Complete Pulpotomy using Biodentine in Mature Permanent Teeth with Symptomatic Irreversible Pulpitis: A Quasi-Experimental Study

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ABSTRACT:

Objective: This quasi-experimental study assessed the clinical and radiographic outcomes of complete pulpotomy using Biodentine in mature permanent molars with symptomatic irreversible pulpitis over a 12-month follow-up period. Methods: Thirty-three mature permanent molars in 30 patients (mean age 25.9 years) diagnosed with symptomatic irreversible pulpitis underwent complete pulpotomy. Hemostasis was achieved within ≤10 minutes using 2.5% sodium hypochlorite. Biodentine was placed over the radicular pulp stumps, followed by a permanent resin-composite restoration after one week. Clinical and radiographic evaluations were performed at 3, 6, and 12 months post-operatively. Success was defined as absence of pain, swelling, sinus tract, tenderness to percussion, pathological mobility, restoration failure, and radiographic evidence of periapical pathology, resorption, or periodontal ligament changes. Results: The overall success rate at 12 months was 94.0% (31/33 molars), with success rates of 100% at 3 months and 97.0% at 6 months. Treatment failure occurred in 6.0% of cases, primarily associated with persistent symptoms or restorative complications. Age, sex, and tooth location (maxillary vs. mandibular) were not significantly associated with treatment outcome ($p>0.05$). Pain resolved rapidly following the procedure, with only 3.0% of patients reporting persistent pain at 12 months. Conclusion: Complete pulpotomy using Biodentine is an effective and minimally invasive treatment option for mature permanent teeth with symptomatic irreversible

pulpitis, demonstrating high clinical and radiographic success rates over a 12-month period.

Keywords: Pulpotomy; Biodentine; Irreversible pulpitis; Vital pulp therapy; Mature permanent teeth; Calcium silicate cement

Introduction

Pulpitis is characterized by pulpal inflammation in response to irritants of microbial, chemical, mechanical, or thermal origin. It is traditionally classified into reversible and irreversible pulpitis based on clinical symptoms and diagnostic findings [1]. However, from a biological perspective, this classification primarily reflects variations in the expression of inflammatory mediators within the pulp tissue [2]. Although pain is a major clinical indicator of inflammation, its intensity or presence does not necessarily correspond with the actual extent of pulpal involvement or the severity of histopathological changes [3].

Caries-induced irreversible pulpitis is frequently characterized histologically by bacterial invasion, necrotic tissue formation, and in some cases micro-abscess development, which ultimately compromises the healing capacity of the pulp. Nevertheless, surrounding areas of the pulp may initiate immune defense mechanisms that restrict the spread of infection, leaving certain portions of pulp tissue relatively free from inflammation or necrosis [3]. If the infected portion of the pulp can be removed before necrosis extends deeper, the remaining healthy pulp may retain its vitality [4].

Histological investigations have demonstrated that inflammation in cases diagnosed as irreversible pulpitis is often confined to the coronal pulp, while the radicular pulp frequently remains free from bacterial invasion and inflammatory changes [5]. These findings highlight the need for a biologically oriented diagnostic approach that more accurately reflects the actual condition of the pulp tissue.

In recent years, the concept of minimally invasive dentistry has significantly influenced clinical decision-making, emphasizing the preservation of natural tooth structures. Complete or coronal pulpotomy involves the removal of the entire coronal pulp followed by placement of a biocompatible material over the remaining pulp tissue at the level of the root canal orifices [6-8]. By removing the inflamed coronal pulp, this procedure eliminates potentially necrotic tissue and reduces pain while preserving the vitality of the radicular pulp [5].

Among currently available bioactive materials, Biodentine (Septodont, France) has gained considerable attention as a calcium silicate-based dentin substitute. Biodentine stimulates the release of transforming growth factor-β1 (TGF-β1), which plays a crucial role in angiogenesis, recruitment of progenitor cells, cellular differentiation, and reparative dentin formation [9]. When placed in direct contact with the pulp, Biodentine preserves pulp vitality while promoting proliferation, migration, and adhesion of pulp stem cells [10]. Compared with earlier calcium silicate cements, Biodentine offers several advantages including easier handling, reduced risk of coronal discoloration, and a shorter setting time [11].

Several clinical studies have reported promising success rates for pulpotomy performed in mature permanent teeth [12-15]. However, further research is required to validate the effectiveness and safety of this approach. Accordingly, this study aimed to evaluate the clinical and radiographic outcomes of complete pulpotomy using Biodentine in mature permanent teeth presenting with signs and symptoms indicative of symptomatic irreversible pulpitis.

Materials and Methods

This in vivo quasi-experimental study was conducted in the Department of Conservative Dentistry and Endodontics, Bangladesh Medical University (BMU), Dhaka, Bangladesh, over a 12-month period. Ethical clearance was obtained from the Institutional Review Board of BMU

prior to study commencement. Written informed consent and assent with parents' consent was obtained from all participants.

Patients of 16-50 years with noncontributory medical history attending the department of Conservative Dentistry and Endodontics at BMU, were considered for the study using purposive sampling. A total of 33 teeth calculated based on a previous study [16] restorable molar tooth with fully matured root, normal probing pocket depth and mobility; having clinical diagnosis of symptomatic irreversible pulpitis but without periapical rarefaction, no signs of pulpal necrosis including sinus tract or swelling were considered as study sample. Teeth indicative pulpal necrosis with presence of sinus tract or swelling, negative response to electric pulp test and teeth with external or internal resorption or calcification were excluded from the study.

Preoperative pulpal and periapical diagnosis was established after history taking and clinical examination including soft tissue palpation, percussion, cold testing (Endo-Ice, Coltene/Whaledent Inc, OH, USA), and electric pulp testing (Parkell, Inc, NY, USA). Periapical radiographs were taken using the parallel technique with a sensor holder. Pain intensity was recorded using a verbal descriptive scale before treatment.

Clinical Procedure

All procedures were performed in a single visit by a single operator following standardized steps: the tooth was anesthetized using local infiltration or nerve block with 2% lidocaine containing 1:80,000 adrenaline. Strict aseptic conditions were maintained using a rubber dam. The tooth and surrounding dam were disinfected with 5% povidone-iodine. Access cavity preparation was performed using a high-speed diamond bur under continuous water cooling. The entire pulp chamber roof was removed, and coronal pulp tissue was amputated down to the level of the root canal orifices using a sterile high-speed long-shank round diamond bur with copious water spray. Cotton pellets saturated with 2.5% sodium hypochlorite (NaOCl) were placed over the pulp stumps with gentle pressure for up to 5-10 minutes. If hemostasis was not achieved after complete pulpotomy with cotton pellet soaked in 2.5% NaOCl within 10 minutes or if there was insufficient bleeding after pulp exposure; the sample was excluded from the study and the procedure was converted to conventional root canal treatment. While once hemostasis was confirmed, a 2-mm thick layer of Biodentine (Septodont, France) was placed over the pulp stumps according to the manufacturer's instructions. After 12 minutes of initial setting, a layer of interim restoration was placed with glass ionomer cement and checked radiograpically. The tooth was finally restored with light-cured composite resin after one week under rubber dam isolation. (Figure 1)

Clinical and radiographic evaluations were performed at 3, 6, and 9 months postoperatively. (Figure 2& 3) Outcomes were determined according to criteria established by Zanini et al. [17] and the European Society of Endodontology [7]. No spontaneous or elicited pain, no soft tissue swelling, absence of sinus tract, no tenderness to percussion, physiological mobility (<1mm), intact restoration with no marginal leakage were considered as clinical success whereas normal width of periodontal ligament space, intact lamina dura, absence of periapical radiolucency, absence of internal/external root resorption, and absence of root canal obliteration with associated symptoms were considered for radiographic success. Any presence of pain, swelling, sinus tract, abnormal mobility, tenderness, restoration failure, or radiographic evidence of apical pathosis, resorption, or loss of PDL integrity was categorized as failure.

Statistical Analysis

Data were analyzed using SPSS version 25 (SPSS Inc., Chicago, USA). Descriptive statistics were expressed as number, frequency, percentages, mean, and standard deviation. Associations between age, gender, tooth location and treatment outcome were analyzed using the chi-square test. A p-value<0.05 was considered statistically significant.

Results

Participant Characteristics

A total of 33 molars in 30 patients (mean age 25.9 years) were included in the study. Preoperative assessment revealed that the majority of affected teeth were located in the mandibular arch (81.8%, n=27), while 18.2% (n=6) were in the maxillary arch. Pain intensity distribution showed 45.5% (n=15) with moderate pain, 42.4% (n=14) with severe pain, and 12.1% (n=4) with mild pain. All patients (100%) experienced pain triggered by cold stimuli, while 90.9% (n=30) reported spontaneous pain and 36.4% (n=12) reported referred pain (Table 1).

Table 1. Preoperative assessment of study participants (n=33)

Variable	Frequency (n)	Percentage (%)
Tooth position		
Maxillary	6	18.2
Mandibular	27	81.8
Pain intensity		
Mild	4	12.1
Moderate	15	45.5
Severe	14	42.4
Cold pain trigger	33	100.0
Spontaneous pain	30	90.9
Referred pain	12	36.4

Treatment Outcomes

At the 3-month follow-up, all 33 patients (100%) demonstrated successful outcomes with no clinical symptoms or radiological abnormalities. At 6 months, the success rate was 97.0% (n=32), with one patient (3.0%) showing persistent pain, tenderness to percussion, and radiographic evidence of widened periodontal ligament space and loss of lamina dura. At 12 months, the success rate remained high at 94.0% (n=31), with two patients (6.0%) showing treatment failure (Table 2&3). One failure was associated with coronal fracture and marginal leakage of the restoration.

Table 2. Clinical and radiographic outcomes at 12-month follow-up (n=33)

Variable	Present n (%)	Absent n (%)
Clinical		
Persistent pain	1 (3.0)	32 (97.0)
Swelling	0 (0.0)	33 (100.0)
Sinus tract	0 (0.0)	33 (100.0)
Tenderness to percussion	1 (3.0)	32 (97.0)
Mobility	0 (0.0)	33 (100.0)
Restoration integrity loss	1 (3.0)	32 (97.0)
Marginal leakage	1 (3.0)	32 (97.0)

Radiographic		
Widened PDL space	1 (3.0)	32 (97.0)
Lamina dura loss	1 (3.0)	32 (97.0)
Periapical radiolucency	0 (0.0)	33 (100.0)

Table 3. Treatment outcome of complete pulpotomy at different follow-up periods (n=33)

Follow-up period	Success n (%)	Failure n (%)
3 months	33 (100.0)	0 (0.0)
6 months	32 (97.0)	1 (3.0)
12 months	31 (94.0)	2 (6.0)

Factors Associated with Treatment Outcome

Age and sex were not significantly associated with treatment outcome ($p>0.05$). Successful cases were predominantly in the 20-30 years age group (41.9%), and females accounted for 67.7% of successful cases (Table 4). Tooth position (maxillary vs. mandibular) also showed no significant association with treatment outcome ($p=0.538$), although mandibular teeth constituted 83.9% of successful cases (Table 5).

Table 4. Association of demographic characteristics with final outcome (N=33)

Variable	Success (n=31) n (%)	Failure (n=2) n (%)	p-value
Age group (years)			
<20	9 (29.0)	0 (0.0)	0.465
20-30	13 (41.9)	2 (100.0)	
31-40	7 (22.6)	0 (0.0)	
41-50	2 (6.5)	0 (0.0)	
Sex			
Male	10 (32.3)	0 (0.0)	0.336
Female	21 (67.7)	2 (100.0)	

Chi-square test; $p<0.05$ considered significant

Table 5. Association between tooth position and final outcome (N=33)

Tooth position	Success (n=31) n (%)	Failure (n=2) n (%)	p-value
Maxillary	5 (16.1)	0 (0.0)	0.538
Mandibular	26 (83.9)	2 (100.0)	

Pain Outcomes

Pain distribution analysis demonstrated a significant reduction in postoperative pain over time. In the immediate postoperative period (within 7 days), only 6.1% (n=2) of patients reported persistent pain. At 3 months, no

patients reported pain (0%). At both 6 and 12 months, only 3.0% (n=1) of patients reported persistent pain (Table 6).

Table 6. Distribution of pain at different follow-up periods (N=33)

Follow-up period	Pain present n (%)	Pain absent n (%)
Immediate postoperative	2 (6.1)	31 (93.9)
3 months	0 (0.0)	33 (100.0)
6 months	1 (3.0)	32 (97.0)
12 months	1 (3.0)	32 (97.0)

Overall, Success Rate

Out of 33 treated cases, 31 (94.0%) achieved successful outcomes, while 2 (6.0%) experienced treatment failure over the 12-month study period (Table 7).

Table 7. Overall treatment outcome (n=33)

Outcome	Frequency (n)	Percentage (%)
Success	31	94.0
Failure	2	6.0
Total	33	100.0

Discussion

The present study demonstrated high success rates for complete pulpotomy using Biodentine in mature permanent teeth with symptomatic irreversible pulpitis, with an overall success rate of 94.0% at 12 months. These findings are higher than those reported by Anta et al. [18] and Linsuwanont et al. [19], who observed an overall success rate of 87% at 12 months. However, the results are slightly lower than those reported by Taha and Abdelkhader [14], who achieved a 98.4% success rate using Biodentine at one year. In contrast, studies by Zhu et al. [20] and Jiménez-Martín et al. [21], reporting success rates of 93% and 94% respectively, are consistent with the present findings. Variations among studies may be attributed to differences in accurately determining the inflammatory status of the pulp and the condition of odontoblasts.

At the 3-month follow-up, all patients demonstrated favorable clinical and radiographic outcomes, yielding a 100% success rate. This aligns with previous studies such as Taha and Khazali [22], which reported high short-term success rates. At 6 months, a slight decline in success rate was observed, with 3.0% of patients reporting persistent pain and tenderness to percussion. Radiographic findings included widening of the periodontal ligament space and loss of lamina dura. Similar trends of gradual reduction in success rates over time have been reported by Kunert et al. [23] and Aguilar and Linsuwanont [24].

The gradual decline in success rate over time may be attributed to residual bacterial contamination, microleakage, or progression of pulpal inflammation in a small proportion of cases. One failure in this study was associated with coronal fracture of the restored tooth, emphasizing the critical importance of achieving a high-quality coronal seal for long-term success of vital pulp therapy [25].

The use of 2.5% sodium hypochlorite (NaOCl) in this study provided effective disinfection of the dentin-pulp interface. Hemostasis was achieved within a maximum of 10 minutes,

consistent with recommendations by Qudeimat et al. [13], the American Association of Endodontists position statement [26], and Duncan et al. [27], although the optimal duration remains debated. NaOCl not only achieves hemostasis through its tissue-dissolving properties but also provides antimicrobial action and removes the smear layer, potentially enhancing the seal of the biomaterial [28].

Demographic factors such as age and gender were not significantly associated with treatment outcomes in this study. Although younger patients may have greater regenerative potential [29], other studies suggest that age does not significantly influence long-term success [23]. Similarly, gender was not found to affect outcomes, consistent with Taha et al. [30], although conflicting findings have been reported by Anta et al. [18]. Tooth location also showed no significant association with treatment outcome, consistent with Shafie et al. [31].

Pain outcomes in the present study showed rapid resolution following pulpotomy, supporting previous findings by Galani et al. [12] and Taha et al. [32]. This rapid pain relief is likely due to reduction in intrapulpal pressure and elimination of inflammatory mediators following removal of the inflamed coronal pulp. In contrast, pain following root canal treatment may originate from instrumentation leading to acute periapical inflammatory response resulting from injury to tissues of mechanical, chemical, or microbial origin [33].

The favorable biological properties of Biodentine have been extensively documented in the literature. Biodentine's high alkaline pH inhibits bacterial growth and promotes odontoblast-like cell proliferation, contributing to its bioactivity and suitability for dentin-pulp complex regeneration [9,10]. Cushley et al. [34] demonstrated in a systematic review that Biodentine and mineral trioxide aggregate (MTA) exhibit significantly higher success rates compared to calcium hydroxide, which has declined in use due to limitations such as poor sealing ability, solubility, and formation of porous reparative dentin that may allow bacterial ingress.

Comparative studies between pulpotomy and root canal treatment further support the effectiveness of pulpotomy in symptomatic irreversible pulpitis cases. Koli et al. [35], Galani et al. [12], and Asgary et al. [36] reported comparable success rates between pulpotomy and root canal treatment over follow-up periods ranging from 1 to 5 years. Systematic reviews further support these findings, with Santos et al. [37] highlighting favorable outcomes of vital pulp therapy in mature permanent teeth. Additionally, Taha et al. [32] demonstrated similar success rates (93%) for both treatments, with significantly lower pain levels in the pulpotomy group.

Study Limitations

Despite the promising results, this study has several limitations. The sample included only molar teeth, and the study design lacked a control group, limiting direct comparison with conventional treatment protocols. The clinical diagnosis of symptomatic irreversible pulpitis relies heavily on patient-reported symptoms, which may not accurately reflect the histological extent of pulpal inflammation. The twelve-month follow-up period may be insufficient to detect late-stage complications, such as asymptomatic pulpal necrosis, internal resorption, or extensive canal calcification. Furthermore, the study did not evaluate factors such as postoperative sensibility test results or hemostasis time correlation with postoperative pain.

Conclusion

Complete pulpotomy using Biodentine is a highly effective and predictable treatment modality for mature permanent teeth diagnosed with symptomatic irreversible pulpitis, demonstrating a 94% clinical and radiographic success rate over a 9-month follow-up period. The use of bioactive materials such as Biodentine provides favorable conditions for pulpal healing by ensuring marginal integrity and promoting tissue repair. This minimally invasive approach represents a technically simpler and more accessible alternative to conventional root canal treatment, particularly in resource-limited clinical settings. The findings support reconsideration of

irreversible pulpitis as an automatic indication for root canal treatment and highlight the potential of vital pulp therapy as a viable treatment option.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Complete pulpotomy should be considered a conservative and effective alternative to root canal treatment in mature permanent teeth with irreversible pulpitis, especially in resource-limited settings.
2. Diagnosis alone should not dictate treatment decisions; case selection must rely on clinical judgment and intraoperative findings, particularly the ability to achieve hemostasis within 10 minutes.
3. Greater emphasis on education in vital pulp therapy is needed in dental curricula and continuing education programs.
4. Future research should focus on long-term, multicentric studies using different bioactive materials and improved diagnostic tools, including biomarkers for more accurate assessment of pulpal inflammation.
5. A revision of current endodontic diagnostic terminology is recommended to better reflect pulp healing potential rather than relying solely on symptom-based classification.
6. Further long-term prognosis should be recorded with response to postoperative sensibility test results for stronger evidence to establish pulpotomy as an alternative treatment in mature permanent teeth with irreversible pulpitis.

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Conflict of Interest

The authors declare no conflicts of interest.

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Figures

Figure 1: showing the procedure of Complete pulpotomy using Biodentin a) Access Cavity Preparation b) Hemostasis c) Biodentin placement d) GIC Restoration

Figure 2: showing complete pulpotomy in mandibular left 1st molar. a) Pre-Op X-ray b) Immediately Post-Op x-ray c) 3 months follow-up x-ray d) 6 months follow-up x-ray e) 12 months follow up x-ray

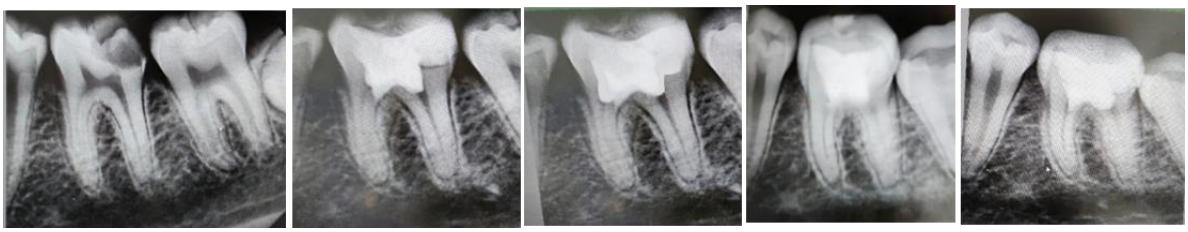
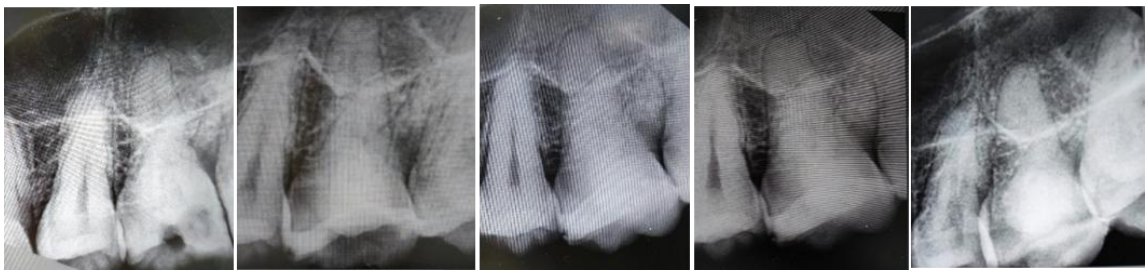
Figure 3: showing complete pulpotomy in maxillary left 1st molar. a) Pre-Op x-ray b) Immediately Post-Op x-ray c) 3 months follow-up x-ray d) 6 months follow-up x-ray e) 12 months follow up x-ray