomes may be influenced by the medicament or obturating material used

before final restoration, evaluation of GIC should be interpreted within a clearly defined treatment protocol. Therefore, the present study was conducted to evaluate the clinical, restorative, periodontal, and radiographic outcomes of high-viscosity conventional GIC following standardized pulpotomy and pulpectomy procedures in primary teeth and to determine whether restoration integrity was associated with overall treatment success.

MATERIALS AND METHODS

This prospective clinical study was conducted at Shaheed Zulfikar Ali Bhutto Medical University, Islamabad, from January 2025 to June 2025. The study was designed to evaluate the surgical, restorative, and oral biological effects of glass ionomer cement (GIC) when used as the definitive coronal restorative material following pulpotomy and pulpectomy procedures in primary teeth. Particular attention was given to postoperative clinical symptoms, healing of surrounding oral tissues, periodontal response, restorative integrity, and overall treatment success.

There were 75 children with pulpopathy in primary teeth enrolled in the study. Only one treated tooth was included per patient; thus, the final analytical sample included 75 patients and 75 primary teeth. Eligible children were identified during the study period when they attended the paediatric dental outpatient department. All patients who met the predetermined inclusion criteria were sequentially recruited until the desired number of patients was reached.

Eligible children were those aged around 4-10 years with primary teeth showing signs of pulpotomy or pulpectomy. When there was sufficient coronal tooth structure to restore with GIC and when it was likely that the tooth would be in function for the anticipated follow-up time, teeth were included. The teeth included in the pulpotomy group had vital radicular pulp with no clinical and radiographic evidence of irreversible pulp disease, while the teeth included in the pulpectomy group had some clinical and radiographic evidence of irreversible pulp involvement and/or pulp necrosis but were still restorables. Exclusion criteria included children with systemic illnesses that might affect the healing process, immunocompromised patients, teeth with severe physiological root resorption, non-restorable crowns, high mobility of teeth, extensive furcal and/or periapical bone destruction, and teeth close to the time of natural exfoliation. Patients who were not capable of co-operating with the clinical procedure requested were excluded as were patients whose parents or guardians refused to give consent.

The study was conducted according to accepted ethical principles for research involving children. Written informed consent was obtained from the parent or legal guardian of each participant, while age-appropriate verbal assent was obtained from cooperative children wherever applicable. Patient confidentiality was maintained throughout the study, and all collected data were used solely for research purposes.

A detailed clinical examination was done on each child prior to treatment. A structured data collection form was used to collect demographic data such as age and sex. The tooth, dental arch, presenting complaint, history of pain, swelling, sinus tract formation, tenderness and mobility were documented. Gingival and periodontal tissue condition also was evaluated. Preoperative radiographs were taken whenever clinically necessary to assess the amount of caries, remaining root structure, furcal or periapical changes, pathological root resorption and the relationship of the primary tooth roots to the developing permanent tooth. The final decision of pulpotomy or pulpectomy was based on clinical and radiographic findings.

For teeth indicated for pulpotomy, local anesthesia was administered and the tooth was isolated using appropriate isolation techniques. Carious tissue was removed and an access cavity was prepared. The entire coronal pulp tissue was removed using a sterile excavator or suitable rotary instrument. The pulp chamber was gently irrigated, and bleeding from the radicular pulp stumps was controlled using a sterile moist cotton pellet. After adequate hemostasis had been achieved, mineral trioxide aggregate (MTA) was used as the pulpotomy medicament and was placed directly over the radicular pulp stumps according to the manufacturer's recommended protocol. The use of a standardized pulpotomy medicament was intended to reduce treatment-related variability among pulpotomy cases. Following placement of the pulpotomy medicament, the chamber was adequately sealed and prepared for definitive coronal restoration.

For teeth indicated for pulpectomy, access cavity preparation was performed after local anesthesia and isolation. Necrotic or irreversibly inflamed pulp tissue was removed from the canals using appropriate paediatric endodontic instruments. The canals were irrigated carefully with 1% sodium hypochlorite solution to facilitate microbial reduction and removal of organic debris, followed by sterile normal saline irrigation. Care was taken to avoid extrusion of the irrigating solution beyond the apical region. The canals were subsequently dried using sterile paper points. A resorbable calcium hydroxide–iodoform-based paste, such as Metapex/Vitapex, was used as the obturating material for primary teeth. The material was placed into the prepared canals according to the manufacturer's recommendations, and adequate canal filling was verified clinically and, where indicated, radiographically. Following obturation, the access cavity was sealed before placement of the definitive restoration. The original manuscript had described these only as “suitable endodontic irrigants” and “a resorbable root canal filling

material," so these details are the key additions requested by the reviewer.

High-viscosity conventional glass ionomer cement (GIC), specifically Fuji IX GP Extra (GC Corporation, Tokyo, Japan), was used as the definitive coronal restorative material for all treated teeth. The same GIC formulation was used throughout the study in order to minimize variability related to restorative material composition and handling characteristics. The cement was manipulated strictly according to the manufacturer's recommended powder-to-liquid ratio, working time, and setting instructions. Cavity surfaces were prepared where necessary, and the material was inserted with particular attention to complete adaptation to the cavity walls and margins. The restoration was contoured to reproduce normal tooth anatomy and occlusion was checked after initial setting. Excess material was removed, and, where recommended, the restoration surface was protected against early moisture contamination or dehydration using an appropriate protective coating. Particular emphasis was placed on obtaining an adequate coronal seal because restoration integrity was considered an important determinant of pulp therapy success.

The use of MTA for pulpotomy, calcium hydroxide–iodoform paste for pulpectomy obturation, and a single high-viscosity conventional GIC formulation for the definitive restoration was kept consistent within the respective treatment groups. This standardization was intended to reduce procedural heterogeneity and allow the observed clinical and restorative outcomes to be interpreted in relation to a defined treatment protocol.

Postoperative instructions were provided to parents or caregivers regarding oral hygiene, dietary precautions, and expected temporary discomfort after treatment. They were advised to return promptly if the child developed severe or persistent pain, swelling, fever, or any other unexpected complication. Follow-up clinical examinations were carried out during the early postoperative period and at 1 and 3 months after treatment. At each visit, postoperative pain, tenderness to percussion, swelling, sinus tract formation, abnormal mobility, and other clinical signs of treatment failure were assessed and recorded.

The biological response of the tissues surrounding the GIC restoration was also evaluated during follow-up. Gingival health adjacent to the restoration was categorized as healthy, mildly inflamed, or moderately inflamed based on the presence of redness, edema, and bleeding. Plaque accumulation around restoration margins was assessed clinically. Additional oral biological parameters included bleeding on probing, localized soft-tissue irritation, swelling, and evidence of persistent infection. These findings were recorded to determine whether the condition of the restoration and its marginal adaptation were associated with the biological response of the surrounding gingival and periodontal tissues.

The integrity of the GIC restoration was evaluated clinically at each follow-up visit. Restorations were classified as completely intact and clinically acceptable, showing minor marginal deterioration, or showing partial or complete loss. Marginal adaptation was assessed using visual examination and a dental explorer. Recurrent caries adjacent to the restoration was also recorded. A restoration was regarded as satisfactory when it remained retained, demonstrated acceptable marginal adaptation, showed no clinically evident recurrent caries, and maintained an adequate coronal seal.

Follow-up radiographic examinations were performed where clinically indicated to evaluate the biological response of the treated tooth and surrounding structures. Radiographic success was defined as the absence of newly developed or progressive furcal or periapical radiolucency, pathological root resorption, or progressive bone destruction. New or worsening furcal or periapical pathology, pathological internal or external root resorption, or other radiographic evidence of persistent infection was regarded as an unfavorable outcome.

Overall treatment success was determined using combined clinical, restorative, and radiographic criteria. A treated tooth was classified as successful when it remained asymptomatic and functional, with no spontaneous or persistent pain, swelling, sinus tract formation, pathological mobility, progressive radiographic pathology, or clinically unacceptable GIC restoration. Treatment failure was defined by the presence of one or more major adverse findings, including persistent or recurrent pain, swelling, sinus tract formation, pathological mobility, progressive radiographic pathology, need for retreatment or extraction, partial or complete GIC loss, unacceptable marginal breakdown, or recurrent caries.

All clinical findings were recorded on a structured proforma developed for the study. To minimize measurement variability, the same predefined clinical and radiographic assessment criteria were applied to all participants. Whenever possible, follow-up examinations were performed by the same calibrated examiner or by clinicians trained to use standardized assessment criteria. Completed data collection forms were routinely checked for missing or inconsistent information before data entry.

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS), version 26. Continuous variables such as age were summarized using mean and standard deviation or median and interquartile range, depending on the distribution of the data. Categorical variables, including sex, type of pulp therapy, tooth location, postoperative symptoms, gingival response, plaque accumulation, restoration integrity, radiographic findings, and treatment success, were presented as frequencies and percentages. The Chi-square test was used to assess

associations between categorical variables, while Fisher's exact test was applied when expected cell frequencies were small. Treatment success was compared between pulpotomy and pulpectomy groups, and the association between GIC restoration integrity and overall treatment success was assessed. The relationship between restoration condition and adverse gingival or plaque responses was also statistically evaluated. A p-value of <0.05 was considered statistically significant.

RESULTS

Seventy-five paediatric patients, with 75 primary teeth, who underwent pulpotomy and/or pulpectomy and were restored with glass ionomer cement were included in the analysis. The mean age of the participants was 6.8 ± 1.7 years, ranging from 4 to 10 years. Of the total participants, 41 (54.7%) were boys and 34 (45.3%) were girls. The 44 (58.7%) treated teeth were the mandibular primary molars and 31 (41.3%) were maxillary primary molars. A total of 43 (57.3%) teeth received pulpotomy while 32 (42.7%) teeth received pulpectomy.

Table 1: Baseline characteristics of the study participants and treated teeth

Variable	Frequency (n)	Percentage (%)
Total participants/teeth	75	100.0
Sex		
Male	41	54.7
Female	34	45.3
Age group		
4–6 years	31	41.3
7–8 years	29	38.7
9–10 years	15	20.0
Arch involved		
Maxillary	31	41.3
Mandibular	44	58.7
Type of pulp therapy		
Pulpotomy	43	57.3
Pulpectomy	32	42.7

In the first postoperative examination, 16 (21.3%) patients complained of mild pain and 59 (78.7%) patients were not experiencing pain. There was significant reduction in the frequency of postoperative pain over the follow-up period with 6 (8.0%) children reporting pain at 1 month and 3 (4.0%) children at 3 months. In 5 (6.7%) cases, swelling was noted in early follow up, and in 2 (2.7%) cases at 3 months. In the same way, tenderness to percussion, which was 13.3% (10 cases) initially was reduced to 4.0% (3 cases) at the final assessment.

Table 2: Clinical outcomes following pulpotomy/pulpectomy and GIC restoration

Clinical parameter	Initial follow-up n (%)	1 month n (%)	3 months n (%)
Postoperative pain	16 (21.3)	6 (8.0)	3 (4.0)
Tenderness to percussion	10 (13.3)	5 (6.7)	3 (4.0)
Swelling	5 (6.7)	3 (4.0)	2 (2.7)
Sinus tract	3 (4.0)	2 (2.7)	1 (1.3)
Abnormal mobility	4 (5.3)	3 (4.0)	2 (2.7)
Asymptomatic teeth	57 (76.0)	67 (89.3)	70 (93.3)

Overall, oral tissues surrounding the GIC restorations showed good biological response. Healthy gingival tissue with no clinical signs of gingivitis was seen around 61 (81.3%) restorations at 3 months. Eleven (14.7%) cases showed mild gingival inflammation while three (4.0%) cases showed moderate gingival inflammation. In 63 of the treated teeth (84.0%), there was no or little plaque around the margins of the restoration.

Table 3: Oral biological and periodontal findings at three-month follow-up

Parameter	n	%
Gingival response		
Healthy gingiva	61	81.3
Mild inflammation	11	14.7
Moderate inflammation	3	4.0
Plaque accumulation		
Absent/minimal	63	84.0
Moderate	9	12.0
Heavy	3	4.0
Bleeding on probing	8	10.7
Local soft-tissue irritation	4	5.3

Assessment of restorative performance showed that 64 (85.3%) GIC restorations remained completely intact at the three-month follow-up. Minor marginal deterioration without complete restoration loss occurred in 7 (9.3%) cases, while partial or complete restoration failure occurred in 4 (5.3%) cases. Recurrent caries adjacent to the restoration was identified in 5 (6.7%) teeth.

Table 4: Restorative performance of GIC at three months

Restorative outcome	n	%
Restoration completely intact	64	85.3
Minor marginal deterioration	7	9.3
Partial/complete restoration loss	4	5.3
Recurrent caries	5	6.7
Acceptable marginal adaptation	66	88.0
Unsatisfactory marginal adaptation	9	12.0

At the last follow-up period, 67 (89.3%) teeth showed no pathological furcal or periapical changes on radiographic examination. In 5 (6.7%) cases, furcal or periapical radiolucency was identified and in 3 (4.0%) teeth pathological root resorption was observed.

Table 5: Radiographic findings at final follow-up

Radiographic finding	n	%
No pathological radiographic change	67	89.3
Furcal/periapical radiolucency	5	6.7
Pathological root resorption	3	4.0

The overall success rate was 90.7% (68/75), while 7 (9.3%) teeth met one or more of the treatment failure criteria. The success rate for pulpotomy was slightly higher at 93.0% (40/43) than that of pulpectomy (28/32). But the difference obtained between two procedures was not statistically significant (p = 0.421).

Table 6: Treatment success according to type of pulp therapy

Type of treatment	Successful n (%)	Failed n (%)	Total	p-value
Pulpotomy	40 (93.0)	3 (7.0)	43	
Pulpectomy	28 (87.5)	4 (12.5)	32	0.421
Overall	68 (90.7)	7 (9.3)	75	

Table 7: Association of GIC restoration integrity with treatment outcome

Restoration status	Successful n (%)	Failed n (%)	Total	p-value
Acceptable/intact restoration	64 (97.0)	2 (3.0)	66	
Unsatisfactory restoration	4 (44.4)	5 (55.6)	9	<0.001

Teeth with poor restorations also had a higher incidence of gingival inflammation. The 9 teeth with poor marginal integrity had 5 (55.6%) that had moderate level of plaque or clinically obvious gingival inflammation, compared with 9 (13.6%) of the 66 teeth with acceptable restorations. This association was statistically significant (p = 0.003).

Table 8: Relationship between restoration integrity and adverse oral biological response

Restoration status	Adverse gingival/plaque response n (%)	No significant adverse response n (%)	p-value
Acceptable restoration (n=66)	9 (13.6)	57 (86.4)	
Unsatisfactory restoration (n=9)	5 (55.6)	4 (44.4)	0.003

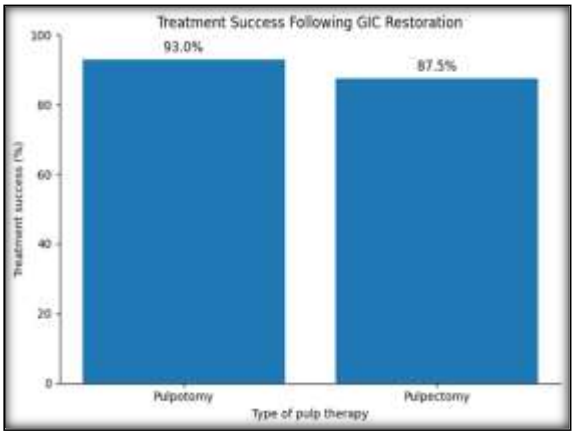

Figure 1: Comparison of treatment success rates following glass ionomer cement (GIC) restoration after pulpotomy and pulpectomy in paediatric patients. Pulpotomy showed a success rate of 93.0%, while pulpectomy demonstrated a success rate of 87.5%.

Overall, the findings indicated that GIC provided satisfactory clinical, restorative, and oral biological outcomes following pulpotomy and pulpectomy. Most treated teeth remained asymptomatic, demonstrated healthy surrounding gingival tissues, and retained satisfactory marginal integrity. The strongest unfavorable pattern was observed among teeth in which the GIC restoration became defective or lost, suggesting that maintenance of an adequate coronal seal was closely associated with successful pulp therapy.

DISCUSSION

The present study evaluated the surgical, restorative, and oral biological outcomes of glass ionomer cement (GIC) restorations following pulpotomy and pulpectomy in 75 primary teeth. Overall, favorable outcomes were observed, with 90.7% of treated teeth meeting the criteria for clinical success at the final follow-up. Postoperative symptoms progressively declined, and by three months, 93.3% of teeth were asymptomatic. These findings indicate that preservation of primary teeth through appropriate pulp therapy followed by an adequately sealed restoration can provide satisfactory short-term clinical outcomes. Maintaining primary teeth until their normal exfoliation is important for mastication, preservation of arch space, speech, and proper development of the permanent dentition. Contemporary paediatric restorative literature similarly emphasizes that the success of pulp-treated primary teeth depends not only on the endodontic procedure but also on the ability of the coronal restoration to prevent reinfection.[11,12] In the present study, a standardized treatment protocol was followed, with mineral trioxide aggregate (MTA) used for pulpotomy, calcium hydroxide–iodoform paste used for pulpectomy obturation, and high-viscosity conventional GIC used as the definitive coronal restoration. Therefore, the observed outcomes should be interpreted as the result of the combined pulp-therapy and restorative protocol rather than the effect of GIC alone.

In clinical success rate, the pulpectomy had lower rate (87.5%) compared to the pulpotomy (93.0%), but not statistically significant (p=0.421). The comparatively favorable outcome of pulpotomy may partly reflect the preservation of healthy vital radicular pulp and the biological properties of MTA, which was used as the pulpotomy medicament in the present study. MTA is widely used in vital pulp therapy because of its biocompatibility, sealing characteristics, and ability to promote a favorable hard-tissue response. In contrast, pulpectomy is generally performed in teeth with more extensive irreversible inflammation or pulpal necrosis, and its outcome can be influenced by the complex morphology of primary root canals, accessory canals, residual microorganisms, irrigation effectiveness, obturation quality, and the initial extent of infection. In the pulpectomy group, 1% sodium hypochlorite was used for canal irrigation to assist microbial reduction and removal of organic debris, while a resorbable calcium hydroxide–iodoform paste was used for canal obturation. These procedural factors may independently influence healing and should therefore be considered when comparing the outcomes of pulpotomy and pulpectomy. Nevertheless, the high success rates observed for both procedures suggest that appropriately selected primary teeth can be maintained in a functional and symptom-free condition when adequate pulp therapy is combined with an effective coronal restoration.[13,14]

An important observation was the restorative performance of GIC. Of the restorations, 85.3% were still intact at 3 months, and 88.0% had acceptable marginal adaptation. A high-viscosity conventional GIC was used consistently as the definitive restorative material in all treated teeth, reducing variation related to differences between GIC formulations.

Glass ionomer materials have several properties that make them especially desirable in paediatric dentistry, such as: chemical bonding to enamel and dentin, fluoride release properties and relatively easy placement, and good biological compatibility. High-viscosity conventional GICs are formulated to provide improved mechanical performance compared with earlier conventional formulations, although their clinical durability remains dependent on cavity design, remaining tooth structure, moisture control, occlusal loading, and correct material manipulation. Traditional GIC, however, might be vulnerable to moisture contamination during early setting and may have less fracture and wear resistance than some of the resin-based restorative materials. Studies highlighted the adhesive, biocompatible, and anticariogenic properties of glass ionomer materials, but acknowledged that these materials also had relatively low toughness and stress resistance to high functional stresses. Laboratory studies also

have shown that resin-modified GIC shows good sealing ability in pulpotomized primary molars. Therefore, the specific GIC formulation used is an important methodological consideration when interpreting restorative survival and marginal integrity.[15,16]

The strongest association observed in the present study was between the integrity of the GIC restoration and overall treatment success. Successful outcomes occurred in 97.0% of teeth with acceptable or intact restorations compared with only 44.4% of those with unsatisfactory restorations ($p<0.001$). This finding reinforces the importance of an effective coronal seal as an essential component of successful pulp therapy. Marginal deterioration may permit saliva, bacteria, and bacterial products to penetrate the restoration–tooth interface, potentially causing recurrent caries and reinfection of the pulp chamber or root canal system. Microleakage and marginal sealing ability differ among restorative materials and even among different formulations within the same material category. The use of high-viscosity conventional GIC in the present study may have contributed to the favorable short-term marginal adaptation observed; however, the strong association between restoration integrity and treatment success does not establish that GIC alone produced the successful pulpal outcome. The biological effects of MTA in pulpotomy cases and adequate chemomechanical disinfection and obturation in pulpectomy cases also contribute to treatment success. Thus, even when pulp therapy is technically adequate, deterioration or loss of the coronal restoration may eventually permit microbial reinfection and compromise the long-term outcome.[17]

Oral biological findings also tended to be favorable. The gingiva around 81.3% of the GIC restored teeth was healthy, while moderate gingival inflammation was observed around 4.0% of the GIC restored teeth. Likewise, minimal to no plaque was seen on majority of teeth. It was however found that adverse gingival or plaque related responses were significantly higher around restorations with compromised marginal integrity (55.6%) than around clinically acceptable restorations (13.6%), $p=0.003$. This finding suggests that the local biological response was closely related to restoration quality and marginal contour rather than simply to the presence of GIC itself. If the space between the teeth is irregular or if the margins are also not good, then there are areas that retain plaque and that oral hygiene is more difficult, that is why local gingival inflammation is encouraged. The value of sealing around the crowns or restorations is also supported by evidence from the paediatric restorative research; crown or restoration margins can be potential areas for plaque accumulation and microleakage. At the same time, the fluoride-releasing and adhesive characteristics of high-viscosity GIC may contribute to a relatively favorable environment around adequately placed restorations by reducing susceptibility to recurrent caries. Nevertheless, these benefits depend on appropriate material handling, good marginal adaptation, and adequate oral hygiene.[18]

Radiographically, 89.3% of treated teeth showed no pathological changes at final follow-up, while 6.7% demonstrated furcal or periapical radiolucency and 4.0% showed pathological root resorption. These findings generally corresponded with the favorable clinical response. However, radiographic outcomes following pulp therapy reflect several biological and procedural factors, including the condition of the radicular pulp, the pulpotomy medicament, effectiveness of canal disinfection, quality and resorbability of the obturating material, and maintenance of the coronal seal. In the present study, MTA was used in pulpotomy cases and calcium hydroxide–iodoform paste was used in pulpectomy cases, both of which may have contributed to the observed radiographic response in their respective treatment groups. Radiographic assessment remains particularly important in primary teeth because treatment failure may develop without obvious clinical symptoms. Furcal or periapical radiolucency, pathological root resorption, and progressive bone changes may indicate persistent or recurrent infection even in an asymptomatic tooth. Therefore, treatment success should be determined using both clinical and radiographic criteria rather than the absence of pain alone.[19-22]

Limitations: The findings of the present study should be interpreted in view of several limitations. The sample size was relatively small, comprising 75 treated teeth, and the follow-up duration of three months was insufficient to determine the long-term survival of either the pulp-treated primary teeth or the GIC restorations. Furthermore, this was not a comparative study of GIC against other definitive restorative materials such as stainless steel crowns, resin-modified GIC, composite resin, or zirconia crowns. Stainless steel crowns, in particular, remain important for pulp-treated primary molars with substantial loss of coronal tooth structure, whereas intracoronal restorative materials may be more appropriate in selected teeth with adequate remaining structure.

Another important limitation is that the study used only one standardized material protocol within each procedure. MTA was used as the pulpotomy medicament, calcium hydroxide–iodoform paste as the pulpectomy obturating material, and high-viscosity conventional GIC as the definitive coronal restoration. Consequently, the study cannot determine whether similar outcomes would have been obtained with alternative pulpotomy medicaments, obturating materials, irrigating protocols, or different GIC formulations. Nor can the independent contribution of the pulp medicament and restorative material to the final outcome be separated. Future randomized comparative studies should directly evaluate

different combinations of pulpotomy medicaments, pulpectomy obturating materials, and restorative GIC formulations, with larger multicenter samples and follow-up periods of at least 12–24 months. Such studies would help determine whether specific interactions between pulp-therapy materials and coronal restorative materials influence long-term clinical, periodontal, restorative, and radiographic outcomes.

CONCLUSION

Glass ionomer cement demonstrated favorable short-term restorative and oral biological performance when used as the definitive coronal restoration following standardized pulpotomy and pulpectomy procedures in primary teeth. The overall treatment success rate was 90.7%, with pulpotomy demonstrating a slightly higher success rate than pulpectomy, although the difference was not statistically significant. Most treated teeth became asymptomatic, retained satisfactory restorations, and demonstrated healthy surrounding gingival tissues and favorable radiographic findings.

The findings should, however, be interpreted in the context of the complete treatment protocol. MTA was used as the pulpotomy medicament, while pulpectomy involved sodium hypochlorite irrigation and obturation with a calcium hydroxide–iodoform-based material, followed by definitive restoration with high-viscosity conventional GIC. Therefore, successful outcomes cannot be attributed to GIC alone but rather to the combined effectiveness of appropriate pulp therapy, biological pulp-treatment materials, microbial control, and maintenance of an adequate coronal seal.

Most importantly, the integrity of the GIC restoration was strongly associated with treatment outcome. Teeth with intact and well-adapted restorations demonstrated substantially higher success and fewer adverse gingival responses than teeth with compromised restorations. These results highlight restoration integrity as an important component of successful paediatric pulp therapy while also emphasizing that the medicament or obturating material used before final restoration may independently influence biological and radiographic healing. High-viscosity GIC may therefore represent a useful definitive restorative option for appropriately selected primary teeth because of its adhesion, fluoride release, biocompatibility, and relatively straightforward clinical handling. Longer-term comparative studies are required to determine whether different GIC formulations and pulp-therapy medicaments produce differences in clinical and radiographic outcomes.

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