Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/16318
DOI URL: http://dx.doi.org/10.21474/IJAR01/16318

RESEARCH ARTICLE

APEXIFICATIONUSINGDIFFERENTAPPROACHES- CASE SERIES REPORT WITH A BRIEF LITERATURE REVIEW

Sangeetha K.V[1], Deepak Baby[2], Sreedevi P.V[3], Laubel John[4], Anusha Anish[5] and P.T Annamala[6]

1. PG Resident, Department of Conservative Dentistry and Endodontics.
2. Professor and Head,Department of Conservative Dentistry and Endodontics.
3. Professor, Department of Conservative Dentistry and Endodontics.
4. Senior Lecturer, Department of Conservative Dentistry and Endodontics.
5. Deputy Research Director.
6. Research Director.

……………………………………………………………………………………………………....

Manuscript Info …………………….

Abstract ………………………………………………………………

Manuscript History
Received: 20 December 2022
Final Accepted: 24 January 2023
Published: February 2023

Copy Right, IJAR, 2023,. All rights reserved.

……………………………………………………………………………………………………....

Introduction:-

Review Of Literature:-

Root development of tooth is facilitated by the stimulation and differentiation of Hertwig's Epithelial Root Sheath (HERS) and surrounding progenitor cells, which results in the continuous deposition of dentine and cementum (1). If some damage to the tooth occurs during this period, it will impede the process of root apex closure and the root canal will be widened with thin and delicate walls resulting in more susceptibility to fracture, both during and after treatment.This impairs the instrumentation of the root canal and prevents an appropriate apical stop. It is fundamental that an artificial apical barrier is made, or the apical foramen is closed with the calcified tissue to allow the build up of the filling material and to facilitate apical sealing (2). Apexification is a viable option for the management of immature permanent tooth with open apex. According to American association of endodontists, apexification is defined as a method to induce a calcified barrier in a root with an open apex or continued apical development of an incompletely formed root in teeth with necrotic pulp tissue (3).

Calcium hydroxide has been widely used for apexification. The alkaline pH of calcium hydroxide collapse the dentinal structure owing to the destruction of carboxylate and phosphate groups, which can cause break of thin dentinal walls of the root canal (4). The reparative dentine bridge which is shaped by calcium hydroxide is incomplete with numerous tunnel defects, which destroy the sealing ability of the bridge, allowing the migration of calcium hydroxide particles and the leakage of the bacteria (5) which include islands of soft connective tissue, giving the barrier a “Swiss cheese” consistency (5). Due to the irregular nature of the barrier, it is to be expected that the cement or mellowed filling material be pushed through it into the apical tissues during filling. Taking into account the different downsides related with calcium hydroxide apexification, the use of the apical plug method is by all means a reasonable substitute treatment plan for these cases.

Corresponding Author:- Dr. Anusha Anish
Address:- Clinical Research Center, PSM College of Dental Science & Research, Akkikavu, Thrissur, India.

Calcium hydroxide was introduced by Hermann in 1920 and this highly alkaline white odorless powder is classified as a strong base, and its main actions come from the dissociation and resultant effect of calcium and hydroxyl ions on vital tissues. The highly alkaline pH of calcium hydroxide provides antimicrobial activity and encourages tissue repair by promoting tertiary dentine secretion (6). Long-term calcium hydroxide treatment can be utilized to actuate apexification of the immature tooth. Calcium hydroxide degrades over time, has a low compressive strength, and has poor sealing properties (7). Multiple tunnel defects were found in 89% of dentine bridges after calcium hydroxide pulp capping, and 41% of these bridges were associated with recurring pulpal inflammation or necrosis and with the presence of bacteria and inflammatory cells.Tunnel defects in dentinal bridges under calcium hydroxide can act as pathways for bacterial microleakage (8). Bacterial microleakage can impede the formation of the dentinal bridge by odontoblasts like cells.

The introduction of mineral trioxide aggregate (MTA) helped the endodontics domain by allowing its use in root perforations, capping and apexification procedures. MTA is a fine hydrophilic powder consisting of tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide, and bismuth oxide (9). The original gray colored MTA was later replaced by a white MTA (WMTA) due to esthetic concerns of gray MTA (GMTA) staining tooth structure. The WMTA contains lesser amount of iron, aluminum, and magnesium oxides than GMTA. GMTA has been investigated more than the white MTA, and while some reports suggest that GMTA may invoke a more desirable biologic response than WMTA.WMTA, however, may still cause tooth discoloration, most likely due to reaction of MTA with blood (10). MTA predictably induced the formation of a calcific barrier demonstrating that it could be used as an osteo-inductive artificial barrier or “apical plug”. The choice of fixing the apical foramen with MTA transformed the treatment of immature teeth with pulpal necrosis. The procedures could be accomplished in a single appointment, or transient in multiple appointments with similarly high achievement rates, without any concern of apical extrusion of the material. Although MTA apexification procedures allowed for resolution of symptoms without weakening the teeth observed in long-term use of calcium hydroxide(11). MTA has a pH of 10.2 immediately after mixing that increases to 12.5 after 3 hours of setting. It is similar to the pH of calcium hydroxide. MTA does not show signs of solubility contributing to the good seal achieved with MTA and prevention of bacterial contamination of the pulp (12). MTA induces a dentine bridge formation that is faster and with better integrity than that formed by calcium hydroxide. This is achieved with a more favorable pulpal tissue reaction as there is less pulpal inflammation, hyperemia, and less necrosis of the pulp than has been associated with the use of calcium hydroxide (13). Since the set time for MTA is several hours, the manufacturer recommends the placement of the final restoration at a second appointment to assure the set of the material. In the first visit, a wet cotton pellet is placed over the MTA, and then temporary restoration given. In the second visit, the cotton pellet is removed, and the permanent restoration applied after the MTA has been sufficiently hardened (14).

Biodentine™, a new calcium silicate-based cement is used as a dentine replacement material and has gained popularity in recent years as a biocompatible and bioactive dentine substitute (15). It is a synthetic nano-particle multipurpose material, indicated to replace damaged dentine, both in the crown and in the root. Its chemical composition is not quite the same as that of MTA, as it has no gypsum and has less water. Biodentine™ combines the biocompatibility of MTA with many additional and desirable characteristics such as bioactivity-inducing hard tissue formation, good handling characteristics, self-adhesion to dentine, no shrinkage, better antibacterial action and ease of handling (17), negative solubility, and high compressive strength, while providing a good seal without any dentine conditioning (18). Further, Biodentine™ has a setting time significantly shorter than MTA (12–15 minutes). In endodontics, the indications for using Biodentine™ are the same as that for MTA; namely, pulp capping, partial pulpotomy, deciduous teeth pulpotomy, apexification, perforation, and apical surgery. Biodentine™ has been shown to form hydroxyapatite on its surface as a result of contact with tissue fluids (17).This property produces a material that is not soluble and is dimensionally stable. Although more studies are needed, Biodentine™ holds promise for use in clinical procedures as a biocompatible and easily handled product with a short setting time (16).

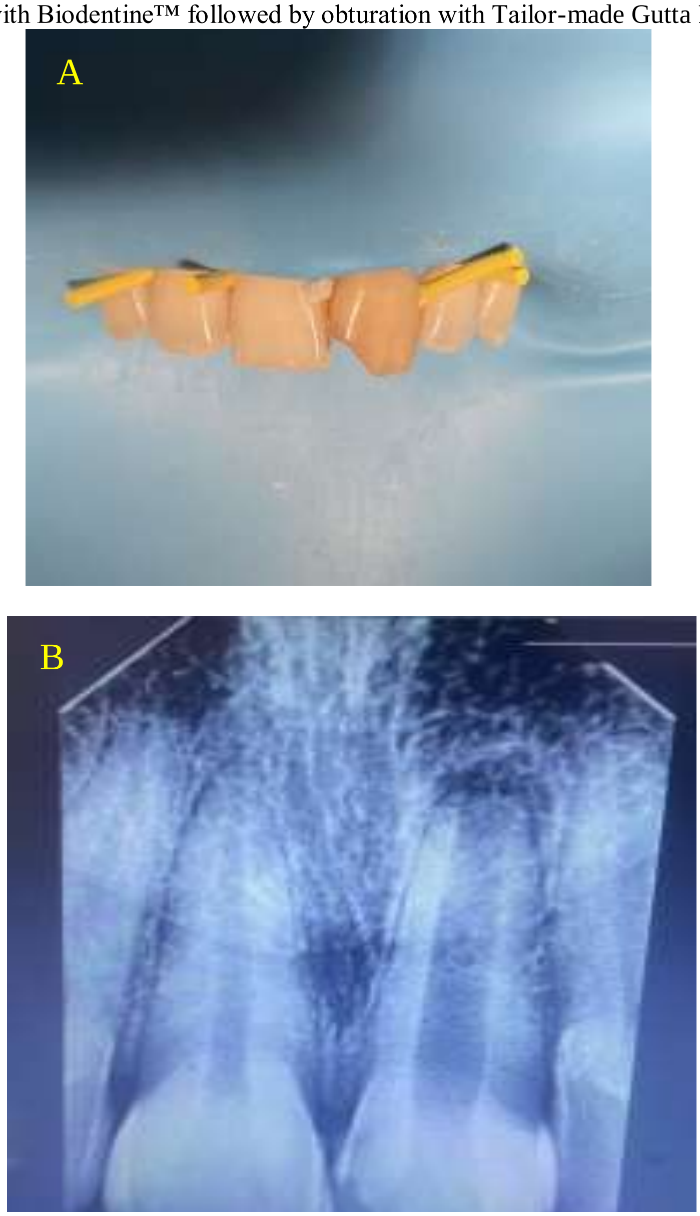
Case Reports

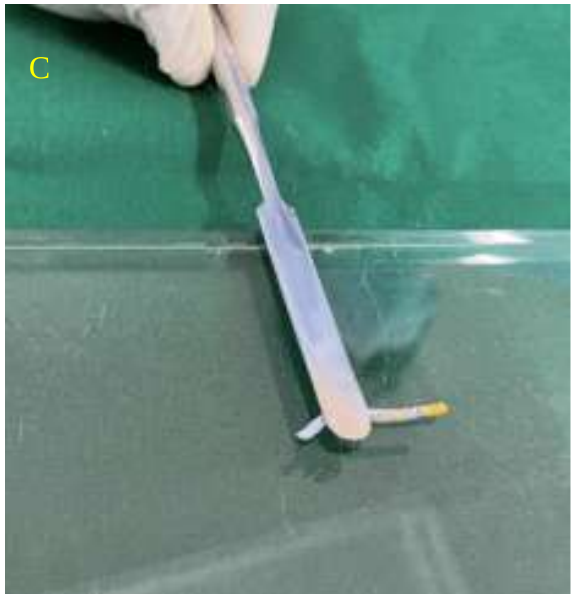
Case 1

A 29 year old male patient reported with the chief complaint of fractured tooth in the upper front tooth region of the jaw with a history of trauma at the age of 6 years. Clinical examination revealed Ellis class III fracture with 21. The tooth did not demonstrate any abnormal mobility or sensitivity to percussion. Both cold and electric sensibility tests failed to elicit any response. Radiographs revealed wide canal with open apex and periapical radiolucency in relation to 21.Root end closure with Biodentine™ as an apical plug followed by obturation with custom cone technique using a bio-ceramic sealer (MTA fillapex) was planned as the treatment option. The treatment plan was discussed with the patient and consent obtained.

Rubber dam was applied, an endodontic access was established using Endo Access bur. After establishing the working length radiographically, root canal was chemo-mechanically debrided with circumferential filing with 80K file in conjunction with copious amount of 0.5% sodium hypochlorite (NaOCl) irrigation. A volume of 3 ml of 17% ethylene diaminetetraacetic acid (EDTA) solution was used for smear layer removal followed by a final rinse with NaOCl.Care was taken so that irrigant should not extrude through open apex. Calcium hydroxide medicament paste was placed in the root canal, and access cavity was restored with Temp Paste. After one week, tooth was again accessed, and copious amount of normal saline was used to remove any remnants of the calcium hydroxide medicament. After drying the canal with paper points, Biodentine™ was mixed as per manufacturer's instructions and was placed at the apical region to form the apical plug of 4mm. After 12 minutes, the hardness of the Biodentine™ was examined using a plugger to confirm its set and the canal was obturated with guttapercha.The access cavity was closed temporarily with glass ionomer cement. After 3 weeks, the glass ionomer was replaced by a bonded resin restoration and the patient was kept on follow up.

Figure 1:- Apexification with Biodentine™ followed by obturation with Tailor-made Gutta Percha (Case 1).





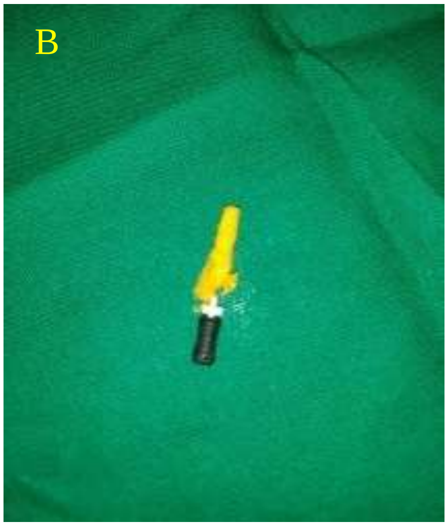
(A) Ellis class III fracture in relation to 21. **(B)** Preoperative radiographs revealed wide canal with open apex and periapical radiolucency in relation to 21. **(C)** Customization of the gutta percha to mold to the shape of the canal. **(D)** Biodentineplaced at the apical region to form the apical plug of 4mm.Then, rest of the canal was obturated with tailor made guttapercha.

Case 2

A 16 year old male patient reported with the chief complaint of discoloration in his maxillary anterior region with the history of trauma in the same tooth at the age of 7 years. Medical history was non-contributory. Clinical examination revealed 11 with Ellis class II fracture and 21 with Ellis class I fracture. Radiographic examination revealed a large blunderbuss canal with associated periapical lesion in relation to both the teeth. The treatment plan was decided to do apexification by using Biodentine™ as an apical plug followed by obturation with custom made prefabricated BioRoot inlay in 11 and apexification by using Biodentine™ as an apical plug followed by obturation with thermoplasticized gutt apercha in 21. The tooth 11 was accessed and working length was established radiographically . Chemo-mechanical preparation was done as discussed in Case 1. Calcium hydroxide medicament paste was placed in the root canal, and access cavity was restored with Temp Paste. In the next appointment, after 1 week, the canal was irrigated and dried and a light body impression of the root canal space was made with elastomeric light body impression material. The light body impression of the root canal space was placed in a putty impression material. Putty impression was split into two halves to aid in retrieving Biodentine™ as a single plug. This split putty was stabilized. A thick mix of Biodentine™ was prepared and carried with a carrier into the putty canal impression. Biodentine™ was compacted with a plugger. The root inlay was allowed to set for 12 minutes. After 12 minutes BioRoot inlay was removed and tried in and was confirmed by digital radiograph. BioRoot inlay along with a bio-ceramic sealer was used to obturate the root canal space which was confirmed by a postoperative radiograph.

For 21 also similar treatment protocoal was adopted. Canal was thoroughly dried with absorbent paper points. After drying the canal, Biodentine™ was mixed as per manufacturer's instructions and it was carried into the canal with an amalgam carrier and condensed with hand pluggers to form apical plug of 4mm thickness. The excess material from the walls was removed with paper point, and after 12 minutes, the rest of the canal was obturated with thermoplasticized gutta percha and bio-ceramic sealer by using the continuous heat wave technique. The access cavity was then restored with glass ionomer cement (GIC). One week follow up appointment was completed without any post operative complications.

Figure 2:- Apexification with Biodentine™ followed by obturationwith custom made prefabricated BioRoot inlay in relation to 11 and thermoplasticised gutta percha in relation to 21 (Case 2).



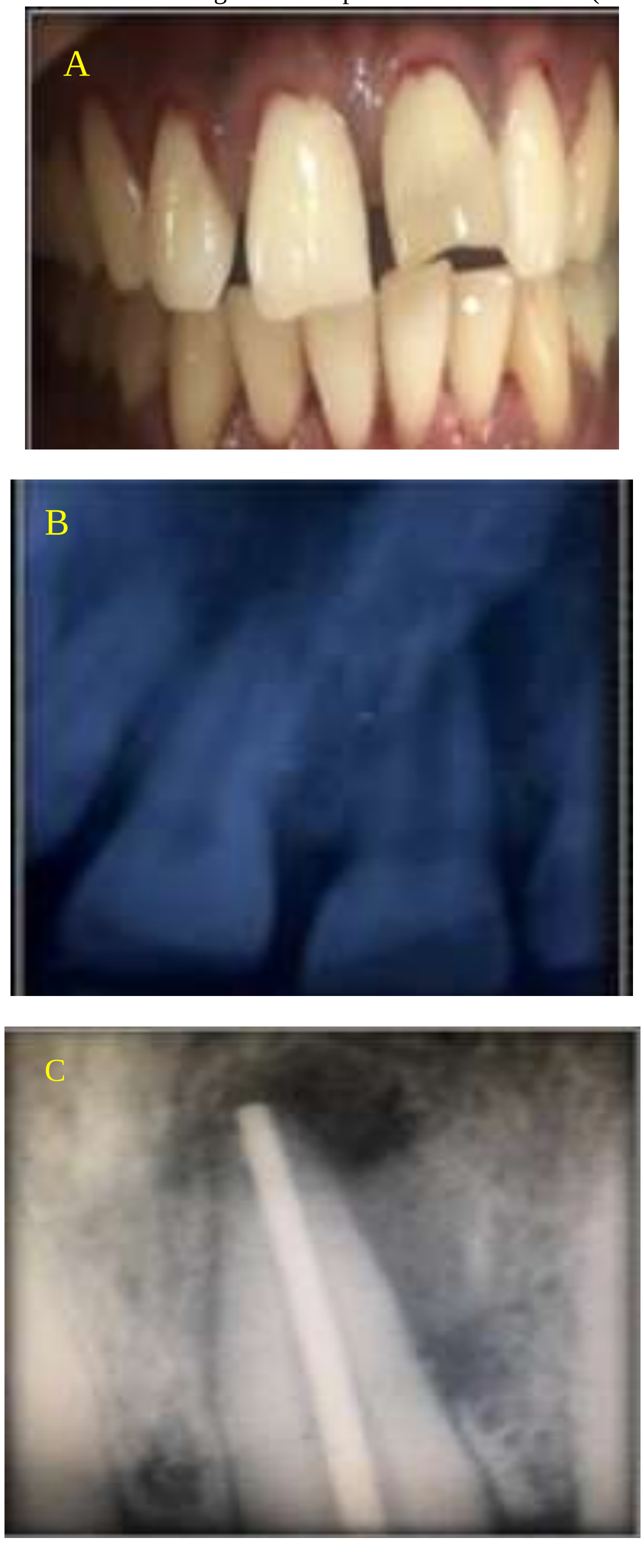
(A) Preoperative radiograph of Ellis class II fracture with respect to 11 and Ellis class I fracture with respect to 21. **(B)** The light body impression of the root canal space. **(C)** BioRoot inlay. **(D)** For 11, BioRoot inlay along with a bio ceramic sealer was used to obturate the root canal space and For21, The canal was obturated with thermoplasticizedguttapercha and bio-ceramic sealer by using the continuous heat wave technique.

Case 3

A 24 year old male patient reported with the chief complaint of discoloured teeth in his maxillary front tooth region with a history of trauma at the age of 9 years. Clinical examination revealed Ellis class II fracture with respect to 21. Radiographic examination revealed a large blunderbuss canal with associated periapical lesion .The patient was given a detailed explanation concerning the treatment and prognosis and informed consent was obtained.

A similar protocol of treatment was adapted. In this case root end closure was done with the help of MTA plug. After confirming the apical plug with radiograph, a sterile wet cotton pellet was placed over the canal orifice and the access cavity was sealed with temporary filling. After 24 hours, the hardness of MTA was confirmed and the rest of the root canal was obturated with lateral condensation using MTA fillapex bio-ceramic sealer. The access cavity was then restored with composite. One week follow up appointment was completed without any post operative complications.

Figure 3:- Apexification with Mineral trioxide aggregate (MTA) in relation to 21 followed by obturation done with lateral condensation using MTA fillapex bio-ceramic sealer (Case 3).



A) Ellis class II fracture with respect to 21. **(B)** Pre operative radiograph revealed a large blunderbuss canal (**A**) with associated periapical lesion. **(C)** Root end closure was done with the help of MTA plug. **(D)** Root canal space was obturated with lateral condensation using MTA fillapex bio-ceramic sealer.

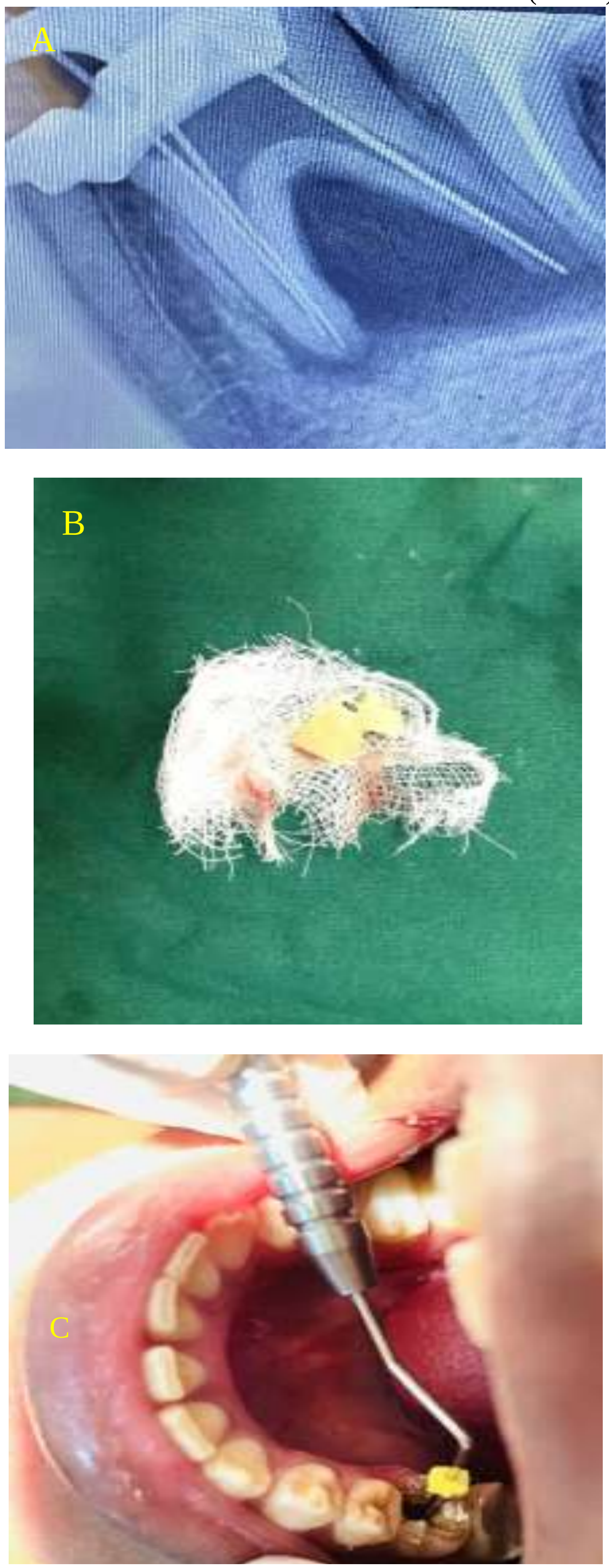
Case 4

A 23yearold female patient reported for a routine check up. Intraoral examination revealed generalized discoloration and hypoplasia of teeth. Patient had a history of intake of tetracycline by the mother during first trimester of pregnancy. The preoperative radiograph revealed poorly obturated root canal in relation to 36 with immature wide open apex in the distal root and also furcation and periapical radiolucency. Informed consent was obtained from the patient. Treatment plan was decided to do single visit apexification using Biodentine™ and platelet rich fibrin (PRF).

After removing the gutta percha, circumferential filing was done with 50K file along the walls of distal root and rotary preparation done with mesial roots. Then calcium hydroxide was placed in the root canal and sealed with temporary restoration and in the subsequent appointment canals were copiously irrigated and filled with triple antibiotic paste. The patient was recalled after 2 weeks

PRF membrane was prepared by drawing 10 ml of whole blood of patient into a sterile glass test tube without anticoagulant and was immediately centrifuged at 3000 rpm for 10 min. The resultant product consisted of three layers: top most layer consisting of acellular platelet-poor plasma, PRF clot in the middle, and red blood cells at the bottom . The freshly prepared PRF membrane was placed into the canal and then compacted at the level of the apex. Biodentine™ was mixed and placed into the canal and condensed against the PRF matrix .Canal underwent lateral condensation of gutta percha with bio-ceramic sealer. The tooth was immediately restored with glass ionomer cement (GIC) restoration and confirmed with post operative intraoral radiograph.

Figure 4:- Apexificationwith Biodentine™and platelet rich fibrin (PRF)followed by obturation bylateral condensation of GuttaPercha with bio-ceramic sealer (Case 4).



(A) Wide-open apex in the distal root In relation to 36 and also furcation and periapical radiolucency. **(B)** PRF membrane placed in gauze pieces. **(C)** The freshly prepared PRF membrane was placed into the canal and then compacted at the level of the apex. **(D)** Biodentine™ was mixed and placed into the distal canal and condensed against the PRF matrix. Canal was then undergo lateral condensation ofguttapercha with bio-ceramic sealer.

Discussion:-

In endodontic procedures, premature permanent teeth with wide-open apex and delicate thin dentinal walls raise extraordinary trouble. Traditional calcium hydroxide apexification procedure takes somewhere around three to four months and demands several appointments (2).This prolonged care regimen could be poorly complied with and many would not return to scheduled visits. The treatment discussed in this case series envisages to assemble an apical barrier in one appointment, which wouldobstructinfiltration of poisons and microbes from root canal into periapical tissues. The root canal space was obturated with different methods in this case series.

According to Morse et al., (19) single-visit apexificationprocedure is the nonsurgical condensation of a biocompatible material into the apical end of the root canal. The rationale behind this was to establish an apical stop that would enable the root canal to be filled immediately. There is no endeavour to instigate root-end closure rather than an artificial apical stop is created at the apex. A number of materials have been proposed including tricalcium phosphate, calcium hydroxide, freeze-dried bone and freeze-dried dentine, MTA, and Biodentine™ for this purpose (20).

Although the use of calcium hydroxide, a traditional treatment option, has stood the test of time and is still valid until today and has higher rate of success in apical barrier development, long term monitoring is important. Clinicians have to get themselves updated of the changes that occur in the field regarding the recommendations for treatment, and also of the studies that support or disprove such treatment protocols..

The above-described cases had different degrees of open apices and associated apical periodontitis and were treated with different techniques of obturation. Significant differences were found in the treatment procedure and consequences with these materials but since host reaction assumes a fundamental part in the result,it would be unwise to compare these materials as such.

When treating non-vital teeth, the main issue is eliminating bacteria from root canal system. Cleaning and disinfection rely on disinfecting substances like calcium hydroxide as an intracanal dressing and sodium hypochlorite as an irrigant since instruments cannot be used adequately on teeth with open apices.(21). Moreover, there is a risk of extrusion of these disinfecting agents beyond apical foramen. It is advised to utilise a less concentrated form of sodium hypochlorite because it is knownto be toxic to the periapical tissues if goes beyond the apex. In all the above cases, 0.5% sodium hypochlorite was used. Alternative antibacterial agents such as calcium hydroxideor triple antibiotic pastes have proven to be effective in cases with open apices for canal disinfection (22).

Many materials have been proposed for root-end closure, however, according to Torabinejadet al., (23) MTA has become material of choice for apexification. MTA has a range of advantages such as biocompatibility,hard tissue formation, sealing ability, and antibacterial property..Torabinejad et al., (23) found that MTA has an antibacterial effect on five of nine facultative bacteria but no effect on any strict anaerobes and also it is not affected by the presence of blood. Prolonged setting times, handling difficulties, high material costs and possible coronal staining associated with tooth structure, presence and release of arsenic are its main drawbacks and this led to a search for other alternative materials(12).

Biodentine™ is a bioactive replacement dentine based on Active Biosilicate Technology is similar to MTA in its basic composition with the addition of setting accelerators which is calcium chloride (20) and it not only results in fast setting but also improves handling properties and strength. Powder in a capsule and liquid in a pipette make up Biodentine™(24). Biodentine™ is superior to MTA because its consistency is better suited to clinical use, ensures better handling, safety and does not require a two-step obturation as setting time is faster, there is also a lower risk of bacterial contamination (25). The compressive strength, elasticity and micro-stiffness of Biodentine™ is comparable to that of natural dentine. It produces a tag-like crystalline structure in the dentinal tubules which help the binding ofdentine with new calcium silicate substances.

In all these cases we have used MTA fillapex , bio-ceramic sealer with good biocompatibility, lack of sensitivity to moisture, provide a better seal laterally and apically , which improve the efficiency of root canal obturation and success rate of endodontic therapy.

In the first case, Biodentine™ was directly introduced into the canals forming an apical plug of 4mm in a controlled manner. Then, rest of the canal was obturated with tailor made guttapercha. It is superior to lateral compaction because the presence of a thin fragile dentinal wall in a wide canal enhances their susceptibility to fracture during instrumentation and compaction .

In the second case, an innovative technique, BioRoot inlay was used to obturate the canal in 11 and thermoplasticizedguttapercha in 21.An intra-radicular custom-made prefabricated restoration called a "BioRoot inlay" helps in building an apical barrier and provides a three-dimensional seal of the root canal area.ThisBioRootinlayalongwith the MTA fillapex as sealer forms a monoblock when placed in the canal and can act as a good seal laterally and apically. This bio-ceramic sealer helps in sealing milder discrepancies between the plug and the root providing three-dimensional seal which had resulted in good healing of periradicular bone. Obturation using thermoplasticizedguttapercha helps in achieving a better seal and also prevents compaction forces on the thin dentinal walls, unlike the lateral condensation technique.

In the third case, root end closure was done with the help of MTA plug and the rest of the root canal wasobturated with lateral condensation. MTA needs two sitting to complete the total apexification technique, in all other cases Biodentine™ was used as the apical barrier mainly due to its easier manipulation and faster setting.

In the fourth case, PRF membrane was used as an internal matrix over which the sealing material, Biodentine™ placed. It consists of leukocyte-PRF matrix composed of a tetramolecular structure with cytokines, platelets, and stem cells within it which acts as a biodegradable scaffold that guides epithelial cell to migrate to its surface. The cells involved in tissue regeneration may be carried by PRF and release growth factors in a period between 1 and 4 weeks. Platelet rich fibrin has shown considerable success rates as an alternative to matrix materials. Hence, it was also tried in one of these cases,along with thermoplasticized gutta-percha, bio-ceramic sealer also used for obturation proved to be equally good as MTA and Biodentine™alone in performing one-step apexification.

Following that all the recommended protocols of adequate cleaning and shaping was undergone. Steinig, et al., (25) stated that the importance of one-step apexification technique lies in the expedient cleaning and shaping of the root canal system, followed by its apical seal with a material. Furthermore, the potential for fractures in immature teeth with thin roots is reduced, as a bonded core can be placed immediately within the root canal especially if BioRoot inlay is used instead of guttapercha. In all these cases follow up was satisfactory and patients were asymptomatic.

Conclusion:-

It can be concluded that despite the different types of material used in various cases, the success in all the cases depends on proper disinfection of the canal, obturation within the canal, fluid-tight seal with void less obturation and healthy response to the patient’s body. The healing could be attributed to following recommended protocols and response of the patient’s body but still more comparative longer followup and large-scale studies need to be conducted to devise the exact material and technique which could give 100% results.

Referances:-

1. Galli, M., Yao, Y., Giannobile, WV and Wang, HL., (2021) Current and future trends in periodontal tissue engineering and bone regeneration. Plastic and aesthetic research. 8: 3 -22.
2. Sanju, Dahiya and Neha, Singhal., (2022). Apexification using biodentinee: A case report. Int J Appl Dent Sci., 8(1):293-295.
DOI:https://doi.org/10.22271/oral.2022.v8.i1e.1440
3. American Association of Endodontists: Glossary of endodontic terms. Available from: http://www.aae.org/ glossary.
4. Murray, PE. and García-Godoy, F., (2006). The incidence of pulp healing defects with direct capping materials. Am J Dent., 19(3):171-177. PMID: 16838483.
5. Yoshiba. K., Yoshiba, N and Iwaku, M., (1994). Histological observations of hard tissue barrier formation in amputated dental pulp capped with alpha-tricalcium phosphate containing calcium hydroxide. Endod Dent Traumatol. 10:113–120
6. Cox. CF and Suzuki, S., (1994). Re-evaluating pulp protection: calcium hydroxide liners vs. cohesive hybridization. J Am Dent Assoc., 125:823–831.
7.Farhad, A and Mohammadi, Z., (2005). Calcium hydroxide: a review. International Dental Journal. 55(5):293-301.
8. Arandi, NZ., (2017). Calcium hydroxide liners: a literature review. Clinical, Cosmetic and Investigational Dentistry., 13:67-72.
9.Cox, CF., Bergenholtz, G., Heys DR., et al., (1985). Pulp capping of dental pulp mechanically exposed to oral microflora: A 1-2 year observation of wound healing in the monkey. J Oral Pathol., 14:156–168.
10.Camilleri, J., Montesin FE., Brady K, et al., (2005). The constitution of mineral trioxide aggregate. Dent Mater., 21:297–303.
11. Felman, E and Parashos, P., (2013). Coronal tooth discoloration and white mineral trioxide aggregate. J Endod., 39:484–487.
12.Chang, SW., Oh, TS., Lee, W., Shun-Pan Cheung, G and Kim HC., (2013). Long-term observation of the mineral trioxide aggregate extrusion into the periapical lesion: a case series. International Journal of Oral Science. 5(1):54-7.
13.Akhlaghi, N andKhademi, A., (2015). Outcomes of vital pulp therapy in permanent teeth with different medicaments based on review of the literature. Dental Research Journal. 12(5):406 - 417.
14. Kumar, SM., Kumar, T., Keshav, V., Arora, S and Singla, A., (2019). Open apex solutions: One-step apexification, salvaging necrosed teeth with open apex. Endodontology , 31:173-178
15. Eid, AA., Komabayashi, T., Watanabe, E., Shiraishi, T and Watanabe, I.,(2012). Characterization of the mineral trioxide aggregate–resin modified glass ionomer cement interface in different setting conditions. Journal of Endodontics. 38(8):1126-1129.
16. Malkondu, Ö.,Kazandağ, MK and Kazazoğlu, P., (2014). A review of Biodentinee, a contemporary dentine replacement and repair material. BioMed Res Int. 2014:160951.
17.Jaikaria, A., Negi, P andKukreja, S., (2019). Apexification: Use of MTA and Biodentin to form apical barrier in immature permanent teeth. Int J Appl Dent Sci. 5(4):156-158.
18. Kaup, M., Schäfer, E andDammaschke, T., (2015). An in vitro study of different material properties of Biodentine compared to ProRoot MTA. Head & Face Medicine. 11(1):1-8.
19. Morse, DR., O'Larnic, J and Yesilsoy, C., (1990). Apexification: Review of the Literature. Quintessence Int., 21(7):589-98. PMID: 2094860.
20. Kaur, M., Singh, H., Dhillon, JS., Batra, M and, Saini, M., (2017). MTA versus Biodentine: review of literature with a comparative analysis. Journal of Clinical and Diagnostic Research.,11(8):ZG01.
21. Iqbal, A., (2012). Antimicrobial irrigants in the endodontic therapy. International Journal of Health Sciences., 6(2):186-192.
22. Kumar, SM., Kumar, T., Keshav, V., Arora, S and, Singla, A., (2019). Open apex solutions: One-step apexification, salvaging necrosed teeth with open apex. Endodontology. 31(2):173 – 178.
23. Torabinejad, M., Hong, CU., Pitt Ford, TR and Kettering, JD., (1995). Antibacterial effects of some root end filling materials. J Endod., 21(8):403-406. DOI: 10.1016/s0099-2399(06)80824-1. PMID: 7595152.
24. Steinig, TH., Regan, JD and Gutmann, JL., (2003). The Use And Predictable Placement Of Mineral Trioxide Aggregate® In One-Visit Apexification Cases. Australian Endodontic Journal. 29(1):34-42.
25. Khetarpal, A., Chaudhary, S., Talwar, S and Verma, M., (2014). Endodontic management of open apex using Biodentine as a novel apical matrix. Indian Journal of Dental Research. 25(4):513 – 516.