Original Article

Comparison of Radiographic and Survival Outcomes of Immature Teeth Treated with Either Regenerative Endodontic or Apexification Methods: A Retrospective Study

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Abstract

Introduction: Regenerative endodontic procedure (REP) is a progressive treatment modality for immature permanent teeth with necrotic pulp. The ambiguousness about the predictability of REP outcome in relation to complete disinfection of the root canal system and the occurrence of discoloration still exists. **Materials and Methods:** The study was standardized and was approved by the Ethical Committee of the University. All the patients who had treatment for the management of immature permanent teeth were referred to the Department and were studied over a period between 2007 and 2019, the teeth were treated either with calcium hydroxide apexification, mineral trioxide aggregate (MTA) apexification, or revascularization. Revascularization procedure was established in three-appointment procedure with rubber dam isolation, irrigation using 2.5% NaOCl, and no instrumentation during the first visit. MTA apexification procedure consist of placement of apical plug of MTA for at least 3 mm followed by obturation with placement of glass ionomer cement and resin composite. Calcium hydroxide apexification procedure consists of a rubber dam isolation and placement of $Ca(OH)_2$16 ± 12.8 months followed by obturation with gutta-percha. **Results:** An analysis of the radiographic outcomes indicated a significant effect ($P < 0.0001$) for the effective revascularization treatment on the overall root width particularly at the apical third. There were no statistically significant differences between the calcium hydroxide apexification and the MTA apexification groups. Teeth that were treated with revascularization resulted a significantly higher percentage of increase in root length (14.9%) when compared with those teeth treated by either MTA apexification (6.1%) or calcium hydroxide apexification (0.4%). **Conclusion:** In addition, the methods that were described in this study, including standardized clinical follow-up checklists, may provide the framework for continuing this study with both prolonged follow-up periods and increased numbers of patients that were included in the study.

Keywords: Immature, Apexification, Regeneration, MTA.

Introduction

Immature necrotic teeth are the most complicated one to completely clean and shape the entire root canal system because of apex is not fully formed,[1] thin dentinal walls, blunderbuss shape, and more susceptible to fracture.[2,3] The most common causes for the infected/necrotic immature teeth are due to trauma, caries, or because of developmental malformations like dens invaginatus leading to immature root development and pulp necrosis in young permanent teeth.[4,5] Over the past decades, calcium hydroxide medicament is used for the management of immature young permanent teeth with an open apex. This procedure aids in creating an apical barrier to avoid extrusion of obturating materials. However, the drawbacks of this traditional technique are that poor dentin bridge and multiple dental visits.[6] Alternative methods for apexification procedure using Mineral trioxide aggregate (MTA) which creates a good apical barrier aid in placement of obturating material. It is been found that MTA had higher success rate with reduced visit.[7,8] A recent proposed treatment to apexification procedure is

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hard-tissue formation in the apical third and root closure.[9] Revascularization is a regenerative procedure which aids in continuity of root development, strengthen the root structure, and continued increase in root width and length of immature young permanent teeth with necrotic pulp. Till date, there is no study which compare the outcome of various treatment procedure for immature tooth with infected/necrotic pulp.[10,11] This study compares and evaluates the outcome of calcium hydroxide, MTA apexification, and revascularization procedure in the treatment of immature teeth with necrotic immature teeth.

Materials and Methods

The study was standardized and was approved by the Ethical Committee of the University. All the patients who had treatment for the management of immature permanent teeth were referred to the Department and were studied over a period between 2007 and 2019, the teeth were treated either with calcium hydroxide apexification, MTA apexification, or revascularization. All the patient data were collected for their pre-operative, post-operative, and follow-up radiograph for at least a time-period of 6 months after the completion of treatment procedure. The signs and symptoms of clinical data during the pre-operative and follow-up visits were recorded regularly. Patient data collected includes the patient age, sex, tooth number, clinical signs and symptoms, diagnosis of pulpal and periapical condition, clinical treatment procedure, size of periapical radiolucency, length of the root, and dentin thickness. If required when the tooth with poor prognosis was extracted and excluded from the study. The collected data were standardized which permit the assessment and analysis of radiograph, subjective and objective symptoms such as pain, percussion, presence of sinus tract, swelling, and fracture of crown portion after completion of the treatment.

Revascularization procedure was established in three-appointment procedure with rubber dam isolation, irrigation using 2.5% NaOCl, and no instrumentation during the first visit. The triple antibiotic paste mix was placed as described by Hoshino *et al*.[12] for a mean interval that was placed for a mean of 28.85 ± 13.08 days in between appointments and teeth were given temporary restoration after each visit. During the second rubber dam isolation, irrigated with 2.5% NaOCl, and apical tissue penetration using either a K file or an endo spreader. The blood clot which was formed in the root canal a matrix (Collaplug; Zimmer Dental, Carlsbad, CA) was placed on the blood clot.

MTA apexification procedure consists of placement of apical plug of MTA for at least 3 mm followed by obturation with placement of glass ionomer cement and resin composite. Calcium hydroxide apexification procedure consists of a rubber dam isolation and placement of $Ca(OH)_2$16 ± 12.8 months followed by obturation with gutta-percha. The pre-operative and post-operative images were saved in a JPEG format and then transferred to the imaging program software (Sopro; Acteon, La Cirotat Cedex, France) for measuring the root length, dentin thickness, and the size of the periapical lesions. The root length pre-operative and post-operative images were measured and modified according to Bose *et al*.[13] All the radiographic measurements were collected and evaluated by the same investigator, and images were subjected to analysis according to the kappa reliability. The measurements were repeated at a time interval of 1 week apart (n = 18 cases) which produced an intra-examiner agreement of k = 0.9845 indicating reliability. The treatment outcomes were assessed by the criteria described by Friedman and Mor,[14] which consisted of the following categories:

1. Healed: Both the clinical (subjective and objective) and radiographic assessments were normal.
2. Healing: The periapical radiolucency was reduced with a normal clinical presentation.
3. Disease: The radiolucency was either increased or persisted without change even when the clinical presentation was normal or clinical signs or symptoms were present regardless of the radiographic presentation.

Results

The retrospective study found 90 cases meeting the eligibility criteria, of which 70 had documented recall information for a recall rate of 77.77%. From these 70 cases included in the study which were segregated as 25 revascularization cases, 23 MTA apexification cases, and 22 calcium hydroxide apexification cases. Patient demographical data and the clinical characteristics of all the study participants are tabulated briefly in Table 1. An analysis of the radiographic outcomes indicated a significant effect ($P < 0.0001$) for the effective revascularization treatment on the overall root width particularly at the apical third. There were no statistically significant differences between the calcium hydroxide apexification and the MTA apexification groups. Teeth that were treated with revascularization resulted a significantly higher percentage of increase in root length (14.9%) when compared with those teeth treated by either MTA apexification (6.1%) or calcium hydroxide apexification (0.4%, $P < 0.01$ for both comparisons).

Following the above briefed criteria, clinical outcomes were evaluated where in the tooth survival analysis as well as clinical success analysis was taken into consideration. In terms of tooth survival which is tabulated in Table 2, revascularization had similar survival rates (25/25 teeth [100%]) when compared with teeth treated with MTA apexification (22/23 teeth [94.7%]) although the follow-up times were nearly 50% longer in the revascularization cases. Both of these treatments produced a higher survival rate ($P < 0.05$) compared with teeth treated with calcium hydroxide apexification (17/22 teeth [77.3%]). The second clinical outcome analysis was based on the success defined by radiographic, objective, and subjective findings as shown in Table 3. Teeth that were treated with the revascularization protocol had rates of complete healing (20/25 cases [60%]) similar to the teeth treated

Table 1: A summary of patient demographics and the clinical characteristics of the study population

Variables	Revascularization (*n*=25)		MTA (*n*=23)		Calcium hydroxide (*n*=22)	
	Teeth	%	Teeth	%	Teeth	%
Sex						
Female	13	52.00	8	34.8	8	36.4
Male	12	48.00	15	65.2	14	63.6
Tooth type						
Incisor	8	32.00	14	60.8	19	86.3
Premolar	17	68.00	9	39.2	3	13.7
Tooth location						
Maxilla	8	32.00	13	56.5	19	86.3
Mandible	17	68.00	10	43.5	3	13.7
Etiology						
Caries	2	8.00	5	21.7	0	0.00
Dens evaginatus	15	60.00	5	21.7	5	22.7
Trauma	8	32.00	13	56.6	17	77.2
Signs and trauma						
Absent	5	20.00	7	30.4	2	9.1
Present	20	80.00	16	69.5	20	90.9
Apical periodontitis						
Absent	2	8.00	8	34.8	9	40.9
Present	23	92.00	15	65.2	13	59.1
Age (years)(mean±SD)	13.1±5.09		14.7±6.19		10.6±3.91	
Follow-up time (mo)	21.17±11.74		14.23±7.86		27.35±30.49	

Table 2: The survival rate of immature permanent teeth after the treatment

Outcome	Revascularization (*n*=25)		MTA (*n*=23)		Calcium hydroxide (*n*=22)	
	Teeth	%	Teeth	%	Teeth	%
Survival rate	25	100.00	22	94.70	17	77.3

Table 3: The success rate of immature permanent teeth after the treatment

Outcome	Revascularization (*n*=25)		MTA (*n*=23)		Calcium hydroxide (*n*=22)	
	Teeth	%	Teeth	%	Teeth	%
Healed	20	60.00	16	68.42	17	77.27
Healing	5	40.00	6	26.32	0	0.00
Disease	0	0.00	1	5.26	5	22.73

with either MTA (16/23 [68.42%]) or calcium hydroxide (17/22 [77%]) apexification methods. Alternatively, when applying the loser outcome of "healed + healing," teeth treated with the revascularization protocol had similar overall rates (25/25 teeth [100%]) compared with teeth treated with MTA apexification (22/23 teeth [94.74%]) and both of these treatments produced greater rates ($P < 0.05$) compared with teeth treated with calcium hydroxide apexification (17/22 teeth [77.27%]).

Discussion

After publishing the good radiographic and clinical outcomes after revascularization treatments when applied to immature permanent teeth has increasingly stimulated the knowledge and idea in this method. Since most of the data were basically derived from case reports or relatively few small case series, one retrospective study has demonstrated a significantly greater increase in root width and length after revascularization when compared with the MTA apexification or traditional nonsurgical root canal therapy.[13] The present study basically gives an independent portrait of this before any retrospective studies and extends these values were obtained by analyzing calcium hydroxide apexification and applying an outcome analysis of both tooth survival and clinical success rate.

There are various relatable issues related to the present study. First, the regular use of a standardized clinical checklist for all recall patients allows the assessment of subjective and objective clinical outcomes that vastly expand an analysis of only the positive radiographic outcomes. Second, the observed overall recall rate (77%) is slightly higher than that reported in various other clinical studies which supports that the studied data might reveal the actual outcomes that were obtained in this study group. Third, the radiographic outcomes of the percentage show increase in root width and length for effective revascularization (28.2% and 14.9%, respectively) and MTA apexification (0% and 6.0%, respectively) reveal the dramatic effect of this newer treatment protocol. In addition, the data obtained were almost identical to the results of the Bose *et al*. study[13] in terms of relative effects (increases in radiographic root width >increases in length) and the magnitude of the effects. Although the Bose *et al*. data observed median effects because of the heterogeneity of variance in their clinical material, a reanalysis of their clinical data for the mean effects shows similar relative percentage increases in root width and length for both the revascularization (48% and 11%, respectively) and MTA apexification (0.2% and 0.2%, respectively) as observed in the present study.

On the whole, these researches provide independent evaluation of the efficacy of revascularization methods. Further, to the best of our knowledge, this is the first study to quantitatively analyze both tooth survival and clinical success after revascularization treatment. When combined together, these factors reveal the clinical applications of revascularization protocols and establish a framework for the future studies in this field. Another clinically significant finding in this study was the clinical outcomes observed in teeth treated with calcium hydroxide apexification. This study found that the clinical and radiographic success rate for calcium hydroxide apexification was 77.3% (healed), and for MTA apexification, it was 68.4% (healed). This result was somewhat lower than that reported by El-Meligy and Avery,[15] who observed a success rate for calcium hydroxide apexification of 87% and for MTA apexification 100%. Another finding in the present study regarding the differences in the tooth survival. The tooth

survival after calcium hydroxide apexification was less than the other two treatments in this study. The reason for extraction was because of the non-restorable root fracture in case of trauma. The duration of calcium hydroxide apexification ranges from 3 to 21 months.[15] During that time of treatment, the tooth is moreprone to reinfection from coronal leakage and may become susceptible to fracture because the immature tooth with an open apex has a thin dentin wall and a short root. In addition, Andreasen *et al*.[3] observed that a long-term calcium hydroxide dressing in the root canal might weakens the root structure. Therefore, in this study, the time of a calcium hydroxide dressing in the root canal of the calcium hydroxide apexification group was 14.5 months. However, there were various other factors that might pose an impact on this outcome, such as restoration.

Conclusion

In addition, the methods that were described in this study, including standardized clinical follow-up checklists, may provide the framework for continuing this study with both prolonged follow-up periods and increased numbers of patients that were included in the study.

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