

<https://doi.org/10.36377/ET-0235>

Radiographic healing of periapical lesions after root canal treatment with bioceramic sealers: A case series

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Abstract

INTRODUCTION. Periapical lesions result from bacterial infection of necrotic pulps, triggering immune responses that cause periapical bone resorption. Nonsurgical root canal treatment with effective infection control remains the primary approach to promote healing. The advent of bioceramic sealers, with their bioactivity, biocompatibility, and excellent sealing ability, has enhanced the potential for periapical healing and tissue regeneration. Their use may improve clinical outcomes and support predictable long-term success.

CASE SERIES. This case series reports on mature teeth with periapical lesions treated using root canal treatment with bioceramic sealers. Pre-operative and follow-up imaging, including periapical radiographs and Cone-Beam Computed Tomography up to a period of 48 months, was assessed. All cases showed radiographic healing, with periapical tissues exhibiting favorable biological responses. The bioactive properties of bioceramic sealers may have contributed to tissue repair. Careful clinical protocols, including appropriate case selection, thorough canal disinfection, and precise obturation technique, were consistently applied.

DISCUSSION. Bioceramic sealers are highly biocompatible and non-cytotoxic, promoting predictable periapical healing. This series emphasizes the importance of integrating material selection, meticulous clinical technique, and systematic radiographic follow-up to monitor healing and guide prognosis. These findings support the clinical advantages of bioceramic-based obturation in enhancing tissue regeneration and long-term treatment success. Finally, non-surgical root canal treatment remains a reliable and effective approach for the management of periapical lesion of endodontic origin.

Keywords: apical periodontitis, bioceramic sealers, root canal treatment, tissue regeneration

Article information: received – 16.04.2026; revised – 21.05.2026; accepted – 18.06.2026

Conflict of interest: The authors declare no conflict of interests.

Acknowledgements: There are no funding and individual acknowledgments to declare.

For citation: Salah K.B., Ferjani D., Gnaba I., Youssef S.B. Radiographic healing of periapical lesions after root canal treatment with bioceramic sealers: A case series. *Endodontics Today*. 2026;24(3):681–691. <https://doi.org/10.36377/ET-0235>

Рентгенологическое заживление периапикальных поражений после лечения корневых каналов с использованием биокерамических пломбировочных материалов: серия клинических случаев

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Резюме

ВВЕДЕНИЕ. Периапикальные поражения возникают вследствие бактериальной инфекции некротизированной пульпы, вызывающей иммунный ответ, который приводит к резорбции периапикальной костной ткани. Нехирургическое лечение корневых каналов с эффективным контролем инфекции остается основным методом, направленным на достижение заживления. Появление биокерамических силеров, обладающих биосовместимостью и высокой герметизирующей способностью, расширило возможности для периапикального заживления и регенерации тканей. Их применение может улучшить клинические результаты и способствовать достижению предсказуемого долгосрочного успеха лечения.

СЕРИЯ КЛИНИЧЕСКИХ СЛУЧАЕВ. В данной серии клинических случаев представлены зрелые зубы с периапикальными поражениями, которым было проведено эндодонтическое лечение с использованием биокерамических силеров. Оценивали результаты предоперационной и последующей лучевой диагностики, включая прицельные рентгенограммы и конусно-лучевую компьютерную томографию, в течение периода наблюдения до 48 месяцев. Во всех случаях отмечалось рентгенологическое заживление, при этом периапикальные ткани демонстрировали благоприятную биологическую реакцию. Биоактивные свойства биокерамических силеров могли способствовать восстановлению тканей. Во всех случаях

применялись тщательно разработанные клинические протоколы, включавшие правильный отбор пациентов, тщательную дезинфекцию корневых каналов и точную технику obturation.

ОБСУЖДЕНИЕ. Биокерамические силеры обладают высокой биосовместимостью и низкой цитотоксичностью, способствуя предсказуемому периапикальному заживлению. Данная серия клинических случаев подчеркивает важность комплексного подхода, включающего правильный выбор материала, тщательное соблюдение клинической техники и систематический рентгенологический контроль для оценки процесса заживления и определения прогноза. Полученные результаты подтверждают клинические преимущества obturation с использованием биокерамических материалов в отношении стимуляции регенерации тканей и достижения долгосрочного успеха лечения. Таким образом, нехирургическое лечение корневых каналов остается надежным и эффективным методом лечения периапикальных поражений эндодонтического происхождения.

Ключевые слова: апикальный периодонтит, биокерамические силеры, лечение корневых каналов, регенерация тканей

Информация о статье: поступила – 16.04.2026; исправлена – 21.05.2026; принята – 18.06.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Салах К.Б., Ферджани Д., Гнаба И., Юссеф С.Б. Рентгенологическое заживление периапикальных поражений после лечения корневых каналов с использованием биокерамических пломбировочных материалов: серия клинических случаев. *Эндодонтия Today*. 2026;24(3):681–691. <https://doi.org/10.36377/ET-0235>

INTRODUCTION

Inflammatory periapical lesions of endodontic origin (LIPOE) represent a direct consequence of pulpal necrosis and microbial contamination of the root canal system. They reflect the clinical and histopathological expression of the host response to endodontic infection, resulting from an imbalance between bacterial aggression and local immune defense mechanisms. [1; 2]. These lesions are often asymptomatic and develop in response to chronic infection, leading to localized bone resorption radiographically detectable as a periapical radiolucency. [3]

The diagnosis of periapical lesions requires a comprehensive clinical and radiological assessment. Patient history and clinical examination help identify subjective symptoms and objective signs, while pulp sensibility tests, percussion, and palpation assist in differentiating pulpal, periodontal, or combined pathologies. Radiological examination remains essential to confirm the presence and the extension of the lesion. In this regard, cone-beam computed tomography (CBCT) provides enhanced three-dimensional assessment, improving the evaluation of lesion extension. [4; 5]

Management of LIPOE relies primarily on conventional root canal treatment, combining chemomechanical preparation with three-dimensional obturation. Periapical healing represents the biological indicator of treatment success and occurs with subsequent regeneration of bone and periapical tissues. This reparative process is influenced by the biocompatibility and bioactive potential of the materials used. [6]

Therefore, periapical lesions should no longer be viewed solely as a consequence of pulpal necrosis but rather as a dynamic condition requiring both infection control and biological tissue repair. Recent advances in regenerative endodontics and bioactive biomaterials have redefined therapeutic objectives, emphasizing biological restoration over purely mechanical obturation.

Given that the management of teeth presenting with LIPOE is a common yet complex clinical proce-

sure, continuously evolving with the introduction of advanced techniques and innovative biomaterials, the present study aims to analyze the main factors influencing healing of LIPOE and to evaluate the mechanisms of periapical repair through clinical case analysis managed with a conventional endodontic approach using bioceramic sealer.

MATERIALS AND METHODS

Case Selection

This case series included five patients presenting with inflammatory periapical lesions of endodontic origin (LIPOE) affecting mature permanent teeth. Cases were selected from patients treated at the Department of Dental Medicine of Farhat Hached Hospital-Tunisia.

Inclusion criteria included: mature permanent teeth diagnosed with apical periodontitis based on clinical and radiographic findings; the absence of systemic conditions that could interfere with healing; the availability of preoperative radiographs, including periapical radiographs or CBCT; and patient compliance with follow-up appointments.

Teeth with root fractures, advanced periodontal disease, previous endodontic treatment, or incomplete clinical documentation were excluded.

All patients were informed about the treatment procedure and provided written consent prior to management. The selected cases were managed using a standardized nonsurgical endodontic protocol, and clinical as well as radiographic outcomes were evaluated during follow-ups.

Standardized Treatment Protocol

All teeth were treated using a standardized root canal treatment protocol under strict aseptic conditions. All procedures were performed by the same operator, a specialist in Endodontics, in order to ensure consistency and reduce operator-related variability.

Following local anesthesia when required, rubber dam isolation was applied and conventional ac-

cess cavity was performed. Working length was established using an electronic apex locator (integrated apex locator, Econnect-S, Eighteeth) and confirmed radiologically. Mechanical preparation was carried out using a rotary nickel-titanium system (OneCurve, MicroMega) according to the manufacturer's instructions. Throughout instrumentation, copious irrigation with 3.25% sodium hypochlorite was performed and frequently renewed, combined with passive ultrasonic activation to enhance disinfection. In cases presenting with suppuration, complete transcanal drainage was achieved prior to intracanal medication.

Calcium hydroxide was placed as an intracanal medicament, and the access cavity was temporarily sealed. At the subsequent visit, once the tooth was asymptomatic, the canals were irrigated, dried, and obturated using gutta-percha in combination with a bioceramic sealer (Ceraseal, Meta Biomed) using a single-cone technique. The bioceramic sealer was activated with ultrasonic tips for 20 s. Postoperative radiographs

were taken to verify the quality of obturation. Patients were scheduled for periodic clinical and radiographic follow-ups to evaluate periapical healing.

CASE DESCRIPTIONS

Case 1

A female patient in her 20's consulted our department for continuous spontaneous pain that did not respond to analgesics.

Clinical examination revealed that the tooth 23 is sensitive to the axial percussion, whereas lateral percussion and palpation were negative. The patient reported a history of impaction of tooth 23, managed by orthodontic traction five years earlier. The diagnosis was "symptomatic apical periodontitis".

Radiographic assessment demonstrated a well-defined periapical radiolucency associated with the apex of tooth 23. According to Ørstavik's Periapical Index (PAI), the lesion was classified as PAI score 5. (Fig. 1, A) [7].

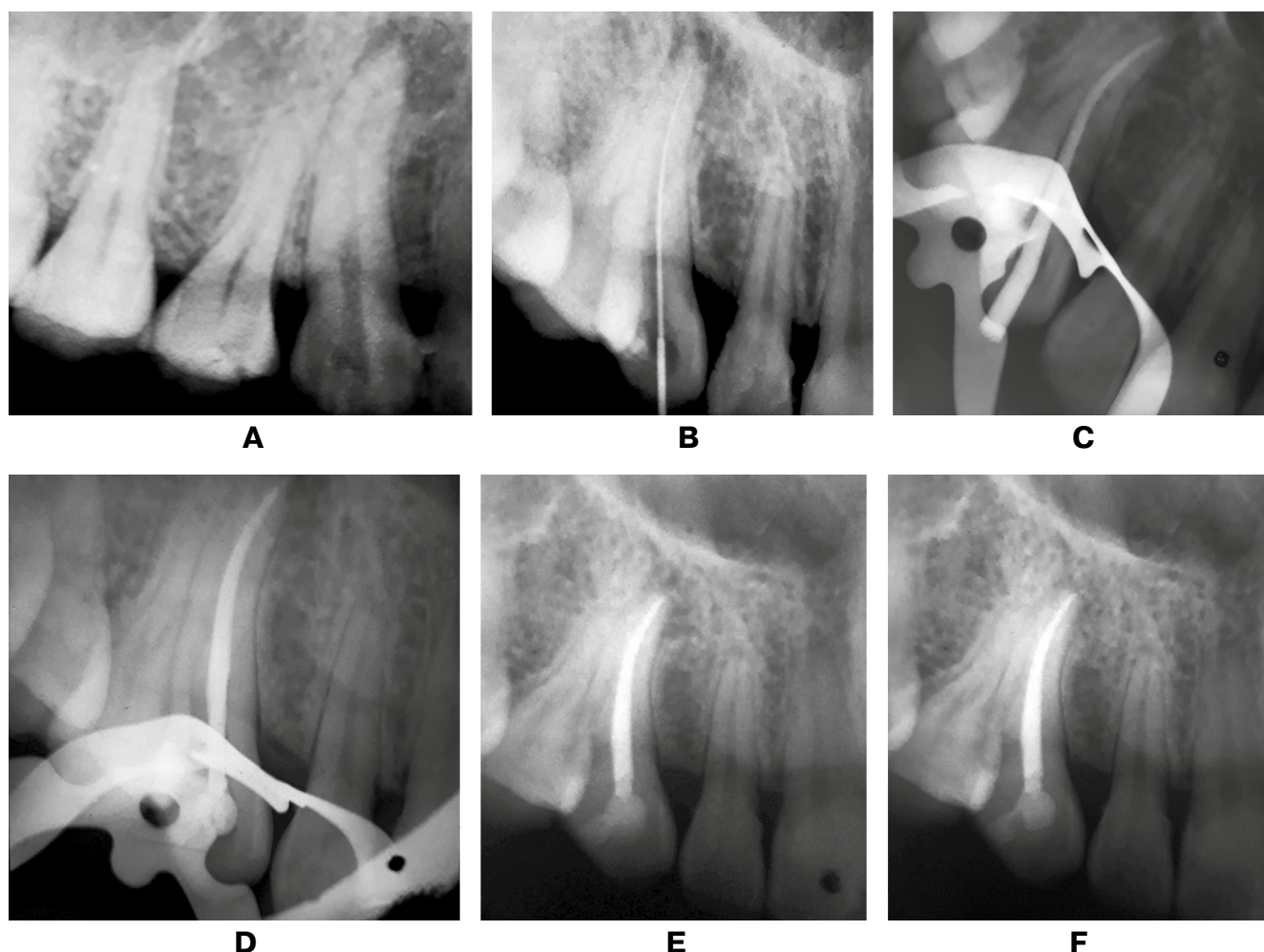


Fig. 1. Case 1: (A) Preoperative radiograph showing an Ørstavik's PAI score 5; (B) Determination of working length; (C) Cone-fit radiograph; (D) Post operative radiograph; (E) Periapical radiograph at 1 month follow-up; (F) Periapical radiograph at 3-month follow-up

Рис. 1. Клинический случай 1: (A) предоперационная рентгенограмма, демонстрирующая оценку по шкале PAI по Орставику равную 5; (B) определение рабочей длины; (C) рентгенограмма с конусом; (D) послеоперационная рентгенограмма; (E) периапическая рентгенограмма через 1 месяц наблюдения; (F) периапическая рентгенограмма через 3 месяца наблюдения

Thus, the tooth was treated according to the standardized endodontic protocol described above. (Fig. 1, B–D).

Follow-up visits were scheduled. Clinical examinations after 1 month and 3 months revealed an asymptomatic tooth and a healthy soft tissue. Periapical radiographs showed a complete healing after 3 months and a significant trabecular bone formation around the treated tooth. (Fig. 1, E, F)

Case 2

A 21-year-old female patient, in good general health, presented to our department six months after a road traffic accident that resulted in extrusion of tooth 21 and an uncomplicated enamel-dentin fracture of tooth 11 (Fig. 2). The patient did not report spontaneous pain at the time of consultation. Clinical examination of tooth 11 revealed slight tenderness to axial percussion and a negative response to pulp sensitivity test. Radiographic evaluation revealed a periapical radiolucency associated with the apex of tooth 11. Cone-Beam Computed Tomography (CBCT) analysis, based on Estrela's periapical index, showed a score of 3. (Fig. 2, A) [8]

Based on the clinical and radiographic findings, a diagnosis of asymptomatic apical periodontitis was established. Thus, the tooth was treated according to the standardized endodontic protocol described above (Fig. 2, B, C).

Follow-up visits were scheduled. Clinical examinations after 3, 6 and 24 months revealed an asymptomatic tooth and a healthy soft tissue. Periapical radiographic examinations showed a complete healing after 24 months with a trabecular bone formation around the treated tooth (Fig. 2, D–F).

Case 3

A 25-year-old female patient, in good general health, presented to our department, complaining of a mild discoloration and loss of translucency of tooth 21. The patient reported a history of dental trauma at the age of 12 years (Fig. 3, A). Clinical examination revealed negative responses to pulp sensitivity test and to axial percussion. Radiographic assessment demonstrated a well-defined periapical radiolucency associated with the apex of tooth 21. According to Ørstavik's Periapical Index (PAI), the lesion was classified as PAI score 5 [7] (Fig. 3, B).

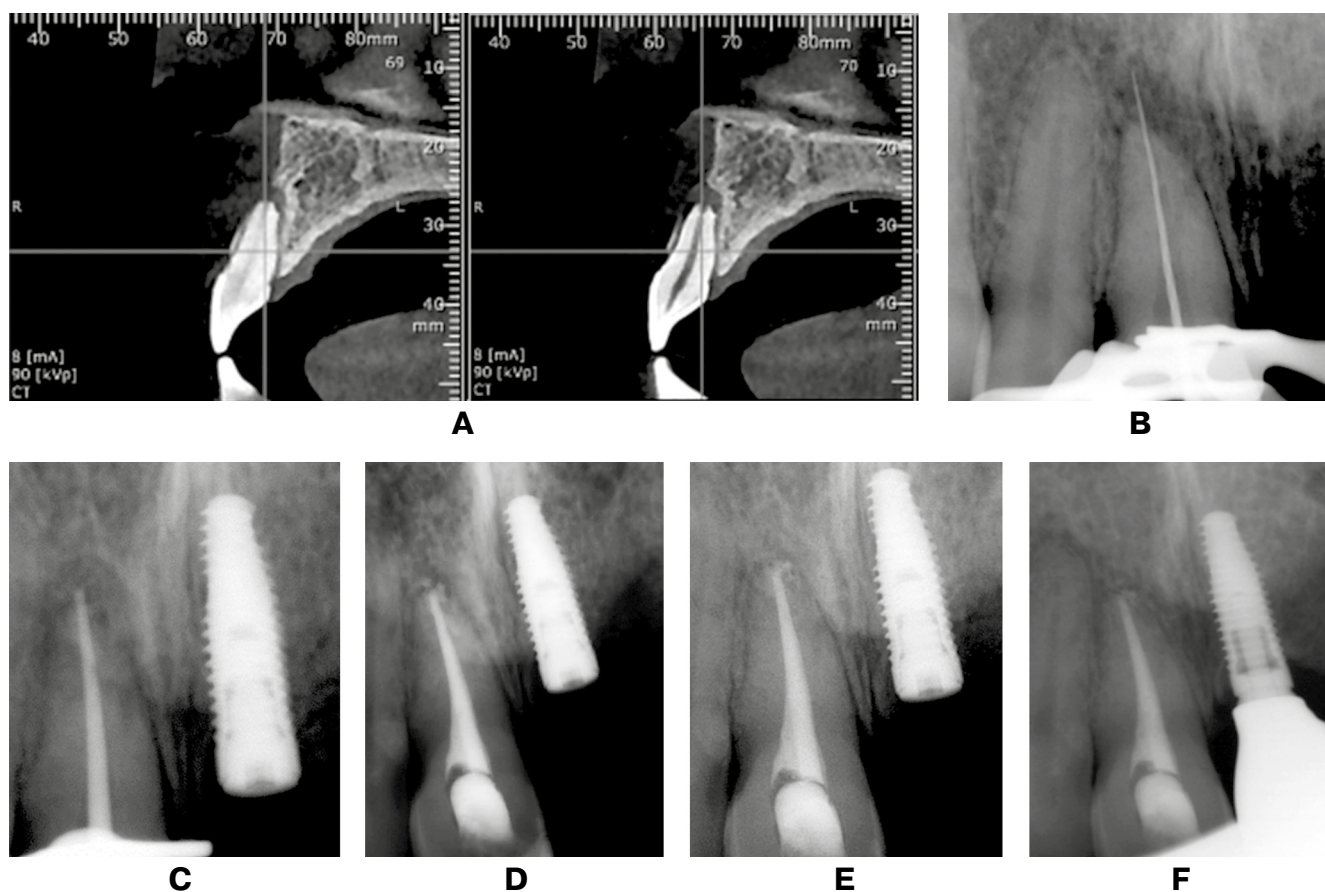


Fig. 2. Case 2: (A) Preoperative cone-beam computed tomography showing an Estrela's PAI score 3D; (B) Determination of working length; (C) Cone-fit radiograph; (D) Periapical radiograph at 3 months follow-up; (E) Periapical radiograph at 6-month follow-up; (F) Periapical radiograph at 24 months follow-up

Рис. 2. Клинический случай 2: (A) предоперационный снимок конусно-лучевой компьютерной томографии, демонстрирующий трехмерное изображение по шкале PAI Эстреллы; (B) определение рабочей длины; (C) рентгенограмма с конусом; (D) периапическая рентгенограмма через 3 месяца наблюдения; (E) периапическая рентгенограмма через 6 месяцев наблюдения; (F) периапическая рентгенограмма через 24 месяца наблюдения

Based on the clinical and radiographic findings, a diagnosis of asymptomatic apical periodontitis was established for tooth 21. Endodontic treatment was performed in accordance with the standardized protocol detailed in the Materials and Methods section (Fig. 3, C, D).

Clinical examinations after 3, 6 and 12 months revealed an asymptomatic tooth and a healthy soft tissue. Periapical radiographic examinations showed a complete healing after 12 months with a trabecular bone formation (Fig. 3, E, F).

Case 4

A 34-year-old female patient presented complaining of a discomfort on mastication related to tooth 36, which had been restored with a composite resin two years earlier. Clinical examination revealed a defective coronal restoration. Positive response to axial percussion when lateral percussion and pulp sensitivity test were negative. Radiographic evaluation demonstrated a well-defined periapical radiolucency associated with the apex of tooth 36. According to Ørstavik's Periapical Index (PAI), the lesion was scored as PAI 5 [7] (Fig. 4, A).

Based on clinical and radiographic findings, a diagnosis of symptomatic apical periodontitis was estab-

lished. The tooth was treated according to the standardized nonsurgical endodontic protocol described above (Fig. 4, B, C).

Clinical and radiographic follow-up at 12, 36, and 48 months demonstrated resolution of clinical signs and complete healing of the periapical lesion (Fig. 4, D–F).

Case 5

A 27-year-old female patient presented with mild discomfort on mastication related to tooth 46. Clinical examination revealed an axial percussion slightly positive, whereas lateral percussion was negative. Radiographic evaluation demonstrated a periapical radiolucency associated with the apex of tooth 46. According to Ørstavik's PAI, the lesion was scored as PAI 3 [7] (Fig. 5, A).

Based on clinical and radiographic findings, a diagnosis of asymptomatic apical periodontitis was established. The tooth was treated according to the standardized nonsurgical endodontic protocol described above (Fig. 5, B, C).

Clinical and radiographic follow-up at 3 and 6 months demonstrated resolution of clinical signs and complete healing of the periapical lesion (Fig. 5, D, E).

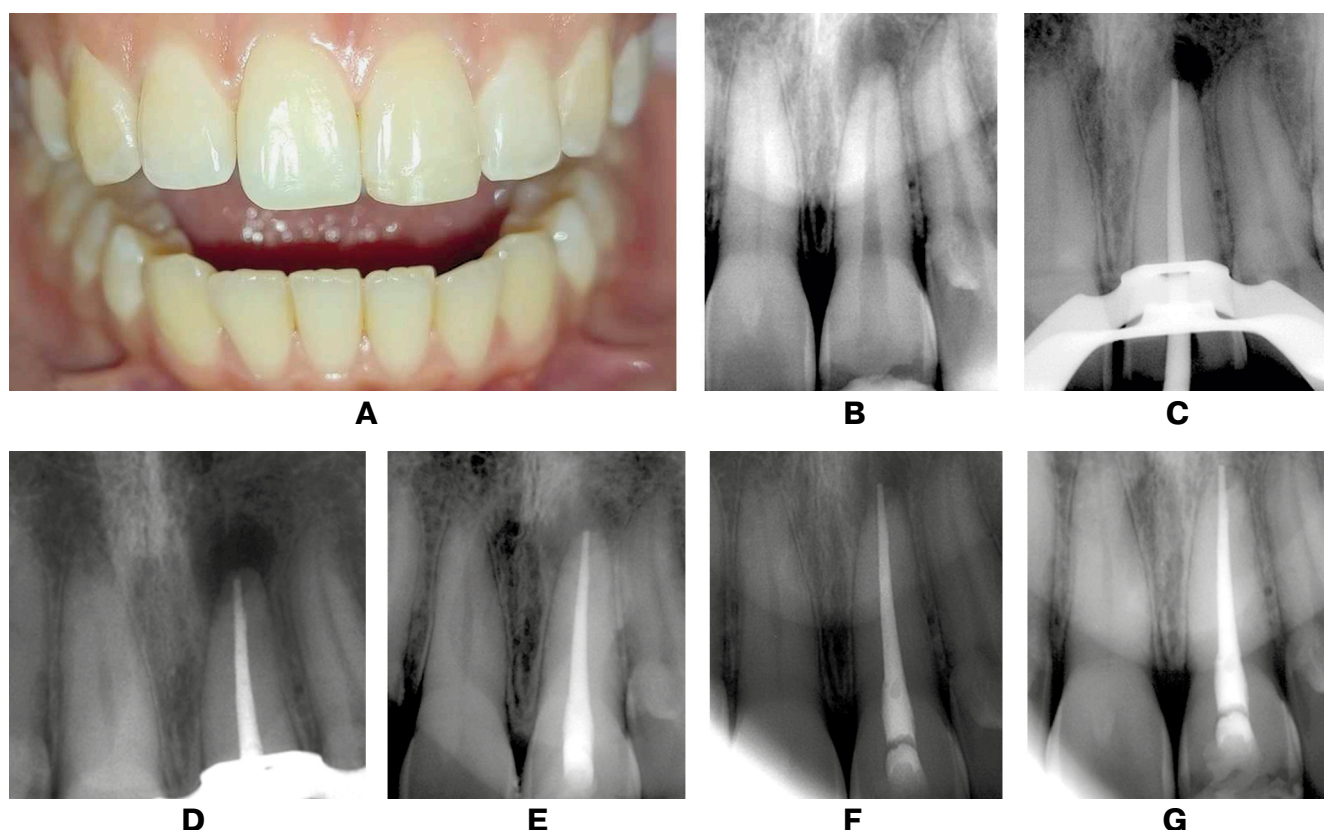


Fig. 3. Case 3: (A) Preoperative view showing mild discoloration and loss of translucency of tooth 21; (B) Preoperative radiograph showing an Ørstavik's Periapical PAI score 5; (C) Cone-beam CT scan; (D) Post-operative radiograph; (E) Periapical radiograph at 3 months follow-up; (F) Periapical radiograph at 6-month follow-up; (G) Periapical radiograph at 12 months follow-up

Рис. 3. Клинический случай 3: (A) дооперационная фотография, демонстрирующая изменение цвета и потерю прозрачности зуба 21; (B) дооперационная рентгенограмма, показывающая оценку по шкале PAI Ørstavik 5; (C) рентгенограмма с конусным фильтром; (D) Послеоперационная рентгенограмма; (E) периапикальная рентгенограмма через 3 месяца наблюдения; (F) периапикальная рентгенограмма через 6 месяцев наблюдения; (G) периапикальная рентгенограмма через 12 месяцев наблюдения

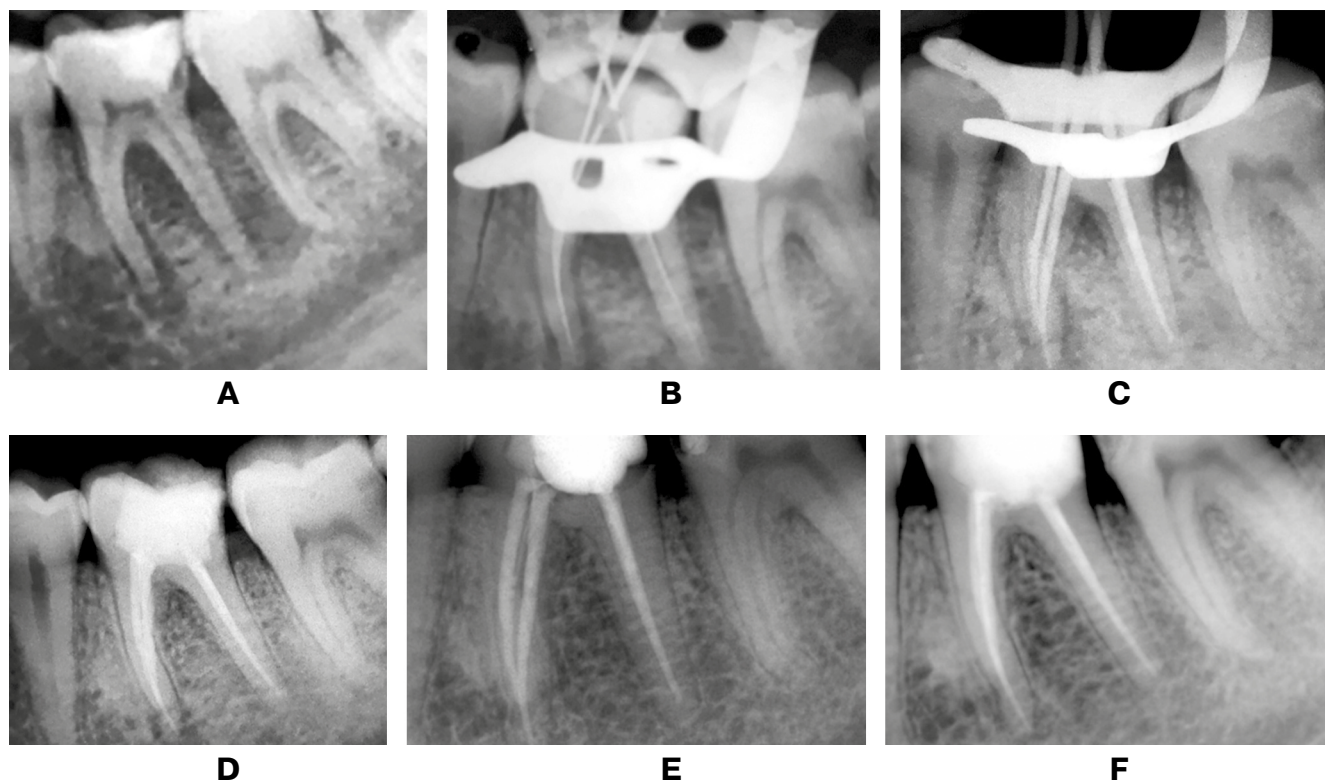


Fig. 4. Case 4: (A) Preoperative radiograph showing an Ørstavik's PAI score 5; (B) Determination of working length; (C) Cone-fit radiograph; (D) Periapical radiograph at 12 months follow-up; (E) Periapical radiograph at 36-month follow-up; (F) Periapical radiograph at 48 months follow-up

Рис. 4. Клинический случай 4: (A) предоперационная рентгенограмма, демонстрирующая оценку по шкале PAI по Орставику равную 5; (B) определение рабочей длины; (C) рентгенограмма с конусом; (D) периапическая рентгенограмма через 12 месяцев наблюдения; (E) периапическая рентгенограмма через 36 месяцев наблюдения; (F) периапическая рентгенограмма через 48 месяцев наблюдения

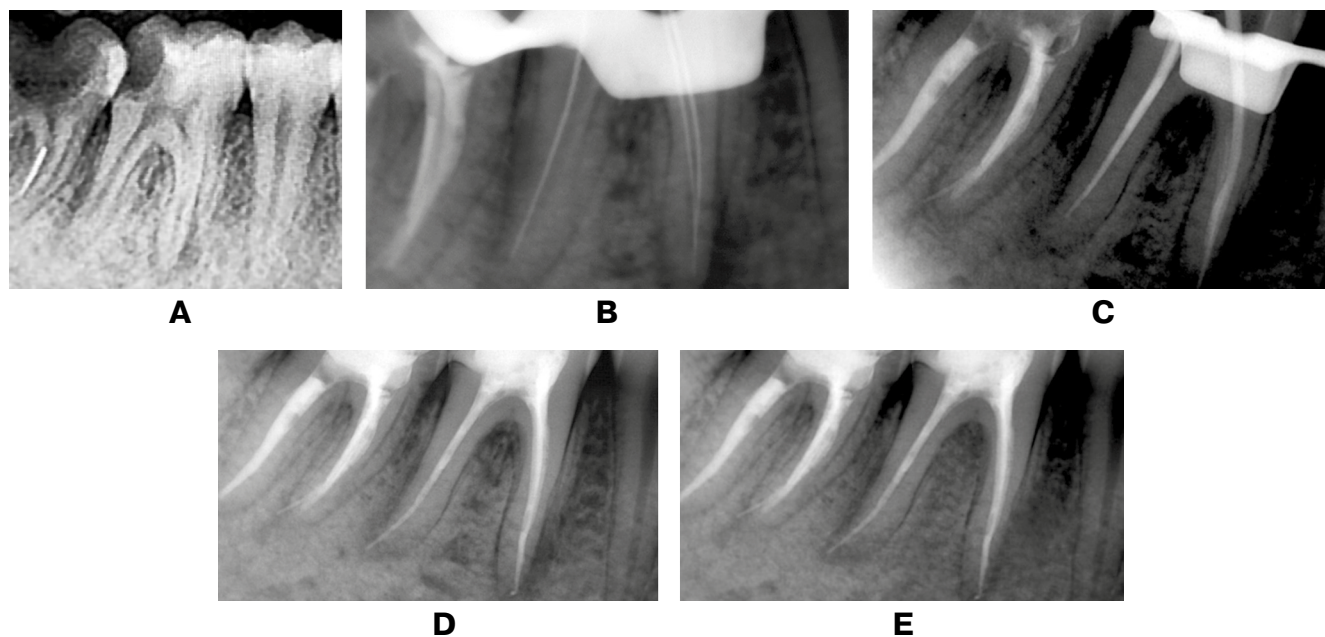


Fig. 5. Case 5: (A) Preoperative radiograph showing an Ørstavik's PAI score 3; (B) Determination of working length; (C) Cone-fit radiograph; (D) Periapical radiograph at 3 months follow-up; (E) Periapical radiograph at 6-month follow-up

Рис. 5. Клинический случай 5: (A) предоперационная рентгенограмма, демонстрирующая оценку по шкале PAI по Орставику 3; (B) определение рабочей длины; (C) рентгенограмма с конусом; (D) периапическая рентгенограмма через 3 месяца наблюдения; (E) периапическая рентгенограмма через 6 месяцев наблюдения

Table 1. Summary of clinical cases and radiographic healing outcomes after nonsurgical endodontic treatment

Таблица 1. Краткое описание клинических случаев и рентгенографических результатов заживления после нехирургического эндодонтического лечения

Clinical Case	Tooth Involved	Initial Diagnosis	Sealer	Radiographic Evaluation	Outcome
Case 1	23	Symptomatic apical periodontitis	Bioceramic	Periapical radiograph: Ørstavik PAI score 5	Complete radiographic healing after 3 months
Case 2	11	Asymptomatic apical periodontitis	Bioceramic	CBCT: Estrela periapical index score 3	Complete healing after 24 months
Case 3	21	Asymptomatic apical periodontitis	Bioceramic	Periapical radiograph: Ørstavik PAI score 5	Complete healing after 12 months
Case 4	36	Symptomatic apical periodontitis	Bioceramic	Periapical radiograph: Ørstavik PAI score 5	Complete periapical healing after 48 months
Case 5	46	Asymptomatic apical periodontitis	Bioceramic	Periapical radiograph: Ørstavik PAI score 3	Complete healing of the periapical lesion after 6 months

DISCUSSION

The present case series demonstrates favorable clinical and radiographic outcomes following nonsurgical endodontic treatment using bioceramic sealer, with complete resolution of periapical lesions and evident bone regeneration during follow-up. These findings highlight the effectiveness of thorough chemo-mechanical disinfection and adequate apical sealing in promoting periapical healing. Similar outcomes have been reported by Dinger and Bodrumlu [9], who showed that conventional endodontic treatment and three-dimensional obturation, can result in complete healing of periapical lesions, even when they are large.

In fact, periapical lesions result from multiple etiological factors, including mechanical, traumatic, chemical, and bacterial insults that enable microorganisms to progressively invade the pulp [3; 10; 11]. Once microorganisms reach the pulp, they trigger an inflammatory response that may progress to pulp necrosis if the irritant persists, allowing bacterial proliferation and the release of inflammatory mediators. The subsequent spread of infection beyond the apical foramen induces an immune response within the periapical tissues, resulting in bone resorption and the formation of inflammatory lesions [3; 10; 11]. These mechanisms are consistent with the etiological factors identified in the present case series, where traumatic, mechanical, and bacterial origins contributed to the development of periapical lesion.

Inflammatory periapical lesions of endodontic origin are traditionally classified based on histopathological features, which identify entities such as acute inflammatory reactions, periapical abscesses, granulomas, and apical cysts according to the classification proposed by Ramachandran Nair et al. [12]. However, because histological examination is rarely feasible in clinical practice, radiological classifications are widely used for diagnosis and follow-up. Brynolf [13] first established a radiographic classification correlating radiological appearance with histopathological findings, highlighting those early inflammatory changes may

remain radiographically undetectable. To standardize radiographic assessment, Ørstavik et al. [7] later introduced for the first time the Periapical Index (PAI), a five-point scoring system ranging from normal periapical structures (PAI 1) to severe bone destruction (PAI 5). This index has been adopted in several clinical studies due to its reproducibility and ability to quantify disease severity and healing over time [14].

Nevertheless, systematic reviews have highlighted important limitations of two-dimensional radiography, including low sensitivity for small bone lesions, and difficulty in distinguishing between granulomas and cysts, which may lead to underestimation of lesion prevalence and size [14]. In response to these limitations, Estrela et al. [8] developed a CBCT-based periapical index (CBCT-PAI), enabling three-dimensional assessment of lesion dimensions, cortical bone involvement, and spatial relationships with adjacent structures (Fig. 6).

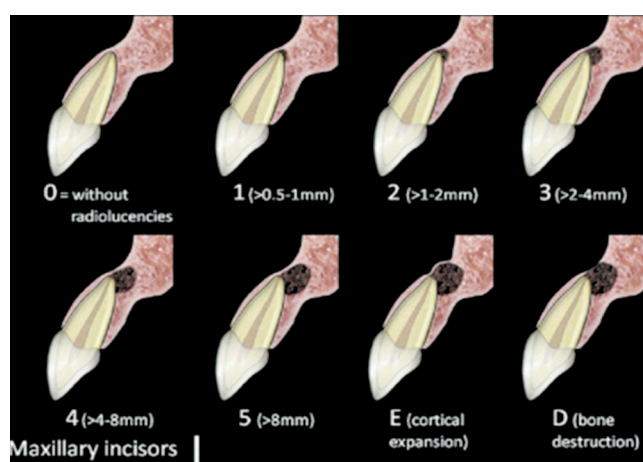


Fig. 6. Schematic representation of the CBCT periapical Index (CBCT-PAI) at the level of the incisors
Source: [8]

Рис. 6. Схематическое изображение периапикального индекса КБКТ (CBCT-PAI) на уровне резцов
Источник: [8]

This volumetric evaluation significantly improves diagnostic accuracy, particularly for large lesions, and enhances the reliability of treatment monitoring. The choice of radiological classification therefore has a direct impact on clinical decision-making, prognosis evaluation, and the interpretation of healing, as different imaging modalities may yield different assessments of lesion extent and resolution [14]. In the present case series, the Ørstavik PAI was used for most cases to ensure comparability with existing literature, while the Estrela CBCT classification was applied in the second case to provide a more precise three-dimensional evaluation of lesion severity and treatment outcome.

The diagnosis of inflammatory periapical lesions of endodontic origin is based on a systematic integration of clinical and radiological findings. Clinical assessment includes patient history, evaluation of symptoms, and the use of clinical tests to differentiate endodontic from periodontal conditions [15]. Radiographic examination plays a key role in confirming the diagnosis and assessing lesion severity. While periapical radiography remains the first-line imaging modality for detecting periapical bone loss, it may underestimate early lesions. CBCT provides a more accurate three-dimensional evaluation of lesion extent and its relationship with surrounding anatomical structures [14]. Standardized radiological indices, such as the Periapical Index proposed by Ørstavik and the CBCT-PAI developed by Estrela, further improve diagnostic reliability and support treatment planning and follow-up [7; 8].

Since periapical lesions of endodontic origin are commonly associated with pulp infection, the primary objective of endodontic treatment is to eradicate this infection, restore the biological balance of periapical tissues, and maintain tooth functionality. Contemporary endodontics is guided by Schilder's triad, which encompasses three interdependent steps: canal shaping, chemo-mechanical disinfection, and three-dimensional obturation. Each of these steps is critical to eliminating pathogenic microorganisms, removing organic and inorganic debris, and achieving a hermetic seal to prevent reinfection, thereby optimizing periapical healing [15; 16].

Here, proper shaping facilitates irrigant penetration, ensures effective obturation, and minimizes the risk of procedural errors such as ledging, perforation, or apical transportation, which could compromise the healing of periapical lesions [17]. According to the recommendation of the American association of endodontists [18], Chemo-mechanical disinfection is achieved through a combination of sodium hypochlorite, EDTA, and chlorhexidine, applied in a sequential manner to maximize antimicrobial efficacy and smear layer removal. The use of activation techniques further enhances irrigant penetration, disrupts biofilms, and removes residual debris, particularly in complex anatomical regions [19].

Finally, obturation represents the final step of endodontic treatment, aiming for complete three-dimensional sealing of the root canal system. The choice of sealer significantly influences the long-term outcome

and periapical healing [20]. Traditional epoxy-resin sealers provide reliable mechanical sealing, good dimensional stability, and moderate antimicrobial activity. However, the introduction of bioceramic sealers has marked a paradigm shift in endodontics. Composed mainly of hydraulic calcium silicates, bioceramic sealers are bioactive, biocompatible, and capable of chemically bonding to dentin [20]. These materials set in the presence of moisture, release calcium ions, and generate a hydroxyapatite-like layer at the dentin-sealer interface, enhancing adhesion and promoting periapical tissue regeneration. Their high pH confers antimicrobial properties, while slight expansion during setting improves marginal adaptation and reduces microleakage [21; 22].

Recent studies have reinforced the significant role of bioceramic sealers in optimizing endodontic outcomes, particularly in cases of periapical lesions. Bioceramic sealers, primarily composed of calcium silicate, demonstrate superior bioactivity and biocompatibility compared to conventional resin-based sealers, promoting hydroxyapatite formation at the dentine-sealer interface and enhancing tissue regeneration [23]. Their ability to set in the presence of moisture, coupled with a high pH, contributes not only to antimicrobial activity but also to accelerated periapical healing [23; 24]. Moreover, techniques such as ultrasonic or sonic activation have been demonstrated to increase the penetration of bioceramic sealers into dentinal tubules, which likely enhances mechanical interlocking, reduces voids, and may further improve the seal and entomb residual microorganisms, especially in complex area [25]. Ultrasonic activation has also been observed to influence certain physicochemical properties of calcium silicate-based sealers. When applied for 20 seconds, they increase flow and ion release, which could further promote antimicrobial action and bioactivity in the periapical environment [26]. These findings support that the combination of bioceramic sealers with optimized activation techniques not only improves the physical seal of the root canal system but also promotes a biologically favorable environment for tissue healing and regeneration, aligning with the clinical outcomes observed in the present case series.

Clinical and radiographic evidence indicates that bioceramic sealers can accelerate periapical healing compared with resin-based sealers, particularly in lesions with high PAI scores, achieving complete resolution in shorter timeframes [27; 28]. Histologically, healing involves the replacement of inflammatory granulation tissue with new bone, cementum, and periodontal ligament structures, a process facilitated by the bioactive properties of these sealers [13; 29]. CBCT provides an advanced tool for three-dimensional assessment of periapical healing, allowing precise evaluation of lesion size, density, and trabecular bone formation [5; 30; 31].

The integration of bioceramic sealers into conventional endodontic protocols represents a shift toward a biologically oriented approach, combining effective disinfection, optimal sealing, and stimulation of tissue

regeneration. Their use, alongside rigorous chemo-mechanical preparation and appropriate irrigation protocols, enhances the predictability of periapical healing and supports the long-term success of root canal treatment [27; 32].

LIMITATIONS OF THE STUDY

This case series has several strengths, notably the diversity of clinical situations, illustrating the different etiologies of endodontic periapical lesions and the standardized therapeutic protocol. It emphasizes the central role of root canal disinfection in periapical healing and highlights the growing interest in bioceramic sealers, particularly for extensive lesions, due to their bioactive properties and regenerative potential.

However, several limitations must be acknowledged. The small number of cases, and the absence of a control group limit the ability to draw robust statistical conclusions. A prospective study with a standardized protocol, a larger sample size and a quantitatively analyze healing parameters to better assess the true impact of bioceramic sealers on LIPOE prognosis.

These results nonetheless provide a foundation for future research, particularly regarding the long-term clinical performance of bioceramic sealers and their regenerative potential, as well as the effects of standardized activation techniques on periapical healing.

CLINICAL IMPLICATIONS AND RECOMMENDATIONS

Effective management of endodontic periapical lesions requires a structured, evidence-based approach that integrates accurate diagnosis, meticulous canal preparation, thorough chemical disinfection, and appropriate obturation. Initial diagnosis should combine clinical tests with high-quality periapical radiographs, assessed using Ørstavik's PAI, and CBCT when lesions

are extensive or differential diagnosis is critical. Root canal shaping must maintain apical patency and progressive taper, using thermally treated NiTi instruments to minimize procedural errors and ensure effective irrigant penetration. Chemical disinfection relies on optimized irrigation sequences, including sodium hypochlorite, EDTA, and, when indicated, chlorhexidine, with ultrasonic activation to disrupt biofilms and enhance penetration. The choice of sealer significantly influences periapical healing; bioceramic sealers, with their bioactive, highly biocompatible properties and pH-induced antimicrobial effect, promote faster and more predictable tissue regeneration compared to conventional resin-based sealers. Obturation must achieve a three-dimensional hermetic seal, complemented by an immediate and durable coronal restoration to prevent reinfection. Follow-up protocols at 1, 3, 6, and 12 months are essential to assess healing and guide retreatment if necessary. This standardized approach supports optimal biological outcomes and reinforces the growing role of bioactive materials in modern endodontics.

CONCLUSION

This case series highlights the key factors influencing the healing of periapical lesions of endodontic origin. Conventional endodontic treatment, allows predictable healing regardless of initial PAI scores. Strict canal disinfection remains essential for eliminating persistent intraradicular infection. Bioceramic sealers enhance obturation quality and create a bioactive environment that promotes tissue regeneration. Three-dimensional imaging improves diagnostic precision and enables reliable monitoring of periapical healing. Clinical and radiographic follow-up confirmed favorable outcomes, including reduced PAI scores, increased bone density, and restored trabeculation, reflecting effective periapical regeneration.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.