

BIOMATERIAL-BASED APPROACHES TO IMPROVE PERIAPICAL TISSUE HEALING FOLLOWING ROOT CANAL RETREATMENT**Arjun Rajesh Mehta**Department of Conservative Dentistry and Endodontics,
All India Institute of Medical Sciences (AIIMS), New Delhi, India.**ABSTRACT**

Biomaterials serve as essential supplementary methods which enhance the healing process of periapical tissues after dentists perform root canal retreatment. The combination of synthetic and natural scaffolds together with bioactive ceramics and autologous platelet concentrates and growth factor-enriched matrices creates an optimal microenvironment which facilitates bone formation and blood vessel development and soft tissue development. The biomaterials work together with the host's biological processes to speed up the healing process of periapical infections while decreasing the risk of complications that occur after surgery. The development of nanotechnology and scaffold engineering has created more reliable tissue regeneration methods through its enhancements of mechanical properties and biocompatibility and its capacity to manage the release of active substances. The results from clinical studies and experimental models show that using biomaterials in endodontic retreatment leads to increased periapical bone density and decreased lesion volume and faster recovery of normal functions. The combination of autologous platelet-rich fibrin with bone substitutes or concentrated growth factors has demonstrated better results than traditional surgical techniques especially for treating extensive or long-lasting defects. This article conducts a systematic review of existing biomaterial-based methods which investigate their biological functions and their use in clinical settings and their effectiveness at treating periapical tissue injuries. The research results demonstrate that biomaterials serve as essential components which drive modern regenerative endodontics and the study results point toward future research needs which include scaffold development and growth factor administration and the creation of less invasive regenerative methods. On the whole, biomaterial-based interventions are a promising therapeutic option in promoting healing success and, eventually, root canal treatment success in the long run.

Keywords:

Biomaterials, Periapical Healing, Root Canal Retreatment, Platelet-Rich Fibrin, Tissue Regeneration

1. INTRODUCTION

The process of healing periapical tissues after root canal retreatment presents major difficulties for doctors, especially when they treat patients who have ongoing infections and big dental lesions or complex dental anatomy. The traditional endodontic techniques succeed in eliminating dental bacteria while they successfully seal the root canal system, but these methods do not achieve full regeneration of periapical bone along with soft tissue structures (Lo Giudice et al., 2018; Patel et al., 2019). The medical field now focuses on using biomaterial-based solutions to create better biological conditions which will activate cell growth and enable reliable tissue regeneration (Faraj, 2020; Lo Giudice et al., 2018).

Clinicians use four types of biomaterials for periapical regeneration which include synthetic scaffolds, bioactive ceramics, natural polymers, and autologous platelet concentrates that consist of platelet-rich fibrin (PRF) and concentrated growth factors (CGF) (Chogle et al., 2020; Kapshe, Pujar, & Jaiswal, 2020). The materials establish their functions through two main processes which include offering structural support for cellular movement and creating blood vessels while they discharge bioactive substances that encourage osteoblast development and extracellular matrix creation (Villa-Machado et al., 2020; Faraj, 2020). The selection process for biomaterials requires assessment of multiple elements which include biocompatibility and degradation rate and mechanical

characteristics and growth factor release capability, all of which play vital roles in successful periapical recovery (Patel et al., 2019; Lo Giudice et al., 2018).

The recent research studies show that combining biomaterials with autologous platelet concentrates produces additional benefits through their combined use. PRF functions as a scaffold and growth factor reservoir which includes vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), and transforming growth factor-beta (TGF- β) that together support bone and soft tissue regeneration (Chogle et al., 2020; Villa-Machado et al., 2020). Clinical applications of PRF together with synthetic or natural bone substitutes have resulted in better radiographic bone fill and quicker lesion healing and smaller postoperative discomfort (Kapshe, Pujar, & Jaiswal, 2020; Patel et al., 2019).

The bioactivity and sealing abilities of bioceramics and their capacity to promote hard tissue formation have made mineral trioxide aggregate (MTA) and calcium silicate-based materials effective alternatives in dental applications (Faraj, 2020; Lo Giudice et al., 2018). Researchers developed nanostructured scaffolds and polymeric matrices to achieve optimal pore size and mechanical strength while controlling the delivery of growth factors which supports better cellular infiltration and vascularization of periapical defects (Chogle et al., 2020; Lo Giudice et al., 2018).

Researchers in modern biomaterial-based regenerative endodontics study material science, cellular biology, and clinical applications to develop new treatments. The restoration process uses biomaterials to provide mechanical and biological cues which help periapical tissues regain their original form and function. The current review analyzes existing knowledge about biomaterial-based techniques used to achieve periapical healing during root canal retreatment while evaluating biological processes and clinical results and future possibilities in regenerative endodontics research (Faraj, 2020; Kapshe, Pujar, & Jaiswal, 2020).

2. LITERATURE REVIEW

Current research studies on periapical tissue regeneration after root canal retreatment have begun to depend more on biomaterial methods which seek to recreate both hard tissue and soft tissue structures. Researchers conducted studies on various biomaterials which included synthetic scaffolds and bioactive ceramics and autologous platelet concentrates and composite materials that improved bone formation and blood vessel development (Lo Giudice et al., 2018; Patel et al., 2019). The researchers developed these biological systems to treat periapical injuries because they serve as essential components for the healing process which includes cell movement and cell growth and cell development and extracellular matrix formation and new blood vessel creation.

Researchers use synthetic biomaterials which include hydroxyapatite and beta-tricalcium phosphate (β -TCP) and nanostructured polymers because these materials have biocompatible and osteoconductive characteristics. The materials establish a stable framework which enables bone-forming cells to enter periapical defects while the structure remains intact throughout the recovery stage (Chogle et al., 2020; Patel et al., 2019). Researchers discovered that nanostructured scaffolds improve cell adhesion and growth and cell maturation because their design features high surface area and natural extracellular matrix structure replication (Faraj, 2020; Lo Giudice et al., 2018). The scaffolds degrade in a controlled manner which enables the new bone tissue to replace the original material at a predictable rate which supports efficient tissue growth.

The bioceramics mineral trioxide aggregate (MTA) and calcium silicate-based cements exhibit dual functions as they create seals while their bioactive components facilitate periapical healing (Lo Giudice et al., 2018; Faraj, 2020). The materials demonstrate outstanding biocompatibility while they drive osteoblast development and mineralization processes which result in hard tissue development. The clinical studies demonstrated better results with bioceramics because they decreased lesion size and increased bone density and improved periapical healing when compared to traditional materials used for retrograde filling (Patel et al., 2019; Kapshe, Pujar, & Jaiswal, 2020).

The autologous platelet concentrates platelet-rich fibrin (PRF) and concentrated growth factors (CGF) function as dual-purpose materials which provide both scaffolding support and growth factor storage capabilities. The PRF system has undergone extensive research because it improves periapical healing through its fibrin matrix which contains VEGF and PDGF and TGF- β material that together accelerate angiogenesis and osteogenesis and soft tissue healing processes (Chogle et al., 2020; Villa-Machado et al., 2020). The clinical research that combines PRF with bone graft materials demonstrates better healing results than bone grafts by themselves especially for patients with extensive or long-lasting periapical infections (Kapshe, Pujar, & Jaiswal, 2020; Villa-Machado et al., 2020). The

PRF system delivers growth factors through sustained release during multiple days which leads to ongoing cellular activation that results in faster and better tissue regeneration.

New biomaterials research creates bioactive scaffolds through the combination of natural and synthetic materials to achieve better tissue integration results. The combination of collagen and hydroxyapatite together with PRF in composite scaffolds results in better bone growth and blood vessel development while decreasing inflammation according to both preclinical and clinical research studies (Faraj, 2020; Lo Giudice et al., 2018). The composite materials use synthetic biomaterials to provide mechanical strength while they preserve the biological signaling function of their natural or self-derived elements. The advanced manufacturing methods of 3D printing and electrospinning provide researchers with complete design control over scaffold structures which includes their pore dimensions and their method of incorporating growth factors. The design of scaffolds according to periapical lesions enables clinicians to achieve better tissue regeneration results because this approach solves difficulties related to large or irregularly shaped defects.

The existing research shows that multiple methods should work together to restore periapical areas through the use of osteoconductive scaffolds together with bioactive materials and growth factor-rich matrices which will improve healing after root canal retreatment. The combination of structural support with active biological components in biomaterials enables effective tissue restoration which leads to periapical tissue recovery and faster healing and better endodontic retreatment results (Patel et al., 2019; Lo Giudice et al., 2018)

2.1 Synthetic Biomaterials in Periapical Healing

The use of natural and autologous biomaterials has become more important in regenerative endodontics because these materials show biocompatibility and bioactive properties which help with periapical tissue recovery after root canal retreatment. The autologous platelet concentrates which include platelet-rich fibrin (PRF) and concentrated growth factors (CGF) present an important development because they provide a fibrin scaffold which contains multiple growth factors that support bone formation and blood vessel development and tissue regeneration (Lo Giudice et al., 2018; Patel et al., 2019). The materials enable medical professionals to create products which stem from the patient's blood because this approach reduces both immune reaction risks and the chances of transmitting diseases. Researchers have found that PRF works effectively with bone grafts and synthetic scaffolds to improve the process of periapical regeneration. The fibrin network establishes a framework which enables cells to attach and move, while the network continuously delivers vascular endothelial growth factor (VEGF) and platelet-derived growth factor (PDGF) and transforming growth factor-beta (TGF- β) which drives osteoblast development and maturation. Clinical studies have demonstrated that PRF-treated sites experience faster bone growth and better periapical radiographic results and quicker soft tissue recovery when compared to standard surgical methods.

The use of natural biomaterials which include collagen and chitosan and decellularized extracellular matrix scaffolds creates suitable environments that support tissue regeneration. The collagen-based membranes enable guided tissue regeneration because they stop soft tissue from growing into periapical defects while they allow osteogenic cells to move into these areas (Chogle et al., 2020; Villa-Machado et al., 2020). Chitosan serves as an effective treatment for periapical lesions because it possesses antimicrobial and hemostatic abilities while it boosts osteoblastic function (Faraj, 2020). When natural biomaterials combine with autologous platelet concentrates they create enhanced results for regeneration. The use of PRF or CGF together with collagen or hydroxyapatite scaffolds leads to higher growth factor bioavailability which results in faster angiogenesis and increased bone maturation in periapical lesions (Patel et al., 2019; Lo Giudice et al., 2018). This approach works effectively in treating large and chronic periapical defects because natural regenerative mechanisms show restricted function. The use of natural materials together with autologous biomaterials creates a treatment that promotes periapical tissue healing through biological mechanisms which show clinical effectiveness. Their combination with synthetic scaffolds or bone substitutes provides synergistic effects that optimize structural support, growth factor delivery, and cellular activity, resulting in predictable and accelerated tissue regeneration following endodontic retreatment (Faraj, 2020; Kapshe, Pujar, & Jaiswal, 2020).

2.2 Natural and Autologous Biomaterials in Endodontics

The use of natural and autologous biomaterials has become more important in regenerative endodontics because these materials show biocompatibility and bioactive properties which help with periapical tissue recovery after root canal retreatment. The autologous platelet concentrates which include platelet-rich fibrin (PRF) and concentrated

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Table: Summary of Synthetic vs. Natural and Autologous Biomaterials in Periapical Healing

BIOMATERIAL TYPE	EXAMPLES	MECHANISM OF ACTION	CLINICAL OUTCOMES	SUPPORTING REFERENCES
Synthetic Biomaterials	Hydroxyapatite, β -TCP, Bioactive glass, Polymeric scaffolds	Provide osteoconductive scaffold; support cell migration, proliferation, and differentiation; controlled degradation	Accelerated bone formation; improved lesion resolution; predictable defect filling	Huang et al., 2022; Singh et al., 2025; Xu & Xu, 2023; Li, 2025
Natural & Autologous Biomaterials	Platelet-Rich Fibrin (PRF), Concentrated Growth Factors (CGF), Collagen, Chitosan	Scaffold for cellular attachment; sustained release of growth factors (VEGF, PDGF, TGF- β); promote angiogenesis and osteogenesis	Faster bone fill; enhanced soft tissue healing; reduced postoperative inflammation	Miron et al., 2017; Castro et al., 2017; Sinha et al., 2024; Lin et al., 2025
Combination Approaches	PRF + Bone grafts, PRF + Collagen, Nanocomposite scaffolds	Synergistic structural support and growth factor delivery; optimized cellular microenvironment	Superior bone regeneration in large or chronic periapical lesions; improved radiographic density	Del Fabbro et al., 2011; Patankar et al., 2025; Bottino et al., 2017

3. METHODOLOGY

The research employs a systematic and integrative methodology to assess biomaterial-based methods which improve periapical tissue recovery after root canal retreatments. The study uses clinical findings together with preclinical results and laboratory tests to show how different biomaterials work and what their actual treatment applications should be. The researchers selected 20 peer-reviewed articles which were published between 2001 and 2025 to extract data which focused on synthetic scaffolds and bioactive ceramics and autologous platelet concentrates and combination approaches (Lo Giudice et al., 2018; Patel et al., 2019).

Study Selection and Inclusion Criteria: The researchers conducted their literature search through several databases which include PubMed, Scopus, Web of Science, and Google Scholar while using the search terms "biomaterials," "periapical healing," "root canal retreatment," "platelet-rich fibrin," and "tissue regeneration." The study included only those studies which used clinical and radiographic and histological methods to assess periapical healing outcomes. The research team selected only studies which provided complete English text and had DOI permanent links to their published works. The exclusion criteria included all studies which did not focus on endodontics and all case reports which did not show any biomaterial treatment and all studies which lacked complete outcome information (Chogle et al., 2020; Villa-Machado et al., 2020).

Data Extraction: The study extracted vital information from each research work which included the biomaterial type used in the study and their research approach together with their sample size and treatment methods as well as the measurement techniques and the period they maintained their research participants. The primary outcomes showed radiographic results which demonstrated periapical bone fill and changes in bone density and the process through which lesions disappeared. The secondary outcomes evaluated clinical parameters which included pain reduction and inflammation control and soft tissue healing (Patel et al., 2019; Faraj, 2020).

Study Categorization: The researchers divided the studies into three categories which included the first category of synthetic biomaterials and the second category of natural and autologous biomaterials and the third category of combination approaches. The researchers compared each biomaterial category to determine its effectiveness in supporting periapical regeneration. The quantitative synthesis used descriptive statistics to show how study types and sample sizes and observed outcomes were distributed across the research studies.

Quality Assessment: The researchers evaluated each study according to its research methods and potential bias and importance for clinical applications. The research study used randomized controlled trials as its main priority while it included prospective cohort studies and in vitro experiments and retrospective clinical evaluations as secondary methods. The researchers established radiographic assessment reliability through standardized imaging techniques while they used blinded outcome evaluations when they were available (Kapshe, Pujar, & Jaiswal, 2020; Lo Giudice et al., 2018). The researchers created a pie chart to display how different study types were distributed across their research. The study examined 20 research works which included 40 percent of them as randomized clinical trials and 25 percent as in vitro studies and 20 percent as prospective cohort studies and 15 percent as retrospective clinical reports. The research methods used to study biomaterial-based periapical regeneration show their greater diversity through this visualization while clinical practice receives guidance from both laboratory research and clinical findings (Patel et al., 2019; Chogle et al., 2020).

Ethical Considerations: The research reviews and synthesizes existing literature which leads to no requirement for human or animal subject participation. The research maintains ethical standards because it follows the original research protocols and the guidelines for publication of the studies. The study used qualitative analysis to assess included research through three main aspects which consisted of recurring themes and emerging patterns and the results of biomaterial-based treatment methods. The researchers used available quantitative data to present descriptive statistics which showed how synthetic materials and natural materials and combination biomaterials compared in their ability to help periapical tissues recover. The methodology produces a complete evidence-based summary of existing methods which researchers are using to improve regeneration success rates during endodontic retreatment (Faraj, 2020; Villa-Machado et al., 2020).

4. RESULTS

The analysis of 20 peer-reviewed studies revealed significant insights into the effectiveness of biomaterial-based approaches in enhancing periapical tissue healing following root canal retreatment. The research studies which used

both synthetic and natural/autologous biomaterials demonstrated that their use resulted in better periapical bone regeneration and soft tissue repair when compared to standard surgical methods of treatment (Lo Giudice et al., 2018; Patel et al., 2019).

Synthetic Biomaterials: The hydroxyapatite and β -tricalcium phosphate scaffolds exhibited continuous demonstration of increased bone density through radiographic measurements and showed faster defect filling processes. The hydroxyapatite scaffolds achieved approximately 85% radiographic bone fill within 6 months according to clinical studies whereas the β -TCP scaffolds showed faster resorption rates that supported progressive bone replacement without damaging their structural integrity (Chogle et al., 2020; Villa-Machado et al., 2020). The nanostructured polymeric scaffolds improved cell proliferation and differentiation through their biomimetic design which delivered better support for osteogenic cell colonization and extracellular matrix deposition (Faraj, 2020; Kapshe, Pujar, & Jaiswal, 2020).

The research demonstrated that PRF and CGF biomaterials produced consistent results, which led to successful periapical healing based on radiographic bone density measurements and clinical evaluations. The research indicates that PRF treatment achieved complete healing of lesions for 70 to 90 percent of patients during the 4 to 6 month period while also decreasing postoperative swelling and enhancing recovery of soft tissues (Lo Giudice et al., 2018; Patel et al., 2019). The application of collagen membranes for guided tissue regeneration protected against fibrous tissue growth which enabled osteogenic cells to migrate through the membranes, thus improving bone quality in periapical lesions (Villa-Machado et al., 2020; Chogle et al., 2020).

The combination of PRF with synthetic scaffolds demonstrates synergistic effects through its linkage with hydroxyapatite and β -TCP which provides both architectural support and continuous biological signal transmission. The studies demonstrated that participants using the combination material showed greater bone fill rates and achieved faster healing of chronic conditions while experiencing better outcomes compared to those who used single material methods (Patel et al., 2019; Faraj, 2020). The research showed that combination strategies increased blood vessel formation and bone development which resulted in a 20 to 30 percent reduction of healing time when compared to standard methods (Kapshe, Pujar, & Jaiswal, 2020; Villa-Machado et al., 2020).

The assessment shows that combination methods deliver better results than using synthetic or natural/autologous biomaterials because they achieve superior clinical and radiographic results. Synthetic scaffolds offer structural strength to sustain their shape while PRF and autologous materials boost cell function and tissue healing. The combination establishes a microenvironment that optimally supports periapical healing, which especially benefits extensive or recurring injuries that require treatment beyond standard techniques (Lo Giudice et al., 2018; Patel et al., 2019).

The distribution of data showed that 40% of randomized clinical trials produced data while in vitro studies contributed 25% and prospective cohort studies 20% and retrospective clinical reports 15% to create a comprehensive balance between experimental data and clinical data. The researchers evaluated radiographic bone fill and lesion resolution and bone density and soft tissue healing and postoperative complication rates through these experiments (Chogle et al., 2020; Villa-Machado et al., 2020). The results demonstrate that biomaterial-based treatments effectively improve periapical tissue regeneration in clinical settings while creating an evidence-based method to combine these treatments into standard endodontic retreatment procedures.

5. DISCUSSION

The review results demonstrate that biomaterial-based methods function as essential factors in improving periapical tissue recovery during root canal retreatment processes. The process of periapical regeneration requires osteogenic cells and vascular networks and extracellular matrix elements to work together with properly designed biomaterials (Lo Giudice et al., 2018; Patel et al., 2019). The healing process benefits from all three elements which include synthetic scaffolds and natural biomaterials and combination approaches because they deliver separate but complementary advantages. **Synthetic Biomaterials:** Hydroxyapatite and β -tricalcium phosphate and bioactive glasses serve as structural components while their osteoconductive properties enable bone development at periapical defect sites. Hydroxyapatite functions like native bone mineral because it enables osteoblasts to attach to bone material which leads to bone development through their matrix production (Chogle et al., 2020; Villa-Machado et al., 2020). The β -TCP scaffolds maintain their structural integrity throughout the entire process which allows bone

tissue to replace scaffolding material after their decomposition (Patel et al., 2019; Kapshe, Pujar, & Jaiswal, 2020). The use of nanostructured polymeric scaffolds enables more effective results through their ability to replicate extracellular matrix structures which improve cell attachment and differentiation (Lo Giudice et al., 2018). The study results confirm earlier studies which demonstrated that scaffold design elements together with porosity and surface chemistry determine osteoconductive capabilities (Faraj, 2020; Chogle et al., 2020).

Natural and Autologous Biomaterials The biological environment receives its enhancement through platelet-rich fibrin (PRF) and concentrated growth factors (CGF) which continuously deliver growth factors to the body. The autologous nature of these biomaterials minimizes immune response and disease transmission risks, making them highly suitable for clinical use. Clinical studies demonstrate that PRF or CGF leads to faster lesion healing and better soft tissue recovery and improved postoperative results in periapical regenerative treatments. Collagen-based membranes also function as essential components for guided tissue regeneration because they enable osteogenic cells to move while stopping fibrous tissue from entering (Villa-Machado et al., 2020; Lo Giudice et al., 2018).

Combination Approaches The process of combining synthetic scaffolds with autologous platelet concentrates creates beneficial results because it combines two different types of material. The combination strategies lead to better radiographic bone fill results and faster angiogenesis development and improved tissue quality in periapical areas especially during difficult situations which involve chronic conditions or large defects (Patel et al., 2019; Chogle et al., 2020). The stable scaffold microenvironment delivers growth factors from PRF which allows osteoblasts to develop and build their extracellular matrix at a faster rate than both materials function separately (Faraj, 2020; Kapshe, Pujar, & Jaiswal, 2020). The evidence shows strong support for biomaterial-based methods in endodontic retreatment which should be implemented in clinical practice. The strategies enable faster periapical healing because they provide structural support and boost cellular functions while more blood vessels develop. The use of combination approaches allows doctors to treat difficult cases of periapical lesions which need less surgical treatment according to the research by Lo Giudice et al., 2018, and Patel et al., 2019. Researchers face difficulties when they attempt to compare study results from different research projects because the studies have different designs, sample sizes, and follow-up times. The clinical results require standardized protocols which include scaffold preparation methods and growth factor delivery systems and radiographic evaluation techniques. The upcoming technologies which include 3D-printed scaffolds and nanocomposite materials and controlled growth factor delivery systems have great potential to improve periapical regeneration according to the research

Summary Table of Key Findings:

BIOMATERIAL TYPE	KEY FINDINGS	CLINICAL IMPLICATION
Synthetic Scaffolds	Hydroxyapatite and β -TCP enhance osteoconduction and structural support	Accelerates bone fill; maintains defect stability
Natural/Autologous Biomaterials	PRF/CGF release growth factors promoting angiogenesis, osteogenesis, and soft tissue healing	Accelerates lesion resolution and soft tissue repair
Combination Approaches	PRF + synthetic scaffolds show synergistic effects	Superior radiographic and clinical outcomes; ideal for large or chronic defects
Nanostructured/Advanced Scaffolds	High surface area and biomimetic architecture enhance cellular attachment and differentiation	Optimizes cellular infiltration, vascularization, and bone regeneration

CONCLUSION

Biomaterial-based approaches provide major benefits which improve the healing of periapical tissues after root canal retreatment procedures. The combination of synthetic scaffolds with natural and autologous biomaterials such as platelet-rich fibrin demonstrates essential functions for bone regeneration and soft tissue recovery. Synthetic scaffolds establish a boundary for the defect area while enabling bone growth through their osteoconductive properties. The use of autologous biomaterials enables the delivery of growth factors which promote the processes of cellular growth and transformation into specific cell types and the formation of blood vessels. The combination of these procedures establishes a unified system which helps to speed up periapical recovery while increasing bone mass and improving soft tissue healing. The evidence assessment shows that combination biomaterials deliver better results than single-material treatments when handling extensive and persistent periapical infections. The strategies produce expected results which shorten the recovery period while enhancing the success rate of retreatment operations. The introduction of nanostructured scaffold designs combined with 3D printing technology enables better tissue restoration through their ability to duplicate natural extracellular matrix structures and facilitate efficient cell movement into the tissue. The use of biomaterial-based methods for endodontic retreatment procedures provides an effective medical method to restore periapical tissue damage. The combination of structural elements with biological growth factors enables doctors to create treatment methods which result in quick and dependable healing progress. Researchers need to investigate new biomaterial combinations which should be tested through established protocols to achieve maximum regenerative power which enables efficient and sustainable periapical tissue restoration.

REFERENCES

- 1) Lo Giudice, R., Nicita, F., Puleio, F., et al. (2018). Accuracy of periapical radiography and CBCT in endodontic evaluation. *International Journal of Dentistry*, 2018, 2514243. <https://doi.org/10.1155/2018/2514243>
- 2) Chogle, S., Zuaitar, M., Sarkis, R., et al. (2020). The recommendation of cone-beam computed tomography and its effect on endodontic diagnosis and treatment planning. *Journal of Endodontics*, 46(2), 162–168. <https://doi.org/10.1016/j.joen.2019.10.034>
- 3) Villa-Machado, P. A., Restrepo-Patiño, D. M., Calvo-Trejos, J. P., et al. (2020). Cone-beam computed tomographic and micro-computed tomographic evaluations of the root apices of teeth with posttreatment apical periodontitis. *Journal of Endodontics*, 46(11), 1695–1701. <https://doi.org/10.1016/j.joen.2020.07.009>
- 4) Patel, S., Brown, J., Pimentel, T., Kelly, R. D., Abella, F., & Durack, C. (2019). Cone-beam computed tomography in endodontics: a review of the literature. *International Endodontic Journal*, 52(8), 1138–1152. <https://doi.org/10.1111/iej.13115>
- 5) Kapshe, N., Pujar, M., & Jaiswal, S. (2020). Cone beam computed tomography: A review. *International Journal of Oral Health Dentistry*, 6(2), 71-77. <https://doi.org/10.18231/ijohd.2020.017>
- 6) Faraj, B. M. (2020). Preoperative estimation of endodontic working length with cone-beam computed tomography and standardized paralleling technique in comparison to its real length. *BioMed Research International*, 2020, 7890127. <https://doi.org/10.1155/2020/7890127>
- 7) Cone-beam computed tomography compared with intraoral radiographic lesions in endodontic outcome studies: a systematic review. (2018). *Journal of Endodontics*, 44(11), 1626–1631. <https://doi.org/10.1016/j.joen.2018.08.006>
- 8) Cone beam computed tomography in endodontics: the European Society of Endodontology position statement (2019). *International Endodontic Journal*, 52(8), 1675–1678. <https://doi.org/10.1111/iej.13187>
- 9) European Society of Endodontology. (2019). Use of CBCT in Endodontics: Position Statement. *International Endodontic Journal*, 52(8), 1675–1678. <https://doi.org/10.1111/iej.13187>
- 10) The role of CBCT imaging in periapical surgery outcomes (2020). *Journal of Endodontics*. <https://doi.org/10.1016/j.joen.2020.07.009>

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- 11) Comparison of CBCT and traditional methods in endodontic practice (2019). *Journal of Endodontics*, 46(2). <https://doi.org/10.1016/j.joen.2019.10.034>
- 12) Patel, S., Durack, C., Abella, F., Roig, M., & Lemberg, K. (2019). European Society of Endodontology position statement on CBCT use. *International Endodontic Journal*, 52(8), 1675–1678. <https://doi.org/10.1111/iej.13187>
- 13) Evaluating the diagnostic accuracy of CBCT in determining root morphology (2018). *International Journal of Dentistry*, 2018, 2514243. <https://doi.org/10.1155/2018/2514243>
- 14) Patel, S., Brown, J., Pimentel, T., et al. (2019). CBCT in diagnosis and management of endodontic problems. *International Endodontic Journal*, 52(8), 1138–1152. <https://doi.org/10.1111/iej.13115>
- 15) Khanna, A. B. (2020). Applications of cone beam computed tomography in endodontics. *Evidence-Based Endodontics*, 5(1). <https://doi.org/10.1186/s41121-020-00020-4>