Original Article

Outcome Assessment of Three Different Methods of Root-end Preparation and Filling Materials in Endodontic Surgery: A Comparative Clinical Prospective Study

Ibadat P. Kaur[1], Renu B. Sroa[2], Monalisa Debbarma[1], Sinha Pallawi[3], Ashok Kumar[4]

[1]Department of Conservative Dentistry and Endodontics, Agartala Government Dental College and IGM Hospital, Agartala, Tripura, India, [2]Department of Conservative Dentistry and Endodontics, Punjab Government Dental College and Hospital, Amritsar, Punjab, India, [3]Department of Prosthodontics, Hi-Tech Dental College and Hospital, Bhubaneswar, Odisha, India, [4]Department of Dentistry, AIIMS, Deoghar, Jharkhand, India

Abstract

Introduction: The technique of endodontic surgery had evolved tremendously in the recent years with introduction of new instruments and materials. **Aim:** This study aims to compare the clinical outcome of endodontic microsurgery using three different techniques with three different root-end filling materials for 16 months. **Materials and Methods:** A total of 45 maxillary incisors indicated for root-end surgery were selected for the study. They were enrolled into three groups, i.e. Group A (traditional [TRS]/heat burnished gutta-percha), Group B (concave [CON]/Retroplast), and Group C (cavity/DiaRoot BioAggregate), of 15 teeth each. The clinical and radiographic outcome was recorded at 1, 6, 12, and 16 months using various criteria. **Statistical Analysis:** The data were analyzed by one-way analysis of variance and Tukey's *post hoc* test using SPSS V. 21 software (IBM Corp., Somers, NY, USA). **Results:** All patients had uneventful healing at the final follow-up. Radiological intratime analysis concluded a highly high significant ($P < 0.0001$) decrease in the size of radiolucency between the three groups at the third recall visit. Intertime analysis recorded no significant decrease in radiolucency between Groups A and B, a significant decrease in B and C, and a highly significant decrease between Groups A and C at 12 months. **Conclusions:** There was no significant difference in the clinical outcome after endodontic surgery when comparing TRS/heat burnished gutta-percha, CON/Retroplast, and cavity/DiaRoot BioAggregate techniques at 16 months. However, cavity/DiaRoot BioAggregate resulted in significantly rapid and predictable healing at 12 months.

Keywords: *BioAggregate, endodontic microsurgery, endodontic surgery, periapical surgery, Retroplast, root-end filling materials*

Introduction

Endodontic surgery encompasses surgical procedures performed to treat persistent apical periodontitis after nonsurgical treatment or in certain instances after primary endodontic treatment with the ultimate aim of preservation of natural teeth by the restoration of periodontium to a state of biological and functional health.[1] The concept of periapical surgery has been introduced by various clinicians in the late 19th and early 20th centuries.[2] It has been consistently evolving since inception with multiple modifications and iterations in the techniques and materials, with diverse acceptance and success rates.[1,2] Postresection, the preparation of the resected root end has broadly been described into three types in literature, i.e. traditional (TRS), a concave (CON), and a cavity (CAV) retrograde preparation (rep) technique.[3,4] TRS (rep) involves root-end preparation with surgical burs, followed by smoothening of the orthograde gutta-percha or retrograde amalgam restoration.[3] CON (rep) technique involves the creation of a shallow concavity over the entire resected root surface with round surgical bur and placement of bonded resin material over it.[4,5] The prepared concavity increases the surface area for bonding and provides bulk for the placed resin restoration.[6] In contrast to both, CAV (rep) technique, popularly known as endodontic microsurgery, prepares an axial root-end CAV using ultrasonic tips and endodontic microinstruments under an operating microscope followed by its restoration with more biocompatible materials.[3,5,6]

Root-end filling materials apically seal the prepared root end to prevent microbial

How to cite this article: Kaur IP, Sroa RB, Debbarma M, Pallawi S, Kumar A. Outcome assessment of three different methods of root-end preparation and filling materials in endodontic surgery: A comparative clinical prospective study. Contemp Clin Dent 2024;15:77-83.

Submitted : 17-Dec-2023
Revised : 29-Jan-2024
Accepted : 08-Feb-2024
Published : 10-Jul-2024

Address for correspondence:
Prof. Ashok Kumar, Department of Dentistry, AIIMS, Deoghar, Jharkhand, India.
E-mail: drashokpedo@gmail.com

Access this article online

Website: https://journals.lww.com/cocd

DOI: 10.4103/ccd.ccd_570_23

Quick Response Code:

egress[7] and subsequent contamination of the periradicular tissues. They act as a "physical seal" that is further superimposed by the "biological seal" formed by the circumferential cemental deposition from the resected root end to the center of the root canal, thereby achieving the double seal.[7] An ideal root-end filling material should have good marginal sealing ability and adhesion to root dentin, adequate radiopacity, dimensional stability, biocompatibility, low cytotoxicity, antimicrobial activity, bioactivity, and biomimetic properties under static and functional conditions. The root-end filling materials have also been stupendously advanced from the TRS amalgam, gold foil, gutta-percha to the use of zinc oxide-eugenol cements (IRM, Super EBA), glass ionomer cement, composite (Retroplast), compomer (Geristore), and most recent bioactive cements, etc., in the past few decades.[1] However, none of them meets all the standards required for an ideal root-end filling material.[1]

The biocompatibility, staining, corrosion, and poor overall performance retrograde amalgam have almost declined its use in the past few decades.[8] The TRS (rep) with smoothening of orthograde gutta-percha is still being practiced with inconsistent results. It successful healing has been reported to be comparable to IRM but significantly lesser than mineral trioxide aggregate (MTA).[8-10] Retroplast, introduced by Rud *et al*. in 1989, is a BISGMA/TEGDMA-based, two-component chemically curing liquid composite material exclusively recommended for CON (rep) technique.[5,6] It involves the application of Retroplast in a dome-shaped fashion onto a CON resected surface in combination with a dentine-bonding agent (GLUMA), with the intention of sealing of patent dentinal tubules, isthmuses, and accessory canals along with the main root canal.[5,6] Relatively reduced success rates of 73%–80% have been reported for Con (rep) + Retroplast in multiple studies, due to the associated limitations.[6] Evidently, the manipulation is also considered more susceptible to iatrogenic errors and requires above average clinical skills to allow for successful outcome.[6]

Since the development of white MTA in 2002, it has been represented as a nearly ideal, gold standard retrograde filling material in the literature due to its remarkable physical and biological properties.[11] The last two decades have added multiple purified formulations of tri-calcium silicate-based root-end filling materials, e.g. BioAggregate, EndoSequence Root Repair Material Putty and Paste (ERRM), iRoot BP Plus RRM (BP-RRM), calcium enriched mixture, and Biodentine.[8] These are further gaining widespread popularity due to high biocompatibility, radiopacity, better handling properties, and cost-effectiveness.[8] DiaRoot BioAggregate is modified hydrophilic, white hydraulic powder cement composed of calcium silicate hydrate, calcium hydroxide, hydroxyapatite, tantalum oxide, and amorphous silicon oxide.[12] It utilizes the advanced science of nanotechnology to produce ceramic particles that, upon reaction with water, produce biocompatible and aluminum-free ceramic biomaterials.[13,14] The powder, upon mixing with BioA Liquid (deionized water), precipitates calcium phosphate and undergoes a complicated set of reactions, leading to the formation of a nanocomposite network of gel-like calcium silicate hydrate intimately mixed with hydroxyapatite bioceramic to form a hermetic seal inside the root canal.[13-15] It is nontoxic, dimensionally stable, promotes cementogenesis, sets in the presence of moisture, and is strongly antibacterial due to its high initial pH (12.8). The substitution of bismuth oxide by titanium oxide has minimized the discoloration potential and made the material more biocompatible.[14] Although various *in vitro* and animal studies have reported DiaDent BioAggregate to be comparable to MTA as a root-end filling material, its clinical efficacy has not been investigated till date.

Therefore, the aim of this prospective *in vivo* study was to compare the healing outcome of the TRS periapical surgery technique (root-end resection + heat burnished gutta-percha) with two different modern techniques (Con and Cav rep), when using Retroplast and DiaRoot BioAggregate as retrograde filling materials in permanent maxillary anterior teeth.

Materials and Methods

This prospective study was supposed to be conducted on permanent maxillary anterior teeth among the patients reporting to the department of conservative dentistry and endodontics of the institution within a time period of 16 months. The ethical approval was obtained from the institutional ethical committee (EC/GDCA/2016-4). Healthy patients (ASA I or II) aged between 18 and 40 years, presenting with persistent periradicular disease and definite periapical radiolucency (more than 5 mm) after endodontic treatment with an intact coronal seal, irrespective of sex, caste, religion, or socioeconomic status, were included in the study. Teeth associated with severe periodontal bone loss, more than Grade I mobility, endo-perio lesions, and apicomarginal lesions were excluded. According to the departmental census, an average of at least three permanent maxillary incisors underwent endodontic surgery in a month. Thus, at least 54 teeth could be enrolled in our study. Considering that 20% of these patients may decline participation or may be excluded because of the reasons listed earlier, we decided to enroll 45 teeth in our study, with an equal number of 15 teeth in each group. A detailed history was taken, and a comprehensive clinical examination (systemic, intraoral, and extraoral) was carried out for each potential individual. The information sheets were distributed, and the procedure was thoroughly explained to them. After obtaining written informed consent from the patient, all clinical procedures were performed by the same surgical team of a single operator and three assistants. A full-thickness

mucoperiosteal flap was reflected after achieving adequate local anesthesia using 2% lignocaine with 1:80,000 adrenaline (Xicaine, ICPA). The amount of facial cortical bone associated with the tooth to be treated was assessed, and the minimally required osteotomy was performed. The bony crypt was gently curetted to remove the granulation tissue and expose the root end. The apical 3 mm of root end was resected perpendicular to the long axis of the tooth with a high-speed standard straight fissure bur (Mani, Japan) under copious irrigation with 0.9% saline water. The site was then inspected under 8x-10x for the detection of overlooked residual tissue and anatomical details.

The teeth with resected root ends were divided into three groups, i.e., Group A, Group B, and Group C of fifteen roots each. In Group A, the resected root ends were sealed by smoothening of orthograde gutta-percha using a heated medium-sized burnisher without any root-end CAV preparation [Figure 1a]. The resected root surfaces in Group B were made slightly CON using the round bur no. 2, which inserted half of its diameter. Gelatin hemostatic sponge gauze (Spongestone, Rennex Medical, India) was moistened with not more than 2–3 drops of 1% adrenaline and placed for about 2 min in the bone CAV. A solution of 0.5 mol/L ethylenediaminetetraacetic acid, pH 7.4, was rubbed onto the concavity for 20 s, followed by rinsing and drying with physiological saline and compressed air, respectively. The dentine-bonding agent Gluma Desensitizer (Hereaus Kulzer, Wehrheim, Germany) was then applied to the root end for 20 s and dried with compressed air. Equal amounts of Retroplast A and B were dispensed on the paper pad from the respective syringes and mixed for 10 s using a plastic spatula. It was applied to the entire concavity and resected root end, excluding the periodontal membrane [Figure 1b]. After a 2-min wait period, the surface was cleaned twice with 96% ethanol using a miniature brush, followed by rinsing with saline. The placement and adaptation of the Retroplast were finally evaluated under the surgical operating microscope (Visine Instruments, India) at 10x magnification. In the BioAggregate group (Group C), root-end cavities were prepared parallel to the long axis of the tooth at the magnification of 4x using the ultrasonic retrotip (7D/S12 F00118; Satelac Supresson, Merignac, France), driven by an ultrasonic piezoelectric unit (P6; ART Bonart, USA) set at not more than the power of 6. In order to standardize the dimensions of root-end preparation, the length of the retrotip (5 mm) determined the depth of the preparation (3 mm), and the final diameter was established by the circumferential preparation of the retrograde CAV. The prepared CAV was examined at 10x magnification. 1 g of BioAggregate (DiaRoot BioAggregate, DiaDent, Canada) was homogeneously mixed with a vial of BioA liquid (0.38 ml) and condensed incrementally into the prepared CAV [Figure 1c]. The adaptability of the material was also checked at 10× magnification. An immediate chairside radiograph was taken in all the groups, followed by the closure of the surgical sites with 4-0 interrupted sutures. Postoperative verbal and written instructions and prescriptions were also given to the patients before dismissal.

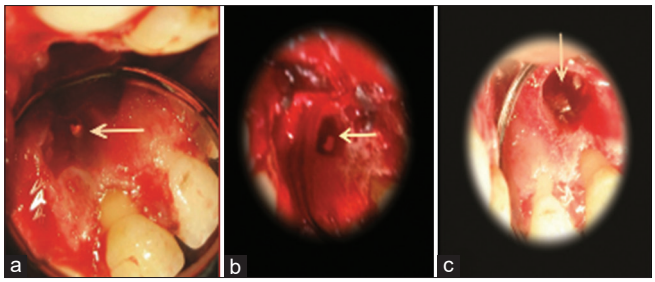

Figure 1: Clinical Image showing – (a) Heat burnished guuta-percha; (b) Retroplast placement; (c) DiaRoot BioAggregate placement

The first follow-up scheduled at 1 week for suture removal was followed by routine clinical and radiographic analysis at 1 month, 6 months, 12 months, and 16-month time periods [Figures 2-4]. The healing outcome was quantified for each tooth according to the three parameters described by Von Arx criteria[15] i.e. Pain score [0 – No Pain, 1 – Mild Pain (Temporary), 2 – Mild Pain (Permanent), 3 – Severe Pain]; Clinical Manifestations [0 – No clinical manifestations, 1 – Apical area tender to palpation, 2 – Apical swelling or tooth tender to percussion, 3 – Sinus tract or abscess]; and Osseous Regeneration. Standardized radiographs taken at each follow-up were transformed digitally, and the dimension (D) of the periradicular bone defect was calculated as $D = A/2 + B/2$ (A = length, and B = height of radiolucency) using CorelDraw version 18.1. The percentage of osseous regeneration (R) was calculated by comparing the area of the recall radiograph with the immediate postoperative radiograph, using the formula: $R = 100 - (S \text{ recall} \times 100/S \text{ Postop})$, where $S = A/2$ X B/2 X. The radiographic changes at the last two follow-ups were additionally assessed using Rudd's radiographic criteria.[16]

Statistical analysis

The whole data were transferred to a Microsoft Excel sheet, and intratime and intertime changes in periapical radiolucency were analyzed by one-way analysis of variance and Tukey's *post hoc* test, respectively, using SPSS V. 21 software (IBM Corp., Somers, NY, USA).

Results

The sample consisted of 45 consecutively treated maxillary central incisors in 43 patients (33 males and 10 females; mean age: 35 years). All patients had uneventful healing at the final follow-up. The pain assessments obtained a score of 1, i.e., mild temporary pain, for eight patients (two in Group A, four in Group B, and two in Group C) at the first follow-up. At the same time, five teeth clinically manifested tenderness on palpation of the apical area (Score 1; two in

Groups A and B, and one in Group C), whereas two in Group A presented with tenderness on percussion, i.e. Score 2 at the same follow-up. The radiological evaluation is enumerated in Tables 1 and 2. Intratime analysis concluded a highly significant ($P < 0.0001$) decrease in the size of radiolucency between the three groups at the third recall visit. Considering intertime analysis, the decrease was not significant in various groups at the first and second follow-up visits. The third follow-up visit at 12 months evidenced no significant decrease between groups A and B, a significant decrease in Groups B and C, and a highly significant decrease between Groups A and C [Table 3]. The outcome was ultimately categorized according to the two different criteria [Tables 4 and 5] at the final two follow-ups.

Discussion

Maxillary anterior teeth, the most frequent teeth requiring apical surgery due to various biological and technical factors, were selected for the present study. In accordance with previous literary evidence, an overall 88.89% success rate was recorded during the follow-up period of 16 months. The pooled percentages of completely healed cases after TRS, Con (rep), and Cav (rep) techniques at 1–2 year follow-ups have been reported to be 59%, 82.20%, and 94.42%, respectively, in recent meta-analyses.[3,5] Their respective analogous Groups A, B, and C in the present study also recorded similar values of 60.00%, 66.67%, and 93.33% as per Rudd's radiographic criteria, whereas a comparatively higher successful outcome of 73.33%, 93.33%, and 100% was observed using von Arx's quantitative assessment at the final follow-up of 16 months. These differences are attributed to the variable evaluation parameters followed for the estimation of periapical changes among these two criteria.

Table 1: Mean size of periradicular radiolucency (D) in mm at various follow-ups

Group	Follow up period (months)			
	1	6	12	16
A	8.32	6.69	4.86	2.58
B	8.22	6.66	4.42	1.84
C	8.56	5.64	2.46	1.77

Table 2: Mean osseous regeneration using von Arx criteria at various follow-ups

Group	Follow up period (months)			
	1	6	12	16
A (%)	18.49	47	67.88	90.62
B (%)	20.72	49.72	78.73	96.17
C (%)	37.81	70.96	94.26	98.23

Table 3: Intertime variation in size of periapical radiolucency using *post hoc* Tukey's test treatment period

Treatment period (months)	Groups	*P*
1	A–B	0.99
	C–A	0.97
	C–B	0.93
6	A–B	0.10
	A–C	0.37
	B–C	0.38
12	A–B	0.74
	A–C	<0.001***
	B–C	0.004**
16	A–B	0.16
	A–C	0.12
	B–C	0.99

**Significant; ***Highly significant

The literature inferred the method of root-end preparation as most significant factor influencing the outcome after periapical surgery.[17] The smaller osteotomy window, use of microinstruments, minimal bevel, aligned ultrasonic C-I root-end preparation, the potential identification of microfractures, isthmuses, and additional canals under the high magnification of a microscope along with the bioactive root-end filling materials have substantially increased the success rates of the modern periradicular surgeries.[1] The placement of root-end filling in radiographically well-obturated teeth was argued in previous studies.[9] Contrarily, multiple studies have also concluded the selection of root-end filling material as a significant prognostic factor for the outcome of endodontic surgery.[18,19]

The most recent randomized clinical trial recorded significantly less ($P < 0.0001$) healing after smoothing of the existing orthograde gutta-percha root filling (52%), compared to MTA (96%).[9] Similar results have also been reported in network meta-analyses comparing the effects of MTA, RRM, and Super EBA with baseline gutta-percha data at 12 months.[8] The comparatively increased positive outcome in TRS Group A can be accredited to inclusion of the root-end resection without bevel and magnified inspection of the adaptability of the material in the present study,[10,17] while the physical properties of gutta-percha and persistent microgaps along with unnoticed buccal and palatal voids are the major suggested negative influencers for it.[9,20]

Group B (Con rep) in the present study recorded the intermediate success rates among the three study groups. The clinical comparative studies on Retroplast recorded success rates in the range of 73% and 80%.[5,6] Significantly higher ($P = 0.003$) success rates of 91.3% for MTA as compared to 79.5% for Retroplast were reported in a recent clinical prospective study.[6] Obviation of the recommended ideal apical therapeutic length of 6 mm (integrating 3 mm length of root-end resection and 3 mm depth of the retro-CAV) is a speculated unfavorable factor for the successful outcome.[15] Moreover, the material

Table 4: Quantitative assessment of healing using von Arx criteria* (*n*=45)

Group	12 months			16 months		
	Success, *n* (%)	Improvement, *n* (%)	Failure, *n* (%)	Success, *n* (%)	Improvement, *n* (%)	Failure, *n* (%)
A	0	15 (100.00)	0	11 (73.33)	4 (26.67)	0
B	1 (6.67)	14 (93.33)	0	14 (93.33)	1 (6.67)	0
C	14 (93.33)	1 (6.67)	0	15 (100.00)	0	0

*Von Arx Criteria.[15] Success - Complete healing: Osseous regeneration >90% and pain and clinical scores=0, Improvement - Partial healing: Osseous regeneration 50%–90% and pain and clinical scores=0, Failure - Uncertain/no healing: Osseous regeneration <50% and pain and clinical scores ≥1

Table 5: Radiographic assessment of healing* (*n*=45)

Group	12 months				16 months			
	Complete, *n* (%)	Incomplete, *n* (%)	Uncertain, *n* (%)	Unsatisfactory, *n* (%)	Complete, *n* (%)	Incomplete, *n* (%)	Uncertain, *n* (%)	Unsatisfactory, *n* (%)
A	0	8 (53.33)	7 (46.67)	0	9 (60.00)	5 (33.33)	1 (6.67)	0
B	1 (6.67)	11 (73.33)	3 (20.00)	0	10 (66.67)	5 (33.33)	0	0
C	12 (80.00)	3 (20.00)	0	0	14 (93.33)	1 (6.67)	0	0

*Rudd's criteria.[16] Complete healing: Complete bone regeneration and a normal or slight increase in the width of the periodontal periapical space; re-establishment of the lamina dura, Incomplete healing: Partial reduction of the former radiolucency; asymmetric rarefaction with irregular border demarcated by compact bone, Uncertain healing: Partial reduction in radiolucency with greater than twice the width of the periodontal space; symmetric rarefaction with a circular or semicircular hard lamina periphery, Unsatisfactory healing: No reduction or increase of the former radiolucency

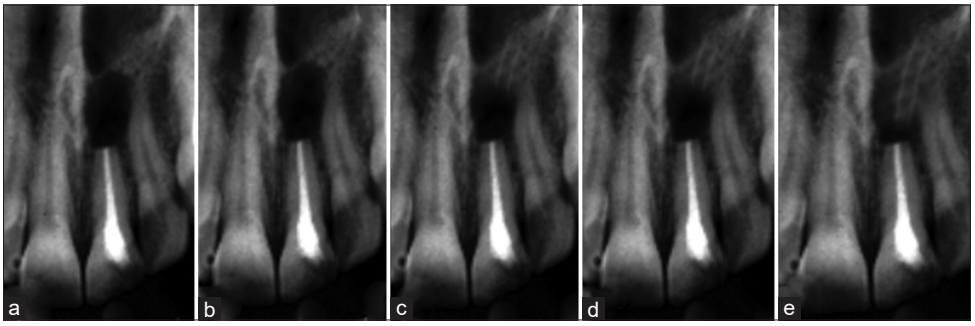

Figure 2: Radiographic periapical healing in Group A (Case No. 1, Tooth No. 21 showing Improvement/Uncertain healing) (a) Immediate postoperative; (b) 1 month; (c) 6 month; (d) 12 months; (e) 16 months

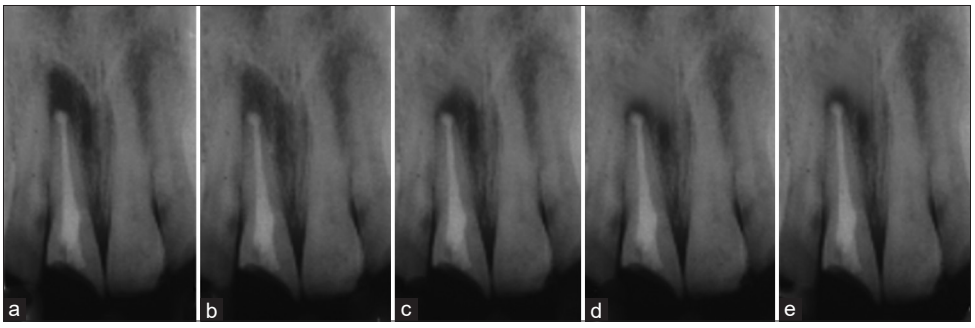

Figure 3: Radiographic periapical healing in Group B (Case No. 6, Tooth No. 11 showing Success/Incomplete healing) (a) Immediate postoperative; (b) 1 month; (c) 6 month; (d) 12 months; (e) 16 months

is nonbioactive, promotes bacterial growth, is prone to microleakage, and requires moisture-sensitive manipulation, making it vulnerable to displacement.[5] Evidently, the technique is considered more susceptible to iatrogenic errors and requires above-average clinical skills to allow for a successful outcome.[6]

The highest success rates in the present study have been achieved with the CAV (rep) restored with DiaRoot BioAggregate. Cavi (rep) with MTA has consistently reported a higher percentage (above 90%) of successful outcomes in the literature.[6,8,9] Bioactive endodontic cement, DiaRoot BioAggregate, is a tailored adaptation of MTA

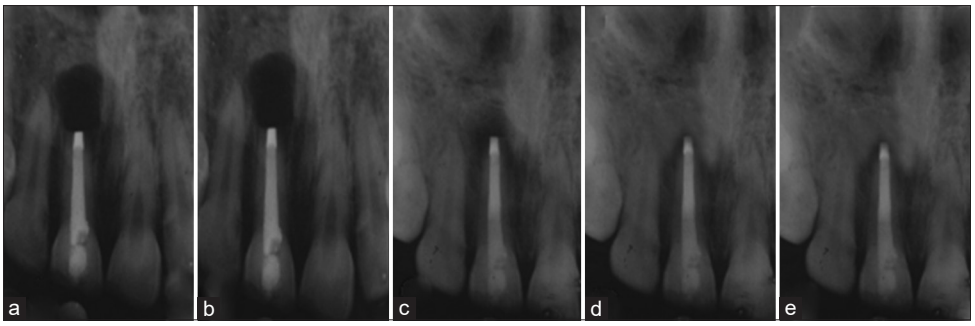

Figure 4: Radiographic periapical healing in Group C (Case No. 11, Tooth No. 11 showing success/certain healing) (a) Immediate postoperative; (b) 1 month; (c) 6 month; (d) 12 months; (e) 16 months

utilizing the advanced science of nanotechnology.[21] *In vitro* studies revealed that compared to MTA; this modified version is more biocompatible,[21] has more flexural[22] and less push-out bond strength[23] with similar sealing ability and less microleakage.[24] Higher expression of Type I collagen, osteocalcin, and osteopontin genes by Bioaggregate enhances osteoblastic growth and makes it more bioactive, osseoconductive, and osseoinductive material.[25] The expression of RANK, TRAF6, NF-κB, and NFATc1 is significantly decreased, resulting in suppressed osteoclastogenesis and bone resorption *in vitro*.[26] Animal studies after the subcutaneous inoculation in rats demonstrated similar biocompatibility reactions to MTA.[27] Although no comparative clinical studies or experimental trials of the material are reported, the improved properties of the material reasonably account for the higher success rates achieved in Group C at the final follow-up. However, the higher successful outcome cannot be exclusively attributed to the DiaRoot BioAggregate, as the method of root-end preparation is completely different from that of other groups. It is suggested that the modern surgical technique combined with advanced root-end filling material has resulted in the obtained inferences at 16 months.

Statistical evaluation of the present study further recorded significant differences between Groups B and C and highly significant differences between Groups A and C at the 12-month follow-up period. The findings validate the recommendation of 1 year as the minimum required time period to predict future outcomes after endodontic surgery.[28,29] It is also inferred that the majority of cases quantitatively classified as "improved" were qualitatively classified as "incompletely healed" at the same follow-up. Similar delayed healing for the Retroplast technique had also been observed previously[6,30] and suggested to be caused by the initial osseotoxic effect of the glutaraldehyde component of GLUMA desensitizer.[6] The "improved," "incomplete", and "uncertainly" healed cases have a predisposition toward complete healing,[28,29] whereas "uncertain radiographic healing" at 12 months manifests the most diverse results at long-term follow-ups.[30,31] Since the uncertain category was minimally recorded at the final follow-up, further progressive healing can also be hypothesized for the remaining cases of Groups 1 and 2 over a period of time.

The small sample size and lack of a three-dimensional assessment of healing are the major limitations of the study. The maximum sample size as per feasibility was included, whereas the use of CBCT was not possible due to financial issues and nonavailability in the department. Von Arx's quantitative criteria were combined with Rudd's criteria to establish a more precise evaluation of radiological healing after periapical surgery.

Conclusions

The present study recorded the positive outcome of endodontic surgery with a rate of 88.89% of completely healed cases. The technique and type of retrograde filling material have a distinctly significant effect on healing patterns at 12 months. Although the successful outcome is comparable at 16 months, CAV (rep) with DiaRoot BioAggregate is more efficacious than TRS and Con (rep) techniques. More studies with a larger sample size are required for more consistent results.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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