EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 68, 3925:3936, OCTOBER, 2022
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
CONSERVATIVE DENTISTRY AND ENDODONTICS
Submit Date : 22-06-2022 • Accept Date : 02-08-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.145633.2159

DIFFERENT MANAGEMENTS OF NON VITAL PERMANENT ANTERIOR TEETH WITH OPEN APEX

Mahmoud M. Badr* *and* Amgad H. Soliman*

ABSTRACT

Aim In patients having non vital anterior teeth with open apex and periapical abscess . This study was done to find whether or not the revascularization is more effective than MTA apexification in the following: 1. change in length of the root measured in mm. 2. change of dentin thickness: measured in millimeters. 3. closure of the apex: measured in millimeters

Materials and Methods: twenty two patients suffering from non vital upper incisors with open apices were randomly assigned into two equal groups with 11 patients each. One group was treated by regeneration and the other by MTA apexification. Cases were assessed: clinically assessing swelling presence. Radiographically by digital radiography and parallel technique for more standardized results that allow accurate measurements of changes in root length, width of dentin, and apical diameter.

Results: Results showed that there was no statistically significant difference between the 2 groups in 1 month, after 3 months, after 6 months, after 9 months and after 12 months. Also showed that the healing outcome of radiolucency was greatest at the re-vascularization gp (90.9 %), followed be the apexification by mineral trioxide aggregate gp (63.6 %) which showed high percentage of success. Moreover, the healing outcome of the swelling is greater at the re-vascularization gp (81.8 %), followed by the apexification by mineral trioxide aggregate gp (72.7 %) which showed high percentage of success. It also showed that the percentage increase of root length and dentin width is greater in re-vascularization gp followed by the apexification by mineral trioxide aggregate gp. However differences between apexification group and re-vascularization group were statistically not significant. On the other hand, regarding the decrease in apical width, better results were shown in MTA apexification group than the regeneration group. Although differences between MTA apexification group and regeneration group were statistically not significant.

Conclusion 1- Re-vascularization and apexification by mineral trioxide aggregate are considered successful techniques for the management of non-vital teeth with immature apex yet re-vascularization procedure is still preferable. 2- Regeneration has a higher rate of success concerning resolution of swelling and radiolucencies. 3- Regeneration is superior in adjusting crown-to-root ratio.

* Department of Endodontics, Faculty of Dentistry, Future University in Egypt. Cairo, Egypt

INTRODUCTION

Necrotic immature permanent teeth present a problem in dentistry as no further root completion occurs leaving open apices that make cleaning and shaping of wide blunderbuss roots, and creating an apical stop or having an apical seal in endodontic treatment difficult. Having incomplete dentin deposition, the root is more liable to fracture during mechanical preparation or obturation due to thin dentinal walls.

Endodontic surgery and retrograde filling were used for treating such cases but this approach is invasive and has its disadvantages as surgical complications and the already fragile root (1, 2).

Apexification in which calcium hydroxide is used to induce apical closure is also used in such cases (2, 3,4); it was first introduced by Kaiser (3) in 1964. Many disadvantages appeared to that technique, as the long treatment period that might reach 34 weeks, the porous barrier with inadequate seal (1), and the thin newly formed walls that are more prone to fracture (1, 6).

Mineral trioxide aggregate (MTA) apexification was introduced by Torabinejad and Chivian (5) in 1999 . The main advantage of this technique is that it reduces the treatment time and increases healing of the periradicular tissues, but the radicular dentin still remains thin and subject to fracture during obturation, and the root length remains unchanged with bad crown-to-root ratio (6).

Revascularization allows the stimulation of apical development and root maturation in comparison with Ca(OH)2 or/and MTA apexification. Therefore, re-vascularization provides superior outcome regarding the preservation of the natural teeth (7, 8, 9). Other authors (10) have found that apexification techniques have the same clinical and radiographic outcome as revascularization. More experimental studies are required, either with bigger number of samples and extended follow-up durations to investigate whether re-vascularization procedure is considered the better treatment plan considering the biological, radiographic and the clinical treatment outcomes.

This clinical study was performed to assess the treatment outcome of both the apexification using mineral trioxide aggregate and the re-vascularization procedures in immature teeth with open apices. Moreover, to assess the best treatment option regarding clinical and radiographic outcome.

Aim of this study which was done on non vital anterior teeth with open apex to find whether the revascularization is more effective than MTA apexification in the following or not:

1. Resolution of periapical radiolucency: binary outcome.
2. Maturation of root: measured in mm.
3. Increase of dentin thickness: measured in mm.

MATERIALS AND METHODS

Trial design:

In RCT, participants presented randomly to have one of several visits (two at least) following the study design. These interventions may be drug, placebo or certain procedure which is not usually known whether it will be helpful, harmful or with no difference than the available alternatives.

Eligibility criteria:

i) Inclusion criteria:

- All patients were medically free.
- Age ranging between 7-16 years old.
- No sex predilection.
- Patients having asymptomatic and/or symptomatic immature necrotic anterior teeth.

ii) Exclusion criteria:

- Patients allergic to the antibiotics that are utilized through out the procedures.
- Patients suffering from any systemic illness such as diabetes , blood diseases, heart diseases, liver diseases, kidney diseases, genetic disorders and syndrome.
- Psychologically disturbed patients.
- Patients who had radiographic evidence of external / internal root resorption or cystic lesion.
- Patients refused participation in the study.

Setting and location:

Candidates for our study were obtained from the pediatric clinic, Faculty of Oral and Dental Medicine, Future University in Egypt. Thorough diagnosis regarding the dental history and the medical history were obtained from all patients participating in this research. Clinical and radiographic evaluations for each tooth included in this study were also recorded. Prior to treatment, data of the tooth type, arch, patient's age, and gender had been gathered. The status of the pulp was confirmed through the negative response to thermal testing using hot instrument test and ethyl-chloride cold test. Moreover, PA x-rays were taken by bisecting angle technique and periapical status was assessed. Dental records were obtained from each patient in form of extraoral and intraoral photograph. Alginate impression was taken to have a study cast for recording the swelling (if present) and making an acrylic stent used as a radiographic aid for standardization. After the treatment plan discussion, the parents had been assigned to put their signature on a detailed informed consent that was presented in English and Arabic. Candidates were instructed to come after 1/3/6 and 9 months for follow up visits. Then the patients returned in due time. A broad spectrum antibiotic was prescribed to the patients to strictly take on regular basis 72 hours prior the treatment begins (EMOXCLAV 312mg). Also, they were instructed not to take analgesics.

Intervention:

Twenty two patients were equally divided into two main groups, 11 patients in every group. The procedure was finalized in two visits.

1st visit: The antibiotic agent (TAP) was properly placed in all the samples in the two groups.

2nd visit:

Group A: Mineral trioxide aggregate apexification procedure was performed.

Group B: Re-vascularization procedure was performed.

Procedure:

a. 1st visit: The procedures in this 1st visit were applied to all of the 22 cases participating in the study. Patients were anesthetized by 1 carpule of mepivacaine without vasoconstrictor (mepivacaine HCl 3%) using disposable short needles and metallic dental syringe, with a buccal infiltration for the tooth which was previously anesthetized with topical anesthesia. The tooth was isolated with rubber dam using clamp and frame, After preparing the access cavity using a size 2 round bur and an Endo-z bur, aK -file size 15 was introduced precisely in a watch winding motion till the estimated working length, and the working length was determined radiographically. The canals were then flushed using 20ml of 5.25% NaOCl solution through a side-vented irrigation needle 1-2 millimeters away from the WL. An acid etch was placed over the internal walls of the access cavity 35% phosphoric acid for 20 seconds and then properly rinsed. Bonding agent applicated and subjected to 20 seconds curing, a layer of 1mm thickness of flowable resin bonded

composite was applicated and subjected to 40 seconds curing. Canal dryness was performed using sterile paper points.

Preparation and placement of tri-antibiotic paste: the antibiotic agent made of metro-nidazole (Flagyl), cipro-floxacin (Ciprofar) and doxy-cycline (Vibramycin). Both Flagyl and Ciprofar are supplied in tablet form and were ground using a sterile mortar and pestle. 100 mg of each of them were scaled using a sensitive scale and then mixed with 100 mg of Vibramycin which was directly evacuated from the capsule to obtain a homogenous powder of 1:1:1 of the three antibiotics. A creamy paste was obtained by mixing the powder with 3ml of distilled water. Then the agent was properly placed inside the root canal using suitable condenser and furtherly condensed trying to decrease its placement in cervical part. The canal was obturated just beneath the CEJ level. Afterwards, sealing the cavity using an intermediate restorative material(GI) was done.

If the patient had no relief of pain or swelling persisted, the first visit procedure was repeated, if there was a relief; second visit was initiated. (10, 11)

b. 2nd visit: 3-weeks later, patients were classified into two main groups:

Re-vascularization gp: patients were anesthetized by 1 carpule of mepivacaine without vasoconstrictor (mepivacaine HCl 3%), appropriate rubber dam isolation was performed then the intermediate restorative material was removed and the access was regained. A side vented needle was used for irrigation with 5.25% NaOCl(20 ml). Dryness of the canal was performed utilizing sterile paper points. Afterwards, a sharp needle was utilized to induce bleeding from the periodical tissues entering the apical portion of the canal to act as a biological scaffold for the re-vascularization procedure to occur.

After 20 minutes, clotting of the blood was allowed to occur to around 3 millimeters just below the CEJ. Afterwards, grey mineral trioxide aggregate (3 millimeters) was placed utilizing a properly sized carrier. A damped cotton pellet on a tweezer was placed above the unset MTA and large condenser was used for proper sealing of the orifice. The access cavity was sealed with Fuji IX (GI) material and acid etched composite resin bonded filling material.

Apexification group: Patients were anesthetized by 1 carpule of mepivacaine without vasoconstrictor (mepivacaine HCl 3%), appropriate rubber dam isolation was performed then the intermediate restorative material was removed and the access was regained. A side vented needle was used for irrigation with 5.25% NaOCl(20 ml). Dryness of the canal was performed utilizing sterile paper points. Afterwards, mineral trioxide aggregate was properly mixed according to the manufacturing instructions and then properly introduced into the canal from the apical constriction till the level just below the CEJ utilizing a suitable sized plugger #25. X-rays were then taken to confirm the level of the MTA apical plug by bisecting angle technique. After the placement of MTA, the tooth was restored immediately, as the top of the MTA was dried, and then the placement of the intermediate restorative material (GI). Finally, etching and bonding of the access cavity was performed and composite filling material was then applied to seal the entire cavity. In both groups, X-rays were then taken postoperatively for each patient.

Follow-up: follow up for the patients were done in 1/3/6 and 9 months. The posttreatment follow-up examination was accomplished as follows: an evaluation was performed on each patient to assess the patient' soft tissue and radiographical changes.

Outcome:

Resolution of periapical pathosis: This was a binary outcome and was assessed:

1- Clinically: by visual inspection of the patient's soft tissue at 1/3/6 and 9 months months (swelling).

2- Radiographically:

· Radiolucency: by comparing the preoperative radiolucency with that after 9 months postoperative.

· The maturation of root: scale was set in Digora software by coinciding a known clinical dimension to its radiographic dimension. The scale was calculated by the number of measured pixels for length in mm.

Root length was calculated by measuring a line extending from the cement-enamel junction to the radiographic apex (in mm). Then on the 9 months follow up radiograph was compared to the baseline radiograph, the difference was calculated as follows: increase in length = (follow up length – base line length).

Amount of maturation in the root dentinal wall thickness: Using the preset measurement scale, the level of the apical third was determined and fixed from the cement-enamel junction. The root thickness was measured at this level in mm. Dentin thickness was measured on the 9 months follow up radiograph as follows: dentin thickness = (root thickness-pulp space) and compared to the preoperative radiograph . The increase in thickness was calculated as follows: increase in thickness = (follow-up thickness –base line thickness).

Decrease of apical diameter: using the preset measurement scale, the width the apical foramen was measured in millimeters on the 9 months follow up radiograph and compared to the preoperative radiograph. The decrease of apical diameter was calculated as follows: decrease of apical diameter = follow-up apical diameter-base line apical diameter).

Success in both groups was assessed:

1) Clinically: Absence of signs and symptoms (pain and swelling).

2) Radiographically: Decrease in periapical radiolucency, evidence of root maturation, increase of dentinal wall width, and decrease of apical diameter (although in apexification, continued root development was not expected).

Statistical Analysis:

The Statistical analysis was done with the software of Statistical Package for Social Sciences (SPSS)* statistics version 20.

All the data about age, gender, tooth type and duration from trauma were collected from each patient. Moreover, the baseline clinical and radiographic findings were gathered along with the postoperative clinical findings (swelling, fistula and coronal discoloration) and the radiographic findings (resolution of periapical radiolucency, formation of calcific barrier, blunt apex and the radiographic changes of the root length, thickness and apical diameter). The mean and standard deviation values were calculated for each group. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests.

All the data regarding diameter at the apex, width of the apical dentin and length of the apical portion of the root showed parametric (normal) distribution. Independent samples t-test was done to compare the difference between both groups. The significance level was set at $P \leq 0.05$.

RESULTS

Twenty two patients were equally divided into two main groups, 11 patients in every group. The procedure was finalized in two visits.

1st visit: The antibiotic agent (TAP) was properly placed in all the samples in the two groups.

2nd visit:

Group A: Mineral trioxide aggregate apexification procedure was performed.

Group B: Re-vascularization procedure was performed.

Root maturity, dentinal width and apical diameter in mm and healing percentage:

The mean, standard deviation values, and percentage of the variables of the two groups are shown below

i) Increase in root length:

There wasn't any statistical significance between mineral trioxide aggregate apexification group(A) and the re-vascularization group(B) (p = 0.9).

ii) Increase in dentin thickness:

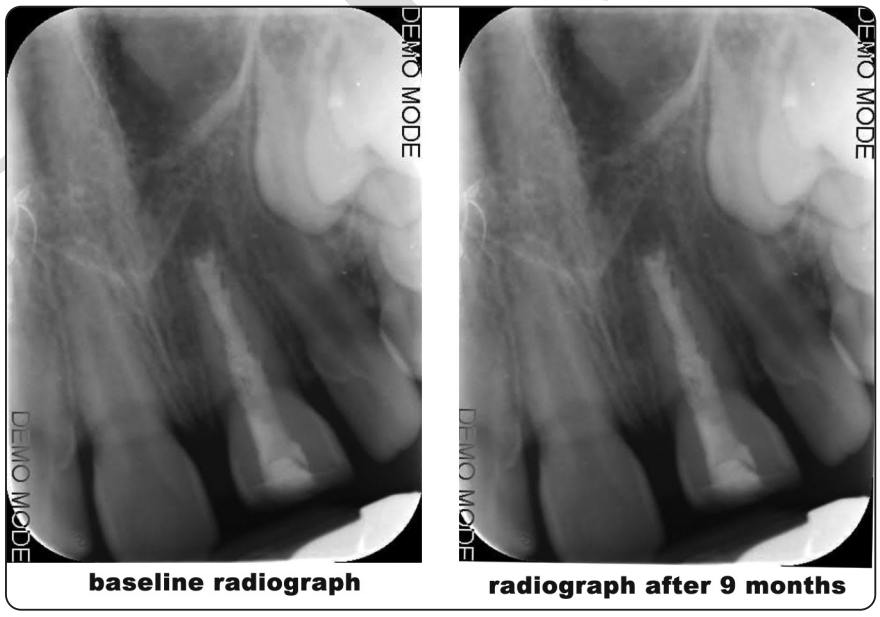
There wasn't any statistical significance between mineral trioxide aggregate apexification group(A) and the re-vascularization group (B) (p = 0.6).

iii) Decrease in apical diameter:

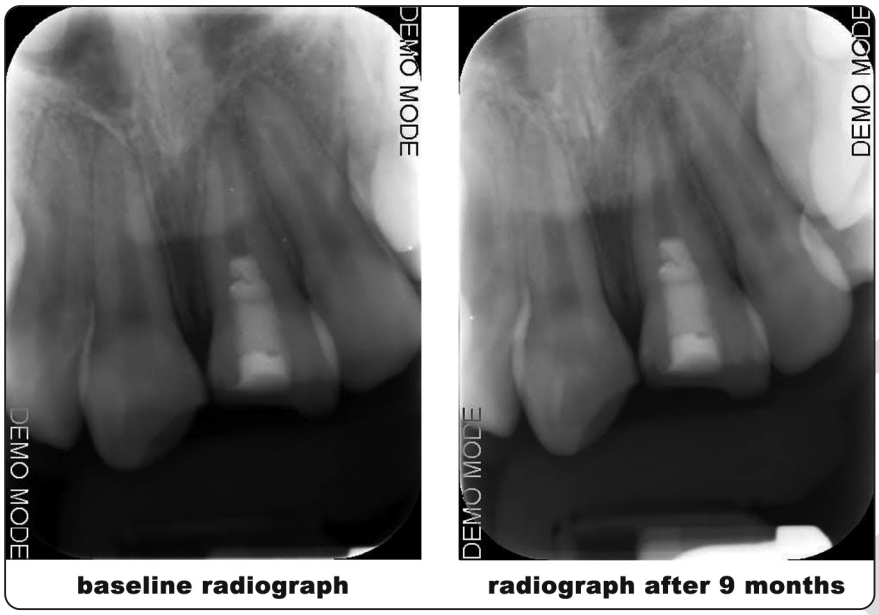
There wasn't any statistical significance between mineral trioxide aggregate apexification group(A) and the re-vascularization group(B) (p= 0.5).

Table Representing means value and standard deviation between the two groups regarding the different variables; increase in root length, increase in dentin thickness and decrease in apical diameter (millimeters) and percentage.

	Apexification (A)		Regenerative (B)		P value
	Mean ± SD	%	Mean ± SD	%	
Increase in Root length	0.44 ± 0.81	4.27 ± 11.32	0.49 ± 1.01	2.90± 9.79	0.9ns
Increase in Dentin thickness	0.01 ± 0.31	2.64± 13.46	0.09 ± 0.42	4.16± 25.51	0.6ns
Decrease in Apex diameter	0.40 ± 0.78	30.76± 54.63	0.22 ± 0.4	23.90 ± 26.41	0.5ns



Radiograph showing a successful mineral trioxide aggregate apexification case. Lack of radiographic changes in the thickness of apical portion of the root dentine nor the length of the apical portion of the root where (Ai) baseline radiograph, and (Aii) radiograph after 9 months



Radiograph showing a successful regeneration case with obvious radiographic changes regarding an increase in the thickness of apical portion of the root dentine, the length of the apical portion of the root , and the decrease of the diameter of the apex with complete root formation.

DISCUSSION

Non-vital teeth with open apex cause major problem in dentistry. The open apices present a difficulty in creating an apical stop and apical seal in endodontic treatment. Cleaning and shaping of wide blunderbuss root apex is extremely difficult. During mechanical preparation and obturation root fracture is possible due to thin dentinal walls caused by incomplete dentin depositioning. These teeth also have increased mobility due to periodontal breakdown resulting from the poor crown-to-root ratio [1-4] .

The literature reported the use of MTA apexification by placing MTA plug at the apex of the root to create apical seal and apical stop that allows the obturation of the canal with gutta percha. However it had not explained the distorted crown root ratio along with the more liability of root fracture because of the limited thickness of dentine that makes the root more prone to fracture. [1, 13, 13, 9, 14, 15, 16] . Re-vascularization was introduced and widely used as a biological procedure providing the appropriate biological environment for stimulation of continuous formation of the root aiming for increased thickness and length of the apical portion of the root and thus decreasing the apical diameter and apical closure [2, 17]. This study was conducted on 22 patients with immature necrotic anterior teeth. The participants' age in this study ranged between 7-16 years, older patients would have lower regenerative power according to Shah et al [2] in 2008, Trope [18] in 2008, and Law [19] in 2013.

Anesthesia without vasoconstrictor (1 carpule of mepivacaine HCl 3%) was used in this study to allow enough amount of blood to fill the canal and clot to act as scaffold and a source for the undifferentiated mesenchymal cells (UMC) in regeneration cases as recommended by literature (20). For successful re-vascularization and mineral trioxide aggregate apexification procedure, disinfecting the canal and removal of microorganisms is mandatory for superior treatment outcomes gained through the strict rubber dam isolation of the field, chemo-mechanical preparation of the canal and placing interappointment intracanal medications. [18, 21]. Due to the reduced thickness of dentine, no mechanical instrumentation was performed relying only on the chemical disinfection in the two groups (non-instrumentation disinfection) by tri-antibiotic paste (TAP) and using sodium hypochlorite; a potent anti microbial irrigating solution as recommended by

Martin T. [18], Schin [22], Thom and Kalher [21]. The reason for non-instrumentation in group A in the 1st visit was to unify the disinfection techniques between both groups and decrease the variables that may affect the study outcome.

Sodium hypochlorite is considered the most widely used irrigating solution due to its high antimicrobial action, eradicating most of bacteria, with its unique dissolving action of the pulpal tissue and collagen as previously approved by many researchers [23, 17, 22, 21, 18, 24, 25]. Haridson [68] suggested the use of diluted solution of sodium hypochlorite to minimize the risk of periradicular irritation and the subsequent pain postoperatively because its main drawback is being cytotoxic to the periradicular tissues. Though Kalher and Thompson [21] suggested the use of minimal concentrations of sodium hypochlorite (up to 1%) and claimed that this low concentration will be enough for disinfecting the canal during the re-vascularization procedure to avoid the death of the viable stem cells that is mandatory for the regeneration procedure to take place, we used in our study 20ml NaOCl (5.25%) in accordance to Banchs and Trope [36] in 2004, and Reynolds et al [23] in 2008. They stated that lower concentration is not effective in eradication of infection in canals without mechanical instrumentation and that concentration more than 6% will be lethal to the remnants of the viable stem cells.

Irrigation was performed using the safe side-vented needles placed 2 mm away from the working length were used in this study to avoid irrigant extrusion as described by Bradford et al [26] in 2002. Reeh and Messser [27] in 1989, and Hülsmann and Hahn [28] in 2000 stated that more apically-directed pressure is created if the irrigating needle tip is introduced in close proximity to the apex increasing risk of irrigant extrusion causing periapical tissue necrosis, severe pain, and swelling.

In this study, we used triple antibiotic paste (TAP) as an interappointment intracanal medicament for 21 days for the chemical disinfection of the canal in both groups as it has a great effect in eradication of root canal infection even without mechanical instrumentation as concluded by many researchers [29, 30, 31, 32, 18, 23, 33, 21]. It consists originally of ciprofloxacin 200 mg, metro nidazole 500 mg, and mino-cycline 100 mg in ratio 1: 1: 1 and mixed by mocrigel and propyl glycal as proposed at a previous study [29]. Doxycycline was found to have the same topical anti microbial action as minocycline as claimed by Riter et al [32], however it has much decreased staining action and that was concluded by Raynolds et al [23] and Kim et al [34]. That is why doxycycline was used instead of minocycline with other components in this study with proportion of 1:1:1 and then properly stirred with saline or distilled water [23, 34]. It's advisable to coat the access cavity walls with resin material before the placement of the tri-antibiotic paste to reduce the possibility of staining. Then TAP was placed into the root canal utilizing a suitable condenser and then further adapted into narrow canals by finger pluggers to avoid placement into the coronal pulp space to decrease the discoloration.

In our study, MTA was used in both groups; apically for apexification and coronally for regeneration. This decision to use MTA came in respect of its superior biocompatibility, antibacterial effect, good marginal adaptation, sealability, expansion upon setting, and reasonable setting time preventing bacterial leakage. It provides great apical and coronal seal thus allowing regeneration of apical tissue in non-vital teeth with open apex as stated by Torabinejad and Chivian [35] in 1999, D'Arcangelo and D'Amario [36] in 2007, Pace et al [37] in 2008, and Raldi et al [38] in 2009. In the Regeneration group bleeding was initiated by sterile long anesthesia needle as recommended by Shah [2] (2008), Kalher and Thomson [21] (2010), who avoided the use of k-files in order to prevent the damage of the canal walls and the remaining vital cells.

In opposition, Reynolds et al [23] in 2008, reported successful regeneration using k-files. MTA was not recommended to be pushed beyond the cervical third to allow proper coronal blood penetration into the canal to create sufficient amount of scaffold after its clotting thus allowing regeneration as recommended by Martin [18], Reynolds [23] in 2008, Thompson et al [21]. In both groups the access cavity was sealed with intermediate restorative material (GI) and resin-modified restorative material to prevent bacterial leakage into the canal as stated by Thomson and Kahler [21] in 2010.

In the two groups, X-rays were taken using the paralleling method to provide preoperative and postoperative X-rays during the follow up appointments at 1,3,6 and 9 months. This method allowed a proper assessment of periradicular radiolucencies whether it's obvious on radiograph or not, and an accurate comparison of the changes in mm in the diameter at the apex, thickness and length of the apical portion of dentin. This was done to insure getting an exact replicated radiograph in the follow up visits with the only variable in the radiograph being the change in radiolucencies, root length, dentin width, and diameter of the apex as described by as recommended by Holden et al [15] in 2008.

Regarding the outcome of healing percentage of the radiolucencies (90.9 %) and the swelling (81.8 %) that were greater in re-vascularization gp than in the mineral trioxide aggregate apexification gp (63.6 % and 72.7 %). In a study made by Shah et al [2] in 2008, revascularization in 14 cases resulted in complete resolution of signs, symptoms, and periapical radiolucencies in 78% of the cases. While in another study made by Mante et al [39] in 2013, out of 252 cases treated by MTA apexification, 90% of the cases were healed. The differences in results are probably due to difference in number of participants, baseline data and manipulative measures. In our study one case in each group failed to heal. This was due to the probability of secondary trauma and loss of the inter-visit dressing that broke the coronal seal and reinfected the canals leading to formation of abscess as discussed by Law [19] in 2013.

Although there wasn't any statistically significant differences between the two main groups regarding decreased diameter at the apex, increased root length and dentine width, re-vascularization group obtained superior outcome in terms of increased length of the root. While group B demonstrated superior outcome in terms of decreased diameter of the apex. This was in agreement with Shah et al [2] in 2008, where 57% of their regeneration cases showed widening in root walls and 71% of their cases showed increase in root maturation. In a previous literature [40] in 2015, 100% of the 20 cases treated with MTA apexification showed decrease in apical diameter. Lovelace et al [41] in 2011, and Torabinejad and Faras [42] in 2012 suggested that the root formation is established by a vital pulp like connective tissue created by the undifferentiated stem cells coming from the fresh blood induced from the periapical area into the canal. While a study by Chen et al [43] in 2011, treating 20 cases of non-vital teeth with open apex by regeneration, revealed that increase in root maturity and reduction in apical diameter are not as predictable as increase in dentin width in regeneration cases . They stated that the success of regeneration depends on whether epithelial root sheath of Hertwig cells survived or not. In the present study, not as expected one case in apexification group showed increase in root maturity and continued root formation although no blood inducement was stimulated in this case and no scaffold was present inside the canal. This could be due to vital remnants of epithelial root sheath of Hertwig that are surrounding the end of the root that continued the root formation by cementum-like and bone-like tissues suggesting ingrowth of periodontal ligament tissue rather than pulp tissue after disinfection of the canal, coronal seal, and healing of periapical infection as suggested by

Claus et al [44] in 2004, Wang et al [45] in 2010, and Law [19] in 2013.

Re-vascularization procedure posses a superior advantage over the apexification procedure which is the biological continuation of root maturation and formation resulting in increased length and thickness of the root with biological apical closure and that was in accordance with the recently published systematic review by Wikström [46] in 2021. Also, various studies have proved that continuation of root maturation and apical closure is possible in non-vital immature teeth with open apices when the re-vascular action procedure is properly performed (Staffoli et al.[47] in 2019).

Our findings regarding the root maturation and width in endodontic regeneration group are in agreement with other researshers (Silujjai and Linsuwanont [10] in 2017; Yoshpe et al.[48] in 2021).On the contrary, Alobaid et al. (2014) showed limited proof in radiograph to the continued formation of root in group A. There were statistical differences between the two groups regarding the changes in length and width of the apical portion of the root. This is in accordance with most of the studies, case series and/or reports, and the published retrospective and prospective cohort studies (Staffoli et al. [47] in 2019; Hameed et al [49] in 2019) that already proved and reported a significant superior maturation and development of the root apex in terms of increased length and width of the apical portion of the root with superior apical closure outcomes after re-vascularization when compared to the apical plug technique through mineral trioxide aggregate apexification.

REFERENCES

1. Neha K, Kansal R, Garg P, Joshi R, Garg D, Grover HS. Management of immature teeth by dentin-pulp regeneration: A recent approach, Med Oral Patol Oral Cir Bucal 2011;16(7):e997-1004.
2. Shah N, Logani A, Bhaskar U, Aggarwal V. Efficacy of revascularization to induce apexification/apexogenesis in infected, nonvital, immature teeth: A pilot clinical study, J Endod 2008;34:919-925.
3. Kaiser HJ. Management of wide open apex canals with calcium hydroxide, Presented at the 21st Annual Meeting of the American Association of Endodontists, Washington DC April 17 1964. 60) Rafter M. Apexification: a review, Dent Traumatol 2005;21:1–8.
4. Finucane D, Kinirons MJ. Non-vital immature permanent incisors: factors that may influence treatment outcome, Endod Dent Traumatol 1999;15:273–277.
5. Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggregate. J Endod 1999;25:197–205.Safavi KE, N
6. Torabinejad M, Turman M. Revitalization of tooth with necrotic pulp and open apex by using platelet-rich plasma: a case report. J Endod. 2011;37(2):265-268.
7. Kumar H, Al-Ali M, Parashos P, Manton DJ. Management of 2 teeth diagnosed with dens invaginatus with regenerative endodontics and apexification in the same patient: a case report and review. J Endod. 2014. https://doi.org/10.1016/j.joen.2013.10.030.
8. Nagy MM, Tawfik HE, Hashem AAR, Abu-Seida AM. Regenerative potential of immature permanent teeth with necrotic pulps after different regenerative protocols. J Endod. 2014. https://doi.org/10.1016/j.joen.2013.10.027.
9. Elfrink ME, Heijdra JS, Krikken JB, et al. Regenerative endodontic therapy: a follow-up of 47 anterior traumatised teeth. Eur Arch Paediatr Dent. 2021. https://doi.org/10.1007/s40368-020-00584-0.
10. Silujjai J, Linsuwanont P. Treatment outcomes of apexification or revascularization in nonvital immature permanent teeth: a retrospective study. J Endod. 2017. https://doi.org/10.1016/j.joen.2016.10.030.
11. Keswani D, Pandey RK. Revascularization of an immature tooth with a necrotic pulp using platelet-rich fibrin: a case report. Int Endod J. 2013;46(11):1096-1104.
12. Rafter M. Apexification: a review, Dent Traumatol 2005;21:1–8.
13. Simon S, Rilliard F, Berdal A, Matchtou P, The use of mineral trioxide Aggregate in one – visit apexification treatment: a prospective study, Int Endod J 2007;40:186-197.

14. Mente J, Hage N, Pfefferle T, Koch JM, Dreyhaupt J, staehle HJ, et al. Mineral trioxide aggregate apical plugs in teeth within open apical foramina: a retrospective analysis of treatment outcome, J Endod 2009;35(10):1354- 1358.

15. Holden DT, Schwartz SA, Kirkpatrick TC, Svhindler WG, Clinical outcomes of artificial root-end barriers with mineral trioxide aggregate in teeth with immature apices, J Endod 2008;35:812-816.

16. Huang GT. Apexification: the beginning of its end, Int Endod J 2009;42(10):855-866.

17. Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: New treatment protocol?. The American Association of Endodontists Journal of Endodontics 2004;30(4):196-200.

18. Trope M. Regenerative potential of dental pulp. J Endod 2008;34:S13-S17.

19. Law AS1. Considerations for regeneration procedures. J Endod. 2013;39(3 Suppl):S44-56.

20. Petrino JA, Boda KK, Shambarger S, Bowles WR, McClanahan SB. Challenges in regenerative endodontics: a case series. J Endod. 2010;36(3):536-541.

21. Thomson A, Kahler B. Regenerative endodontics-biologically-based treatment for immature permanent teeth: a case report and review of the literature, Australian dental journal 2010;55:446-452.

22. Shin S, Albert J, Mortman R. One step pulp revascularization of immature permanent tooth with chronic apical abcess: a case report. Int Endod J. 2009;42:1118-1126.

23. Reynolds K, Johnson JD, Cohenca N. Pulp revascularization of necrotic bilateral bicuspids using a modified novel technique to eliminate potential coronal discoloration: a case report. Int Endod J 2009;42(1):84-92

24. Grandini S, Balleri P, Ferrari M. Evaluation of Glyde File Prep in combination with sodium hypochlorite as a root canal irrigant. Journal of Endodontics 2002;28(4):300-303.

25. Harrison JW, Svec TA, Baumgartner JC. Analysis of clinical toxicity of endodontic irrigants. Journal of Endodontics 1978;4(1):6-11.

26. Bradford CE, Eleazer PD, Downs KE, Scheetz JP. Apical pressures developed by needles for canal irrigation. J Endod. 2002;28(4):333-335.

27. Reeh ES, Messer HH. Long-term paresthesia following inadvertent forcing of sodium hypochlorite through perforation in maxillary incisor. Dental Traumatology 1989;5(4):200-203.

28. Hülsmann M, Hahn W. Complications during root canal irrigation–literature review and case reports. International Endodontic Journal 2000;33(3):186- 193. 29) Hoshino E, Kurihara-Ando N, Sato I, Uematsu H, Sato M, Kota K, Iwaku M. In-vitro antibacterial susceptibility of bacteria taken from infected root dentine to a mixture of ciprofloxacin, metronidazole and minocycline. Int Endod J. 1996;29(2):125-130.

29. Sato I, Ando-Kurihara N, Kota K, Iwaku M, Hoshino E. Sterilization of infected root-canal dentine by topical application of a mixture of ciprofloxacin, metronidazole and minocycline in situ. Int Endod J. 1996;29(2):118-124.

30. Yanpiset K, Trope M. Pulp revascularization of replanted immature dog teeth after different treatment methods. Endod dent tromatol 2000;16:211- 217.

31. Ritter AL, Ritter AV, Murrah V, Sigurdsson A, Trope M. Pulp revascularization of implanted immature dog teeth after treatment with minocycline and doxycycline assessed by laser Doppler flowmetry, radiography and histology. Dent Traumatol 2004;20:75-84.

32. Mohammadi Z, Abbott PV. On the local applications of antibiotics and antibiotic-based agents in endodontics and dental traumatology. Int Endod J 2009;42:555-567.

33. Kim JH, Kim Y, Shin SJ, Park JW, Jung IY. Tooth discoloration of immature permanent incisor associated with triple antibiotic therapy: a case report. J Endod. 2010;36(6):1086-1091.

34. Floratos S, Tsatsoulis I, Komtakiotis E. Appical barrier formation after incomplete orthograde mta apical plug placement in teeth with open apex – repot of two cases. Br Dent J 2013;24(2):163-166.

35. D'Arcangelo C, D'Amario M. Use of MTA for orthograde obturation of nonvital teeth with open apices: report of two cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:e98-e101.

36. Pace R, Giuliani V, Pagavino G. Mineral trioxide aggregate in the treatment of external invasive resorption: a case report. Int Endod J 2008;41:258–66.

37. Raldi D, Mello I, Habitante S, Lage-Marques J, Coil J. Treatment Options for Teeth with Open Apices and Apical Periodontitis. J Can Dent Assoc 2009;75(8):591-596.

38. Mante J, Leo M, Panagidis D, Ohle M, Schneider S, Bermejo J, Pfefferle T. Treatment outcome of mineral trioxide aggregate in open apex teeth. J Endod 2013;39(1):20-26.

39. Lee LW, Hsieh SC, Lin YH, Huang CF, Hsiao SH, Hung WC. Comparison of clinical outcomes for 40 necrotic immature permanent incisors treated with calcium hydroxide or mineral trioxide aggregate apexification/apexogenesis. J Formos Med Assoc. 2015;114(2):139-46.

40. Lovelace TW, Henry MA, Hargreaves KM, Diogenes A. Evaluation of the delivery of mesenchymal stem cells into the root canal space of necrotic immature teeth after clinical regenerative endodontic procedure. J Endod. 2011;37(2):133-138.

41. Torabinejad M, Faras H. A clinical and histological report of a tooth with an open apex treated with regenerative endodontics using platelet-rich plasma. J Endod. 2012;38(6):864-868.

42. Chen M, Chen K, Chen C, Tayebaty F, Rosenberg P, Lin L. Responses of immature permanent teeth with infected necrotic pulp tissue and apical periodontitis/abcess to revascularization procedures. Int Endod J. 2011;45:294-305.

43. Claus I, Laureys W, Cornelissen R, Dermaut LR. Histologic analysis of pulpal revascularization of autotransplanted immature teeth after removal of the original pulp tissue. Am J Orthod Dentofacial Orthop. 2004;125(1):93- 99.

44. Wang X, Thibodeau B, Trope M, Lin LM, Huang GT. Histologic characterization of regenerated tissues in canal space after the revitalization/revascularization procedure of immature dog teeth with apical periodontitis, J Endod 2010;36(1):56-63.

45. Wikström A, Brundin M, Lopes MF, et al. What is the best long-term treatment modality for immature permanent teeth with pulp necrosis and apical periodontitis? Eur Arch Paediatr Dent. 2021. https://doi.org/10.1007/s40368-020-00575-1.

46. Staffoli S, Plotino G, Nunez-Torrijos BG. Regenerative endodontic procedures using contemporary endodontic materials. Materials (Basel). 2019. https://doi.org/10.3390/ma12060908.

47. Yoshpe M, Kaufman AY, Lin S, et al. Regenerative endodontics: a promising tool to promote periapical healing and root maturation of necrotic immature permanent molars with apical periodontitis using platelet-rich fibrin (PRF). Eur Arch Paediatr Dent. 2021. https://doi.org/10.1007/s40368-020-00572-4

48. Hameed MH, Gul M, Ghafoor R, Badar SB. Management of immature necrotic permanent teeth with regenerative endodontic procedures - a review of literature. J Pak Med Assoc. 2019;69:1514–20