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Assessing the Healing Process in the Periapical Region: A Retrospective Study

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Abstract: ***Periapical lesions are generally accompanied by bone destruction, which is radiographically observed as radiolucency around the apex. A balance is found between microbial factors and the host's defence that allows the persistence of pathogens in the root canal, leading to the formation of various lesions in the periapical area. Periapical lesions are viewed as the consequence of a dynamic encounter between root canal microbes and the host's*** **defence. A total of 287 teeth (n=287) treated by two endodontists over a 7-year-period of time** ***and were studied based on dental records. The treated teeth*** **were placed into three main groups according to the initial periapical index: Group I-PAI2,** ***Group II-PAI3 and Group III-PAI4. Based on the follow-up period, the case results were grouped into three subgroups: 1) follow-up to 2 years; 2) follow-up to 4 years; 3) follow-up to 7 years. The analysis and assessment of the results by parallel radiographs showed that in clinical cases that were followed up within the second year, a successful periapical healing process was observed in 96.39% of cases, and failure was observed in 3.61% of cases. Tissue repair in the periapical area was observed in the three main groups: PAI2, PAI3 and PAI4. The monitored clinical cases for the specified period demonstrate that adhering to the exact clinical protocol results in a satisfactory recovery process in the periapex.***

Keywords: endodontic outcome, monitoring, periapical lesion, radiographs, retrospective study

1. Introduction

Retrospective analyses show a high incidence of chronic apical periodontitis (CAP) in teeth with previous endodontic treatment, which is confirmation of the data by other contemporary scientific studies [1-7]. In 94% of cases, CAP has been associated with unsatisfactory endodontic treatment. Important for the success of treatment is a sufficiently precise diagnosis of the pathological process by non-invasive methods. This requires a detailed analysis of the radiographic image (depending on the technique used) and a diagnosis based on changes in the radiographic image, mainly assessing the density of the tissue in the periapical area. Assessment of the clinical protocol used at the end of treatment can be made through the analysis of the results of microbiological testing, just before the root canal obturation. Critical analysis of the accuracy of the microbiological testing methods used is also controversial. There is no single opinion in the literature on the accuracy and type of study to be conducted, and which one would present reliable data for the interpretation of treatment results and long-term prognosis. Today, there is still no accurate method to fully assess the destruction or restoration of periapical tissues. Upon loss of a sufficiently high percentage (30–50%) of the mineral content of the tissue in the area, it is possible to determine an X-ray diagnosis and localize the changes, but depending on the technique used and the direction of the beam, some areas of destruction are hidden in a two-dimensional radiographic image. Some areas can be displayed in the displacement of the tube with a certain angulation.

Once destroyed, bone and periodontal tissues cannot be recovered *ad integrum*. In addition, if reconstruction processes occur in these tissues, it affects the absorption of the hard tooth tissues [8,9]. After 18 years of age, the absence of apical papilla cannot be associated with the recovery of volume, but with a certain degree of mineralisation, demineralised reserves can create a structure. Of particular relevance to modern endodontic practice are the methods for early diagnosis of CAP, especially in teeth without appropriate treatment. This leads to the introduction of three-dimensional clinical diagnostics: cone-beam computer tomography (CBCT), methods for the study of bone density, nuclear magnetic resonance and ultrasound [9-16]. In search of relatively sufficient and accurate assessment of early and late treatment outcomes and tools for the prognosis of treatment, this clinical study included cases assessed by the periapical index of Ørstavik *et al.*, as PAI 2, PAI3 or PAI4, followed radiographically for 2, 4 and 7 years [17].

This study aims to evaluate the long-term healing process in the periapical region of endodontically treated teeth using radiographic PAI classification over a 7-year follow-up period.

2. Materials and methods

A total of 287 teeth (*n=287*) treated by two endodontists over a 7-year-period of time and were studied concerning the dental records. The 287 teeth were randomly selected for this survey from among all patients who had returned for recall (213 patients; 123 women and 90 men). For statistical purposes, processing results were placed into three main groups according to the initial periapical index: *Group I*-PAI2, *Group II*-PAI3 and *Group III*-PAI4. Based on the follow-up period, the case results were grouped into three subgroups: **1)** follow-up to 2 years; **2)** follow-up to 4 years; **3)** follow-up to 7 years. In each subgroup, clinical cases were grouped by two additional criteria: the type of sealer used (*A = Apexit Plus* and *B = AH Plus*) and two sub-criteria, the method of additional decontamination (*C = Ca(OH)$_2$* and *D = ozone therapy*). The clinical sample included a range of endodontically treated conditions. After providing a strict medical history, patients completed an informed consent form for endodontic treatment. For each tooth, the following preoperative information was recorded: tooth location, number of root canals, previous endodontic treatment, clinical

signs and symptoms, response to percussion, pulp test vitality (in cases without endodontic treatment) and periapical status. For each tooth, the following intraoperative information was recorded: type of irrigation used, the number of treatment sessions, interappointment dressing (if used), the occurrence of procedural complications such as perforation, breakage of files, flare-up, length of canal filling (at apical level, 1 mm short or more and beyond) and temporary restoration placed.

3. Results

First, control radiographs were made immediately after the definitive sealing of the root canal. Obturation showed satisfactory results (Figs.1–3). The apical extent of the filling met the established criteria of the European Society of Endodontics. Lacks of mechanical trauma in the periapical area of the extruded sealer and gutta-percha, and at the same time a well-sealed endodontic space, are important conditions for tissue regeneration [18,19]. Established resorption in teeth with CAP in the outer root surface, in the apex and in the area of invagination of the apical constriction, and deformation of the anatomical features in the area of the apical 3 mm, lack of anatomical narrowing or increase in diameter, increase of the diameter of the apical foramen and invasion of microorganisms in the microtubular system in radicular dentin are prerequisites for possible complications in the postoperative period. On radiographs of monitored cases, the formation of dense mineral apical tissue was seen. The conclusion that can be drawn from the results is that a successful treatment outcome does not directly depend on the volume of the lesion (PAI2, PAI3 or PAI4), as much as on the three-fold healing process, including strict adherence to the clinical protocol, maximum decontamination and maximum sealing of root canals-both apical and coronal.

A satisfactory periapical healing process was seen in 96.39 percent of clinical cases that were followed up during the second year, while failure was detected in 3.61 % of cases, according to the analysis and appraisal of the findings by parallel radiography. Tissue repair in the periapical area was observed in the three main groups: PAI2, PAI3 and PAI4. In teeth that were followed up in the fourth year, successful results were observed in 89% of cases. Additionally, in the group followed up in the seventh year, the observed positive results were 85%. The radiographic assessment of treatment outcome is graphically presented in Figures 4–6.

Of the 287 cases monitored that were treated from 2013 to 2020 inclusive, CAP's highest established prevalence was PAI3 (44.2%). No statistically significant difference was found compared to Group I and Group II, but there was a statistically significant difference between Group III (p=0.05). The distribution by sex and age showed no statistically significant correlation in the presence, extent and distribution of the CAP groups' teeth. In four of the monitored primary cases (1.4%), the Electro Pulp Test (EPT) showed that the teeth were still preserved and had vitality (14–26 µA) (Fig.1).

Figure 1: A/ The initial radiograph on tooth #13-PAI5; **B/** preoperative radiograph with gutta-percha through the sinus tract; **C/** Control radiograph after the root canal obturation-a lateral canal was sealed; **D/** 4 years follow-up-PAI1; E/ 7 years follow-up-PAI1.

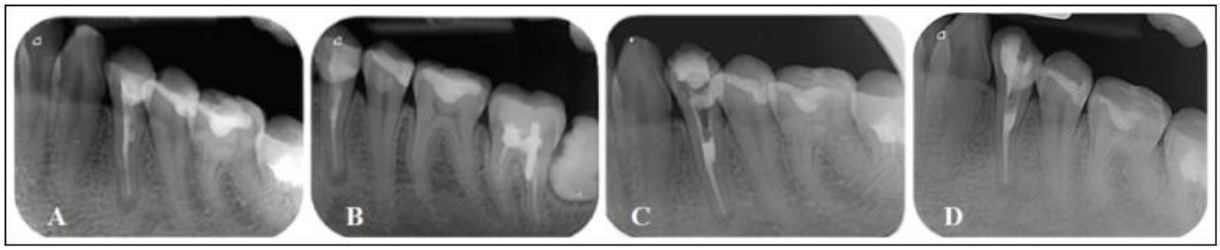

Figure 2: A/ The initial radiograph on tooth #34-PAI4, the fibre-reinforced post should be removed; **B/** Control radiograph after the root canal obturation; **C/** 2 years follow-up-PAI2; **D/** 4 years follow-up-PAI1.

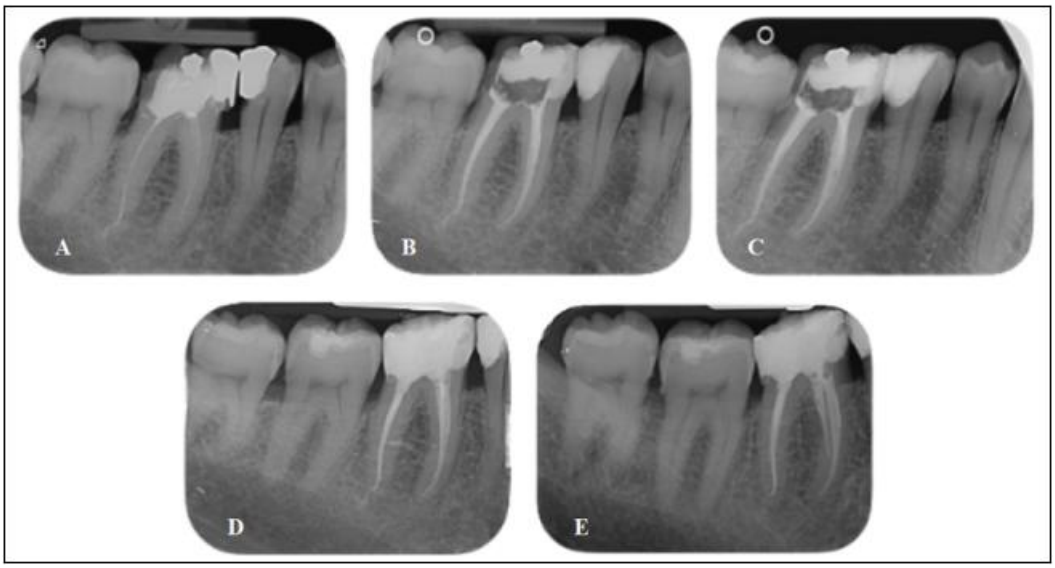

Figure 3: A) The initial radiograph on tooth #47-PAI3, **B)** Control radiograph after the root canal obturation; **C)** Control radiograph 2 years after the obturation of the root canals; **D)** 4 years follow-up-PAI. **E/** 7 years follow-up-PAI1.

According to the literature, destruction in the periapical area can be seen in teeth with vital pulp tissue. This suggests that local microbial invasion can induce periapical destruction even when pulp vitality is retained. [20, 21]. There are demonstrated increased levels of macrophages. Clinically, these processes are observed in vital teeth, notwithstanding the radiographic changes in the apical osteolytic bone structures. In cases like these, it is especially important that the intraoral examination includes an analysis of paraclinical tests for differential diagnostics, including chronic periapical inflammatory lesions or the early stages of cemento-osseous dysplasia, which is related to osteolysis. Both early and late follow-up results confirmed the diagnosis.

The case presented in Figure 1 shows an apical lesion with an intraoral buccal fistula. Tracing the direction of the fistula by radiographic examination, the endodontic etiology of a periapical lesion was confirmed. In all the followed-up retrospective cases, there was a successful healing process with a recovery of the bone structure characteristic of periapical osteolytic lesions with inflammatory etiology.

The analysis of the results found that the prevalence of CAP in the highest percentage was in the first maxillary and mandibular molars, and in at least one canine (Fig.1).

4. Discussion

Strindberg, in 1956, was perhaps the first researcher who presented detailed retrospective endodontic research. His analysis of the studies, the materials used and endodontic techniques, as well as his identification of the need to establish criteria for determining the success of treatment, served as a model for many subsequent researchers.

In the context of chronic apical periodontitis, many dentists still struggle to preserve natural dentition and maximize long-term tooth retention [22]. One of the key goals of primary endodontic therapy is to avoid periapical tissue alterations, which do not occur in the majority of clinical situations in general practice due to the availability of a broad variety of precision endodontic instruments.

Therefore, primary endodontic treatment alone may not prevent or manage future periapical pathology of diseases of the periapical area, which in turn increases the percentage of teeth with CAP and confirmed iatrogenic etiology in a large percentage of cases. This is confirmed in the literature by the studies of Chazel et al., which established the presence of lesions in 5.6% of untreated teeth and in 32.0% of teeth receiving dental treatments carried out with [23].

In recent years, increasing numbers of patients have sought consultation for conservative treatment of teeth with primary and secondary periapical lesions compared with radical treatment (tooth extraction). The data in this study (author's unpublished data) confirmed the findings of other investigators found in the literature [23-25]. Extensive research, from various countries, has shown that the prevalence of apical periodontitis and other postoperative periradicular lesions is more than 30% of all devitalized teeth [1,4,26-28]. These data demonstrate the great need for exact treatment of chronic apical periodontitis. In addition, the treatment plan for cases of retreatment should contain a precise assessment of the state of the hard dental tissues and the periapical structures. Apart from assessing the condition of the tissues, there should be an assessment of the risk of endodontic treatment and of pathological conditions that can be treated by standard methods by general dentists or those cases that should be referred to a specialist endodontist.

The occurrence of a healing process must be the focal point of the discussion and evaluation of treatment results in both surgical and nonsurgical techniques of retreatment [27]. The success of endodontic retreatments and the ensuing healing process can be assessed clinically, radiographically or histologically, and by the combination of two or three methods, after a certain follow-up period. The process is described in many clinical studies. The outcome of endodontic treatment is usually assessed in the first year and categorized as:

a) **Successful endodontic treatment**-includes two subcategories: a *complete healing* process (evaluated radiographically and by the absence of clinical symptoms) and an *incomplete healing* process (absence of clinical

symptoms, but radiographically noticeable reduction of the lesion (radiolucency) and the formation of scar tissue).

b) **Satisfactory endodontic treatment**-the width of the periodontal ligament around the apex is increased about two times without periapical lesion.
c) U**ncertain endodontic treatment**-persistent radiographic lesion in the absence of clinical symptoms or with clinical symptoms associated with the presence of an incomplete radiographic healing process.
d) **Failed endodontic treatment**-the presence of clinical symptoms, combined with the presence of a reduced or persistent radiographic lesion [28,29,30,31].

If at the end of the first year of follow-up, the treatment outcome is evaluated as "uncertain", the tooth should be monitored periodically to the fourth year, and then the outcome should be determined as successful or unsuccessful [32].

In endodontics, a relatively new term to assess the outcome of treatment is functional retention [33, 34]. This term has a greater focus on the patient and is consistent and compatible with a term used in implant studies to assess success. It is not a criterion for the healing process, but is connected with one of the goals of treatment: an asymptomatic and functional tooth. Hoskinson et al. found a statistically significant correlation that each 1 mm increase in the preoperative size of the periapical lesion increased the risk of failure by 18% [35]. On the other hand, Chugal et al. established another type of correlation; the loss of exact working length in primary endodontic treatment of 1 mm leads to a 14% increase in unsuccessful clinical cases [36]. These two scientific studies provide a compelling reason to adhere strictly to the maximum clinical protocol for a successful outcome. The success of endodontic treatment depends on various factors, which are the basis of the study, including:

a) The criterion for inclusion and exclusion of patients for follow-up.
b) The materials used (treatment protocol);
c) The clinical approach.
d) The criteria for the evaluation of success.
e) The experience and clinical skills of the clinician.
f) The ability to assess the radiographic images for the type and location of the lesion, and risk assessment.
g) The use (or not) of a magnifying technique for enhancing visual perception.
h) The patient's lifestyle, diet, and personal oral hygiene after clinical treatments.

There are a limited number of scientific reports that summarize the results of the outcome of orthograde endodontic retreatment and there are differences in their study designs regarding the treatment protocol, methodology and follow-up periods. From a review of the current literature [37-44], only four studies [37,39,40,41] use modern techniques and provide important evidence-based data about the outcome of endodontic retreatments [45]. When the treatment is properly conducted, the healing process in the periapical area occurs with the regeneration of tissues, characterized by reduction of radiolucency at follow-up, as shown in many studies [46].

The levels of success for both therapeutic protocols-nonsurgical and surgical- used in root canal treatment of teeth with primary and secondary infections and apical periodontitis were high. Root canal treatment failures were detected even with rigorous standard clinical protocols [47].

However, a complete healing process with mineralization of tissues or reduction of radiolucency is not observed after every root canal treatment in teeth with periapical lesions. From this point of view, it is very important to assess the quality of the removal of the old obturation sealer and gutta- percha from the root canal space, which will allow for maximum 3D adaptation of new obturation materials in retreatment cases [48]. When clinical procedures have not reached a satisfactory endodontic standard for control and elimination of the infection, periapical radiolucency persists [49-51]. A lack of aseptic control, an incorrectly designed and shaped endodontic access cavity, untreated root canals, inadequate treatment of root canal space, and the lack of a good seal in temporary and definitive fillings are the most common problems that lead to persistent periapical lesions [44]. The invasion of microorganisms of the tubular system of the radicular dentin and periapical tissues, and the presence of bacterial toxins that target activated polymorphonuclear cells in the separation of the matrix metalloproteinases (MMPs), play a major role in the destruction of the periodontal tissues and are considered key biochemical markers for monitoring of CAP, by analysis of the periapical exudate [52-54]. Histological analysis is the only way to make a differential diagnosis between diffuse periapical lesions and cystic lesions. Paula-Silva et al. found that these two pathological processes are characterized by different expressions of the molecules in the extracellular matrix. Their results indicate that the highest enzyme activity of the MMPs (MMP-9 and MMP-13) was found in granulomas, unlike the cysts, which is a sign that can differentiate the two from each other [54].

The analysis of the results of this paper confirmed that the main purpose of orthograde treatment of CAP is the elimination of the host defence, virulence factors and toxins, as well as inhibition of the inflammatory process in the periapical area that is associated with the destruction of tissue. Clinical follow-up demonstrates the reduction of the values of MMP as a result of chemo mechanical root canal preparation. Chlorhexidine, used as a medicine in the protocol of endodontic treatment, inactivates MMPs, including MMP-8. In some recent publications, the use of chlorhexidine as a medicament in the irrigation protocol has been subjected to discussion. The presence of periapical inflammation, with changes in both the tooth apex and the surrounding tissues, draws the attention of clinicians to an exact detailed clinical protocol and the analysis of the anatomical features of the apical zone. Monitoring the healing process over a period of four years is crucial in determining the degree of tissue repair and predicting the treatment outcome in advance. An unsatisfactory healing process should be thoroughly analyzed to reject dysplasia in the periradicular zone in differential diagnostic terms. An unsatisfactory result of orthograde treatment of CAP is followed by apical surgery in combination with a histological examination of the lesion [55-57]. Malignant diseases of the bone tissue in the periapical area are similar to osteolytic inflammatory lesions (*in the*

initial stage), especially where the boundaries are unclear, and it is difficult to identify a lesion by radiographs.

Of particular importance is the analysis of clinical findings and radiographic images when they are unusual. In these cases, the final diagnosis should be reconsidered, as inadequate treatment should be discontinued, and the patient should be referred for a consultation with a maxillofacial surgeon.

In the current study, during the follow-up period, six teeth needed extraction due to fractures. After the analysis of the hard dental tissue, it was found that teeth with minimal supragingival tissue (1 mm or less) showed poor prognosis, necessitating extraction in six cases despite adherence to the clinical protocol, which is a basic prerequisite for poor prognosis for these teeth. Even when the most precise clinical protocol is observed, portions of the radiographic lesion may persist due to the anatomical features of the root canal system, which cannot be prepared and obturated with existing materials and techniques.

According to modern concepts of evidence-based dentistry, the choice between alternative healing methods is based on risk assessment and their advantages can be measured from consecutive examinations with a high degree of proof [27,58]. There is an unanimous view that CAP persisting after orthograde endodontic treatment has a more complex etiology and clinical situation than CAP that affects teeth which have not undergone a proper root canal treatment. For optimal clinical outcomes in the treatment of apical lesions, it is essential that a thorough study of the etiology and pathogenesis of this type of lesion is made. A number of publications have presented some evidence that apical periodontitis is diagnosed less frequently in teeth that have had a good radiographic quality of the endodontic treatment. Interesting data are presented by Eckerbom et al. from a 20-year study of changes in the apical status. They found that among teeth with good quality of obturation of the root canal system the number of teeth with endodontic treatment performed and endodontic periapical lesion increases from 17.3% to 21.4% [3].

This study contributes to the evolving understanding of long-term periapical healing by reinforcing the critical role of strict clinical protocols and radiographic monitoring in achieving successful outcomes in endodontic retreatments.

5. Conclusion

The limitations of this investigation and the reported data indicate that the quality of canal obturation is not the only element that impacts the effectiveness and prognosis of the therapy. Other variables may include microbial invasion in the microtubular dentin system of the root canal, proper diagnosis, the amount of the pathological process at the start of treatment, the quality of the canal system's coronary sealing, and the ultimate restoration of the coronary hard dental tissues.

This study concludes that while obturation quality remains crucial, successful periapical healing also depends significantly on proper diagnosis, infection control, and post-treatment sealing. These factors must be collectively optimized to enhance treatment prognosis in chronic apical periodontitis.

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