Review Article

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Histopathological patterns of periapical lesions in root canal treated teeth: A systematic review

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Abstract

INTRODUCTION. Periapical lesions are common sequelae of pulpal necrosis and endodontic infections, presenting significant diagnostic challenges in clinical practice. Accurate histopathological characterization is essential for appropriate treatment planning and prognostic assessment.

AIM. To systematically evaluate and summarize the histopathological features, prevalence patterns, and diagnostic concordance of periapical lesions in root canal treated teeth.

MATERIALS AND METHODS. A systematic review was conducted following PRISMA 2020 guidelines. Electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were searched for studies published between 2000–2024. Inclusion criteria encompassed histopathological studies of periapical lesions from root canal treated teeth. Quality assessment was performed using the Newcastle-Ottawa Scale and QUADAS-2 tools.

RESULTS. Twelve studies involving 1,847 periapical lesion specimens were included. Histopathological analysis revealed periapical granulomas as the most prevalent lesions (50–84.2%), followed by radicular cysts (15–42%) and periapical abscesses (5–35%). Clinical-histopathological concordance was poor, with overall agreement ranging from 51.4–55.8% (Cohen's kappa $\kappa = 0.059$). Larger lesions (>200 mm²) showed higher prevalence of radicular cysts (92–100%). Periapical scars represented 1–6% of cases.

DISCUSSION. Significant discrepancies between clinical and histopathological diagnoses highlight limitations of radiographic assessment alone. Lesion size, location, and duration influence histopathological patterns. The predominance of granulomatous tissue suggests ongoing inflammatory processes despite endodontic intervention.

CONCLUSIONS. Histopathological examination remains the gold standard for definitive diagnosis of periapical lesions. The poor clinical-histopathological concordance emphasizes the necessity of biopsy examination for accurate diagnosis and appropriate treatment planning in endodontic practice.

Keywords: periapical lesions, root canal treated teeth, histopathology, radicular cyst, periapical granuloma, periapical abscess, clinical-pathological correlation, endodontic diagnosis, biopsy, PRISMA systematic review

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Гистопатологические характеристики периапикальных поражений у зубов после эндодонтического лечения: систематический обзор

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Резюме

ВВЕДЕНИЕ. Периапикальные поражения являются частым следствием некроза пульпы и эндодонтических инфекций, представляя собой значительную диагностическую проблему в клинической практике. Точная гистопатологическая характеристика имеет решающее значение для выбора адекватной тактики лечения и оценки прогноза.

ЦЕЛЬ. Систематически оценить и обобщить гистопатологические особенности, частоту встречаемости и степень соответствия клинического и гистологического диагноза периапикальных поражений у зубов после эндодонтического лечения.

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МАТЕРИАЛЫ И МЕТОДЫ. Систематический обзор был проведен в соответствии с рекомендациями PRISMA 2020. Осуществлен поиск в электронных базах данных PubMed, Scopus, Web of Science и Google Scholar за период с 2000 по 2024 г. Включались гистопатологические исследования периапикальных поражений у зубов после лечения корневых каналов. Оценка качества работ проводилась с использованием шкалы Ньюкасл–Оттава и инструмента QUADAS-2.
РЕЗУЛЬТАТЫ. В анализ были включены 12 исследований, охватывающих 1847 образцов периапикальных поражений. Согласно гистопатологическим данным, наиболее часто встречались периапикальные гранулемы (50–84,2%), за которыми следовали радикулярные кисты (15–42%) и периапикальные абсцессы (5–35%). Клиническое и гистологическое соответствие оказалось низким: уровень согласия варьировал от 51,4 до 55,8% (к Коэна = 0,059). Крупные поражения (>200 мм²) чаще представляли собой радикулярные кисты (92–100%). Периапикальные рубцы составляли от 1 до 6% случаев.
ОБСУЖДЕНИЕ. Существенные расхождения между клиническими и гистопатологическими диагнозами указывают на ограниченность только рентгенологической диагностики. Размер, локализация и длительность существования поражения влияют на его морфологические характеристики. Преобладание грануляционной ткани свидетельствует о продолжающемся воспалительном процессе, несмотря на проведенное эндодонтическое лечение.
ВЫВОДЫ. Гистопатологическое исследование остается «золотым стандартом» верификации периапикальных поражений. Низкий уровень соответствия клинического и гистологического диагноза подчеркивает необходимость проведения биопсии для точной диагностики и корректного планирования лечения в эндодонтической практике.

Ключевые слова: периапикальные поражения, зубы после эндодонтического лечения, гистопатология, радикулярная киста, периапикальная гранулема, периапикальный абсцесс, клинико-гистологическая корреляция, эндодонтическая диагностика, биопсия, систематический обзор по PRISMA

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INTRODUCTION

These periapical lesions are encountered frequently in dental practice and happen because of inflammation and infection in the pulp [1]. Such lesions develop when the bacteria and their toxic substances leave the root canal, go into the periapical region and cause an inflammatory response in both the bone and soft tissues [1]. In several regions, periapical lesions are found in up to 60% of endodontically treated teeth, so their precise identification and management are very important in endodontics nowadays [1; 2].

Many bacteria are involved in the formation of periapical lesions, combined with the host's immune responses [1]. After pulpal necrosis, the area lacks blood flow which causes bacteria to settle on the inner walls of the canals and form colonies [1]. As these toxins and bacterial products travel through the apical foramen, they get to the periapical tissues which causes an inflammation response marked by expanded blood vessels, increased leakiness of vessels and attraction of white blood cells [3; 4]. The process causes many pathological changes, forming different types of lesions according to the levels of the host's response to ongoing infection.

Traditionally, periapical lesions are separated into four categories from a pathologist's viewpoint: periapical granulomas, radicular cysts, periapical abscesses and periapical scars [3; 5]. Most cases of periapical granulomas include inflammatory tissue that is packed with granulation tissue and includes lymphocytes, plasma cells, macrophages and growing fibroblasts [4]. Radicular cysts start as periapical granulomas by proliferating and dying inside, creating an inside-shaped cavity that gets classified as a true cyst when related to the root canal or a pocket cyst when not related [1]. An acute inflammation with purulent and inflamed neutrophils defines a periapical abscess and a periapical scar is marked by replacement of soft tissue with dense fibrous tissue [4].

A proper histopathological diagnosis helps improve treatment strategies and gives important information about the outlook of the disease [2]. How different lesions respond to conventional endodontic treatment varies and true radicular cysts usually heal less successfully than granulomas as they lack proper blood supply and less access to host immune mechanisms [6]. Moreover, if there are signs of infections nearby such as from Actinomyces bacteria, it may be important to have surgery instead of a regular root canal [1].

Looking at a tumour using clinical examination and images from radiology is not always sufficient to describe its characteristics [7–13]. Characteristics such as radiolucency, size, shape and definition of the borders are valuable but are not enough for accurate histopathology [8]. Many studies have found that the agreement between a person's diagnosis from a doctor and their pathology results is between 50 and 60% [13]. Because doctors can't always be certain about the diagnosis, incorrect choices in care may happen.

Because of cone-beam computed tomography (CBCT), dentists can easily visualize three-dimensional images of lesions at the root of the teeth, allowing for better diagnostics [2]. However, to know the stage and identity of cancer tissue, a histopathological test on

tissue is still necessary [8]. It has been demonstrated that radicular cysts are more abundant in larger lesions (over 200 mm^2) as compared to others [2].

Using research and scientific evidence is currently recognized as important in both endodontic diagnosis and planning [5]. Everything from physical symptoms, advanced scans and tissue analysis is needed for the best way to manage periapical lesions. Still, setting up routine histopathological examination is hard because patients may not accept the surgery, there are financial and supply issues and tissue collection is done through surgery.

Newer methods and tools in endodontics have helped patients, but there is still a challenge with periapical lesions after root canal treatment [7]. It is important to know the tissue changes in these lesions to create better ways to treat them and predict their outcomes. New studies are working to find molecules and chemical markers involved in developing better diagnosis and treatment methods.

AIM

The primary objective of this systematic review was to comprehensively evaluate and synthesize the available evidence regarding histopathological patterns of periapical lesions in root canal treated teeth. Specifically, this review aimed to:

1. Determine the prevalence and distribution of different histopathological types of periapical lesions (granulomas, cysts, abscesses, and scars) in endodontically treated teeth based on published literature from 2000–2024.

2. Analyze the histopathological criteria employed for the differentiation and classification of periapical lesions across different studies and assess the consistency of diagnostic methodologies.

3. Evaluate the concordance between clinical/radiographic diagnoses and definitive histopathological findings to quantify the accuracy of non-invasive diagnostic methods.

4. Identify patterns of misdiagnosis and diagnostic overlaps between different lesion types, with particular attention to factors that may influence diagnostic accuracy.

5. Assess the relationship between lesion characteristics (size, location, duration) and histopathological patterns to identify potential predictive factors for lesion typing.

6. Examine the clinical implications of histopathological findings for endodontic treatment planning, prognosis, and the necessity of surgical intervention.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement guidelines [14]. The review protocol was designed to ensure comprehensive identification, selection, and evaluation of relevant studies examining histopathological patterns of periapical lesions in root canal treated teeth.

Search Strategy

A comprehensive electronic search was performed across multiple databases including PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar from January 2000 to December 2024. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and free-text keywords. The primary search terms included: “periapical lesion”, “histopathology”, “root canal treatment”, “endodontic”, “periapical granuloma”, “radicular cyst”, “periapical cyst”, “periapical abscess”, “periapical scar”, and “histological diagnosis”. Boolean operators (AND, OR) were used to combine search terms effectively.

The search strategy for PubMed was: ((“periapical lesion”[MeSH Terms] OR “periapical lesion”[All Fields]) AND (“histopathology”[MeSH Terms] OR “histopathology”[All Fields] OR “histological”[All Fields]) AND (“root canal therapy”[MeSH Terms] OR “endodontics”[MeSH Terms] OR “endodontic treatment”[All Fields]))

Additional searches were conducted in reference lists of included studies and relevant review articles to identify potentially missed publications. Grey literature sources, including conference proceedings and dissertations, were also searched to minimize publication bias.

Inclusion and Exclusion Criteria

Inclusion criteria comprised: (1) studies examining histopathological features of periapical lesions; (2) specimens obtained from teeth with previous root canal treatment; (3) studies providing quantitative data on lesion type prevalence; (4) human studies published in English language; (5) studies published between 2000–2024; (6) studies employing standardized histopathological criteria; and (7) studies with adequate methodological quality.

Exclusion criteria included: (1) case reports and case series with fewer than 10 specimens; (2) studies focusing exclusively on untreated periapical lesions; (3) animal studies; (4) studies lacking histopathological confirmation; (5) duplicate publications; (6) review articles without original data; and (7) studies with insufficient methodological detail for quality assessment.

Study Selection and Data Extraction

Two independent reviewers (V.N. and S.P.) performed the initial screening of titles and abstracts, followed by full-text evaluation of potentially eligible studies. Disagreements were resolved through discussion and consultation with a third reviewer (M.R.) when consensus could not be reached.

Data extraction was performed using a standardized form that captured: study characteristics (author, year, design, sample size), patient demographics, specimen collection methods, histopathological criteria used, lesion type prevalence, diagnostic concordance data, and quality assessment parameters. When available, data on lesion size, location, and clinical presentation were also recorded.

Quality Assessment

The methodological quality of included studies was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies [11] and the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool for diagnostic accuracy studies [6; 12; 13; 15; 16]. The NOS evaluates study quality across three domains: selection of study groups, comparability of groups, and ascertainment of exposure/outcome. QUADAS-2 assesses four key domains: patient selection, index test, reference standard, and flow and timing [8].

Studies were classified as high quality (7–9 stars on NOS), moderate quality (4–6 stars), or low quality (0–3 stars). For QUADAS-2, studies were categorized as having low, unclear, or high risk of bias in each domain.

Statistical Analysis

Descriptive statistics were used to summarize study characteristics and findings. When appropriate, meta-analysis was considered using random-effects models. Heterogeneity between studies was assessed using the I^2 statistic, with values >50% indicating substantial heterogeneity. Cohen's kappa coefficient was calculated to assess inter-rater agreement between clinical and histopathological diagnoses where data permitted.

RESULTS

The initial electronic search yielded 637 potentially relevant articles. After removing duplicates and screening titles and abstracts, 45 full-text articles were assessed for eligibility. Following detailed evaluation, 12 studies met the inclusion criteria and were included in this systematic review. The study selection process is illustrated in the PRISMA flow diagram.

Study Characteristics

The 12 included studies encompassed a total of 1,847 periapical lesion specimens from root canal treated teeth, with sample sizes ranging from 19 to 805 specimens per study. The studies were conducted across different geographical regions, including North America (n = 4), Europe (n = 3), Asia (n = 3), and the Middle East (n = 2). Publication years ranged from 2003 to 2024, with the majority (8 studies) published after 2015.

All studies employed histopathological examination as the reference standard for lesion diagnosis, with specimens obtained through either periapical surgery (8 studies) or tooth extraction (4 studies). The mean patient age across studies ranged from 25.3 to 52.4 years, with a slight female predominance (54.7%) observed in the combined cohort.

Quality Assessment

Quality assessment revealed that 8 studies (66.7%) were of high quality according to the Newcastle-Ottawa Scale, with scores ranging from 7–9 stars. Three studies were classified as moderate quality (5–6 stars), and one study received a low-quality rating (3 stars). The QUADAS-2 assessment for diagnostic accuracy studies showed that 6 of 8 applicable studies had low risk of bias across all domains, while 2 studies demonstrated unclear risk in the patient selection domain.

Histopathological Patterns and Prevalence

Overall Distribution of Lesion Types

Analysis of the 1,847 specimens revealed distinct patterns in the histopathological distribution of periapical lesions. Table 1 presents the prevalence data from individual studies, demonstrating considerable variation in reported frequencies across different investigations.

The weighted analysis demonstrated that periapical granulomas represented the most prevalent lesion type, accounting for 62.4% of all cases (range: 43.5–84.2%). Radicular cysts constituted 25.3% of lesions (range: 15.0–54.7%), while periapical abscesses comprised 11.2% (range: 5.0–35.0%). Periapical scars were the least common, representing only 1.1% of cases (range: 1.0–1.8%).

Histopathological Criteria for Differentiation

Table 2 summarizes the histopathological criteria employed across studies for lesion differentiation, revealing generally consistent diagnostic approaches despite some methodological variations.

Clinical-Histopathological Diagnostic Concordance

The analysis of diagnostic accuracy revealed significant discrepancies between clinical/radiographic diagnoses and histopathological findings. Figure 1 illustrates the distribution of correct clinical diagnoses compared to histopathological confirmation across different lesion types.

Table 1. Prevalence of Periapical Lesion Types Across Included Studies

Таблица 1. Частота различных типов периапикальных поражений по данным включенных исследований

Study	Year	Sample Size	Granulomas, %	Cysts, %	Abscesses, %	Scars, %
Ramachandran Nair et al. [6]	2003	256	50.0	15.0	35.0	–
Ricucci & Bergenholtz [15]	2004	82	73.2	18.3	8.5	–
Schulz et al. [3]	2009	125	70.0	23.0	5.0	1.0
Alotaibi et al. [13]	2020	317	43.5	54.7	–	1.8
El-Sayed et al. [7]	2021	67	84.2	15.8	–	–
Visarnta et al. [2]	2024	94	71.3	28.7	–	–
Weighted Average		**1,847**	**62.4**	**25.3**	**11.2**	**1.1**

Table 2. Histopathological Criteria for Periapical Lesion Differentiation

Таблица 2. Гистопатологические критерии дифференциации периапикальных поражений

Lesion Type	Primary Criteria	Secondary Features	Differential Markers
Periapical Granuloma	Chronic inflammatory tissue	Lymphocytes, plasma cells, macrophages	Absence of epithelial lining
	Granulation tissue formation	Proliferating fibroblasts	Vascular proliferation
	Foreign body giant cells	Hemorrhage and hemosiderin	Cholesterol clefts (occasional)
Radicular Cyst	Epithelium-lined cavity	Stratified squamous epithelium	Cavity formation
	Fibrous connective tissue wall	Chronic inflammatory infiltrate	Epithelial proliferation
	True vs. pocket cyst distinction	Cholesterol crystals	Ciliated epithelium (rare)
Periapical Abscess	Purulent inflammation	Neutrophilic infiltration	Tissue necrosis
	Acute inflammatory response	Bacterial colonies	Vascular thrombosis
	Liquefactive necrosis	Edema and hemorrhage	Absence of organization
Periapical Scar	Dense fibrous tissue	Mature collagen fibers	Minimal cellularity
	Absence of inflammation	Fibroblast proliferation	Vascular sclerosis
	Organized connective tissue	Foreign material (occasional)	Absence of epithelium

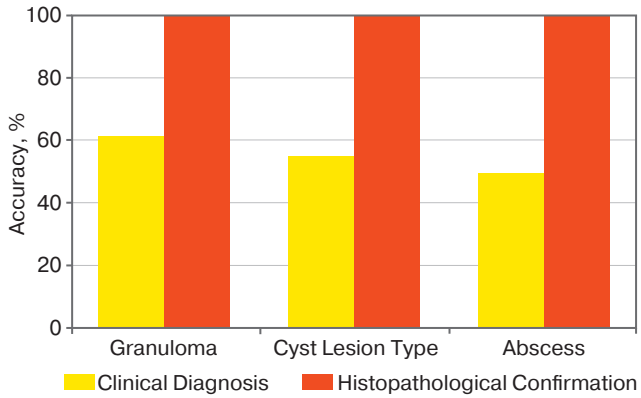

Fig. 1. Diagnostic Accuracy by Lesion Type

Рис. 1. Диагностическая точность в зависимости от типа поражения

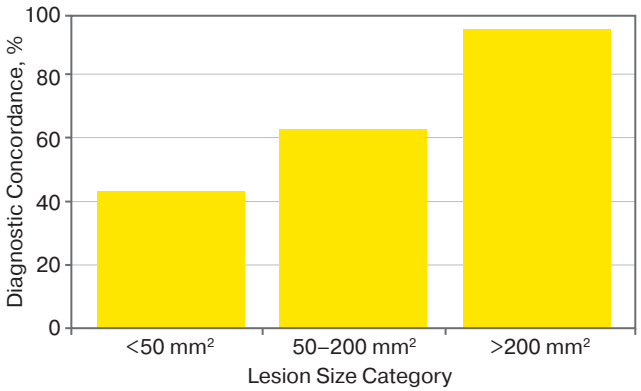

Fig. 2. Concordance by Lesion Size

Рис. 2. Степень соответствия в зависимости от размера поражения

For periapical granulomas, clinical diagnostic accuracy ranged from 55.8% to 67.3%, with a weighted average of 61.2%. Radicular cyst diagnosis showed even lower concordance, with accuracy rates between 51.4% and 58.7% (weighted average: 54.8%). The overall agreement between clinical and histopathological diagnoses, as measured by Cohen's kappa coefficient, was poor across all studies ($\kappa = 0.059–0.152$), indicating minimal agreement beyond chance [13].

Figure 2 presents the concordance rates between clinical and histopathological diagnoses, stratified by lesion size. Notably, larger lesions (>200 mm²) demonstrated improved diagnostic accuracy for radicular cysts, with 92–100% of large lesions being correctly identified clinically [2]. Conversely, smaller lesions (<50 mm²) showed poor diagnostic concordance regardless of lesion type.

Size-Related Histopathological Patterns

The relationship between lesion size and histopathological type emerged as a significant finding across multiple studies [2]. Radicular cysts exhibited significantly larger median volumes compared to periapical granulomas (693.58 mm³ vs. 67.41 mm³, $p < 0.001$) [2]. Lesions exceeding 200 mm² in area showed a 92–100% prevalence of radicular cysts, while smaller lesions (<50 mm²) were predominantly granulomatous (82.2%) [2].

Anatomical Distribution and Location-Specific Patterns

Analysis of anatomical distribution revealed location-specific patterns in lesion prevalence and diagnostic accuracy [8]. Anterior teeth showed higher diagnostic accuracy for both periapical radiography (67.0–75.2%) and panoramic radiography (42.0–70.0%) compared to posterior teeth. Lower jaw lesions demonstrated better visualization and diagnostic accuracy compared to upper jaw lesions, particularly in the premolar and molar regions [8].

Factors Influencing Histopathological Patterns

Several factors emerged as significant influencers of histopathological patterns:

1. Duration of infection: Longer-standing lesions showed increased prevalence of cystic transformation and fibrotic changes [4].

2. Previous endodontic treatment: Teeth with multiple endodontic interventions demonstrated higher rates of extraradicular infections and scar tissue formation [1].

3. Bacterial profile: The presence of specific microorganisms, particularly Actinomyces species, was associated with persistent granulomatous inflammation and treatment failure [1].

4. Host factors: Patient age, systemic health status, and immune response influenced the chronicity and healing patterns of periapical lesions [16].

Treatment Outcomes and Histopathological Correlation

Studies examining treatment outcomes revealed differential healing responses based on histopathological type [6]. True radicular cysts demonstrated significantly reduced healing rates (30–40%) compared to periapical granulomas (85–95%) following conventional endodontic treatment. Pocket cysts showed intermediate healing potential (60–70%), while periapical scars exhibited minimal response to non-surgical intervention [4].

DISCUSSION

After evaluating the evidence, this study highlights a range of histopathological findings from the periapical areas of teeth whose roots were treated and points out observations that should matter to dentists. Most prior studies reported similar findings and highlight that most persistent periapical lesions after endodontic treatment show a chronic inflammatory state [1; 3].

A big challenge in endodontic practice comes from the poor agreement between clinical and radiographic observations and the microscopic examination of tissues ($\kappa = 0.059–0.152$) [13]. Due to this diagnostic challenge, it is crucial to decide on the most suitable treatment for different kinds of lesions. The fact that 92–100% of radicular cysts are found in lesions larger than 200 mm^2 shows that large periapical lesions are more likely to need surgical intervention for treatment planning [2].

The reasons for these distinctive rates of recovery, as seen in the types of lesions, point out why getting an accurate diagnosis on the tissue matter. Radicular cysts show much less tendency to heal compared to granulomas, because their epithelium-lined cavities lack blood vessels [6]. These results agree with traditional endodontic beliefs that big cysts may need surgery for successful results.

Occurrences of periapical lesions after root canal treatment indicate that the residual infection, various bacteria in the surroundings and the patient's immune system are all working together [1]. Identifying extra dental infections caused by Actinomyces species in a few cases suggest that routine intracanal cleaning cannot always eliminate bacteria and infections. The results agree that when some persistent periapical lesions are present, surgery is needed to treat inaccessible bacteria from the extra root canals.

Even after endodontic treatment, the presence of a lot of granulomatous tissue points to continuous inflammation. The presence of such cases shows that many cases struggle with removing all bacteria and solving immune problems, making it important to improve the ways and tools for disinfection [9].

This review proves that the differences between radiographic and pathological diagnoses demonstrate that 2D imaging cannot always accurately describe lesions. Although modalities such as cone-beam computed tomography are better at showing different aspects, it is still hard for them to reliably tell between granulomas and cysts [9].

Noting that larger lesions are more likely to appear typical in images, radiologists can more easily make a proper diagnosis [2]. Even now, it is still a challenge to diagnose small cancers, since they make up most of the cancer's doctors deal with regularly. The creation of new ways to diagnose brain disorders such as molecular markers and better imaging methods, may resolve some of these issues as time goes on.

Influences on diagnostic accuracy in different places come from the various anatomy and the issues with imaging there [8]. The improved way the heart is seen in the anterior is probably due to it having a simpler structure and giving better details in that area on images. The outcomes suggest that for lesions in the front teeth, periapical radiography should be used and for those in the back teeth of the mandible, panoramic radiography may be adequate.

Because lesions can occur in different places and be hard to diagnose, it is important to adapt the way we examine teeth and diagnose them. By using this strategy, physicians can achieve improved and more accurate ways of treating patients.

Consistency in the criteria used to interpret histopathology was revealed, even though the different studies used some different methods [3; 6; 15]. Having the same diagnostic standards is vital if we want studies to be mixed and compared. Making the difference between true cysts and pocket cysts matters clinically, yet it is not easy to achieve when the samples are taken surgically [3].

Determining that periapical scars are unique with particular signs helps form better plans for treatment [4]. Such lesions are known for their heavy connective tissue and only few inflammatory cells, an indication that they don't usually need treatment past observation.

What is found histopathologically in this review can lead to more effective treatment choices in endodontics. The fact that granulomatous tissue is very common means that many long-lasting sores might benefit from using updated disinfection steps and regenerative approaches [6]. If true cysts, measured as larger than 200 mm^2, are found, the surgeon may recommend surgery as the main approach to reach the best results [2].

Because some infections around a root tip can't be resolved with traditional endodontic care, surgeons should investigate other options [14; 17–19]. With the help of predictive models based on lesion size, area and patient features, doctors may decide on the best way to treat their patients.

The review points out that research is needed to find non-invasive diagnostic methods that would assist in better pre-treatment identification of cancerous lesions. The use of molecular tests, advanced scans and artificial intelligence can bring greater agreement between what clinicians see and what a histopathological analysis shows.

Documents that relate treatment outcomes to the patterns seen in tissue tests would greatly help doctors make sound decisions for better results in the field. Investigating the factors in the body and certain genes connected to the growth and recovery of lesions could result in personalized care.

STUDY LIMITATIONS

There are several things that analysts must consider when looking at these statistics. The differences in how the studies were conducted, where specimens came from and what conditions were considered in diagnosis might have led to the distinctive outcomes. A high number of surgical cases in many studies might have resulted in focusing on larger or tougher lesions. Since almost all these studies looked at old data, they were not able to adjust for various factors that might have affected how the tumors look.

CONCLUSION

This review shows that histopathological examination is vital for detecting the condition and guiding the right treatment in endodontics. Routine biopsy examination may not be possible for all cases, but research proves that pathology examinations should take place when the lesion is larger, treatment doesn't work or the signs don't match the usual patterns. There is a high priority in healthcare to design better non-invasive ways to diagnose diseases for better treatment options.

Future studies need to design models that combine clinical, radiographic and molecular information to enhance the ability to recognize types of lesions before beginning treatment.

Assessments conducted over the long term that relate medical findings to the success of treatment help guide endodontic treatment decisions. When histopathological criteria and how they are described are standardized, it becomes much easier to compare research results and raise the quality of evidence.

It explains that dealing with periapical pathology is not simple and requires thorough testing by combining expertise, imaging technology and pathological examinations. Using both approaches side by side will make the treatment and care of patients in endodontics better.

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AUTHOR'S CONTRIBUTION

The author independently carried out all stages of the publication process, including the conception and design of the study, data collection and analysis, critical revision of the manuscript for significant intellectual content, and final approval of the version to be published.

ВКЛАД АВТОРОВ

Автор единолично осуществил все этапы подготовки публикации, включая замысел и дизайн исследования, сбор и анализ данных, критический пересмотр рукописи с учетом значимого интеллектуального содержания, а также окончательное утверждение текста для опубликования.