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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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VOLUMETRIC AND RADIOGRAPHIC OUTCOMES OF BONE REGENERATION AFTER APICOECTOMY WITH PRF-BASED THERAPIES - A PRELIMINARY STUDY

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Abstract.

Background: Successful apicoectomy relies on effective bone healing at the resected root apex. Platelet-rich fibrin (PRF) and bone graft materials have been proposed to enhance regeneration, yet comparative evidence using both two-dimensional (2D) and three-dimensional (3D) imaging remains limited.

Objective: To compare bone regeneration following apicoectomy using PRF, PRF combined with Bio-Oss, and conventional technique, and to evaluate postoperative pain and edema.

Materials and Methods: Thirty patients undergoing apicoectomy were randomly assigned to three groups (n = 10 each): PRF, PRF + Bio-Oss, and control (NaCl 0.9%). Linear defect measurements were obtained from standardized periapical radiographs, while volumetric analysis was conducted using CBCT segmentation software at baseline and 3, 6, and 12 months postoperatively. Regeneration percentage was calculated based on defect reduction. Postoperative pain (VAS 0–10) and edema (0–3 scale) were recorded for 7 days. Data were analyzed using paired t-tests and repeated-measures ANOVA ($p < 0.05$).

Results: All groups showed significant defect reduction ($p < 0.001$). PRF-based treatments achieved greater regeneration than control (2D: $F(2,27) = 12.41$, $p < 0.001$; 3D: $F(2,27) = 18.93$, $p < 0.001$), with the PRF + Bio-Oss group showing the highest percentages (2D: 82.6% ± 7.2; 3D: 90.4% ± 4.8). CBCT analysis demonstrated greater sensitivity and effect size than 2D radiography. No significant differences were observed in postoperative pain or edema.

Conclusion: PRF enhances bone regeneration after apicoectomy, especially when combined with Bio-Oss, without increasing postoperative morbidity. CBCT volumetric assessment provides superior evaluation of regenerative outcomes.

Key words. Apicoectomy, platelet-rich fibrin, bio-Oss, bone regeneration, cone-beam computed tomography.

Introduction.

Apical surgery is indicated for persistent periapical pathology when orthograde endodontic treatment or retreatment is unsuccessful or not feasible, and it often represents the final therapeutic option for tooth preservation [1]. The procedure aims to eliminate apical infection and seal the resected root end with a hermetic retrograde filling to prevent microbial leakage into periradicular tissues [2-4]. Periapical disease may arise from intraradicular [4] or extraradicular sources [5], both of which can compromise healing. Advances in surgical techniques and materials have significantly improved the predictability of apical surgery. Modern microsurgical approaches incorporate magnification and microsurgical instruments [6], ultrasonic retro-tips for conservative and centered root-end preparation [7], and biocompatible retrograde filling materials such as mineral trioxide aggregate (MTA) and other calcium silicate–based cements [8]. In addition, erbium lasers have been introduced for osteotomy and root-end cavity preparation due to their precision and reduced thermal damage, potentially enhancing healing conditions [9]. These technological developments have shifted apical surgery toward minimally invasive and biologically oriented protocols. In parallel, regenerative medicine, often described as a biological solution to biological problems, has gained increasing attention, with growth factors playing a central role in tissue repair [10]. Strategies such as guided tissue regeneration (GTR) with barrier membranes, bone grafting materials, and biologically active adjuncts have been integrated into endodontic microsurgery to optimize bone healing [11]. Autologous platelet concentrates, including platelet-rich fibrin, have emerged as promising regenerative tools due to their sustained release of growth factors that promote angiogenesis and osteogenesis [12]. Furthermore, regenerative endodontic procedures aimed at preserving or restoring pulp vitality represent another biologically driven approach in selected cases, particularly in immature teeth. The potential advantages of platelet concentrates and regenerative strategies in periapical surgery have been widely explored in contemporary literature [12-14].

Platelet-rich fibrin (PRF) represents a second-generation autologous platelet concentrate introduced by Choukroun et al. in 2006 [15]. Unlike first-generation platelet concentrates such as platelet-rich plasma (PRP), which require anticoagulants and exogenous thrombin for activation, PRF is obtained through a simplified centrifugation protocol without biochemical additives [15,16]. This results in a natural fibrin matrix with a three-dimensional architecture capable of gradually releasing bioactive molecules over time. The preparation method is relatively rapid, cost-effective, and technically straightforward, which facilitates its routine use in clinical settings [15,16]. Biologically, PRF acts not only as a reservoir of growth factors, including platelet-derived growth factor (PDGF), transforming growth factor beta (TGF-β), and vascular endothelial growth factor (VEGF), but also as a scaffold that supports cellular migration, adhesion, proliferation, and differentiation [17-20]. Its leukocyte content further contributes to immunomodulation and antimicrobial defense, potentially enhancing early wound stability and angiogenesis [21]. These properties make PRF particularly attractive in surgical endodontics, where both soft tissue closure and hard tissue regeneration are critical for predictable healing.

Despite increasing clinical application, variability in reported outcomes and differences in evaluation methods highlight the need for standardized volumetric assessment and controlled comparative trials. Therefore, the aim of the present study was to evaluate and compare bone regeneration following apicoectomy using PRF alone, PRF combined with Bio-Oss, and conventional saline management, through both two-dimensional radiographic analysis and three-dimensional CBCT volumetric assessment, while also assessing postoperative pain and edema.

Materials and Methods.

Study design:

A prospective comparative clinical study was conducted to evaluate bone regeneration dynamics following apicoectomy using platelet-rich fibrin (PRF), PRF combined with xenograft (Bio-Oss), and conventional treatment. The study was performed at the University Dentistry Clinical Centre of Kosova between 2021 and 2024. This study was designed as a longitudinal follow-up trial with predefined radiographic assessments at baseline (preoperative), 3 months, 6 months, and 12 months postoperatively. This study was prospectively conducted; however, it was not registered in a clinical trial registry. This is acknowledged as a limitation. Future studies will follow CONSORT and prospective registration guidelines.

Ethical Approval:

Ethical approval was obtained from the Ethics Committee of the University Dentistry Clinical Centre of Kosova (Approval No. 648/2-2021). All procedures were performed in accordance with the ethical principles of the World Medical Association Declaration of Helsinki (1975, revised 2013). Written informed consent was obtained from all participants prior to enrollment. To comply with radiation protection principles (ALARA/ALADA), CBCT imaging was strictly limited to clinically justified time points and was not performed for research purposes alone.

Sample Size and Patient Allocation:

Thirty patients, fulfilling eligibility criteria in Table 1, requiring apicoectomy due to persistent periapical lesions were included.

A priori power analysis (G*Power 3.1) was performed assuming a medium-to-large effect size ($f = 0.40$), $\alpha = 0.05$, and power $(1-\beta) = 0.80$ for repeated measures ANOVA, indicating a minimum required sample of 27 participants. Therefore, the final sample size of 30 patients was considered adequate.

Patients were allocated into three equal groups (n = 10 per group):

Group 1 (PRF group): Apicoectomy with placement of autologous A-PRF. **Group 2 (PRF + Bio-Oss group):** Apicoectomy with A-PRF combined with deproteinized bovine bone mineral (Bio-Oss®).

Group 3 (Control group): Apicoectomy with conventional saline irrigation (NaCl 0.9%) without regenerative material

Preoperative Assessment:

Diagnosis of persistent periapical lesions was established based on:

- Clinical examination (pain, sinus tract, tenderness to percussion)
- Periapical radiography
- Cone-beam computed tomography (CBCT)

All radiographic imaging was performed using standardized positioning protocols to ensure reproducibility. Radiographic assessment was standardized and repeated at four defined time points: preoperative, 3 months, 6 months, and 12 months postoperatively.

Surgical Procedure:

All surgeries were performed under local anesthesia by experienced oral surgeons.

1. Full-thickness mucoperiosteal flap elevation
2. Osteotomy and lesion curettage
3. Apical root resection (approximately 3 mm)
4. Retrograde cavity preparation and filling (standard microsurgical protocol)

Defect management differed according to group allocation:

- **Group 1:** Placement of A-PRF clot/membrane into the defect
- **Group 2:** Placement of Bio-Oss® mixed with injectable PRF (i-PRF) to form "sticky bone," covered with PRF membrane
- **Group 3:** Conventional management with saline irrigation only

Flaps were repositioned and sutured with interrupted sutures (Figure 1).

PRF Preparation Protocol:

Advanced PRF (A-PRF) was prepared according to the protocol described by Joseph Choukroun.

- 10 mL venous blood collected without anticoagulant
- Centrifuged at 1300 rpm for 14 minutes
- Fibrin clot separated and shaped for placement

For the PRF + Bio-Oss group, injectable PRF was combined with xenograft particles to form cohesive sticky bone prior to placement (Figure 2).

Radiographic Evaluation:

Radiographic evaluation was performed at:

- Baseline (preoperative)
- 3 months
- 6 months
- 12 months

Linear defect height and width were measured from standardized periapical radiographs using calibrated digital software, volumetric defect analysis was performed using CBCT datasets. Lesion volume (mm^3) was calculated using segmentation software. Bone regeneration (%) was calculated as: Regeneration (%) = [(Baseline Defect Size − Follow-up Defect Size) / Baseline Defect Size] × 100

Clinical Outcome Measures.

Pain Assessment: Pain was recorded using a Visual Analogue Scale (VAS, 0–10) daily for 7 days postoperatively.

Swelling Assessment: Swelling was graded clinically from 0–3 based on visual comparison with the contralateral side:

- 0 = no swelling
- 1 = mild
- 2 = moderate
- 3 = severe

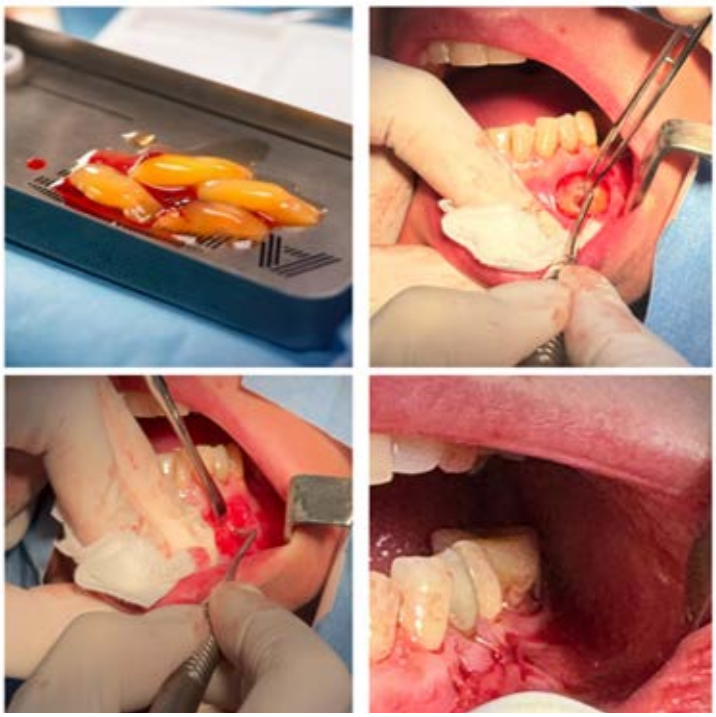

Figure 1. *A-PRF clots and surgical procedures for the treatment of a chronic apical lesion of the left mandibular first premolar.*

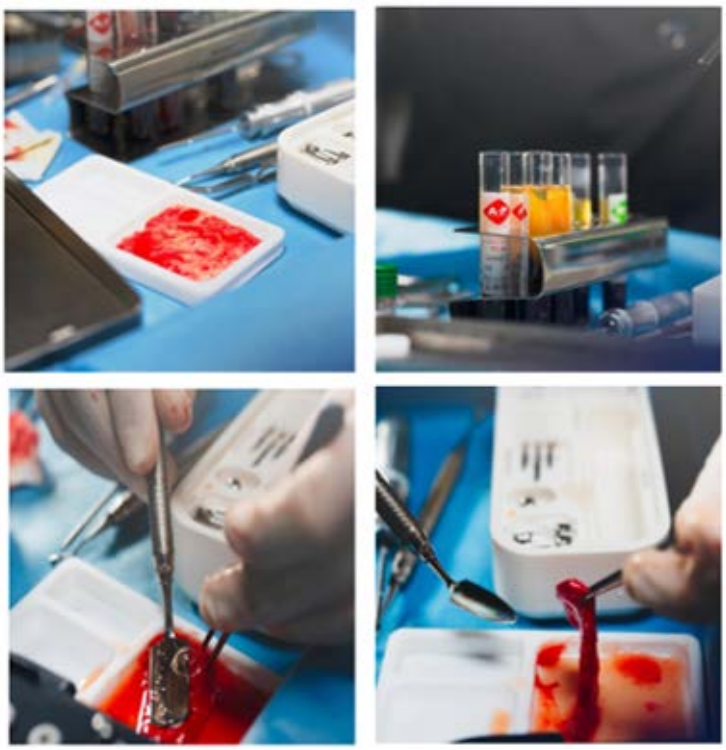

Figure 2. *Preparation of sticky bone by combining injectable PRF with Bio-Oss xenograft particles prior to placement in the defect.*

Table 1. *Eligibility criteria of study participants.*

Inclusion criteria	**Exclusion criteria**
Adults ≥18 years	Uncontrolled systemic diseases (e.g., uncontrolled diabetes mellitus)
Single-rooted teeth	Immunological disorders
Persistent periapical radiolucency following failed root canal treatment	Malignant neoplastic diseases
Indication for apicoectomy	Thrombocytopenia or bleeding disorders
Adequate oral hygiene and compliance	Pregnancy or lactation
No acute infection at the surgical site	Poor compliance or inability to attend follow-ups

Table 2. *Two-Dimensional (2D), 12-month postoperative outcomes compared to baseline.*

Group	Baseline Mean ± SD	Postoperative Mean ± SD	Mean Reduction	95% CI of Reduction	p-value
PRF	29.8 ± 5.6	7.1 ± 2.4	22.7	19.8 – 25.6	<0.001
PRF + Bio-Oss	31.2 ± 6.8	5.3 ± 2.1	25.9	22.4 – 29.4	<0.001
Control	28.9 ± 4.9	11.4 ± 3.6	17.5	14.2 – 20.8	<0.001

Overall paired comparison (all patients combined):
$t(29) = 8.79$, $p < 0.001$
Cohen's $d = 1.60$ (very large effect size)

Table 3. *Three-Dimensional (3D), 12-month postoperative outcomes compared to baseline.*

Group	Baseline Mean ± SD	Postoperative Mean ± SD	Mean Reduction	95% CI of Reduction	p-value
PRF	128.5 ± 62.4	21.3 ± 9.8	107.2	82.5 – 131.9	<0.001
PRF + Bio-Oss	182.6 ± 71.3	18.9 ± 8.1	163.7	128.4 – 199.0	<0.001
NaCl	121.4 ± 54.8	39.6 ± 14.2	81.8	56.3 – 107.3	<0.001

Overall paired comparison:
$t(29) = 9.42$, $p < 0.001$
Cohen's $d = 1.72$ (very large effect size)

Table 4. *Temporal Changes in 2D Defect Size (mm) During Follow-up.*

Group	Baseline	3 Months	6 Months	12 Months
PRF	29.8 ± 5.6	18.6 ± 4.2	11.4 ± 3.1	7.1 ± 2.4
PRF + Bio-Oss	31.2 ± 6.8	16.9 ± 3.8	9.2 ± 2.7	5.3 ± 2.1
NaCl	28.9 ± 4.9	22.5 ± 4.5	16.3 ± 4.1	11.4 ± 3.6

Table 5. *Temporal Changes in 3D Volumetric Defect Size (mm^3).*

Group	Baseline	3 Months	6 Months	12 Months
PRF	128.5 ± 62.4	78.2 ± 31.6	42.8 ± 18.9	21.3 ± 9.8
PRF + Bio-Oss	182.6 ± 71.3	92.4 ± 36.2	45.1 ± 19.4	18.9 ± 8.1
NaCl	121.4 ± 54.8	95.7 ± 41.3	62.5 ± 23.6	39.6 ± 14.2

Table 6. *Regeneration Percentage (%) Based on 2D and 3D Measurements.*

Group	2D Regeneration % Mean ± SD	95% CI	3D Regeneration % Mean ± SD	95% CI
PRF	74.8 ± 9.4	68.1 – 81.5	85.2 ± 6.1	80.8 – 89.6
PRF + Bio-Oss	82.6 ± 7.2	77.5 – 87.7	90.4 ± 4.8	87.0 – 93.8
NaCl	60.3 ± 11.5	52.1 – 68.5	67.8 ± 9.7	60.9 – 74.7

Table 7. *Peak Postoperative Pain (VAS).*

Group	Mean Peak VAS ± SD	95% CI
PRF	5.1 ± 1.2	4.3 – 5.9
PRF + Bio-Oss	4.8 ± 1.0	4.1 – 5.5
NaCl	5.4 ± 1.3	4.5 – 6.3

Table 8. *Peak Postoperative Edema Score.*

Group	Mean Peak Edema ± SD	95% CI
PRF	1.6 ± 0.5	1.3 – 1.9
PRF + Bio-Oss	1.5 ± 0.4	1.2 – 1.8
NaCl	1.7 ± 0.6	1.3 – 2.1
No significant intergroup differences were detected.		

Statistical Analysis.

Statistical analysis was performed using SPSS (version 22.0). Paired t-tests were applied to compare pre- and post-treatment measurements within groups, while repeated measures ANOVA was used to evaluate time effects and time × group interactions. The level of statistical significance was set at $p < 0.05$. Effect size was calculated using partial eta squared (η^2_p) to assess the magnitude of observed differences.

Results.

Study Population:

Thirty patients (n = 30) completed the study, with 10 patients allocated to each group (PRF, PRF + Bio-Oss, and NaCl control). No dropouts or postoperative infections were recorded. Baseline 2D and 3D defect measurements showed no statistically significant differences between groups ($p > 0.05$), confirming homogeneity at study entry.

Radiographic Outcomes:

1. Two-Dimensional (2D) Defect Reduction: A statistically highly significant reduction in linear defect size was observed across all groups following treatment ($p < 0.001$) (Table 2).

Between-group comparison of regeneration percentage demonstrated a statistically significant difference ($F(2,27) = 12.41$, $p < 0.001$, $\eta^2 = 0.48$), with PRF-based treatments showing superior outcomes compared to conventional control group.

2. Three-Dimensional (3D) Volumetric Defect Reduction: Volumetric CBCT analysis demonstrated highly significant defect reduction in all groups ($p < 0.001$), with greater effect magnitude compared to 2D assessment (Table 3).

Between-group comparison revealed a highly significant difference in regeneration percentage ($F(2,27) = 18.93$, $p < 0.001$, $\eta^2 = 0.58$). Post-hoc analysis demonstrated that PRF + Bio-Oss achieved significantly greater volumetric regeneration compared to both PRF alone and control group.

Temporal Bone Regeneration Dynamics:

Progressive reduction in defect size was observed at each postoperative follow-up interval (3, 6, and 12 months) across all treatment groups. As demonstrated in Table 4, two-dimensional (2D) radiographic analysis revealed continuous linear defect reduction over time, with the greatest improvement observed in the PRF + Bio-Oss group. At 3 months, the PRF + Bio-Oss group already demonstrated lower mean defect size (16.9 ± 3.8 mm) compared to the PRF group (18.6 ± 4.2 mm) and NaCl control group (22.5 ± 4.5 mm). This trend continued throughout the follow-up period, resulting in the smallest residual defect size at 12 months (5.3 ± 2.1 mm). In contrast, the NaCl group exhibited slower and less pronounced healing dynamics, with a residual defect size of 11.4 ± 3.6 mm at the final evaluation. Repeated-measures ANOVA demonstrated a statistically significant time-dependent reduction in defect size in all groups ($p < 0.001$), confirming progressive bone healing throughout the observation period.

Similarly, three-dimensional (3D) CBCT volumetric assessment demonstrated marked and continuous volumetric reduction in all groups during follow-up (Table 5). The PRF + Bio-Oss group showed the most pronounced volumetric healing dynamics, with lesion volume decreasing from 182.6 ± 71.3 mm^3 at baseline to 92.4 ± 36.2 mm^3 at 3 months, 45.1 ± 19.4 mm^3 at 6 months, and 18.9 ± 8.1 mm^3 at 12 months. The PRF-only group also demonstrated substantial volumetric reduction, whereas the NaCl control group showed slower healing progression and larger residual lesion volumes at all time points. Notably, CBCT-based volumetric analysis revealed clearer separation between treatment groups over time compared to 2D assessment, supporting the superior sensitivity of three-dimensional imaging for monitoring postoperative bone regeneration dynamics. Repeated-measures ANOVA confirmed a highly significant time effect for volumetric reduction across all groups ($p < 0.001$).

Bone regeneration evaluation:

Analysis of regeneration percentages demonstrated a clear superiority of biologically active treatment modalities compared to conventional saline management. As shown in Table 4, both PRF-based groups achieved substantially higher mean regeneration percentages than the NaCl control group in both 2D and 3D assessments. In 2D analysis, the PRF + Bio-Oss group showed the highest regeneration (82.6% ± 7.2), followed by PRF alone (74.8% ± 9.4), while the NaCl group exhibited the lowest values (60.3% ± 11.5). A similar pattern was observed in volumetric 3D measurements, where PRF + Bio-Oss reached 90.4% ± 4.8 regeneration, PRF alone achieved 85.2% ± 6.1, and NaCl demonstrated 67.8% ± 9.7. Notably, 3D regeneration percentages were consistently higher and showed narrower confidence intervals compared to 2D values, indicating greater sensitivity and measurement precision of CBCT-based volumetric analysis. Between-group comparisons revealed statistically significant differences ($p < 0.001$), confirming the enhanced regenerative performance of PRF, particularly when combined with Bio-Oss. These findings highlight the clinical advantage of biologically driven regenerative strategies in apical surgery.

Clinical Outcomes:

Postoperative Pain (VAS 0–10): Pain peaked on postoperative Days 1–2 and progressively decreased to near-zero levels by Day 7 across all groups (table 7).

Repeated-measures ANOVA demonstrated:

- Significant time effect ($p < 0.001$)
- No significant group effect ($p = 0.31$)
- No significant time × group interaction ($p = 0.27$)

Postoperative Edema: Swelling peaked on Day 2 in all groups and resolved by Day 7 in the majority of patients (Table 8). Repeated-measures ANOVA showed:

- Significant time effect ($p < 0.001$)
- No significant group effect ($p = 0.27$)

Discussion.

The present prospective comparative clinical study evaluated bone regeneration following apicoectomy using PRF, PRF combined with Bio-Oss, and conventional management. The findings demonstrate that biologically active regenerative approaches significantly enhance bone healing compared to conventional treatment, with the PRF + Bio-Oss group showing the highest volumetric regeneration percentages. Large effect sizes (η^2 up to 0.58) further confirm that the observed differences are not only statistically significant but also clinically meaningful. All groups exhibited significant reduction in defect size over time; however, PRF-based interventions achieved superior regeneration percentages compared to the control group. Volumetric (3D) CBCT assessment demonstrated particularly pronounced differences between groups, indicating enhanced sensitivity for detecting regenerative changes. These findings align with the randomized clinical trial by Gulsever et al. (2025), who reported significantly higher periapical lesion area (PALA) healing rates in L-PRF groups compared to non-PRF groups, with healing rates exceeding 90% at 9 months in PRF-treated cases [22]. Similar to our results, they found no baseline differences between groups and demonstrated accelerated early healing when L-PRF was applied. Their study also supports the concept that PRF enhances both short- and long-term regeneration [22]. In contrast, the systematic review and meta-analysis by Sinha et al. (2023) concluded that while PRF significantly reduced postoperative pain, quantitative

CBCT-based bone healing did not show statistically significant superiority over controls [23]. Our findings differ from that conclusion, as we observed statistically significant volumetric advantages for PRF, particularly when combined with Bio-Oss. This discrepancy may be explained by heterogeneity in PRF preparation protocols, follow-up durations, lesion sizes, and imaging standardization across studies, as also highlighted by Guerreiro et al. (2023), who emphasized significant variability in PRF protocols and clinical applications in endodontics [24]. The PRF + Bio-Oss group demonstrated the highest regeneration percentages in both 2D and 3D analyses. Similar to other studies, these findings suggest synergistic biological-mechanical interaction between the osteoconductive scaffold of deproteinized bovine bone mineral and the sustained release of growth factors from PRF [25,26].

Our results are consistent with the systematic review by Flynn et al. (2024), which demonstrated that regenerative techniques in apical surgery significantly improve healing outcomes compared to conventional surgery alone (OR = 2.18; p = 0.004) [27]. Although subgroup analyses in that review did not show clear superiority for specific graft or membrane combinations, the overall conclusion supports the benefit of regenerative adjuncts, corroborating our superior outcomes in the PRF + Bio-Oss group. Conversely, the histologic animal study by Bernabé et al. (2010) reported that membrane and bone graft materials did not significantly alter periapical healing following MTA root-end filling [28]. The difference between their findings and ours may be attributed to methodological differences: their experimental canine model evaluated histologic healing under controlled conditions, whereas our clinical human study assessed volumetric regenerative dynamics in naturally occurring lesions. Clinical biological variability may allow regenerative adjuncts to exert a more measurable impact in real-world surgical scenarios.

An important methodological contribution of this study is the confirmation that CBCT-based volumetric analysis provides greater sensitivity than conventional 2D radiography. Although both methods detected significant healing, 3D measurements demonstrated stronger effect sizes and narrower confidence intervals. This supports the growing consensus that three-dimensional imaging offers superior diagnostic accuracy in periapical surgery assessment [29,30].

Furthermore, a randomized controlled trial by Karkle et al. (2025) examined volumetric CBCT-based early bone healing after endodontic microsurgery with and without advanced platelet-rich fibrin (A-PRF) and found significant overall lesion volume reduction over time, highlighting the importance of standardized volumetric protocols and 3D imaging for accurate assessment of bone regeneration dynamics [1]. Pain and edema followed expected postoperative patterns, peaking during the first 48 hours and resolving within one week. No statistically significant intergroup differences were observed for pain or swelling. Our findings partially contrast with the meta-analysis by Sinha et al. (2023), which reported a significant reduction in postoperative pain with PRF use (SMD = 0.515; p = 0.026) [23]. Although our PRF groups demonstrated slightly lower mean VAS scores, the differences were not statistically significant. This may be attributed to sample size limitations or standardized postoperative medication protocols minimizing variability between groups. Importantly, the absence of increased morbidity confirms the clinical safety of PRF and PRF + Bio-Oss application. The systematic scoping review by Ardila and Vivares-Builes (2022) highlighted that combined endodontic and regenerative periodontal approaches significantly improve bone defect filling and clinical attachment levels in endo-perio lesions [31]. Although our study focused on periapical surgery rather than combined EPL lesions, the biological principle remains consistent: regenerative stimulation enhances bone repair when combined with proper endodontic management. Collectively, the current evidence, including our findings, suggests a paradigm shift from passive defect healing toward biologically enhanced regeneration in apical surgery. From a clinical perspective, the findings of this study support the integration of PRF-based regenerative protocols into endodontic microsurgery, particularly in cases involving large periapical defects. The enhanced volumetric healing observed with PRF + Bio-Oss suggests that combining biological stimulation with osteoconductive scaffolding may represent an optimal strategy for maximizing regenerative outcomes. At the same time, the lack of increased postoperative pain or edema confirms that these adjunctive techniques do not compromise patient comfort.

Nevertheless, limitations should be acknowledged. The sample size was modest, and follow-up duration, although sufficient to detect significant regeneration, may not fully capture long-term remodeling dynamics. Furthermore, variability in PRF preparation protocols across studies remains an important factor influencing comparability of results. Future multicenter randomized controlled trials with standardized PRF protocols and long-term CBCT evaluation are recommended to further validate these findings. The absence of prospective trial registration is acknowledged as a methodological limitation and may affect external validation. Future studies should adhere to CONSORT guidelines and be registered prior to patient enrolment.

In summary, the present study demonstrates that PRF, particularly when combined with Bio-Oss, significantly enhances bone regeneration following apicoectomy without increasing postoperative morbidity. These findings are consistent with contemporary regenerative literature and contribute additional volumetric evidence supporting the biologically driven enhancement of endodontic surgical outcomes.

Conclusion.

Within the limitations of this prospective clinical study, platelet-rich fibrin significantly improved bone regeneration following apicoectomy compared to conventional management, with the combination of PRF and Bio-Oss demonstrating the greatest volumetric healing. Three-dimensional CBCT analysis proved more sensitive than conventional 2D radiography for detecting regenerative changes. Importantly, the application of PRF, alone or combined with xenograft, did not increase postoperative pain or edema, confirming its clinical safety. These findings support the integration of biologically driven regenerative protocols into contemporary endodontic microsurgery to enhance healing predictability, particularly in larger periapical defects.

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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Author Contributions.

L.L.: Conceptualization, methodology, investigation, data curation, formal analysis, visualization, and writing – original draft preparation.

B.L.: Methodology, investigation, supervision, validation, and writing – review and editing.

I.M.: Radiographic analysis, data interpretation, validation, and writing – review and editing.

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Аннотация.

Цель исследования: Оценить регенерацию костной ткани после апикоэктомии с использованием обогащенной тромбоцитами фибриновой матрицы (PRF), PRF в комбинации с Bio-Oss и стандартной методики, а также изучить послеоперационную боль и отёк.

Материалы и методы: Тридцать пациентов были случайным образом распределены на три группы (PRF, PRF + Bio-Oss, контроль, n = 10). Линейные размеры дефекта определялись по періарикальным рентгенограммам, а объемная оценка проводилась с использованием КЛКТ на исходном этапе и через 3, 6 и 12 месяцев. Рассчитывался процент регенерации. Боль (VAS 0–10) и отёк (0–3) фиксировались в течение 7 дней. Данные анализировались с помощью парных t-тестов и ANOVA повторных измерений ($p < 0.05$).

Результаты: Все группы показали значительное уменьшение дефекта ($p < 0.001$). PRF-терапия обеспечила более высокую регенерацию по сравнению с контролем, наибольшие показатели были в группе PRF + Bio-Oss (2D: 82,6% ± 7,2; 3D: 90,4% ± 4,8). КЛКТ продемонстрировала более чувствительную оценку, чем 2D-рентгенография. Послеоперационная боль и отёк не различались между группами.

Выводы: PRF улучшает регенерацию костной ткани после апикоэктомии, особенно в комбинации с Bio-Oss, не повышая послеоперационную заболеваемость. Объемная КЛКТ позволяет более точно оценивать результаты регенерации.

Ключевые слова: Апикоэктомия, PRF, Bio-Oss, Регенерация кости, КЛКТ.

რეზიუმე.

კვლევის მიზანი: შეფასება ძვლის რეგენერაციის შემდეგ აპიკოექტომიის გამოყენებით თრომბოციტებით მდიდარი ფიბრინის მატრიცა (PRF), PRF Bio-Oss–თან ერთად და სტანდარტული მეთოდიკა, ასევე შეფასება პოსტოპერაციული ტკივილი და შეშუპება.

მასალები და მეთოდები: 30 პაციენტი შემთხვევითი წესით დაიყო სამ ჯგუფში (PRF, PRF + Bio-Oss, კონტროლი, n = 10). ხაზოვანი დეფექტის გაზომვები გაკეთდა სტანდარტიზებული პერიაპიკალური რენტგენოგრამებიდან, მოცულობითი ანალიზი კი CBCT–თ შესრულდა ბაზისზე და 3, 6, 12 თვეში. გამოითვალა რეგენერაციის პროცენტი. პოსტოპერაციული ტკივილი (VAS 0–10) და შეშუპება (0–3) ჩანაწერებულ იქნა 7 დღის განმავლობაში. მონაცემები ანალიზირდებოდა წყვილური t–ტესტით და განმეორებითი ზომების ANOVA–თ ($p < 0.05$).

შედეგები: ყველა ჯგუფმა აჩვენა მნიშვნელოვანი დეფექტის შემცირება ($p < 0.001$). PRF–ს გამოყენებით მკურნალობამ აჩვენა უფრო მაღალი რეგენერაცია კონტროლის ჯგუფთან შედარებით, PRF + Bio-Oss–ის ჯგუფმა კი ყველაზე მაღალი პროცენტები მიიღო (2D: 82.6% ± 7.2; 3D: 90.4% ± 4.8). CBCT–მა აჩვენა უფრო მგრძნობიარე შეფასება 2D რენტგენოგრაფიასთან შედარებით. პოსტოპერაციული ტკივილი და შეშუპება მნიშვნელოვნად არ განსხვავდებოდა ჯგუფებს შორის.

დასკვნა: PRF ამცირებს ძვლის რეგენერაციას აპიკოექტომიის შემდეგ, განსაკუთრებით Bio-Oss–თან კომბინაციაში, პოსტოპერაციული დაავადებების ზრდის გარეშე. CBCT მოცულობითი ანალიზი უზრუნველყოფს რეგენერაციის შედეგების სუფთა შეფასებას.

საკვანძო სიტყვები: აპიკოექტომია, PRF, Bio-Oss, ძვლის რეგენერაცია, CBCT.