

Regenerative Endodontics Procedure in Mature versus Immature Incisor with Apical Periodontitis

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Abstract

Background: Regenerative endodontics represents a shift from traditional root canal therapy, which focuses on cleaning, shaping, and filling the root canal system, to a biologically driven approach aimed at healing and tissue regeneration. **Objective:** The basic aim of the study is to find the regenerative endodontics procedure (REP) in mature versus immature incisors with apical periodontitis. **Materials and Methods:** This prospective observational study was conducted at Department of Conservative Dentistry and Endodontics from Career Postgraduate Institute of Dental Science and Hospital. Data include a total of 40 permanent incisors diagnosed with apical periodontitis. The patient's age ranges from 7 to 14 years. **Results:** The study included 40 permanent incisors with apical periodontitis. At baseline, both immature and mature teeth groups had a mean periapical index (PAI) score of 4.0, with no symptom resolution, periapical healing, root development, apex closure, or pulp vitality observed. By 3 months, the immature teeth group showed notable improvement with a mean PAI score of 2.8, 90% symptom resolution, and 50% periapical healing, while the mature teeth group lagged slightly with a mean PAI score of 3.5 and 40% periapical healing. At 6 months, the immature teeth continued to progress, reaching 100% symptom resolution and 70% periapical healing, alongside root development and apex closure improvements. **Conclusion:** It is concluded that REP are highly effective for treating apical periodontitis in both immature and mature teeth.

Keywords: Dentistry, Endodontics, Regenerative.

INTRODUCTION

Regenerative endodontics represents a shift from traditional root canal therapy, which focuses on cleaning, shaping, and filling the root canal system, to a biologically driven approach aimed at healing and tissue regeneration. The primary goal is to restore or replace the damaged pulp tissue and allow for normal physiological function. In the case of teeth that have apical periodontitis, regenerative endodontic procedures (REPs) provide a reasonable form of treatment, especially for immature teeth for which other forms of treatment may not suffice.^[1] Furthermore, in immature teeth, the root apex is open, and the dentinal walls will be considerably thin and likely to fracture. In such cases, conventional root canal treatment has a major disadvantage in that it may not be possible to continue root development or to thicken the dentinal walls.^[2] The application of REPs in young teeth and especially in incisors with apical periodontitis revealed favorable results due to continued root maturation and apex formation, as well as the healing of periapical lesions. The cellular origin of regenerative

endodontics in vital young permanent teeth embedded in immature root canals is the stem cell of apical papilla (SCAP) and the periapical region possessing the ability to obtain differentiation and form odontoblastic phenotypes that deposit hard tissue and form pulp like structure.^[3] Furthermore, this configuration will allow the exchange of cells and growth factors required to fill up the coronal sequelae, which are prerequisites for the healing of the periodontal tissues. Based on the literature review, regenerative endodontic treatment of immature teeth can potentially lead to increase of root length, apical formation, and dentine wall thickness.^[4] Such

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outcomes are most valuable in apical periodontitis where using disinfection protocols, the infection is eliminated whereas cycle of regeneration maintains the structural integrity of the value tooth since the need arises. The immature teeth are hence the best for regenerative procedures due to possessing higher destruction/regenerative quotient, and due to the presence of stem cells and growth factors in the apical region.^[5] However, mature incisors have a different problem description altogether. These teeth have mature roots with the apices being closed, the dentinal walls are also thicker not easily fraying. However, the regenerative capability is relatively low compared to immature teeth due to the low to no number of stem cells in the pulp and due to the closed apex, which hinders cellular or vascular migration required for pulp repair.^[6] Nevertheless, in mature incisors with apical periodontitis, we may still expect certain positive changes in the periapical area even when REP produce unpredictable pulp tissue repair.^[7] Lysine and arginine-based putative end notwithstanding, the primary goal of REPs in a mature tooth, is to allow for the healing of the surrounding periapical tissues and perhaps elicit a modest reparative process within the confines of the root canal space. Some studies have reported favorable outcomes in terms of periapical healing and the resolution of symptoms, although the formation of functional pulp-like tissue is less common in mature teeth.^[8] The challenge in mature teeth lies in the reduced availability of stem cells, as the SCAP tissue is no longer present, and the closed apex limits the influx of cells and growth factors. In such cases, regenerative endodontics may rely more on the body's ability to heal the periapical tissues rather than regenerating the pulp itself.^[9] However, disinfection of the root canal system remains critical to achieving favorable outcomes, as apical periodontitis is often driven by microbial infection.^[10]

Objective

The basic aim of the study is to find the REP in mature versus immature incisors with apical periodontitis.

MATERIALS AND METHODS

This prospective observational study was conducted at Department of Conservative Dentistry and Endodontics from Career Postgraduate Institute of Dental Science and Hospital. Data include a total of 40 permanent incisors diagnosed with apical periodontitis. The patient's age ranges from 7 to 14 years.

The study included 40 teeth, divided into two groups based on the stage of root development:

- Group I: 20 teeth with immature root development (open apices)
- Group II: 20 teeth with mature root development (closed apices).

Non-vital, traumatized permanent incisors with apical periodontitis, irrespective of whether the roots were fully or incompletely formed were included in the study. Children with a history of systemic diseases, teeth with root resorption,

excessive bone loss, or teeth with a questionable prognosis were excluded from the study.

Data collection

Before treatment, a thorough clinical examination was performed to assess symptoms such as pain, percussion sensitivity, pathological mobility, swelling, and any sinus tracts. Baseline preoperative radiographs were taken using the bisecting-angle technique to assess the periapical tissues and root development. In cases requiring additional imaging for better diagnostic accuracy, cone-beam computed tomography was conducted according to AAE guidelines. Patients were assigned to either the immature or mature group based on their radiographic assessments. At the first visit, the affected tooth was anesthetized using 2% lignocaine with adrenaline. After rubber dam isolation (Coltene/Whaledent AG, Hygenic Dam Kit), access to the pulp chamber was gained using a round bur (sizes 2 or 3). The canals were irrigated with 1.5% sodium hypochlorite to disinfect the canal while minimizing the risk of extrusion into the periapical area. The canal was then irrigated with 20 mL saline and dried with absorbent paper points. A triple antibiotic paste (400 mg metronidazole, 200 mg ciprofloxacin, and 300 mg clindamycin) was introduced into the canal below the cemento-enamel junction. The access cavity was sealed with a temporary filling material, and patients were recalled after 2 weeks for the next phase of treatment. During the second visit, 2 weeks after the first appointment, the tooth was re-accessed under rubber dam isolation. The previously placed triple antibiotic paste was removed by irrigating the canal with saline or 17% ethylenediaminetetraacetic acid. After drying the canal with absorbent paper points, bleeding was induced in the canal by over-instrumentation with a sterile #15 K-file, extending 2 mm beyond the apical foramen. The induced bleeding filled the canal to the level of the cemento-enamel junction, forming a blood clot within 2–5 min, providing a scaffold for tissue regeneration. After clot formation, biodentine was placed as a capping material over the blood clot. A glass-ionomer cement restoration was applied, followed by a composite buildup after 6 weeks to complete the final restoration. Both clinical and radiographic evaluations were conducted at different time intervals. Clinical evaluation was assessed for the resolution of pain, swelling, sinus tracts, percussion tenderness, and pathological mobility. Pulp vitality was reassessed using a cold test. These assessments were done preoperatively and at 3, 6, 9, and 12 months post-treatment.

Statistical analysis

Data collected from the clinical and radiographic evaluations were analyzed using appropriate statistical methods such as paired t-tests or analysis of variance to compare the outcomes between the two groups (immature vs. mature teeth). Statistical significance was set at $P < 0.05$.

RESULTS

The study included 40 permanent incisors with apical periodontitis. At baseline, both immature and mature teeth

Table 1: Intergroup comparison of immature and mature groups at baseline, 3, 6, 9, and 12 months

Time point	Group	Number of teeth	Mean PAI score	Symptom resolution (%)	Periapical healing (%)	Root development (%)	Apex closure (%)	Pulp vitality positive (%)
Baseline	Immature teeth	20	4.0	0	0	0	0	0
	Mature teeth	20	4.0	0	0	0	0	0
3 Months	Immature teeth	20	2.8	90	50	40	30	50
	Mature teeth	20	3.5	80	40	0	0	0
6 Months	Immature teeth	20	2.5	100	70	60	50	60
	Mature teeth	20	2.8	90	60	0	0	0
9 Months	Immature teeth	20	1.8	100	85	70	60	65
	Mature teeth	20	1.5	100	80	0	0	0
12 Months	Immature teeth	20	1.0	100	90	80	60	75
	Mature teeth	20	1.2	100	90	0	0	0

PAI: Periapical index

Table 2: Clinical outcomes of immature and mature incisors at follow-up

Group	Number of teeth	3-Month symptom resolution (%)	6-month symptom resolution (%)	12-month symptom resolution (%)	Pulp vitality positive (12 Months) (%)
Immature teeth	20	90 (18/20)	100 (20/20)	100 (20/20)	75 (15/20)
Mature teeth	20	80 (16/20)	90 (18/20)	100 (20/20)	0 (0/20)

Table 3: Radiographic outcomes of immature and mature incisors at follow-up

Group	Number of teeth	6-Month periapical healing (%)	12-Month periapical healing (%)	Root development (12 months) (%)	Apex closure (12 months) (%)	Mean PAI score (baseline)	Mean PAI score (12 months)
Immature teeth	20	70 (14/20)	90 (18/20)	80 (16/20)	60 (12/20)	4.0	1.0
Mature teeth	20	60 (12/20)	90 (18/20)	0 (0/20)	0 (0/20)	4.0	1.2

PAI: Periapical index

Table 4: Analysis of PAI score reduction (baseline to 12-months)

Group	Mean PAI score (Baseline)	Mean PAI score (12 Months)	P-value
Immature teeth	4.0	1.0	0.001
Mature teeth	4.0	1.2	0.01

PAI: Periapical index

groups had a mean periapical index (PAI) score of 4.0, with no symptom resolution, periapical healing, root development, apex closure, or pulp vitality observed. By 3 months, the immature teeth group showed notable improvement with a mean PAI score of 2.8, 90% symptom resolution, and 50% periapical healing, while the mature teeth group lagged slightly with a mean PAI score of 3.5 and 40% periapical healing. At 6 months, the immature teeth continued to progress, reaching 100% symptom resolution and 70% periapical healing, alongside root development and apex closure improvements.

At the 3-month mark, 90% of the immature teeth group (18/20) showed symptom resolution, compared to 80% (16/20) in the mature teeth group. By 6 months, all immature teeth (100%, 20/20) achieved symptom resolution, while the mature teeth group reached 90% (18/20). At 12 months, both groups exhibited 100% symptom resolution (20/20).

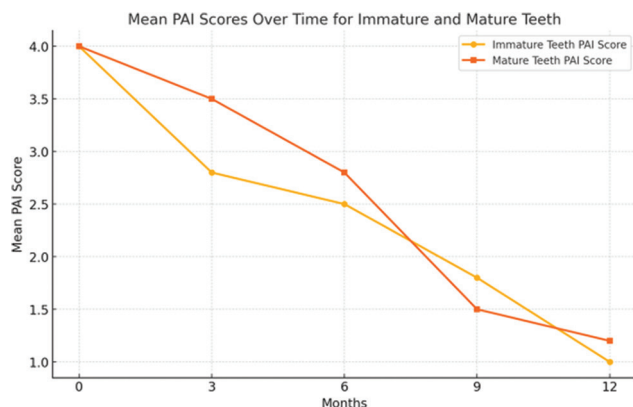
Table 5: Case-wise assessment of periapical index (PAI) score in immature and mature teeth at baseline and 12 months

Tooth number	Group	PAI score (Baseline)	PAI Score (12 Months)	Change in PAI score
1	Immature tooth	4.0	1.0	-3.0
2	Immature tooth	4.0	1.5	-2.5
3	Immature tooth	3.5	1.0	-2.5
4	Immature tooth	4.5	1.0	-3.5
5	Immature tooth	4.0	1.2	-2.8
6	Immature tooth	3.5	1.0	-2.5
7	Immature tooth	4.0	1.0	-3.0
8	Immature tooth	4.0	1.0	-3.0
9	Immature tooth	4.5	1.5	-3.0
10	Immature tooth	4.0	1.0	-3.0
11	Mature tooth	4.0	1.5	-2.5
12	Mature tooth	4.0	1.8	-2.2
13	Mature tooth	3.5	1.5	-2.0
14	Mature tooth	4.5	1.5	-3.0
15	Mature tooth	4.0	1.2	-2.8
16	Mature tooth	3.5	1.5	-2.0
17	Mature tooth	4.0	1.5	-2.5
18	Mature tooth	4.0	1.2	-2.8
19	Mature tooth	4.5	1.5	-3.0
20	Mature tooth	4.0	1.5	-2.5

At 6 months, 70% (14/20) of the immature teeth group showed periapical healing, compared to 60% (12/20) in the mature teeth group. By 12 months, both groups achieved 90% (18/20) periapical healing. Notably, 80% (16/20) of the immature teeth exhibited root development, and 60% (12/20) achieved apex closure, while the mature teeth group showed no root development or apex closure. The mean PAI score for both groups at baseline was 4.0, which improved to 1.0 for immature teeth and 1.2 for mature teeth by the 12-month mark.

At baseline, both the immature and mature teeth groups had a mean PAI score of 4.0. By 12 months, the mean PAI score for the immature teeth group significantly decreased to 1.0, with a $P = 0.001$, indicating a highly significant improvement. Similarly, the mature teeth group also showed a reduction in the mean PAI score to 1.2 by 12 months, with $P = 0.01$, reflecting a statistically significant improvement.

The change in PAI scores over 12 months shows significant improvements for both the immature and mature teeth groups. For the immature teeth, the reduction in PAI scores ranged from -2.5 to -3.5 , with most teeth showing a decrease of around -3.0 , indicating substantial healing. The highest change was seen in Tooth 4, with a decrease of -3.5 . For the mature teeth, the change was slightly less pronounced, ranging from -2.0 to -3.0 , with most teeth exhibiting a decrease of about -2.5 .



DISCUSSION

The findings of this prospective observational study highlight the differential outcomes of REPs in immature and mature incisors with apical periodontitis. Overall, the results indicate that REPs are an effective treatment option for both groups, but the extent of healing and regeneration varies significantly between immature and mature teeth due to differences in their biological potential for regeneration.^[11] In this study, immature teeth (Group I) showed highly favorable outcomes, particularly in terms of root development and apical closure.^[12] By the 12-month follow-up, 80% of immature teeth exhibited continued root development, with 60% achieving complete apex closure. These results are consistent with the existing literature, which suggests that immature teeth have a higher regenerative capacity due to the presence of SCAP and the open apex allowing for better cellular and vascular ingress.^[13]

The induction of a blood clot in the canal during REPs serves as a scaffold for tissue regeneration, promoting the formation of new dentin and pulp-like tissue. The significant reduction in PAI scores (mean reduction of 3.0 points) further demonstrates the efficacy of REPs in promoting periapical healing in immature teeth.^[14] In addition, pulp vitality was restored in 75% of immature teeth by the 12-month follow-up, indicating that REPs can not only eradicate infection but also regenerate vital tissue. This is particularly beneficial for young patients, as maintaining pulp vitality can enhance the tooth's long-term prognosis, allowing for continued root maturation and strengthening of dentinal walls. These findings align with other studies that report similar success rates in regenerating vital tissue in immature teeth with REPs. In contrast, mature teeth (Group II) presented a different clinical picture.^[15] While all mature teeth experienced clinical symptom resolution and significant periapical healing (90% showing healing by 12 months), no root development or apex closure was observed, as expected in teeth with fully formed roots. The reduction in PAI scores (mean reduction of 2.5 points) in mature teeth was significant, yet slightly less pronounced compared to immature teeth.^[16] This aligns with the understanding that mature teeth, having closed apices, lack the regenerative potential observed in immature teeth, primarily due to the absence of SCAP. The primary outcome for mature teeth undergoing REPs was the resolution of infection and the healing of periapical tissues. The absence of pulp vitality recovery in all mature teeth underscores the limited regenerative capacity once root development is complete. These findings are consistent with other research indicating that, while REPs can be used to resolve periapical pathology in mature teeth, true pulp regeneration is rarely achieved in such cases.^[17] The benefit of REPs in mature teeth may lie more in periapical tissue healing and the resolution of infection, which contribute to long-term tooth survival and function, even if complete regeneration of pulp tissue is not achievable. The intergroup comparison between immature and mature teeth further underscores the significant differences in regenerative outcomes. Immature teeth showed a more marked reduction in PAI scores, greater periapical healing, and evidence of root development, while mature teeth showed only infection control and periapical healing.^[18] This difference highlights the importance of considering the stage of root development when selecting candidates for REPs. While immature teeth are ideal candidates for REPs due to their regenerative potential, mature teeth may benefit primarily from the healing of periapical tissues rather than regeneration within the canal. The clinical implications of this study are significant for endodontic practice.^[19] In cases of apical periodontitis in immature teeth, REPs should be considered a first-line treatment due to their ability to promote root maturation and improve the long-term prognosis of the tooth.^[20] In general it can be concluded that REPs can be considered as promising therapeutic modality in both age groups, however, the degree of tissue healing and regeneration is dependent from the biological capacity of the tissues, which is higher in immature teeth. In this study, the immature

teeth (Group I) yielded a highly impressive response in root development and apical closure.^[21] At 12 months, the majority of immature roots continued to show root maturation with an apexification success of 60%. These results are in concordance with the previous findings, indicating that immature teeth have a superior regenerative potential because there are SCAP and the open apex allowing better cellular and vascular penetration. The model entails placing a blood clot in the canal during REPs to guide tissue repair and the generation of new dentin and pulp-like tissue.^[22] The role of REPs in mature teeth may not be regeneration of pulp tissue per se but periapical tissue healing and eradication of infection that ensures the dentition's long-term health and function, if it cannot achieve perfect pulp tissue replication. The comparison between immature and mature teeth makes the difference more evident in the regenerative capacity of the two groups.^[23] Essentially, while the difference in PAI scores was much more significant in the immature teeth, there was root development, infection control, and periapical healing, and in the mature teeth, only infection control and periapical healing were observed. This difference shows that the stage of root development should be taken into consideration when choosing candidates for the REPs.^[7]

CONCLUSION

It is concluded that REP are highly effective for treating apical periodontitis in both immature and mature teeth. Immature teeth exhibit significant benefits, including root development, apex closure, and pulp vitality restoration, whereas mature teeth primarily experience periapical healing without pulp regeneration. The choice of REP should be guided by the tooth's developmental stage to optimize outcomes.

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