ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

Determining the Role of Guided Tissue Regeneration in Endodontic Microsurgery: Establishing a Threshold

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ABSTRACT

Aim: Our objective was to evaluate the radiographic outcomes of conventional and regenerative approaches in endodontic microsurgery (EMS) and to establish a threshold for critical defect sizes that influence healing in both treatment methods.

Methodology: The study analyzed 53 root canal-treated teeth from 33 patients with periapical lesions. Of these, 19 teeth (35.8%) received regenerative treatment, while 34 teeth (64.1%) were treated with the conventional approach. Endodontic and periodontic residents performed both procedures under the guidance of consultants. Healing was assessed after at least six months by comparing pre and post-operative cone-beam computed tomography (CBCT) images. A single-blinded examiner, uninvolved in the surgeries, interpreted the radiographic findings. Due to limitations in existing evaluation methods for endodontic surgery after regenerative treatment, new healing criteria were introduced. Critical measurements for each approach were determined based on the dimensions of the periapical lesions.

Results: The regenerative approach demonstrated significantly better healing outcomes compared to the conventional treatment, with mean scores of 1.21 and 1.59, respectively ($p = 0.047$). According to critical-point calculations, the conventional approach was effective for lesions up to 3 mm in depth and height, while the regenerative approach achieved superior healing in lesions with depths of 3–9 mm and heights of 3–6 mm.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

Conclusion: The regenerative approach in EMS yielded superior healing rates compared to the conventional approach. While the conventional method is recommended for smaller periapical lesions, the regenerative approach proved more effective for larger lesions.

Introduction

Endodontic microsurgery (EMS) is an advanced form of root-end surgical intervention designed to address cases where traditional endodontic treatments have failed and orthograde approaches are no longer viable. Despite the small size of the osteotomy site, significant bone loss around the root can occur, making the healing of periapical lesions a considerable challenge[1]. The primary goal of EMS is to enhance the healing environment for peri-radicular tissues by effectively removing persistent pathogens and providing direct access to the root apices and periapical region[2].

Tissue regeneration refers to the process of reproducing or reconstructing lost or damaged tissue, aiming to fully restore its original structure and function[3]. This is achieved by placing a barrier over the osseous defect, which slows or prevents the rapid growth of oral epithelium and gingival connective tissue, allowing cells with osteogenic potential to repopulate the area[4].

Numerous human and animal studies have investigated the healing rates following EMS, comparing outcomes with and without the use of regenerative approaches[(5,6,7,17)]. Research involving beagle dogs examined the effects of adding calcium sulfate in regenerative treatments compared to conventional methods. While some studies reported no significant benefits, others demonstrated notably improved healing rates with calcium sulphate[(5,16)]. Additionally, one study found that using a resorbable hydroxyapatite filler with an expanded polytetrafluoroethylene (e-PTFE) membrane resulted in 100% complete healing, compared to 77.8% and 88.9% healing rates in cases using only an e-PTFE membrane or conventional therapy, respectively[6].

The outcomes of guided tissue regeneration (GTR) in EMS have been explored in various studies; however, several limitations were identified. A major issue was the lack of consideration for the three-dimensional size of the defects, as most studies relied on two-dimensional periapical radiographs, which often failed to reflect actual healing[(6-11)]. Studies comparing apical surgery outcomes using periapical radiographs versus cone-beam computed tomography (CBCT) found that radiographs significantly overestimated success rates. Conversely, CBCT measurements were found to be highly accurate when compared with intraoperative measurements[12]. While some studies utilized CBCT for pre-operative evaluations[(1,14)], no studies have comprehensively compared CBCT outcomes pre- and post-operatively for EMS with regenerative treatments.

Another limitation is the reliance on surgically created periapical defects in many studies, which differ in healing mechanisms from bacterially infected defects seen in human cases[(15,16,17)]. Furthermore, the frequent use of alloplastic or xenograft materials, primarily as fillers, posed another constraint. Although some new bone formation was observed with these materials, their residual particles often remained un-resorbed for extended periods. For instance, allografts demonstrated a mean new bone formation rate of 65%, compared to 45% and 49% for xenografts and alloplasts, respectively[18].

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In light of these limitations, this study sought to compare radiographic healing outcomes between conventional and regenerative approaches in EMS and determine critical defect sizes for optimal healing in both therapies.

Materials and methods

This retrospective study was carried out at Rama Dental College, Hospital & Research Centre University between December 2023 and December 2024

The study included patients who underwent EMS, with data and surgical details retrieved from patient records and pre-and post-operative CBCT findings. Since the university clinic serves as an educational center, patients typically sign consent forms before treatment, allowing their data to be used for educational and research purposes. Thus, no additional consent was required for this study.

Surgical interventions were performed either by endodontic and periodontic residents under the supervision of specialists or consultants or directly by experienced specialists and consultants. The use of a microscope and endodontic microsurgery is considered the standard of care at the center.

Patients with complete records were not recalled, while those with only pre-operative CBCT findings and detailed surgical records were contacted for voluntary post-operative CBCT examinations.

The study applied the following exclusion criteria:

- Missing detailed surgical information that hindered proper statistical analysis.
- Absence of pre-operative CBCT data.
- Refusal to participate in post-operative CBCT examinations.
- Presence of through-and-through lesions.
- Healing periods shorter than six months.

CBCT measurements were conducted before checking the records for the type of treatment performed.

Radiographic measurements

The CBCT measurements assessed several parameters of the lesion, including height, width, depth, volume, the presence or absence of buccal or palatal perforation, and the buccal plate length. These measurements were recorded as follows:

1. **Height**: Measured from the sagittal section as the deepest point, aligned parallel to the tooth\u2019s long axis.
2. **Width**: Taken from the coronal section at the deepest point of the lesion, perpendicular to the tooth\u2019s long axis.
3. **Depth**: Measured from the sagittal section at the deepest point, perpendicular to the tooth\u2019s long axis.

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4. **Volume**: Calculated by multiplying the height, width, and depth of the defect (Height × Width × Depth).
5. **Buccal or Palatal Perforation**: Documented as either present or absent.
6. **Buccal Plate Length**: Measured in the sagittal section as the distance from the alveolar crest level to the buccal or palatal perforation.

Records data retrievement

After completing the CBCT measurements, additional patient data were collected. This included:

- **Age** and **sex** of the patient.
- **Tooth type**: Whether the tooth was single-rooted or multi-rooted.
- **Tooth position**: Whether the tooth was located in the maxilla or mandible.
- **Type of treatment**: Whether the patient received conventional therapy or guided tissue regeneration (GTR).
- **Type of retrograde filling**: The materials used, such as bioceramics, mineral trioxide aggregate, or zinc oxide eugenol cement.
- **Operator's skill level**: Whether the procedure was performed by a resident or a specialist/consultant.

Healing criteria

Although CBCT-based healing criteria have been previously established in the literature[18-20], these criteria primarily focus on conventional treatments and are not suitable for assessing outcomes in GTR treatments. To address this limitation, new healing criteria were developed specifically for this study to accurately evaluate the outcomes of both conventional and regenerative approaches. The proposed criteria are detailed in Table 1.

Data analysis

A sample size calculation was performed with a test power of 0.80 and a marginal error of 0.2, resulting in a required sample size of 42 patients. In this study, the tooth was treated as the unit of evaluation. Intra-examiner calibration was also conducted to ensure consistency.

Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS) software. The analysis included descriptive statistics, simple linear regression for comparisons between two variables, and multiple linear regression for analyses involving more than two variables. Additionally, cross-tabulation was used to identify critical points within the study. A p-value of < 0.05 was considered statistically significant.

Results

A total of 53 teeth from 33 patients had complete examination data following EMS.

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To ensure the reliability of the measurements, CBCT examinations were repeated at a 2-week interval for a group of patients not included in the study. The intraclass correlation coefficient was 0.98, indicating excellent reliability. Table 2 provides a descriptive analysis of the treated teeth. Smoking habits could not be assessed due to incomplete records. The mean age of the patients was 37.1 years, ranging from 16 to 69 years. The mean follow-up period was 1.47 years, with the longest follow-up being 3.29 years.

For patients treated with GTR, all cases utilized a collagen membrane. Additionally, allograft placement was performed in 78.9% of these cases, while the remaining cases did not involve bone grafting[1].

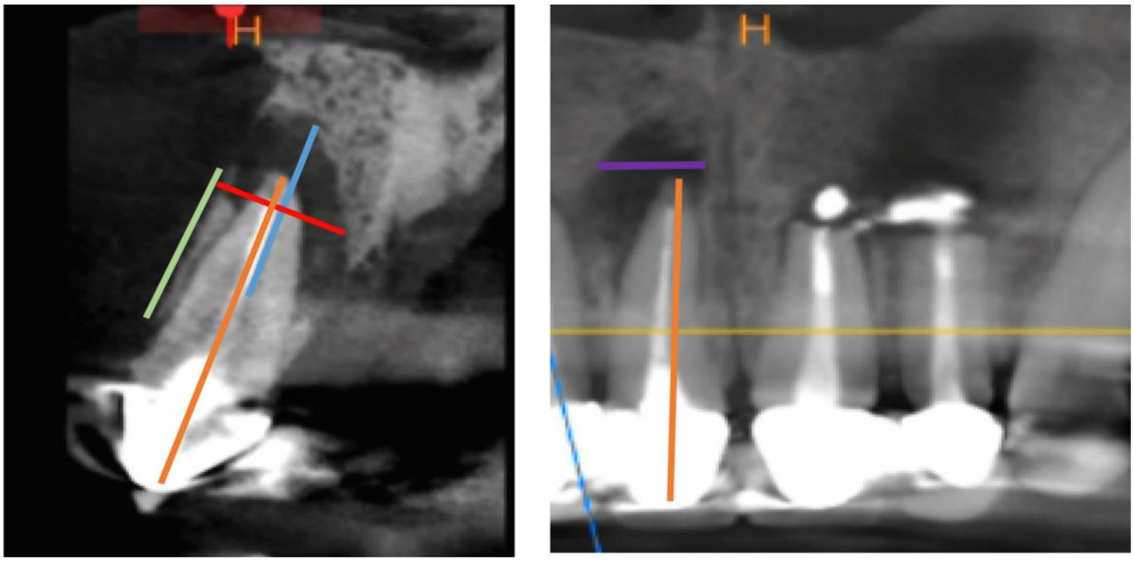

Fig 1. A sagittal and coronal section of CBCT showed the measurements taken Orange = tooth long axis, Blue = height of the lesion, Red = depth of the lesion, Green = buccal plate length, Purple = width of the lesion. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Proposed healing criteria.

	Periapical defect	Around the resected root	The buccal window
Complete healing	Complete absence of periapical defect with bone fill of similar density or more radiopaque than surrounding natural bone	Presence or absence of periodontal ligament around the sectioned tooth apex	Filled with bone with or without cortical bone plate or overbuild with lateral ridge augmentation
Partial healing	Reduction in the size of the defect in pre and post-operative CBCT measurements without complete bone fillPresence of radiopaque bone fill with radiolucent rim around the defect separating natural bone from the lesion	Presence or absence of periodontal ligament around the sectioned tooth apex	Decreased on size but not necessary closed with bone
Failed	no change or increase in the size of periapical defect	Absence of periodontal ligament around resected tooth	no change or increase in the size of buccal window

Table 2
Descriptive analysis of the treated teeth.

	N
Type of treatment	
Conventional treatment	34
GTR treatment	12
Gender	
Male	23
Female	30
Tooth type	
Single rooted	41
Multi-rooted	12
Arch	
Maxilla	41
Mandible	12
Type of retrograde filling	
MTA	11
Bioceram	20
IRM	1
Buccal or palatal plate perforation	
Yes	19
No	33
Skills	
Resident	24
Consultant/ specialist	29

The simple linear regression analysis (Table 3) showed a statistically significant difference in healing between cases treated with GTR compared to conventional treatment. There was no

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

statistically significant effect of the width and volume of the periapical lesion on healing among those treated with GTR and conventional treatment. The multiple linear regression analysis indicated that the depth of the defect had a statistically significant effect on healing among the two treated groups (Table 4). The deeper the defect, the less likely the site to show complete healing. Based on cross-tabulation, 75 % of the sites with a depth of 1–3 mm had healed completely or presented with partial healing in conventional treatment. The healing dropped to 30.6 % when the depth increased to 3–6 mm. Based on that, the critical depth for using conventional treatment is 3 mm[3].

When treated with GTR, all patients experienced complete or partial healing in cases where the site depth ranged from 1 to 9 mm. This suggests that the critical lesion depth for successful GTR treatment is 9 mm, as failures occurred with defects deeper than this. Similarly, the height of the periapical lesion significantly influenced healing outcomes for both conventional and GTR treatments (Table 4). In lesions measuring 1–3 mm in height, both approaches showed a high percentage of complete healing. However, this percentage dropped to 16.7% and 37.5% for conventional and GTR treatments, respectively, when defect heights ranged from 3 to 6 mm. Thus, the critical height for periapical defect healing is 3 mm for conventional treatment and 6 mm for the GTR approach[5].

Prognostic factors, such as the tooth type (single or multi-rooted), arch position (maxilla or mandible), type of retrograde filling, presence of buccal or palatal bone perforation, and crestal bone level, which indicated apicomarginal communication, as well as the skills of the operator (resident or specialist/consultant), did not show a statistically significant effect on the healing rates in the studied sample[4,6].

Table 3
The effect of the type of treatment on healing.

	N	Mean (±SD)		Sum of squares	Df	Mean of squares	F	*p*-Value
Conventional Treatment	34	1.59 (±0.7)	Between groups	1.739	1	1.739	4.145	0.047*
GTR treatment	19	1.21 (±0.53)	Within groups	21.393	51	0.419		
			Total	23.132	52			

Complete healing = 1, partial healing = 2, failed = 3.
* *p*-value is statistically significant < 0.05.

Table 4
The multiple linear regression showing statistically significant measurements that affect the healing among patients treated with conventional approach and GTR.

Variable	B	Std. Error	*p*-value
Healing (Constant)	1.607	0.284	0
Depth of the defect	0.069	0.025	0.009*
Type of treatment (conventional VS GTR)	−0.372	0.175	0.038*
Healing (Constant)	1.809	0.289	0
Height of the defect	−0.382	0.184	0.043*
Type of treatment (conventional VS GTR)	0.032	0.032	0.177

* *p*-value is statistically significant < 0.05.

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Discussion

The introduction of GTR therapy and bone augmentation in EMS aimed to enhance the healing potential of the area by promoting regeneration rather than fibrous connective tissue formation and epithelial migration[2]. This study was conducted to determine the critical defect dimensions beyond which healing may be compromised in both conventional and GTR treatments.

Numerous studies have compared the outcomes of conventional treatment with those of GTR. A review article found that GTR was more effective in treating through-and-through lesions[21] However, no definitive conclusions were drawn for apicomarginal defects, and limitations were identified in isolated defects, justifying their inclusion in this study. Some studies have reported superior results with GTR[2], which aligns with our findings. Conversely, other studies found no significant differences between the two approaches[(6,10)]

Some studies have found no significant differences between the two treatment approaches[(6,10)]

With the introduction of CBCT in dentistry, research has shown that CBCT provides superior post-operative healing assessments compared to periapical radiographs. To the best of our knowledge, no study has compared CBCT findings before and after EMS in patients treated with the GTR approach.

In contrast, previous studies have used CBCT to evaluate the impact of defect size on healing in patients treated with conventional methods. This study demonstrated that lesion depth significantly influenced healing outcomes in both conventional and GTR treatments.[21] found that healed lesions had a smaller mean depth (7.15 mm) compared to non-healed lesions (8.1 mm) in patients receiving conventional treatment. However,[1] reported that defect depth had no significant impact on healing.

Evaluating the height of the defect had a significant effect on healing among the studied population. This was contrary to the findings of [(1,21)]. When comparing the defect size critical measurements that influence the healing in conventional treatment and GTR, our data indicated that the conventional approach is effective in lesions with a depth of up to 3 mm. Using the GTR approach may improve the healing in lesions ≥ 3 mm. The likelihood of complete or partial healing will decrease among patients treated with GTR in > 9 mm depth lesions. Similarly, there was a significant difference in healing between lesion height and treatment approaches. Conventional treatment is effective in lesions up to 3 mm in height. The probability of complete healing decreased with conventional treatment in lesions > 3 mm. Sites with 3–6 mm height may have higher complete healing rates when applying the GTR approach. Areas that showed > 6 mm height had a low healing probability even with GTR treatment. To the best of our knowledge, no study to date has examined the critical points for healing among the two treatment approaches.

This study found that prognostic factors—including tooth type (single or multi-rooted), arch position (maxilla or mandible), type of retrograde filling, presence of buccal or palatal bone perforation, and crestal bone level indicating apicomarginal communication—did not

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

significantly affect healing outcomes, regardless of the treatment approach. Similarly, the operator's skill level (resident or specialist/consultant) had no notable impact on healing. These findings are consistent with previous.

However, this study had several limitations. First, the sample size was limited, with a potential risk of attrition bias. Although the sample size calculation determined that 42 participants were needed, only 33 were enrolled due to case unavailability. Additionally, since participation was voluntary, many patients declined the post-operative CBCT examination, particularly those without symptoms, even after being informed of its benefits. Concerns about additional radiation exposure and extra costs also contributed to this reluctance, potentially leading to an underestimation of treatment effectiveness. Furthermore, as a retrospective study, it was not possible to control all relevant variables, and post-operative signs and symptoms were not evaluated.

Finally, this study was based solely on radiographic interpretation. In an attempt to mask the type of treatment, radiographic measures were taken before retrieving the data from the patients' files; however, the type of treatment provided can be identified based on CBCT appearance most of the time owing to the experience of the author in that field.

Conclusions

The GTR approach appeared to achieve significantly better healing rates than conventional treatment in isolated and apicomarginal periapical lesions. However, further studies are needed to generalize these findings and address the limitations of this study. Based on the results, clinical guidelines could suggest that conventional treatment is effective for periapical lesions with a depth and height of ≤3 mm, while the GTR approach offers a higher likelihood of complete healing for lesions with a depth of 3–9 mm and a height of 3–6 mm. In contrast, lesions exceeding 9 mm in depth and 6 mm in height had a lower probability of successful healing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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