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Characterization of Successful Root Canal Treatment

Carlos Estrela[1], Roberto Holland[2], Cyntia Rodrigues de Araújo Estrela[3], Ana Helena Gonçalves Alencar[1], Manoel Damião Sousa-Neto[1], Jesus Djalma Pécora[1]

[1]Department of Stomatologic Sciences, School of Dentistry, UFG - Federal University of Goiás, Goiânia, GO, Brazil
[2]Department of Restorative Dentistry, School of Dentistry, UNESP - Univ Estadual Paulista, Araçatuba, SP, Brazil
[3]Department of Endodontics, School of Dentistry, University of Cuiabá, Cuiabá, MT, Brazil

Correspondence: Prof. Dr. Carlos Estrela, Praça Universitária s/n, Setor Universitário, 74605-220, Goiânia, GO, Brasil. Tel: +55-62-3209-6254. e-mail: estrela3@terra.com.br

Knowing the outcome of root canal treatment (RCT) is determinant to substantiate the clinical decision making process, especially when RCT is weighed against the extraction of natural teeth or replacement by prosthetic elements. The ideal scenario in all clinical situations should combine healing/prevention of disease (apical periodontitis) and the functional retention of the tooth. Understanding the risk factors associated with endodontic failure is a key factor to increase the chances of success. The logical action is to reverse the existing disease, which requires intervention to neutralize the bacterial invasion and disrupt the bacterial biofilm within the complex anatomy. Success is more predictable when the immune host defenses are favorable. However, success has different meanings to the dentist, to the patient and to the tooth itself. The life of an endodontically treated tooth depends on the accuracy of the diagnosis and planning, excellence of disinfection, instrumentation and filling procedures (antimicrobial strategies, root canal shaping and coronal and apical seal) and finally the rehabilitation management. The interpretation of constant or intermittent pain and/or discomfort associated with apical periodontitis (AP) in endodontically treated tooth may be suggestive of endodontic failure. The success features of RCT, namely absence of pain, regression of AP, tight seal of canal and coronal spaces, and recovery of tooth function, must be reevaluated over time. In case of doubt between success and failure, cone beam computed tomography (CBCT) could be indicated for detection and precise localization of AP. The possibility of map reading on CBCT images characterizes the real multidimensional structure, providing accurate information on the presence, absence or regression of AP. The survival of an endodontically treated tooth implies understanding the biological and mechanical outcomes as multifactorial events over the individual's life span. The objective of this review of literature is to discuss relevant factors associated with patient's health, tooth and dentist that could account for a successful RCT.

Key Words: success, failure, outcome, apical periodontitis, healing.

Introduction

Success is the expected outcome after root canal treatment (RCT), regardless of the clinical conditions. However, predicting success usually requires adopting a referential or criteria, and presupposes that the patient is healthy. It is estimated that RCT should be considered completed when the tooth is permanently restored and in function (1). RCT clinical success can be analyzed based on different points of view, with specific values that involve the dentist, the patient or the tooth itself. References for the dentist are the value of symptom (clinical silence - absence of pain), the value of image (root canal space completely filled with no evidence of periapical inflammation), and the value of clinical condition (a well-restored and functioning tooth). The dentist's skills are crucial to interpret correctly the radiographic features and establish a diagnostic hypothesis. For the patient, the value of symptom (no pain) is essential. Apart from this, RCT success is associated with predictive aspects that eliminate the need of interventions and establishes treatment conclusion. The success for the tooth itself is associated with absence of disease (root canal infection or periapical inflammation).

The life of an endodontically treated tooth implies understanding that biological and mechanical events have a multifactorial nature and cannot be viewed separately. Ideally, it is expected to preserve the largest possible number of teeth until the end of life. Successful RCT prevents pain, apical periodontitis (AP) and tooth loss, but it is a real challenge because several clinical conditions can contribute, alone or in combination, for a poor prognosis, namely root canal perforation, overfilling, endodontic and periodontal lesion, root fracture, periapical biofilm, traumatic dental injury, fracture of instrument, AP, root resorption, etc.

Systemic and periodontal conditions should be carefully examined before RCT. Preoperative diagnosis of dental pulp and/or periapical tissues is an important reference to establish case prognosis. The dentist's health represents a human aspect that is frequently neglected and can also be a risk factor for the occurrence of intraoperative procedural errors. Human error may be associated with stress, working conditions, and lack of attention, adequate planning and sufficient knowledge of new technologies. Renouard and Charrier (2) discussed some human factors that could induce accidents and reported that as far as the interactions between the individual and the working environment, errors could be related to other people (life ware), technology (hardware), documentation (software) and environment.

The objective of this review of literature is to discuss relevant factors associated with patient's health, tooth and dentist that could account for a successful RCT. Table 1 enumerates determinant aspects associated with the health of the individual, the tooth and the professional that must be carefully observed for a successful RCT.

The Value of Diagnosis

Establishing a correct diagnosis is essential for planning clinical procedures. A favorable prognosis in RCT relies on the endodontist's scientific experience level and skills. The challenge is to overcome the complex canal morphology, neutralize the microbial pathogenicity regardless of the type and duration of infection, and disrupt the bacterial biofilm. Host's defense (immune response) is fundamental in this process.

Pulpal or periapical inflammatory diseases are usually identified by the consequences of tissue aggressions. The main purpose of canal therapy is the removal of the causative - bacterial, chemical, mechanical and physical etiological - agents. During the diagnosis, it is essential to recognize the clinical conditions that could have led to tissue response, such as dental caries, pain, inflammation, primary infection, secondary infection, symptomatic/ asymptomatic AP, periapical abscess with/without sinus tract, open/closed cavity, history of traumatic dental injury.

Knowing the clinical factors associated with pulpal and periapical pain may provide important information for planing the therapeutic strategies and predicting RCT outcomes. The most frequent diagnosis of pulpal pain has been associated with symptomatic pulpitis and hyper-reactive pulpalgia, and the most frequent periapical pain is symptomatic AP of infectious origin. Endodontic diagnosis and local factors associated with pulpal and periapical pain suggest that the important clinical factor in pulpal pain is closed pulp chamber and caries, and is periapical pain is open pulp chamber (3).

Understanding the general clinical condition (patient's systemic health) and local (clinical conditions of the tooth) favors the first impression to predict a possible outcome of RCT. The impact of patient's age, smoking status, initial treatment versus retreatment, root canal system exposed to salivary contamination prior to treatment, and the type of instrumentation on RCT outcome were recently evaluated

Table 1. Determinant factors associated with health of individual, tooth and professional that must be carefully observed for RCT success.

Determinants associated with the individual
- Patient's age - Oral health (periodontal disease) - Systemic health (systemic diseases) - Patient's collaboration (level of patient's knowledge about the importance of health and of the RCT)
Determinants associated with the tooth
- Diagnosis of dental pulp and/or periapical tissue previously to RCT - Dental morphology (dental group - anterior, premolar and molar; dental development disturbances) - RCT planning - Time, extension and type of the infectious process - Understanding the disinfection process, the selection of the antimicrobial agents (irrigant solution, intracanal dressing, filling material, quality of coronary restoration) - RCT (root canal space completely filled, with filling material ending 1-2 mm from the radiograph apex, overfilling, root perforation, fracture of instrument, endoperiodontal lesion, traumatic dental injury) - Type of restoration (composite resin, metallic restoration, unitary prosthesis with or without intraradicular post, extensive dental rehabilitation) - Control and longevity of the RCT - Selection of the cases and gumption
Determinants associated with the professional
- Stress - Work environment - Lack of attention - Lack of planning - Domain of new technologies - Technical ability and knowledge (academic level - student, general clinician, specialist, experienced specialist, professor)

(4). The integrity of a patient's nonspecific immune system, which has been neglected in earlier investigations, is a significant predictor for endodontic treatment outcome, and should receive more attention. The immune status of the patient, and the quality of the root filling showed a great influence on RCT outcome in a cohort study (4).

Several non-endodontic diseases suggest a typical case of AP. The differential diagnosis of diseases of non-endodontic and endodontic origin should always be made carefully. Radiolucent or radiopaque images in the mandibular or maxillary areas surrounding the root apexes may be a sign of non-endodontic disease, and may be misdiagnosed as AP (5-7).

Root Canal Infection and its Consequences

The periapical inflammation represents a natural biological defense response, caused by several etiologic agents. The model of the inflammatory response is similar in other parts of the organism. The intensity of periapical inflammation and/or infection can suggest the diagnosis and the treatment option. The traumatic or infectious injury of the dental pulp is able to produce harmful consequences in the periapical region. The infection of the dental pulp mobilizes microorganisms to develop in apical direction, to invade and colonize the periapical tissues. The period of time of an infection process is unpredictable. Microorganisms with different characteristics (structural, metabolic and pathogenic) reaching the periapical region stimulate the inflammatory and immunologic responses. The organic defenses and the degree of virulence of the microorganisms establish several types of periapical alterations and its infection potential (8,9).

Some signs are solid evidence of the pathogenic potential to be neutralized by therapeutic strategies, like a tooth with root canal that remained open for some time and favored the invasion and colonization by different bacterial species, or the presence of a sinus tract, which collaborates with the invasion and development of a structured bacterial biofilm.

The participation of a bacterial complex in the process of pulp and periapical aggression has been thoroughly discussed in several studies (8-17).

Sundqvist and Figdor (13) reported that infection of the root canal is not a random event. The type and mix of the bacterial microbiota develop in response to the surrounding environment. Species that establish a persistent root canal infection are selected by the phenotypic traits that they share and that are suited to the modified environment. Nair (8) has defined pathogenicity as the ability of a microbe to produce disease and virulence; it is the relative capacity of a microbe to cause damage in a host (17). Any metabolically active microbe living in the root canal has the potential to participate in the inflammation of periapical tissues. Individual species in the endodontic microbiota may be of low virulence, but their survival in the necrotic root canal and pathogenic properties are influenced by a combination of several factors. They include the ability to build biofilms, interact with other microorganisms in the biofilm and develop synergistically beneficial partnerships, the capability to interfere with and evade host defenses, the release of lipopolysaccharides and other microbial modulins, and the synthesis of enzymes that damage host tissues (8,10-12,16,17).

The etiology of disease post-treatment in endodontics has been associated with microbial etiologic factors (intraradicular and extraradicular infection – bacteria, fungi); and nonmicrobial etiologic factors (endogenous – true cysts; exogenous – foreign-body reaction) (9-12,16). According to Nair (8,10-12,16), it is important to consider the extraradicular infections occuring by: (a) exacerbating AP lesions, (b) periapical actinomycosis, (c) association with pieces of infected root dentin displaced into the periapex during root canal instrumentation or cut off from the rest of the root by massive apical resorption and (d) infected periapical cysts, particularly in periapical pocket cysts with cavities open to the root canal.

Other etiologic agents should also be correlated as potential periapical aggressors. The periapical inflammation may occur due to a natural defense response against over-instrumentation, over-irrigation or overfilling (18-22). The root canal preparation and obturation should be restricted to the main root canal if there is no evidence contrary to this therapeutic protocol.

Operational Strategies that May Interfere On Success

Apical Limit, Apical Enlargement

The quality of root canal preparation and filling and coronal sealing are essential factors to achieve high rates of success, even in infected root canals. This fact reinforces the concept of eliminating empty spaces that can harbor microorganisms (8,9,23,24). The RCT excellency is associated with the disinfection process, which involves removing microorganisms from the root canal system by emptying, cleaning and enlarging/shaping, combined with the use of antibacterial therapies (8,9,16,23,25,26). Based on the need to control the microbiota of infected root canals, some aspects are necessary in a therapeutic protocol. Thus, the apical limit of instrumentation and obturation must be discussed, the determination of apical enlargement level (anatomical diameter) and the antibacterial efficacy of intracanal medicaments in root canal infections.

Several studies reported that root canal preparation and obturation short of the radiographic apex were associated with a better prognosis (18-22). The clinical characterization of apical morphology is extremely complex. The root level of isthmuses and their frequency do not represent as standard (9,27). The apical constriction and the apical foramen are not reliable anatomic landmarks for the obturation length at the apical end, and their use to calculate obturation length may result in injury to apical and periapical tissues (28). On the basis of biologic and clinical principles, instrumentation and obturation should not extend beyond the apical foramen (18-22,27-33).

A frequent discussion in endodontic therapy, reported by Ricucci (30) and Ricucci and Langeland (31) concerns the apical limit of instrumentation and obturation. The results of longitudinal studies, basic anatomical knowledge of the apical third of the root canal, and the histological pulp reaction to caries progression, demonstrated the presence of a vital apical pulp remnant, even in the presence of a periapical lesion. Wu et al. (29) reported that the biologic and clinical principles after vital pulpectomy that attained highest success rates were achieved when procedures ended 2–3 mm short of the radiographic apex. When there is pulp necrosis, bacteria and their by-products as well as infected dentin debris may remain in the most apical portion of the root canal, and these irritants jeopardize apical healing. In these cases, highest success rates were achieved when obturation ended at 0–2 mm short of the radiographic apex. When shorter than 2 mm from or beyond the radiographic apex, success rates for infected canals were approximately 20% lower than those found for root filling ending 0-2 mm short of the apex. Systematic reviews (32,33) also showed that higher success rates are achieved when obturation is short of the apex (root canal obturation 1-2 mm short of apex).

Thus, the filling material should remain confined to the root canal and in no way its presence beyond the apex is justified. It is appropriate to remind that many injuries seem AP, but it does not mean they really are.

The level of enlargement of the root canal and the action potential of disinfection process reflect the effectiveness of antimicrobial strategies. The estimate of the anatomic diameter of the root canal before enlargement should be considered (34,35). Many instruments do not touch all canal walls (36). Thus, root canal emptying and enlargement represent essential actions for antimicrobial control (35).

Sanitization Process

One of the challenges in RCT is to discover how to sanitize the isthmus areas that harbor microorganisms, which in turn prevents the action of the instruments on bacterial biofilm.

The antimicrobial efficacy of intracanal medicaments on bacterial biofilm is still not confirmed (24,26,37,38). Nair et al. (37) reported the importance and necessity of stringent application of non-antibiotic chemomechanical measures in order to disrupt the biofilm and reduce the intraradicular microbial load to the lowest possible level to ensure the most favorable long-term prognosis for the treatment of infected root canals.

The selection of effective microbial control in infected root canals requires detailed knowledge of the microorganisms responsible for pulp and periapical pathology associated with understanding the action mechanism of the antimicrobial substances (39,40). The success of infected RCT may be influenced by some clinical environments, as the planktonic suspension, presence of biofilm, time and type of infection, host response, and effective antibacterial therapeutic protocol.

Irrigant solutions are necessary during root canal preparation because they help to clean the root canal, lubricate the files, flush out debris, and have an antimicrobial and tissue dissolution effect, without damaging periapical tissues. The selection of an ideal irrigant depends on its action against the root canal microbiota and the biological effect on periapical tissue (24,25,40). Several irrigating solutions have been considered in order to decrease endodontic infection and contribute to canal disinfection, including: halogenated compounds (sodium hypochlorite), chlorhexidine, detergents (anionic, cationic), chelating agents (EDTA, citric acid), MTAD, ozonated water, apple vinegar. However, up to now, sodium hypochlorite and chlorhexidine are the most often indicated antimicrobial agents for treatment protocols against endodontic and periodontal infections (24,25,40).

The antimicrobial effect of sodium hypochlorite by direct contact with *E. faecalis* occurs after 2 min (25). The positive culture of microorganisms following the application of the irrigating solutions (ozonated water, gaseous ozone, 2.5% sodium hypochlorite, 2% chlorhexidine) for 20 min confirmed their inability to sterilize an infected human root canal (24). Thus, when a medicament does not reach the target microorganism, its killing potential cannot be recognized. Therefore, it cannot be stated whether the microbial strains were resistant to one or other medication. In this case, it is likely that the microorganisms were able to survive, adapt and tolerate the critical ecological conditions.

In the same direction, the properties of calcium hydroxide stem from its dissociation into calcium and hydroxyl ions and the action of these ions on tissues and bacteria explains biological and antimicrobial properties of this substance (39). Thus, it was shown that calcium hydroxide induces the deposition of a hard tissue bridge on pulpal and periodontal connective tissue (41-44). Its action on connective tissue (pulpal and periodontal tissues) revealed the ability to stimulate mineralization, from the significant involvement of alkaline phosphatase and fibronectin (39-46).

There is a great release of hydroxyl ions from calcium hydroxide, which are able of altering the integrity of the bacterial cytoplasmic membrane through the toxic effects generated during the transfer of nutrients or by the destruction of the phospholipids of unsaturated fatty acids. The influence of pH alters the integrity of the cytoplasmic membrane by biochemical injury to organic components (proteins, phospholipids) and transport of nutrients. The maintenance of a high concentration of hydroxyl ions can change the enzymatic activity and provide its inactivation (39). In addition, the healing process in teeth with AP after RCT in two appointments with the use of calcium hydroxide paste showed a better status of periapical tissue (with mineralized barrier)(43-44).

The presence of biofilm in the root canal system is a challenge to the outcome of RCT (26,37). The active participation of mechanical action of endodontic instruments combined with antimicrobial strategies appears to be crucial for decreasing root canal infection.

Criteria for the RCT success

The estimation of the RCT prognosis must be related to criteria for understanding the success. This aspect implies in evaluating results based on longitudinal monitoring, which requires a standard. The RCT success criteria and its prevalence should be routinely reevaluated. Among the clinical and radiographic characteristics of the RCT failure there is often observed the presence of symptoms (pain) and/or the presence of a periapical radiolucent area.

AP is a consequence of root canal system infection, which can involve progressive stages of inflammation and changes of periapical bone structure, resulting in resorptions identified as radiolucencies in radiographs (12).

RCT failures may involve microbial and non-microbial factors, as discussed previously (9-12,16). A high rate of failure is associated with endodontically treated teeth associated with AP, overfilling, and teeth that were not properly restored after RCT (18-22,27,47-49).

Thus, utmost care must be taken to establish criteria to define success. On this account, the life of a tooth endodontic treatment may be rely on the time and the age of the individual. In a prospective analysis, an endodontically treated tooth is expected to remain throughout the individual's life. The analysis of the RCT success involves reversion of the inflammatory/infectious process, no symptoms, well restored, in function and no evidence of periapical radiolucency. It is important to recognize that along people's life, some diseases may develop and impact their health. Incidentally, an infection or re-infection may arise some time after RCT.

To characterize the outcomes of endodontically treated teeth with vital pulp (healthy or inflamed pulp), infected pulp, AP and periapical abscess, must be considered the time since RCT conclusion and the definite restoration. The previous status of pulp and periapical tissue may aid in the interpretation of actual clinical conditions.

Strindberg (50) described important clinical and radiographic factors associated with RCT success and failure. A considerable number of clinical studies have discussed the causes of failure of endodontically treated teeth and prospects for prognosis in retreatment (50-75). The correlation of RCT failure with infected root canal was evident in several conditions (1,3,8-20,24-27,35-40,47-75).

Traditionally, three aspects are associated in the analysis of RCT success – the clinical, radiographic and microscopic characteristics. In the clinical context, two of these aspects normally guide the decision-making process: clinical history (symptoms – absence; sensitivity, discomfort and/or pain; physical exam – normality; edema, fistula, excessive mobility) and interpretation of images (signs of periapical health; periapical bone radiolucency).

Clinical and radiographic aspects conventionally associated with the RCT failure include pain, AP and/or sinus tract, swelling. The cases of doubt on the success or failure involve a transition phase and definition of criteria may be imposed by the limitations of the used clinical or imaging exams. Clinical success and clinical silence are different aspects to be analyzed. Clinical failure may present or not a symptomatic (pain) condition.

In this sense, AP cannot be correctly identified by periapical radiography only. The experienced professional has many resources to identify the agent responsible for the failure. Notwithstanding the dentist's skills, the diagnosis of odontogenic pain should always follow an accurate protocol, since the pain felt by the patient may not have a direct association with a well or bad endodontically treated tooth.

Various factors may affect tooth survival, such as dental caries, periodontal disease and RCT. The prevalence of endodontically treated teeth associated or not with AP has been examined in several populations (1,48,49,61,72,73).

Regarding the prevalence of endodontically treated teeth in Brazilian adults, a previous study showed that in a sample of 29,467 teeth, only 6,313 (21.4%) received treatment (73). RCT was most frequent in maxillary premolars and molars, whereas mandibular incisors showed the lowest prevalence. Most endodontically treated teeth were found in people aged 46 to 60 years (47.6%) and the prevalence increased with age in this range. Females (61.9%) showed a higher prevalence of teeth with root fillings than males.

A total of 1,372 periapical radiographs of endodontically treated teeth by postgraduate students were evaluated (1). AP prevalence was significantly higher in teeth with poor endodontic treatment (66.3%) than in teeth with adequate root canal filling (16.5%). Prevalence of AP was also higher in teeth with poor coronal restoration (52.1%) than in teeth with adequate coronal restoration (30.1%). Based on periapical radiographs, the prevalence of AP was low when associated with a high technical quality of RCT.

In health sciences, such as endodontics, various advances were applied to clinical practice. The therapeutic assessment of dental treatment by computed tomography characterizes a sensible advance of information in health (76,77). This contribution may be applied to planning, diagnosis, therapeutic process and prognosis of several diseases. The continuous advance of technology enabled the development of cone beam computed tomography (CBCT) (78,79), which has widen numerous perspectives for application in different research areas and clinical dentistry (80-89). Imaging resources have been routinely used before, during and after dental treatment. Conventional radiographic images provide a two-dimensional rendition of a three-dimensional structure, which may lead to interpretation errors. Periapical lesions of endodontic origin may be present but not visible on conventional 2D radiographs (80-84).

The accuracy of diagnosis is a critical factor for the success. The correct management of CBCT images may reveal abnormalities unable to be detected in periapical radiography and may enhance a more predictable planning and treatment (80-84). The possibility of a map-reading approach with CBCT images reduces the problems related to difficult evaluation conditions that require special care during diagnosis (84).

Estrela et al. (82) evaluated the accuracy of CBCT compared with periapical and panoramic radiography in the identification of AP. In view of the limitations of periapical radiography to visualize AP, a review of epidemiologic studies should be undertaken considering the quality of periapical aspects provided by CBCT images. It will certainly reduce the influence of radiographic interpretation, with less possibility for false-negative diagnoses. AP prevalence in endodontically treated teeth, when comparing the panoramic and periapical radiographs and CBCT images, was 17.6%, 35.3% and 63.3%, respectively. A considerable discrepancy can be observed among the imaging methods used to identify AP. AP was correctly identified in 54.5% of the cases with periapical radiographs and in 27.8% of the cases with panoramic radiographs. Minor changes in sensitivity were found for different teeth groups, except for incisors in panoramic radiographs. ROC analysis suggests that AP is correctly identified with conventional methods in an advanced stage. CBCT was proved an accurate diagnostic method to identify AP. Wu et al. (85) discussed the limitations of previously published systematic reviews assessing the RCT outcomes. A high percentage of cases confirmed as healthy by radiographs revealed AP on CBCT and by histology. In teeth where the small size of the existing radiolucency was diagnosed by radiographs and considered to represent periapical healing, enlargement of the lesion was frequently confirmed by CBCT. In clinical studies, two additional factors may have further contributed to the overestimation of successful outcomes after root canal treatment: (i) extractions and re-treatments were rarely recorded as failures and (ii) the recall rate was often lower than 50%. The outcomes of root canal treatment should be re-evaluated in long-term longitudinal studies using CBCT and stricter evaluation criteria.

Characteristics of the clinical and imaging outcomes from RCT include: success (clinical aspects - absence of pain; tooth with definitive restoration and in masticatory function; imaging aspects - absence of periapical radiolucency); failure (clinical aspects - presence of pain, discomfort; tooth with temporary or definitive restoration; presence of swelling; sinus tract; imaging aspects - presence of periapical radiolucency); doubt (intermediate clinical situations– in these cases may or not present a history involving pain or discomfort, associated with inconclusive image of AP regression).

In case of doubt, it is essential to discuss the clinical case with a more experienced professional, as in some cases it is not easy to determine the differential diagnosis of diseases of non-endodontic and endodontic origin. Various radiolucent images may be associated with the apex, without being diseases of microbial origin and could be misinterpreted as AP (5-7). The time to start the treatment is also a key factor to determine success or failure. The possibility of map-reading in CBCT images minimizes several problems related to complex diagnosis, particularly in dubious cases. Bueno et al. (84) suggested a map-reading strategy to diagnose root perforations near metallic intracanal posts by using CBCT. A strategy to minimize metallic artifact in root perforation associated with intracanal post is to obtain sequential axial slices of each root, with an image navigation protocol from coronal to apical (or from apical to coronal), with 0.2 mm/0.2 mm axial slices. This map reading provides valuable information showing dynamic visualization toward the point of communication between the root canals and the periodontal space, associated with radiolucent areas, suggesting root perforation.

Operative procedural errors (OPE) may occur and they represent risk factors able to compromise a tooth (86,87). Errors characterize disability, non-observance of therapeutic protocol and low level of knowledge involving the endodontic principles. Deficient attendance may be responsible for severe consequences and sequels, which impairs the prognosis, and may result in serious judicial questions (89). Silva et al. (89) detected the OPE in endodontically treated teeth and dental implants, using CBCT images. In endodontically treated teeth, OPE included underfilling, overfilling, and root perforation; OPE in dental implants were thread exposures, contact with anatomical structures, and contact with adjacent teeth. Underfilling, overfilling, and root perforations were detected in 33.5%, 8% and 4.5% of the teeth, respectively. Dental implants with thread exposures, contact with important anatomical structures and contact with adjacent teeth were seen in 37.5%, 13% and 6.5% of the cases, respectively. OPE were detected in endodontically treated teeth and dental implants, and underfilling and thread exposures were the most frequent occurrences, respectively.

The extension of treatment in a tooth with indication for extraction can be a dental implant. The problem of replacing a biological structure by biocompatible materials requires care and precise indication. Information about criteria and rates of success in endodontically treated teeth and dental implants are of utmost importance.

Torabinejad et al. (90) analyzed by a systematic review clinical articles addressing success and failure of nonsurgical RCT, and assigned levels of evidence to these studies. It appears that few high-level studies have been published in the past four decades related to the success and failure of nonsurgical root canal therapy. The data generated by this search can be used in future studies to specifically answer questions and test hypotheses relevant to the outcome of nonsurgical root canal treatment.

The current moment of endodontic science is promising in view of all the knowledge acquired over the last few years (91). New technologies such as CBCT influenced the quality of diagnosis, planning, therapy and longitudinal control. A wide array of endodontic instruments for safer root canal preparation was introduced in endodontics. Some of these advances contributed to the revision of concepts, and to determine adjustments to the treatment protocol. Estrela et al. (82) suggested a review of epidemiologic studies in view of the limits of periapical radiography and the accuracy to visualize AP by CBCT imaging. Wu et al. (85) in function of the limitations of previous systematic reviews evaluating the RCT outcomes, considered the need of re-evaluating the outcome in longitudinal studies using CBCT with rigorous evaluation criteria. One concern discussed at meetings in endodontics and in several recent studies (80-86) relates to overestimated numbers of success in RCT.

Depending on the dentist's knowledge and skills for interpreting CBCT images, higher percentages of errors and failures in RCT may be identified. The possibility of map-reading on the CBCT scans can characterize the reality of a multidimensional structure, aiding with precise information the presence, absence or regression of AP. The life of an endodontically treated tooth implies understanding the biological and mechanical results as a multifactorial event, over the life span of the individual.

Resumo

O sucesso do tratamento endodôntico deve sempre ser o principal objetivo em todas as situações clínicas, evitando-se dentro do possível a perda do dente. O entendimento dos fatores de riscos associados aos fracassos alerta para a importância terapêutica. A lógica é reverter o quadro de doença presente, o que demanda intervenção para neutralizar a agressão e romper biofilme bacteriano presente no complexo anatômico. Quando as defesas imunológicas do hospedeiro são favoráveis, o sucesso é mais previsível. A óptica do sucesso para o profissional, para o paciente e para o dente é distinta. A vida útil do dente tratado endodonticamente (DTE) depende da qualidade do processo de sanificação (estratégias antimicrobianas, alargamento e selamento), cujo referencial apresenta como base o diagnóstico, o planejamento e a excelência da técnica operatória (endodôntica e reabilitadora). A presença de dor contínua, esporádica, e/ou desconforto, associada ao aspecto de uma imagem radiolúcida em DTE pode ser sugestivo de fracasso. As características de sucesso do tratamento (ausência de dor, regressão de periodontite apical (PA), espaço do canal radicular e coronário completamente obturado, e dente em função) devem ser avaliadas ao longo do tempo. Nos casos de dúvida, entre sucesso ou fracasso, a correta localização ou detecção da PA pode ser feita por tomografia computadorizada de feixe cônico (TCFC). A possibilidade de uma navegação pela imagem da TCFC pode caracterizar a realidade de uma estrutura multidimensional, auxiliando com informação precisa sobre a presença, ausência ou regressão da PA. A vida útil do DTE implica no entendimento de resultados biológicos e mecânicos como um evento multifatorial ao longo da vida do indivíduo.

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