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RESEARCH ARTICLE

Assessment of Biodentine Pulpotomy as an Alternative to Conventional Root Canal Treatment for Permanent Teeth in Children: An *In Vivo* Study

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ABSTRACT

Introduction: A vital pulp tissue is responsible for supporting the tooth structure through reparative dentin production. Preserving pulp vitality is essential in maintaining vascularization and nutrition to the tooth that eventually will support tooth structure & reduce teeth mortality. Root canal treatment for permanent teeth in children is a complex procedure requiring lengthy appointments and multiple visits and often require a full coverage restoration. on the other hand vital pulpotomy requires shorter appointments and usually accomplished in one visit. Vital pulp therapy can help to retain vital permanent teeth that are able to withstand normal function. Vital pulp therapy (VPT) has been increasingly considered as a minimally invasive approach for the management of teeth with inflamed pulps compared to the conventional approach of root canal treatment.

Aim:To assess the outcome of Biodentine in complete coronal pulpotomy in permanent teeth with symptomatic reversible pulpitis.

Methodology: In the present study 30 healthy children of age below 12 years requiring pulpotomy were selected after clinical and radiographic assessment. Pulpotomy technique was carried out after local anaesthesia and rubber dam application. After exposure, pulp was amputated to the level of canal orifices (full pulpotomy) using a sterile spoon excavator and high-speed round bur under water coolant. Hemostasis is achieved by cotton pellet moistened with 3 % NaOCl for 2 minutes and repeat as needed, after haemostasis achieved Biodentine was mixed according to the manufacturer's instructions and gently placed over the pulp to a thickness of 2-3 mm and after that a permanent restoration was placed. All treated patients were followed up at 3-month,6-month,9-month interval for clinical and radiographic evaluation. Resulting data were tabulated and statistically analyzed.

Results: Out of the 30 study samples,2 patient cases revealed abnormal clinical and radiographical changes at the end of 3 months and one more patient reported with pain and tenderness to percussion at the end of 6 months. At the end of 9 months follow up, clinical and radiographical success rate was 90.0% respectively.

Conclusion: Biodentine as a pulpotomy agent has a high successful rate and fulfilled all requirements of an ideal pulpotomy medicament. Hence Biodentine can be routinely used in practice for the management of carious permanent tooth in children. Excellent outcome of present study results were truly indicative of Biodentine being a promising pulp repair agent for pulpotomy in clinical practice.

Keywords: Biodentine, Permanent Molar. Pulpotomy, Clinical and radiographic outcome

Introduction

The dental pulp is a soft connective tissue confined within the hard walls of the dentin which plays an important role in the prognosis of the tooth, which is often ignored. Exposure of the pulp due to various reasons like caries, fractures, cracks, or an open restoration margin often results in inflammation of the pulp which can subsequently lead to pulpal death if not treated at the earliest.¹

Therapeutics of dental pulp diseases include vital pulp therapies like direct and indirect pulp capping, pulpotomy in the initial stages, or pulpectomy if the lesion presents in its later stages. Preservation of pulpal vitality is of paramount importance as the vital functioning pulp is capable of initiating several important functions like formation of dentin, providing nutritive support to the tooth, enabling a defensive function, and possessing a unique reparative capacity.²

A vital pulp tissue is responsible for supporting the tooth structure through reparative dentin production. Preserving pulp vitality is essential in maintaining vascularization and nutrition to the tooth that eventually will support tooth structure & reduce teeth mortality. Root canal treatment for permanent teeth in children is a complex procedure requiring lengthy appointments and multiple visits and often require a full coverage restoration. On the other hand, vital pulpotomy requires shorter appointments and usually accomplished in one visit. Also, while an endodontist is usually required to perform root canal treatment (RCT), a pediatric dentist can perform vital pulpotomy for permanent teeth by providing an alternative to the progressive conventional root canal treatment in children. vital pulp therapy (VPT) can help to retain vital permanent teeth that are able to withstand normal function.³

Vital pulp therapy has been increasingly considered as a minimally invasive approach for the management of teeth with inflamed pulps compared to the conventional approach of root canal treatment. It has been reported to have a high success rate (91-93%) in young permanent molars and is recommended as an alternative option.⁴

The use of vital pulp therapy is, however, not necessarily confined to developing teeth. Any tooth can be preserved after traumatic or accidental exposure if the pulp is healthy regardless of whether it has open apex or closed. Success depends on a good understanding of pulp biology, the use of appropriate materials, and sound technical procedures.⁵

Pulpotomy is a vital pulp therapy in which the coronal portion of the pulp is removed surgically and the remaining radicular pulp is preserved intact. Over the remaining radicular pulp tissue, a suitable material is placed which has the potential to protect the pulp from further insult and initiate healing and repair.⁶

The rationale behind pulpotomy procedures is based on the ability of the remaining radicular pulp to recover following the removal of the infected coronal pulp tissue and placement of a suitable medicament. Various materials have been advocated for use in pulpotomy procedures. based on their important properties such as biocompatibility, sealing ability, and antimicrobial efficacy when placed in contact with the inflamed pulp.⁷

Conventionally calcium hydroxide is the material of choice for vital pulp therapy, showing favourable outcomes particularly in permanent teeth. However, its physical limitations such as dissolution in tissue fluids, degradation upon tooth flexure and poor quality of proximal hard tissue barriers are drawbacks.⁸

MTA (Mineral trioxide aggregate) is one of the most commonly used and researched material for such purposes with successful clinical outcomes. However, due to certain inherent drawbacks of MTA, there is a need for the development of newer materials that addresses the requirements of pulpotomy therapies and that can overcome the challenges associated with MTA.⁹

Biodentine is a calcium silicate-based material that has fetched attention in recent years and became commercially available in 2009. It was initially and specifically designed as a "dentin replacement" material. Biodentine is primarily formulated using the MTA-based cement technology with improvement in some properties of these types of cements, such as physical qualities and handling. Biodentine has been shown to induce odontoblastic differentiation of dental pulp stem cells, and produce more uniform and thicker dentin bridge formations, with less inflammatory response and less necrosis of pulp tissue than calcium hydroxide.¹⁰ There is minimal research on Biodentine as a pulpotomy material. Hence the present study has been taken up to evaluate the clinical and radiographic success of Biodentine as a pulpotomy agent for permanent teeth with carious exposure in children.

Methodology

STUDY DESIGN

In-Vivo one group pre-post study design.

Patients were evaluated to a follow up period of 3,6- and 9-month interval.

STUDY SETTING

Department of pediatric and preventive dentistry, KMCT dental college.

STUDY DURATION

Study with 9 months follow up.

SAMPLING

Sample size was calculated using the formula

$$n = \frac{(Z\alpha/2)^2 \times P(1-P)}{E^2}$$

Considering the proportion of success rate

$$Z\alpha/2 = 1.96$$

$$P = 94\%$$

$$E = 10\%$$

$$n = \frac{(1.96)^2 \times 0.94(1-0.94) \times 1}{0.008} = 28$$

Sample size was determined as a minimum of 28 and sample size was up-sized to 30 in this study.

STUDY POPULATION

Present study was conducted on children who had visited the outpatient department of pedodontics and preventive dentistry, KMCT dental college, Calicut, suitable according to the inclusion and exclusion criteria. Written informed consent was obtained from the parents or guardians of children who required pulpotomy treatment. The study was approved by the ethical committee of the institution. A detailed case evaluation/history was recorded.

Criteria of Case Selection to be Followed for Pulpotomy Procedure

INCLUSION CRITERIA:

1. Permanent molar tooth with deep caries and a diagnosis of symptomatic reversible pulpitis.
2. Absence of tenderness to percussion.
3. Absence of physiologic or pathologic tooth mobility.

EXCLUSION CRITERIA:

1. Clinical evidence of pulpal inflammation or degeneration such as history of swelling or presence of sinus tract.
2. Radiographic evidence of internal or external root resorption, pulpal calcifications, or osseous disease (periapical /furcation radiolucency).
3. Teeth with periodontal pathology
4. Non vital teeth

Armamentarium

- Disposable face mask and surgical gloves.
- Diagnostic instruments
- Cutting instruments
- Filling instruments
- Disposable syringes
- Topical anesthetic spray
- 2% lignocaine with 1:100,000 adrenaline
- Rubber dam
- High speed airtor handpiece with water coolant
- Round bur
- Normal saline
- Sterile cotton pellets
- X-ray films

Materials Used In The Study

- Biodentine
- Glass ionomer cement (GIC)
- Miracle mix
- Zinc oxide eugenol cement

Consent Form

The benefits and discomfort of the clinical procedure were explained fully to the parents of the participated children. Signed informed consent were obtained explaining the research protocol approved by the ethical committee.

Intra oral periapical radiographs of 30 selected study participants were obtained prior to the pulpotomy procedure, which was performed as follows;

Pulpotomy technique was carried out after local anaesthesia and rubber dam application (**Figure 1**). Tooth was disinfected with 3% Sodium hypochlorite (NaOCl) before caries excavation. After exposure, pulp was amputated to the level of canal orifices (full pulpotomy) using a sterile spoon excavator and high-speed round bur under water coolant (**Figure 2**). Hemostasis was achieved by cotton pellet moistened with 3 % NaOCl for 2 minutes and repeat as needed, after haemostasis achieved Biodentine was mixed according to the manufacturer's instructions and gently placed over the pulp to a thickness of 2-3 mm (**Figure 3**), after that a permanent restoration was placed. (**Figure 4**)

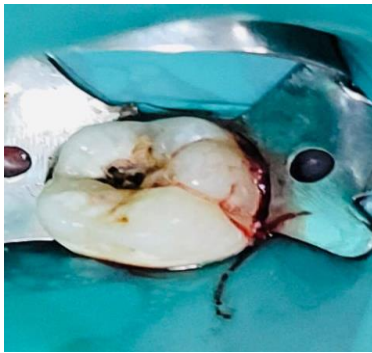


Fig 1: pre operative view



Fig 2: pulpotomy procedure



Fig 3: Application of Biodentine



Fig 4: post operative view

Post-operative radiograph was taken immediately after the treatment. All treated patients were followed up at 3-month,6-month,9-month interval for clinical and radiographic evaluation (**Figure 5, 6 & 7**)

Representative Intra Oral Periapical Radiographs

Figure 5: Tooth no 36; 9 years; female

Pre operative 3 months review 6 months review 9 months review

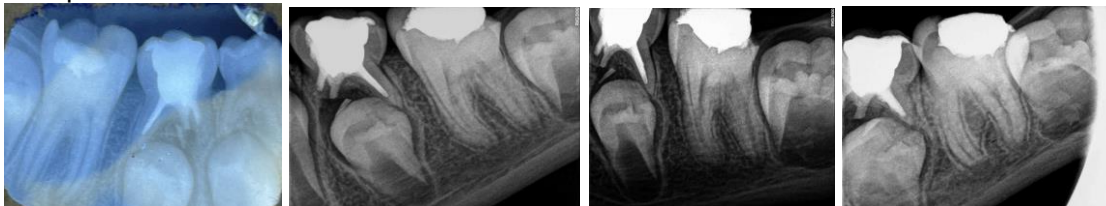


Figure 6: Tooth no 36; 10 years; female

Pre operative 3 months review 6 months review 9 months review

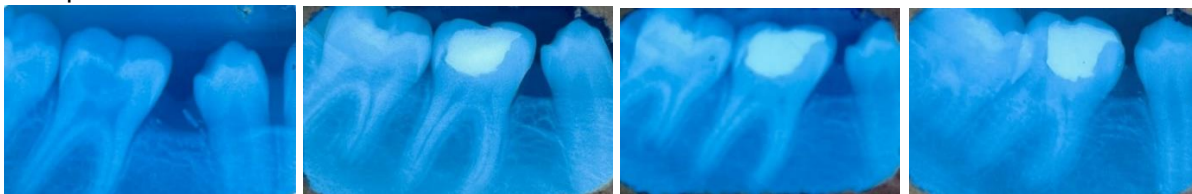


Figure 7: Tooth no 46; 11 years; male

Pre operative 3 months review 6 months review 9 months review



Outcome Measurements

Evaluation of the treatment outcomes were based on clinical and radiographical examination.

1. CLINICAL CRITERIA

- No history of spontaneous pain or discomfort except for the first 2 days after treatment.
- No tenderness to palpations or percussions.
- No swelling or sinus tract.

2. RADIOGRAPHIC CRITERIA

- Presence of normal periodontal ligament space
- Absence of periapical rarefactions.

Outcome Variables

1. SUCCESS

Teeth that remained asymptomatic without radiographic signs of periapical pathology followed up over a period of 9 months will be considered successful.

2. FAILURE

Teeth that became symptomatic with or without radiographic signs of periapical pathology or asymptomatic with radiographic signs of periapical pathology followed up over a period of 9 months will be considered as failure.

Results

The present study was conducted to assess the clinical and radiographic outcome following pulpotomy using Biodentine in permanent molar teeth. All the patients were followed up at 3,6- and 9-months intervals to assess the clinical and radiological success outcome. 30 children permanent teeth indicated for pulpotomy were included in the current study.

The data collected from clinical and radiographic examination were statistically analysed and results are presented under following categories.

Evaluation of Clinical Success at 3 Months

All the 30 children were screened for clinical criteria of spontaneous pain, tenderness to percussion, fistula and soft tissue swelling. At the end of 3 months 2 children reported with tenderness to percussion and spontaneous pain.

Evaluation of Radiographic Success at 3 Months

All 30 children were screened for radiographic success which included widening of periodontal ligament space and periapical rarefactions. At the end of 3 month 2 children reported with widened periodontal ligament space with clinical symptoms.

Table I: Evaluation of clinical success at 3 months

Clinical findings	Total count % 30(100%)
Spontaneous pain	2
Tenderness to percussion	2
Soft tissue swelling	0
fistula	0
Total count within the group	30

Asymptomatic 28 (93.3%) symptomatic 2 (6.7%)

Table II: Evaluation of radiographic success at 3 months

Radiographic findings	Total count% 30 (100%)
Widened periodontal ligament space	2
Periapical rarefactions	2
Total count within the group	30

No radiographic changes noticed 28 (93.3%)
radiographic changes noticed 2 (6.7%)

Evaluation of Clinical Success at 6 Months

Within 3-to-6-month duration a total of 3 children reported with spontaneous pain and tenderness to percussion. No children reported with fistula, soft tissue swelling and pathological tooth mobility at

the end of 6 months.

Evaluation of radiographic success at 6 months

At 6 months one more child reported with symptomatic presentation and widened periodontal ligament space.

No other advanced radiographical changes was noticed.

Table III: Evaluation of clinical success at 6 months

Clinical findings	Total count % 30(100%)
Spontaneous pain	3
Tenderness to percussion	3
Soft tissue swelling	0
fistula	0
Total count within the group	30

Asymptomatic 27 (90.0%) Symptomatic 3 (10.0%)

Table IV: Evaluation of radiographic success at 6 months

Radiographic findings	Total count% 30 (100%)
Widened periodontal ligament space	3
Periapical rarefactions	3
Total count within the group	30

No radiographic changes noticed 27(90.0%) radiographic changes noticed 3 (10.0%)

Evaluation of Clinical Success at 9 Months

At the end of 9 months children who reported with clinical symptoms and radiographical changes at 3 and 6 months were advised root canal treatment. Remaining 27 children were asymptomatic.

symptoms and radiographical changes at 3 and 6 months more radiographical changes with periapical rarefactions were noted.

At the end of 9 months clinical success considering the clinical criteria and radiographical success considering the radiographic criteria for Biodentine was 27(90.0%) which was statistically significance

Evaluation of Radiographic Success at 9 Months

At the end of 9 months 3 children who had clinical

Table V: Evaluation of clinical success at 9 months

Clinical findings	Total count % 30(100%)
Spontaneous pain	3
Tenderness to percussion	3
Soft tissue swelling	0
fistula	0
Total count within the group	30

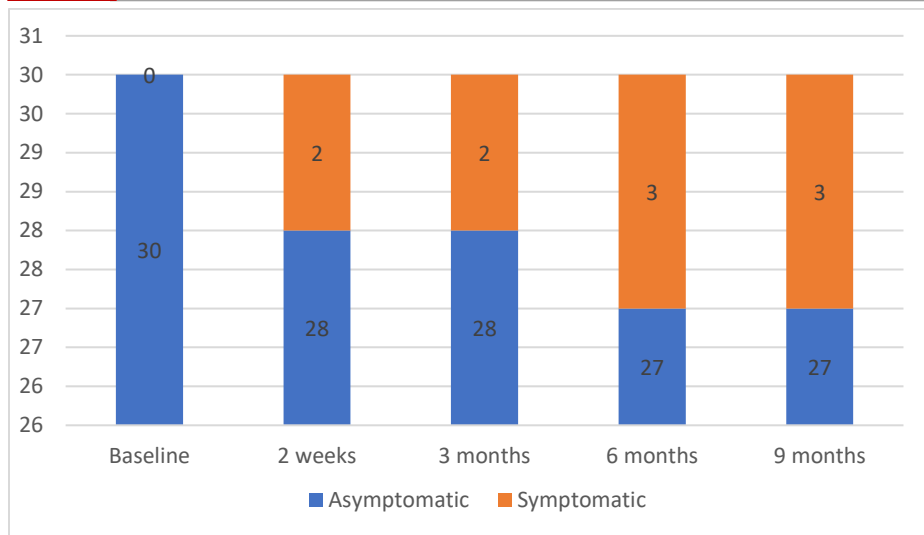
Asymptomatic 27 (90.0%) Symptomatic 3 (10.0%).

Table VI: Evaluation of radiographic success at 9 months

Radiographic findings	Total count% 30 (100%)
Widened periodontal ligament space	3
Periapical rarefactions	3
Total count within the group	30

No radiographic changes noticed 27(90.0%) radiographic changes noticed 3 (10.0%)

Overall clinical and radiographic success was depicted in the graph (figure 8)



Discussion

The treatment of teeth with carious pulp exposure is a controversial issue since long in children. This includes the conservative approach as in vital pulp therapy and more invasive approaches including procedures like pulpectomy and root canal therapy.

Each treatment modality has its advantages and disadvantages in views of the patient and the practitioner. From the point of view of a patient any procedure that relieves the clinical signs and symptoms and which prolongs the lifespan of a tooth is satisfactory and considered as successful. But in the view of a clinician and researcher besides resolution of the clinical signs and symptoms preservation of the functions of the pulp is considered as an important criterion for considering the treatment a real success.¹¹

Clinically, a principal challenge faced by most paediatric dentist, endodontist or general dentist with special interest in treating children is the treatment of pulpally involved and abscessed teeth in a young patient. This is mainly due to factors related to patient's cooperation, the total number of visits required to finish the treatment and the cost of treatment. This is further complicated by disagreement on treatment protocols and outcomes among clinicians, which is often based on little or no documented evidence.¹²

An inherent problem in treating any exposed pulp is the lack of ability of the clinician to accurately diagnose the true condition of the pulp and to predict the pulp's ability to respond to any form of therapy. Root canal treatment imposes many consequences such as making the tooth nonvital, removing of substantial amount of tooth structure, and therefore brittleness of the remaining structure.⁶

At present, endodontology is more shifted toward biologic treatment modalities that would postpone or avoid such non biologic treatment. Vital pulp therapy (VPT) is considered a minimally invasive technique for the treatment of teeth with irreversible pulpitis.¹³⁻¹⁴⁻¹⁵ Pulpotomy can preserve the tooth structure, retain the remaining pulp tissue's proprioceptive defence mechanism, and reduce the risk of tooth fracture. In addition, it is less painful, more convenient as well as it simplifies the treatment protocols, and avoids treatment complications.¹⁶

Recent studies have shown high success rates for vital pulp therapy in maintaining the vitality of dental pulp tissues in young permanent teeth with open root apices. Therefore, maintaining tooth vitality enhances dentinal root deposition and results in stronger root structure.⁸

The aim of vital pulpotomy in permanent teeth in children is to treat reversible pulpal injuries and to maintain radicular pulp vitality and function and therefore maintain the tooth in a viable condition.¹⁷ Clinical signs and symptoms such as the degree and characteristics of pain do not reflect the actual histological status and subsequently the healing potential of the inflamed pulp. Histological studies found inflammation to be confined to the area next to the carious exposure and not extending beyond 2 mm from the exposure site.¹⁸ Radicular pulp was rarely inflamed. Furthermore, it was impossible in a histological study to classify accurately the pulpal condition of all painful teeth or to differentiate clearly between saveable and non-saveable pulps.¹⁹ Therefore, if the infected and most severely inflamed tissue is removed and the pulp is dressed with an adequate material, the conservation of a remaining healthy pulp is potentially possible.⁸

Conventionally calcium hydroxide has been the material of choice for vital pulp therapy, showing favourable outcomes particularly in young teeth.¹⁷ However, its physical limitations such as dissolution in tissue fluids, degradation upon tooth flexure and poor quality of the proximal hard tissue barriers are drawbacks.²⁰ On the other hand, MTA is currently the most commonly used material in vital pulp therapy. It has excellent marginal adaptation and induces cell proliferation and formation of a high-quality hard tissue barrier.²¹⁻²² But the major drawback of MTA is the prolonged setting time which is not desirable in clinical practice.

Biodentine (Septodont, Saint-Maur des-Fossés, France), one of the new-generation, bioactive endodontic cements, has been claimed to have improved properties over MTA.²³ It is a calcium silicate-based material that has fetched attention in recent years and became commercially available in 2009. It was initially & specifically designed as a "dentin replacement material". Biodentine is primarily formulated using the MTA -based cement technology with improvement in some properties of these types of cements such as physical qualities and handling.¹⁰ Biodentine presents high biocompatibility with human dental pulp cells.²⁴ The pulp tissue in contact with Biodentine does not show an irreversible inflammatory response.²⁵ Biodentine has higher flexural strength,²⁶ compressive strength,²⁷ and modulus of elasticity than does MTA.²⁸

This study intended to assess the success of Biodentine pulpotomy on permanent molar teeth in children under in vivo condition, objective being to compare the clinical and radiological outcomes following treatment.

This study was done in 30 permanent molar teeth in children of age below 12 years coming to the department of pediatric and preventive dentistry, KMCT dental college and having at least one permanent molar tooth with carious exposure. Out of the 30 study participants 22 were females and 8 were males.

Pulpotomy procedures was performed under rubber dam isolation to minimize the bacterial contamination at the treatment site. Tooth was disinfected with 3% NaOCl before caries excavation. After exposure, pulp was amputated to the level of canal orifices (full pulpotomy) using a sterile spoon excavator and high-speed round bur under water coolant. Hemostasis achieved by cotton pellet moistened with 3% NaOCl for 2 minutes and repeat as needed, after haemostasis achieved Biodentine was mixed according to the

manufacturer's instructions and gently placed over the pulp to a thickness of 2-3 mm and after that a permanent restoration was placed. Post-operative radiograph was taken immediately after the treatment. All treated patients were followed up at 3-month, 6-month, 9-month interval for clinical and radiographic evaluation.

Healing of dental pulp is not exclusively dependent upon the stimulatory effect of a particular medicament, but it is also directly related to the capacity of both dressing and definitive restorative material to provide a biological seal against immediate and long term microleakage along the entire restoration interface.²⁹

In the present study clinical success of Biodentine pulpotomy was 93.3% at the end of 3 months [Table I] based on the concept that dental pulp has the ability to remain vital after removing infected pulp tissue. In the current study, after the removal of the infected coronal pulp tissue and sealing the remaining pulpal canal with Biodentine, the pulp tissue healed and maintained vitality. This success rate was in accordance with the systematic review conducted by *Aguilar and Linsuwanont et al* has demonstrated the success rate of vital pulp therapies in vital permanent teeth with closed apices, showing a relatively high success rate of 99.4% for partial pulpotomy and 99.3% for full pulpotomy.¹⁷ *Eghbal et al* have evaluated the histological success of pulpotomy in permanent molars of patients in the age ranging from 16 to 28 years and the histological observations revealed a complete dentinal bridge with radicular pulp remaining vital and free of inflammation in all the samples.⁶

In the current study radiographic success of Biodentine pulpotomy was 93.3% at the end of 3 months [Table II]. This finding was in accordance to *Nowicka et al* where in after 6 weeks, they found majority of specimens showing a complete dentinal bridge formation and an absence of inflammatory pulp response. Layers of well-arranged odontoblast and odontoblast-like cells were found to form tubular dentine under the osteodentine. They also found no statistically significant differences between the Biodentine and MTA experimental groups.³⁰

Partial pulpotomy using Biodentine in an immature tooth demonstrated a fast tissue response both at the pulpal and root dentine level with formation of a radio-opaque bridge within 3-6 months as observed by *villat et al* and suggested the use of tricalcium silicate cement should be considered as a conservative intervention in the treatment of

symptomatic immature teeth³¹. Biodentine had significantly higher push-out bond strength than MTA after 24 hours setting time.

At the end of 6 months clinical success of Biodentine pulpotomy was 90.0% [TABLE III] This was in accordance with study done by *Taha & Abdulkader et al* showed 98.4 % success rate clinically at 6 months.⁴ The procedure of pulpotomies in adult teeth with mature apices has been investigated to a much lesser extent and related controversies still exist in the literature.

Zanini et al. evaluated the biological effect of Biodentine on murine pulp cells by studying the expression of several biomolecular markers after culturing OD-21 cells with or without Biodentine. Their results, being consistent with other studies, were in favour of Biodentine, which was found to be bioactive due to its ability to increase OD-21 cell proliferation and biomineralization.³²

The idea behind the pulpotomy therapy was to provide a good biological seal, because if further entry of bacteria is prevented into the exposed pulp tissue, it has an ability to heal with the formation of new dentinal bridge and the periapical tissues undergo regeneration. The success of the pulpotomy procedure depends on the right choice of the biomaterial in terms of its biocompatibility, sealing ability, ability to stimulate reparative dentin formation, and regenerative potential of the pulp. During the treatment procedure, the pulp should be free from bacteria and its toxins and preventing the invasion of bacteria into the pulp is the vital factor for favourable prognosis of this procedure. It can be achieved using rubber dam isolation which prevents the invasion of bacteria from the oral cavity and saliva. Provision of the double seal also prevents the bacterial leakage. Biodentine can be considered as a restorative material of choice because of high mechanical properties and good sealing ability. Hence, in the present case series, double seal provided by Biodentine and miracle mix permanent restoration ensures a tight coronal seal.³¹

In the present study Radiographical success of Biodentine pulpotomy was 90.0% at the end of 6 months [Table IV]. This was in accordance with the study done by *Javaria tairaq et al*, shows a success rate of 87.2% after 6 months.³³

From 3 to 6 months duration 3 children reported with spontaneous pain, tenderness to percussion and radiographic changes of widened pdl space and periapical rarefactions. The unfavourable clinical outcome of pulpotomy treatment in the present

study could be more likely attributable to undiagnosed chronic inflammation existing in the radicular pulp prior to pulpotomy.

As reported by Massler most of the failures in vital pulp therapy and endodontic treatment were attributed to microleakage at the coronal tooth restoration interface. Establishment of proper coronal seal serves as an important determinant in the success of vital pulp therapy. It reduces microleakage and bacterial invasion which will hamper the healing of dental pulp.³⁴

Definite success factors for treatment outcome of a pulpotomy is not published in any review yet. Most of the published data is limited to clinical studies with a smaller number of participants. Another important factor which can cause the failure of pulpotomy treatment is the bacterial contamination of the pulp while accessing the chamber for the removal of the coronal pulp tissue. The high success rate in this case series is attributed to the careful attention given to the case selection, maintenance of proper isolation and to the methods used to prevent pulpal bleeding and cavity closure.

In the current study clinical success of Biodentine pulpotomy was 90.0 % at the end of 9 months [Table V]. This was relatively a higher percentage of success when compared to a study done by *Simon et al.*, of 82% using proRoot MTA at the end of 24 months.³⁵ *Barngkei et al.* evaluated the clinical and radiographic outcome of pulpotomy treatment with MTA in symptomatic mature permanent teeth with carious exposures in adults (mean age 29 years) and the authors reported on a 100% success rate.¹¹ In the present study radiographic success of Biodentine pulpotomy was 90 % at the end of 9 months, [Table VI]. This was in accordance with study by *Taha et al* shows 95 % radiographic success at the end of 12 months.³⁶ The findings in the study showed that it was statistically significant (P value <0.05), both clinically and radiographically at the end of 9 months.

Based on our observations in the present study, both clinically and radiographically Biodentine was found to be a superior pulpotomy medicament. The increased clinical efficiency of Biodentine may be attributed to its properties which include good sealing ability, biocompatibility, and compressive strength, and more calcium ion released as compared to MTA and calcium hydroxide-based materials. Biodentine is mechanically stronger, less soluble, and gives a tighter seal. Hence, in this study, Biodentine had a significantly more pronounced antibacterial effect.³⁷⁻³⁸

Pérard M et al. assessed the biological effects of Biodentine for use in pulp-capping treatment, on pseudo-odontoblastic and pulp cells. They also evaluated the effects of Biodentine and MTA on gene expression in cultured spheroids, and found that Col1a1 expression levels were slightly lower in cells cultured in the presence of MTA than in those cultured in the presence of Biodentine and in control cells. They concluded that both MTA as well as Biodentine are suitable for pulp-capping.³⁹

Considering the clinical outcome in the present study, out of the 30 study samples, 27 subjects showed favourable outcome. 3 unfavourable clinical outcome occurred during the 3 to 6 months duration of follow up. 3 patients reported with spontaneous pain and tenderness to percussion and radiographical changes were also noticed for these teeth. Presence of the status of infection warranted immediate RCT for the designated teeth.

Inflammation is key in the regulation of the maintenance of pulp vitality⁴⁰ but its quantification clinically relies on relatively weak diagnostic and pain assessment tools with limited correlation to the physio-pathological state of the pulp.¹⁹ Consideration of the interplay of inflammation and these various other factors will help to drive appropriate case selection and subsequent treatment planning.

Besides the 3 cases with unfavourable clinical outcome, none of the remaining cases showed any abnormal clinical findings during the entire observation period of 9 months. Therefore, at the end of 9 months follow up, the favourable clinical and radiographical outcome was observed in 90% cases.

The selection of patients is an important criterion for consideration of pulpotomy procedures in permanent teeth with closed apices. When mild to moderate pain is present with no previous history of pain in the tooth under evaluation, the histologic picture usually manifests as mild inflammation or chronic partial pulpitis without histologic areas of necrosis.⁴¹ Increasing age of a patient may negatively affect clinical success. Studies have shown that in older patients, typically more fibrous dental pulp has a reduced ability to overcome insult due to less cellularity with limited blood supply affecting the treatment outcomes.^{2,42} The bleeding from the radicular pulp could be controlled by pressure from cotton pellets dipped in sterile normal saline for 5 minutes showing that the radicular pulp was vital and non-infected. A sluggish bleeding present even after application of pressure suggests

an infected radicular pulp with need of root canal treatment.⁴³

There are various studies which have used the "time to stop bleeding" as a cut-off parameter to discriminate reversible pulpitis from irreversible pulpitis. The pulp is considered severely inflamed if the pulpal bleeding could not be stopped within 5 to 10 minutes. In such cases, partial removal of pulp is not recommended. But there have not been any thorough investigations carried out to evaluate the association between pulpal bleeding time and the degree of pulpal inflammation. Literature suggests various methods for controlling pulpal haemorrhage. This includes the use of sodium hypochlorite solution,⁵ physiologic salines,⁴⁴ hydrogen peroxide⁴⁵ or gentle pressure with a sterile moist cotton pellet. But there is no published data available to suggest the superiority of any of these techniques in clinical outcome compared to others. However, if the bleeding cannot be stopped within 5–10 minutes it suggests that the clinician has failed in removing the entire inflamed pulp or the inflammation of the pulp has progressed to the deeper radicular pulp.⁴⁶ In such cases the treatment plan should be modified to pulpectomy rather than pulpotomy.

Biodentine causes increased calcium and TGF- β 1 secretion from pulp cells which induces angiogenesis, cell differentiation and mineralization. The mechanism of action of Biodentine is its ability to induce odontoblast differentiation and enhanced proliferation, migration and adhesion of human pulp stem cells, when placed in direct contact with the dental pulp. Another major advantage of Biodentine over MTA is its reduced cost.²¹

Vital pulpotomy treatment can be used successfully as an alternative to root canal treatment in the management of carious pulp exposure for fully erupted mature teeth in children to maintain pulp vitality and provide strength that supports tooth structure. By validating this new, less invasive approach, vital pulpotomy has great potential to further improve patient's dental care.

The experience of pain associated with RCT is a major source of fear for patients and a concern for dentists, particularly in cases with preoperative symptoms. The short procedure of pulpotomy compared with single-visit RCT or apexification, complete relief of pain in a relatively short time, patients' cooperation, and cost make the procedure more attractive for both patients and the operator.⁴⁷

The researchers suggest further clinical trials of pulpotomy procedures with Biodentine with larger sample sizes and long-term follow-ups to draw, more accurate findings.

Conclusion

Vital pulpotomy treatment can be used successfully as an alternative to root canal treatment in the management of carious pulp exposure for fully erupted mature teeth in children to maintain pulp vitality and provide strength that supports tooth structure.

In accordance to the favourable results of our cases, a reasonable argument supporting mature tooth pulpotomy in cases of reversible pulpitis can be stated.

In light of observations in the present study, it can be concluded that Biodentine is successful as a

therapeutic material in full pulpotomy treatment of permanent teeth with carious exposures in children. Pulpotomies performed with Biodentine were generally very satisfactory and fulfilled all requirements, covering all needs.

The excellent outcomes of the present study are indicative that Biodentine is a promising biomaterial to promote pulp repair after pulpotomy in clinical practice.

More clinical studies with large sample size and longer follow up periods are required to refine the case selection criteria followed for pulpotomy procedure.

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