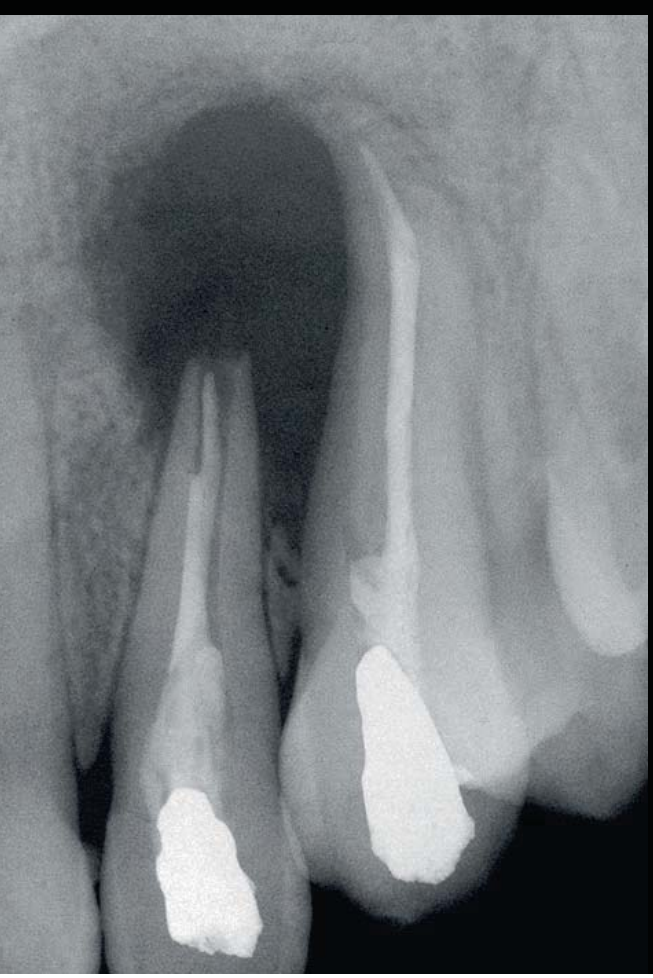
Massimo Gagliani, Fabio Gorni,
Marco Martignoni

01



Failures in endodontics

An epidemiological and clinical analysis

General considerations on failure in endodontics

Being able to talk, in an absolute sense, about success or failure in a dental surgical discipline, such as endodontics, would be a great advantage; however, as our research methods become increasingly sophisticated, the cut-off between success and failure becomes increasingly difficult to establish, due to constant changes in the parameters used. The simplest, but not for that matter simplistic, solution would be to observe and comply with the guidelines drawn up by major international scientific societies in the endodontic field.[1a] In this sense, many scientific societies have endeavored to exemplify clinical situations pertaining the sector and closer attention will be dedicated to this aspect later in this chapter.
Periapical disease of endodontic origin is identified by X-ray.
Figures 1.1-1.8 provide an emblematic overview. As the clinical findings are often separated from radiographic evidence available, the possibility of these scenarios providing discordant results makes it even

Figs. 1.1-1.8: These images represent radiographic scenarios typical of periapical lesions of endodontic origin, secondary to treatment failure. The common denominator is that of a radio - transparent area of variable entity, around the apical limit of each tooth, associated with insufficient canal filling in terms of both length and width. In some cases, the endodontium has not been explored, whereas in others (Fig. 1.5), the fracture of an instrument leads to the suspension of the treatment.


1.2


1.1


1.3

more difficult for the practitioner to formulate a diagnosis and, to an even greater degree, to establish a treatment plan compatible with a favorable prognosis.
In this volume, we will review the inflammatory periapical diseases of endodontic origin[1] that are caused rather than solved by previous treatments – be they apparently correct or incorrect – based on dental elements using an exclusively clinical approach (Figs. 1.9-1.12).
This choice precludes an exhaustive consideration of the issues associated with the pathophysiology of the supporting tissues and with the microbiology underlying development of "posttreatment disease"[2, 3] or disease after endodontic treatment or, in a broader sense, disease not solved by endodontic treatment[4]. This condition involves a bacterial component inside or even outside the root canal[5-7], which represents one of the determining etiological elements (Figs. 1.13-1.14); and concomitant causes associated with the microorganisms present inside the root may play a secondary role in the maintenance of the disease. The term "post-treatment disease" could be considered rather simplistic, since root canal therapy is frequently carried

▶ *continue to page 6*

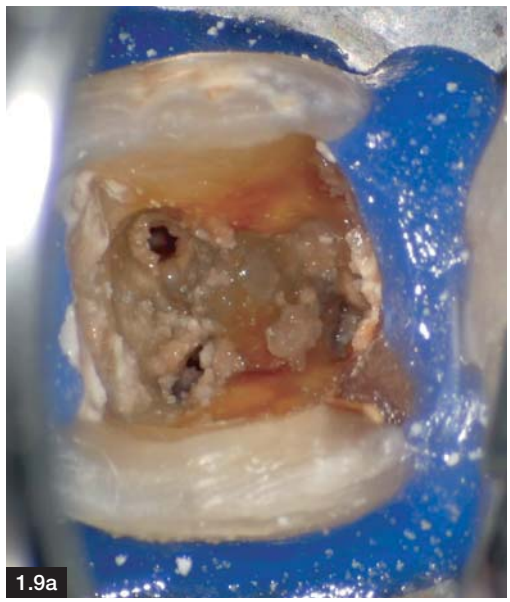

1.4


1.5

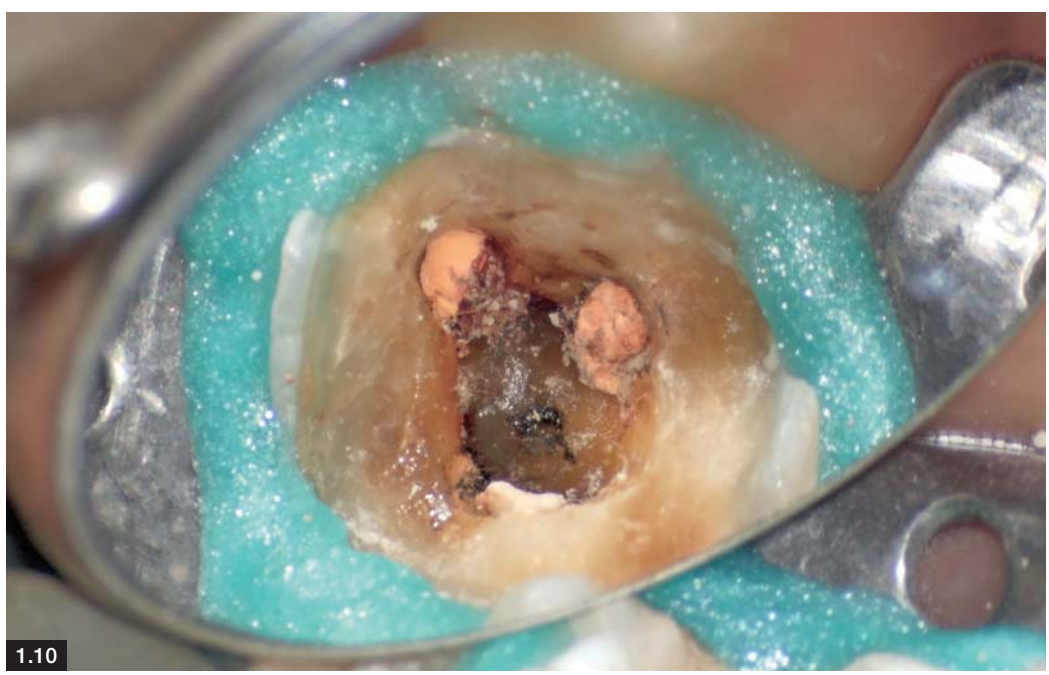

1.6

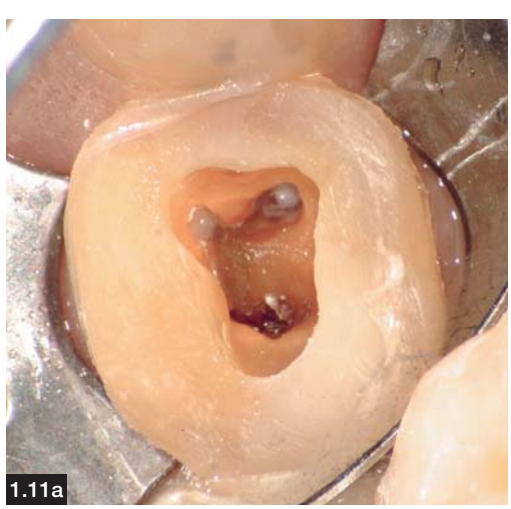

1.7

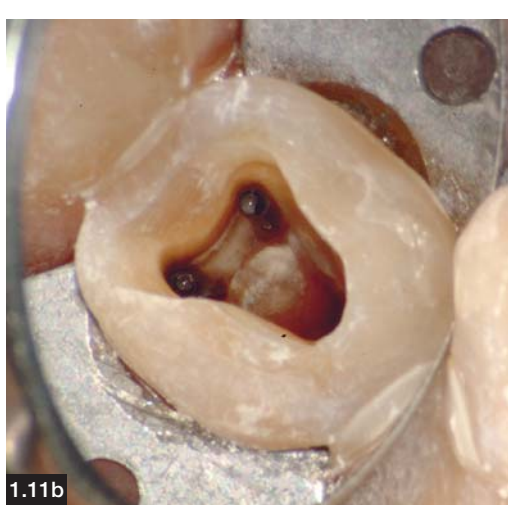

1.8


1.9a

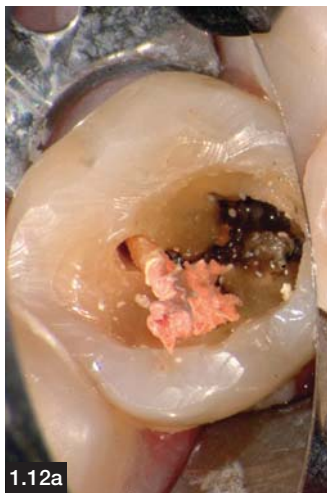

1.9b

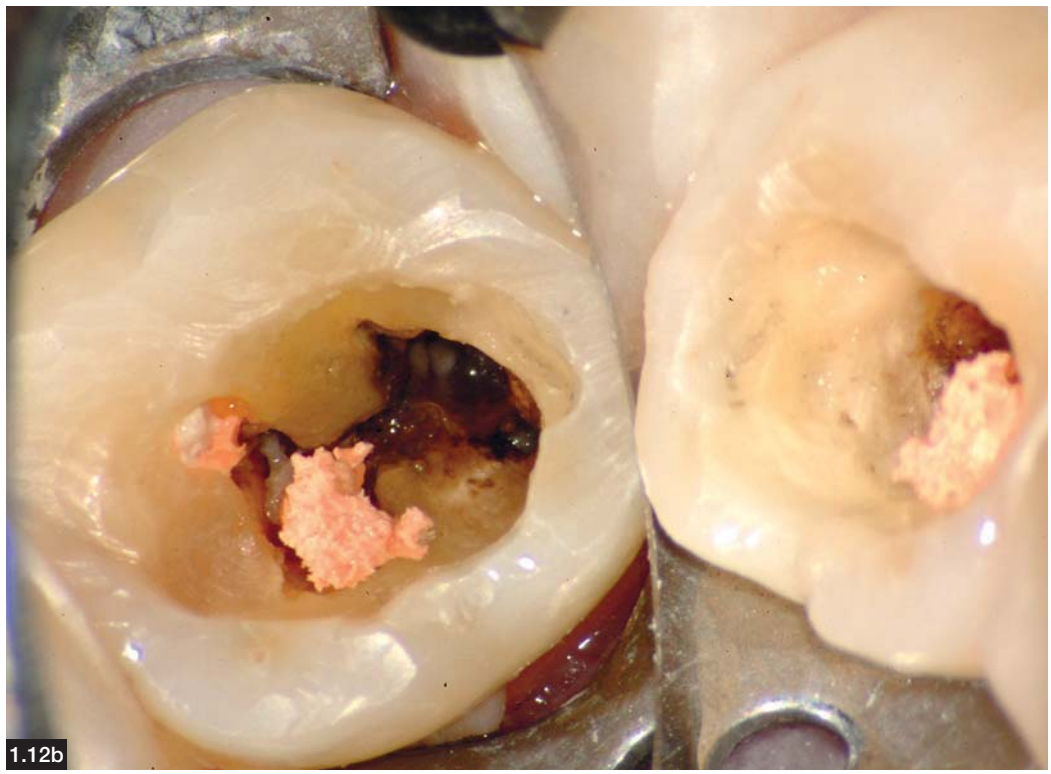

1.10

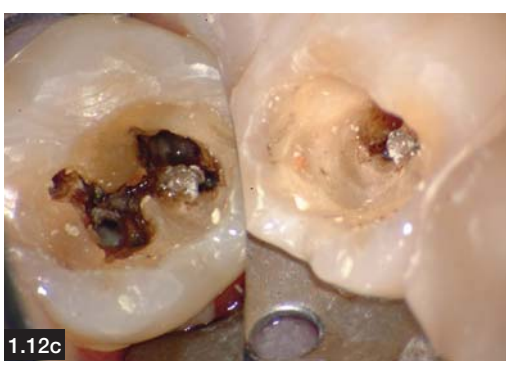

1.11a

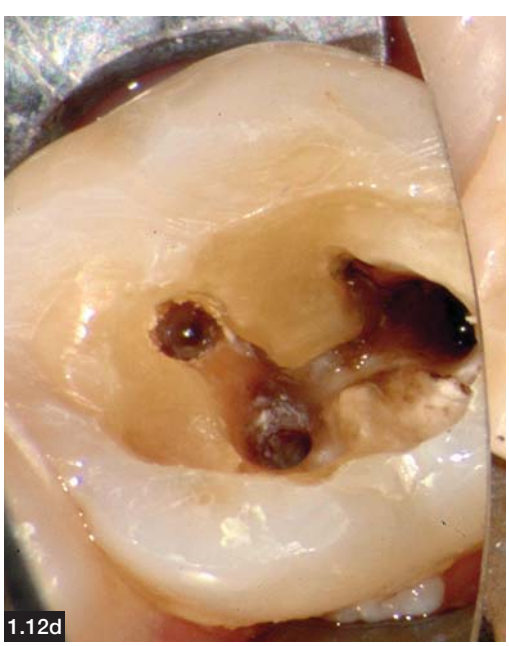

1.11b

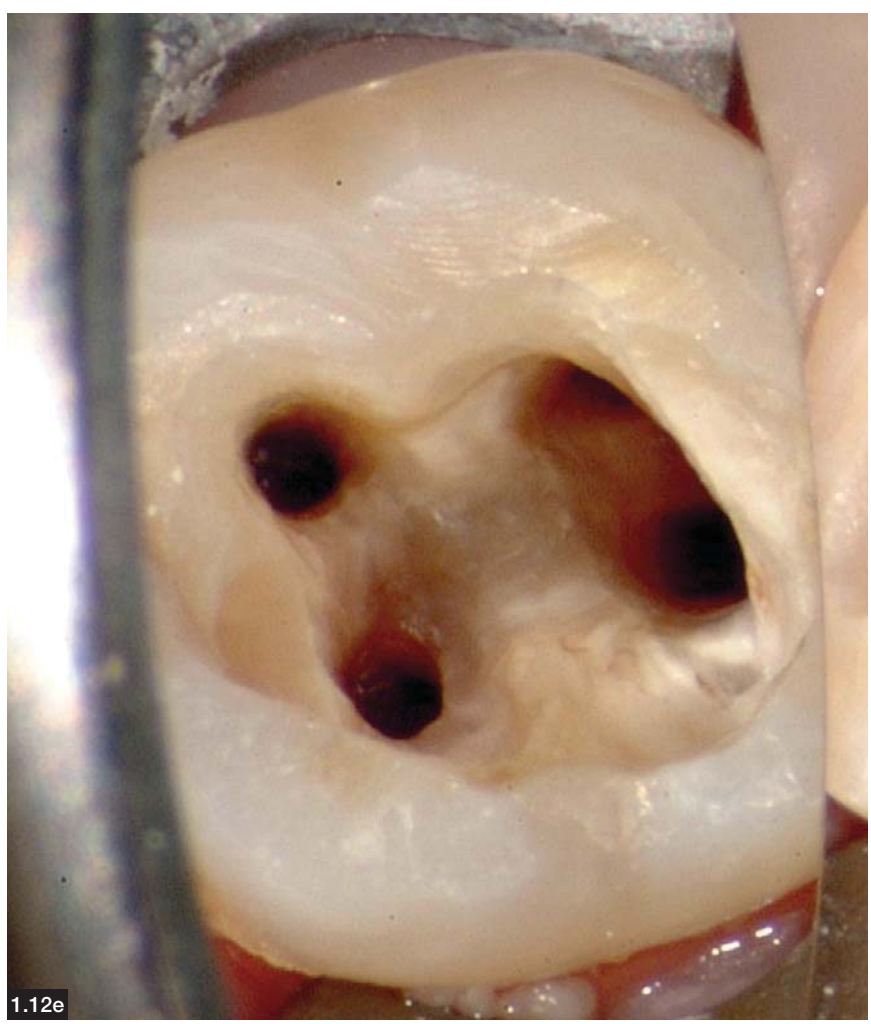
Figs. 1.9-1.12: The clinical scenario of the teeth, which develop periapical disease as a result of sub-optimum endodontic treatment, is often characterized by unsatisfactory pulp chamber openings, the presence of carious tissues in the coronal compartment and a receptacle of bacterial plaque, and lack of correct vision.


1.12a


1.12b


1.12c


1.12d


1.12e

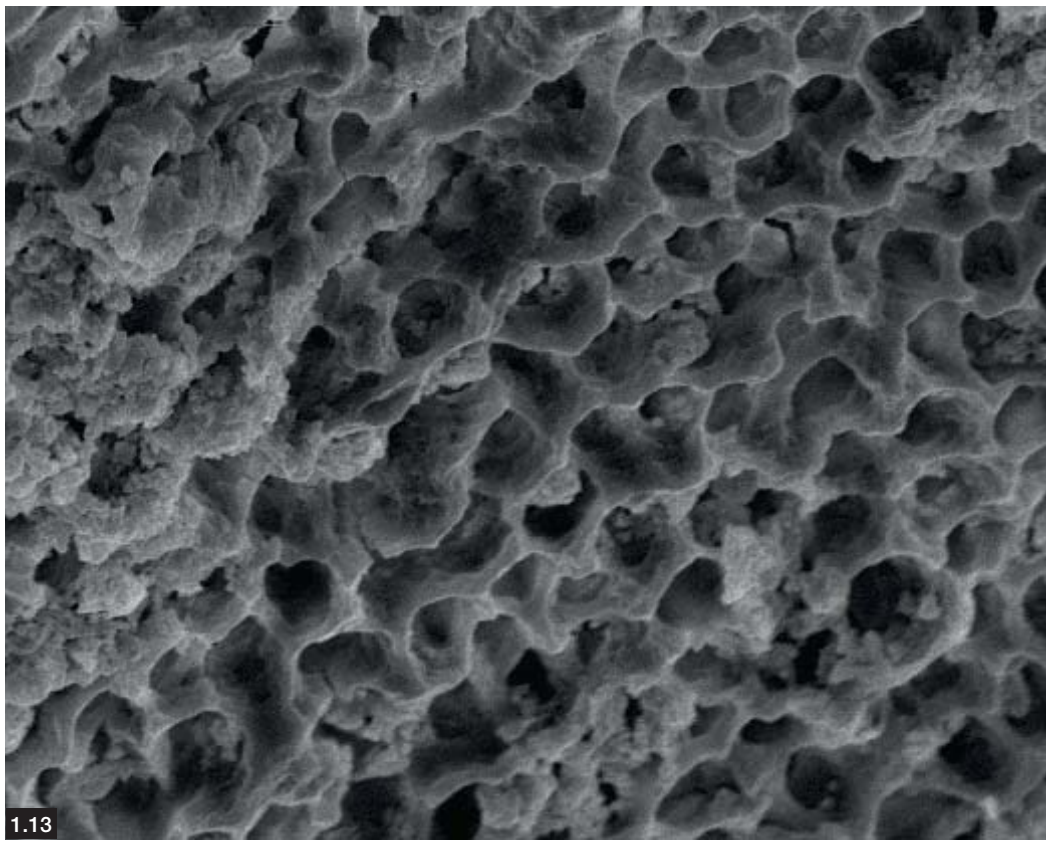


Fig. 1.13: Canal lumen with proliferating bacterial population that is not yet aggregated into biofilm.

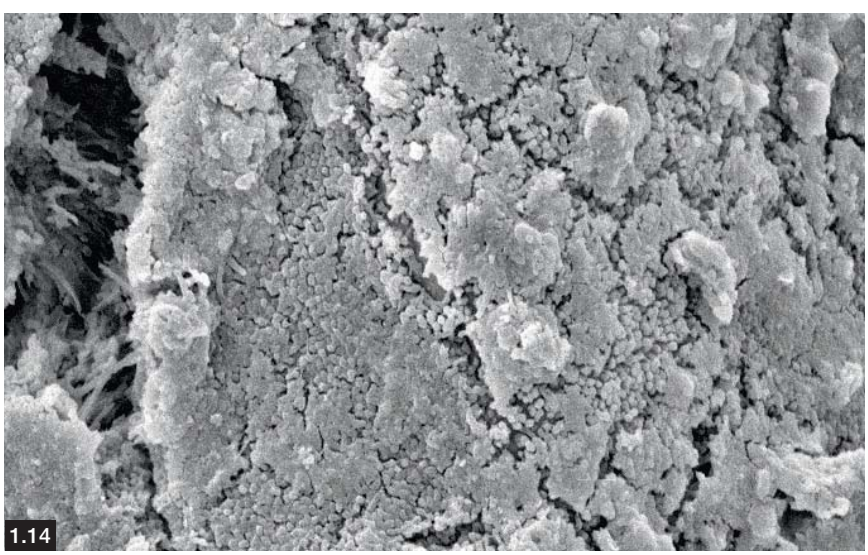
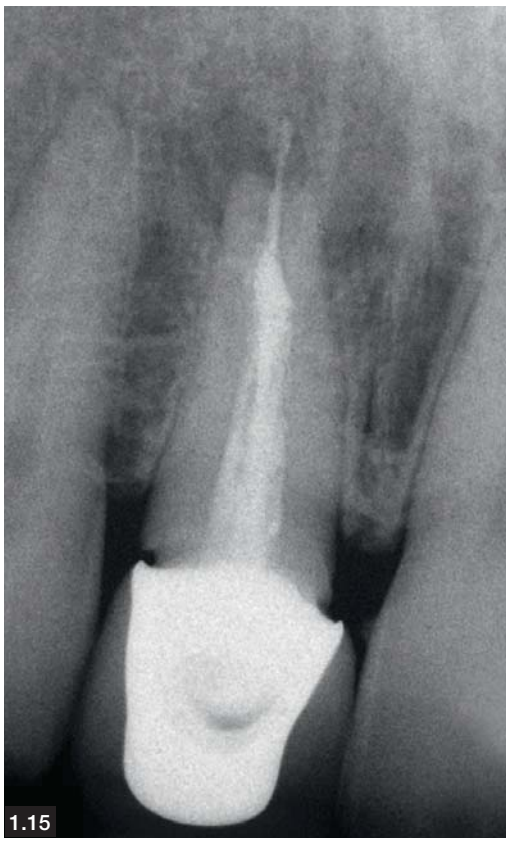


Fig. 1.14: Canal wall with consistent bacterial biofilm and dentin mud.

out in previously untreated teeth.
The content of the root canal is generated by a chronic periapical inflammatory reaction. Therefore, the operational causes that make it impossible to achieve the desired effect cannot always be determined (Figs. 1.15-1.18). Failure remains intrinsic to the clinician's inability to completely remove the *pathogenic noxa* responsible for the radiographically detectable periapical reaction, regardless of whether it is clinically evident. With regard to the microbiological issues, the causes of failure are simultaneously simple and complex. The studies conducted by Kakehashi et al.[8, 9] clarified the etiology of apical periodontitis beyond all reasonable doubt by demonstrating that the vast majority of cases are mainly caused by bacteria. In the absence of bacteria, the periapical reaction in dental elements that have been deprived of their pulp does not develop. This finding was extensively corroborated by subsequent studies by Sjogren[10], Sundqvist[11-13], Moller et al.[14], and Nair[15, 16]. More recently, important contributions were made by Siqueira[17-19] and Ricucci[20, 21].
In some cases, the presence of bacteria inside the root canal may not be the only trigger of periapical diseases, because their proliferation in the ecological niches of the periapical contour[20] may be just one contributing factor for the development of a chronic inflammatory reaction in the periapical tissues that is difficult to treat using conventional orthograde therapies. Having pointed out that the microbiological aspect is the prevailing factor, whether it is already present in the phases of the primary



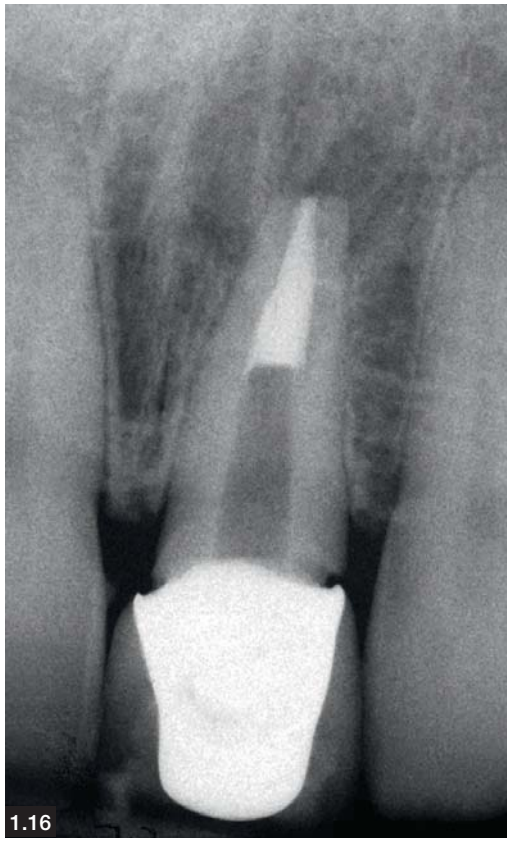
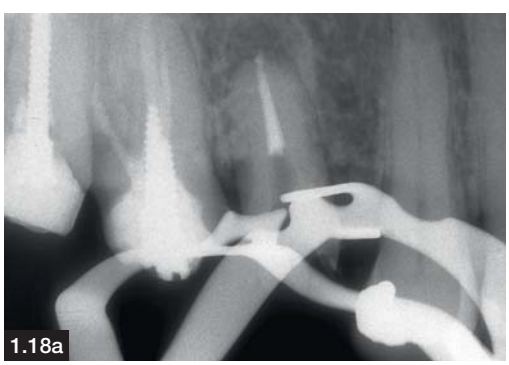
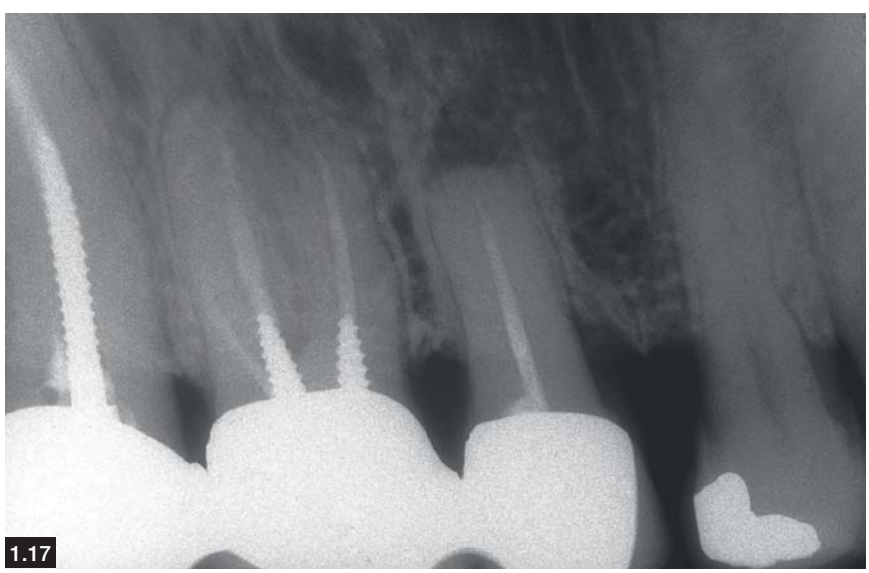


Fig. 1.15: Typical situation of a periapical disease secondary to an incorrect endodontic treatment; a poor relationship exists between the canal lumen and filler material at apical level.

Fig. 1.16: Retreatment performed with a different quality of shaping and filling of the apical limit.





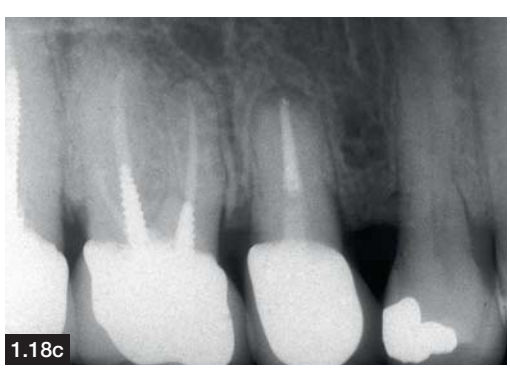


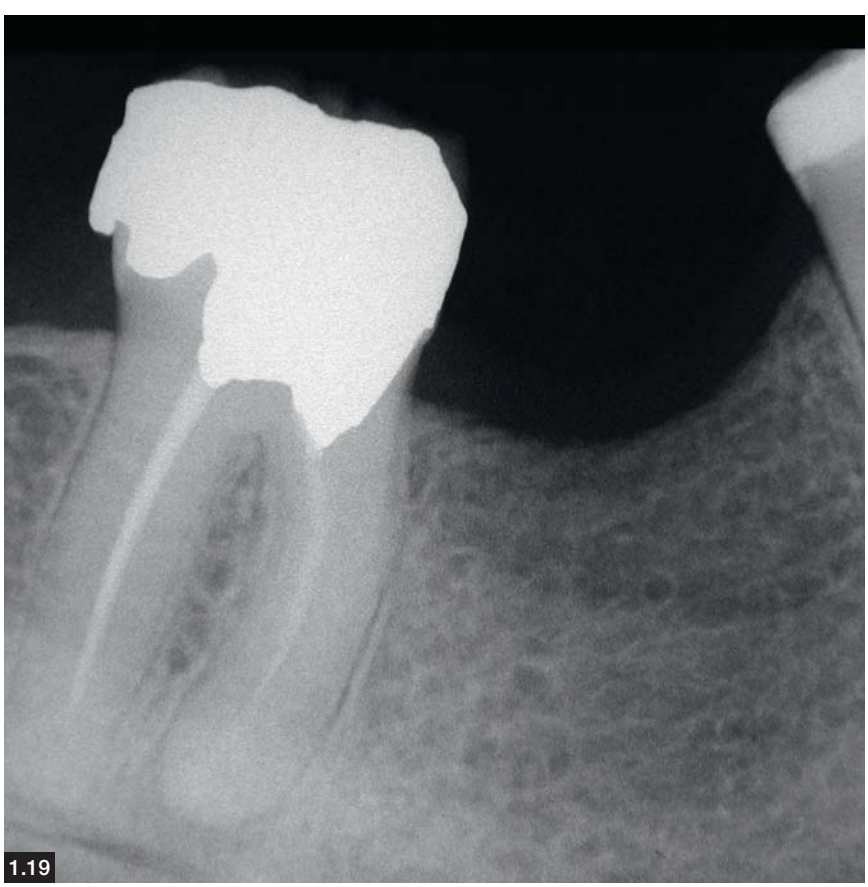
Fig. 1.17: Radiotransparent periapical lesion in the upper premolar.

Fig. 1.18a-c: Retreatment and evaluation at two different time points; the final outcome is clinically satisfactory but the radiographic study, although better than at the beginning, has not given the expected result approximately one year later.

treatment or it is the result of inadequate treatment carried out in the first instance, other factors, such as the concomitant presence of viruses[22, 23] and yeasts (Candida albicans)[24-26] cannot be ignored.
It is also important to remember that foreign body reactions, caused by the filling materials used previously, may occur[27].
A recent systematic review (A) described the role of the apical extrusion of the sealer, reporting a 32% higher risk of contributing to a nonhealing outcome in teeth with extrusion than in those without. In an analogous study, Mello et al. (B) obtained similar final considerations, although the quality of the studies included was not of the highest possible level.
It goes without say that the presence of a rich bacterial flora in the early stages of treatment makes a satisfactory result in the first endodontic treatment less likely[27-29]. This notwithstanding, the practitioner's inability of clinicians to remove the entire bacterial component from the endodontic compartment remains the primary cause of failure, and one that cannot be eradicated with sufficient certainty, regardless of the endodontic procedure adopted. In some cases, once the associated risks and benefits have been weighed up, clinicians find themselves in the position of having to consider retreatment, primarily for clinical reasons. An emblematic situation is shown in Figures 1.19-1.24.
The patient was referred given the need to perform prosthetic work due to the loss of masticatory function in quadrant four.
After a thorough clinical examination, mild pain was observed when chewing in the right lower quadrant at the last molar; the x-ray showed slight ectasia of the periodontal space of element 47.
The proposed therapeutic solution is to retreat this tooth and to rehabilitate the arch to guarantee restored function to the whole area. The clinical and radiographic scenario shows the steps of the retreatment, the steps of the treatment carried out on element 45, and the evolution over time from 3 to 18 years later. In the pages that follow, similar successful cases are reported up to almost 20 years.

Fig. 1.19: The two-dimensional radiographic study shows a slight ectasia of the mesial periapical space of element 47; radiotransparency in this area is only intuitable but not quantifiable.

Fig. 1.20: Work length achieved better than that of the previous endodontic treatment.


1.19

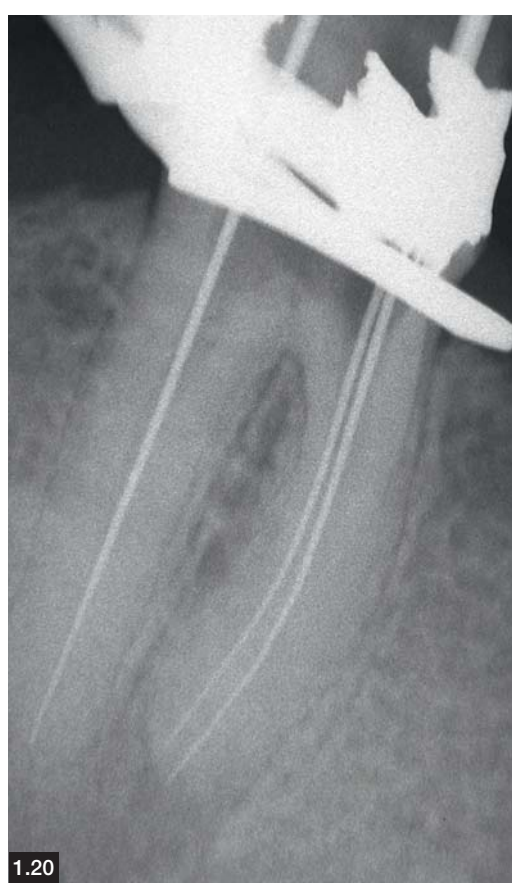

1.20

Fig. 1.21: Filling of the endodontic space with its composite reconstruction; long-term temporary restoration to reevaluate symptomatology and functionality over time.

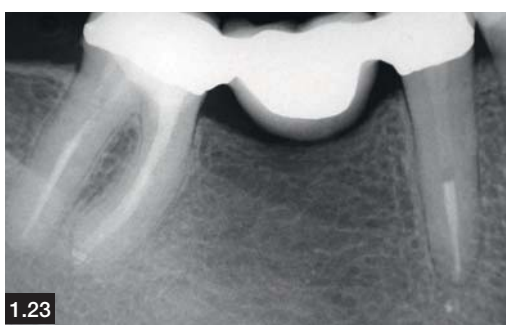


Fig. 1.22: Follow-up x-ray after 1 year warranting the preparation of a bridge.

Fig. 1.23: Follow-up x-ray of the bridge after 3 years.

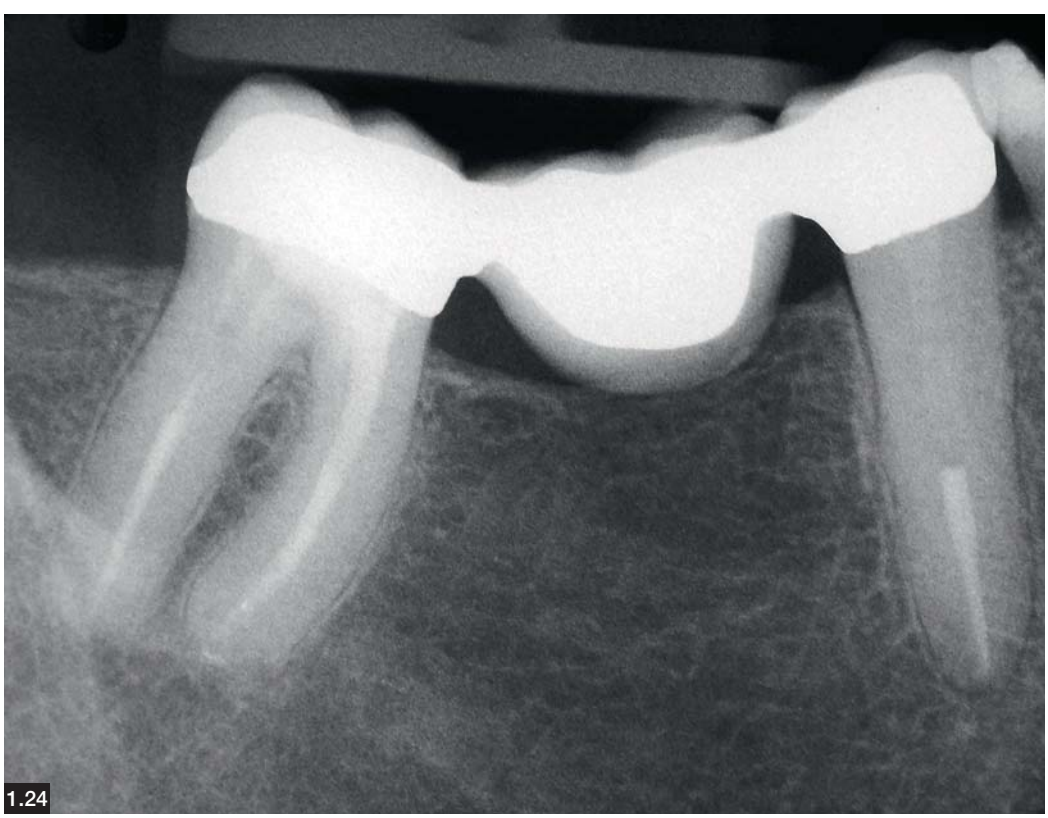


Fig. 1.24: Same prosthetic artifact x-rayed after 18 years.

CASE REPORT 1

Severe root resorption: result after 18 years

The analysis of the case, from the very first consult, seemed to be very complex; the tooth in question had been reconstructed several times with little success. The continuous contamination of the endodontic space with salivary fluids resulted in a consistent periapical reaction that was extrinsic with extensive root resorption at the expense of the distal root canal.

Figure 1: The diagnostic x-ray that shows a clear and extensive pariapical lesion with massive resorption of the distal root of the lower molar; the mesial canals do not appear to have been shaped, and it is possible to observe that part of the distal root canal has not been instrumented.

Figure 2: The clinically-evident fistula is traversed by a cone of gutta-percha to establish the congruence between the periapical lesion and the fistuolous path: the radiograph confirms this contiguity.

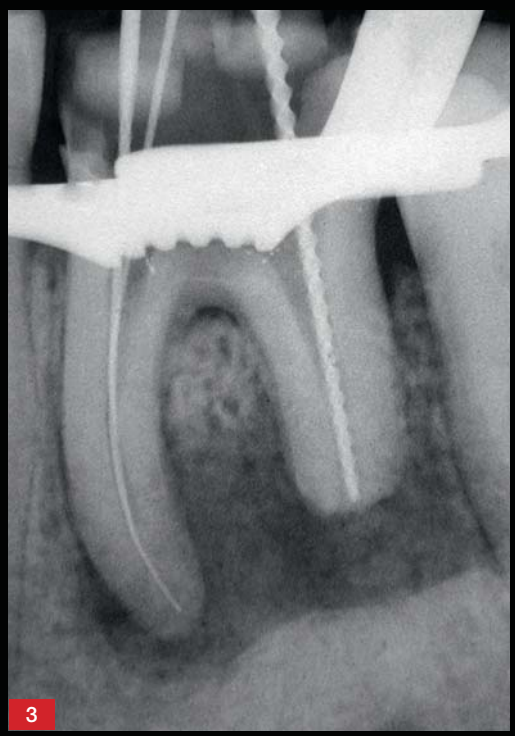


Figure 3: Once the root canal content has been emptied, the length of the root canals is measured.

Figure 4: The new endodontic treatment was completed with direct coronal reconstruction; due to the poor reliability of the tooth element, no further reconstruction was planned.

At the time, there was no pathological periodontal probing or dental mobility such as to suggest an impairment of the supporting tissues. This encouraged the clinician to pursue the path of orthograde retreatment. Although during the examinations carried out, the clinician has always suspected a chronic situation below the lesion, but the absence of clinical symptoms always comforted both the doctor and the patient, until the desired end result was achieved.

Figure 5: Although the 1-year x-ray shows a drastic reduction in radio-transparency, it has not completely resolved.

Figure 6: The same tooth three years later.

Figure 7: The x-ray at 18 years shows the satisfactory resolution of a condition that, at first glance, could have led to the clinician to extract the tooth.

CASE REPORT 2

Lower molars with different anatomies

Although these two cases are similar in terms of clinical condition, they differ greatly in terms of the anatomical features taken into consideration, since they are all lower molars. Anatomical variations often play a decisive role in the evolution of periapical disease and misinterpretations can lead to relevant parts of the endodontium being overlooked.

Figure 1a: A diabetic, patient with well-controlled general health comes in for an appointment complaining of pain in quadrant 4. Two endodontic lesions are observed, a primary lesion in tooth no. 47 and a secondary lesion in tooth no. 46.

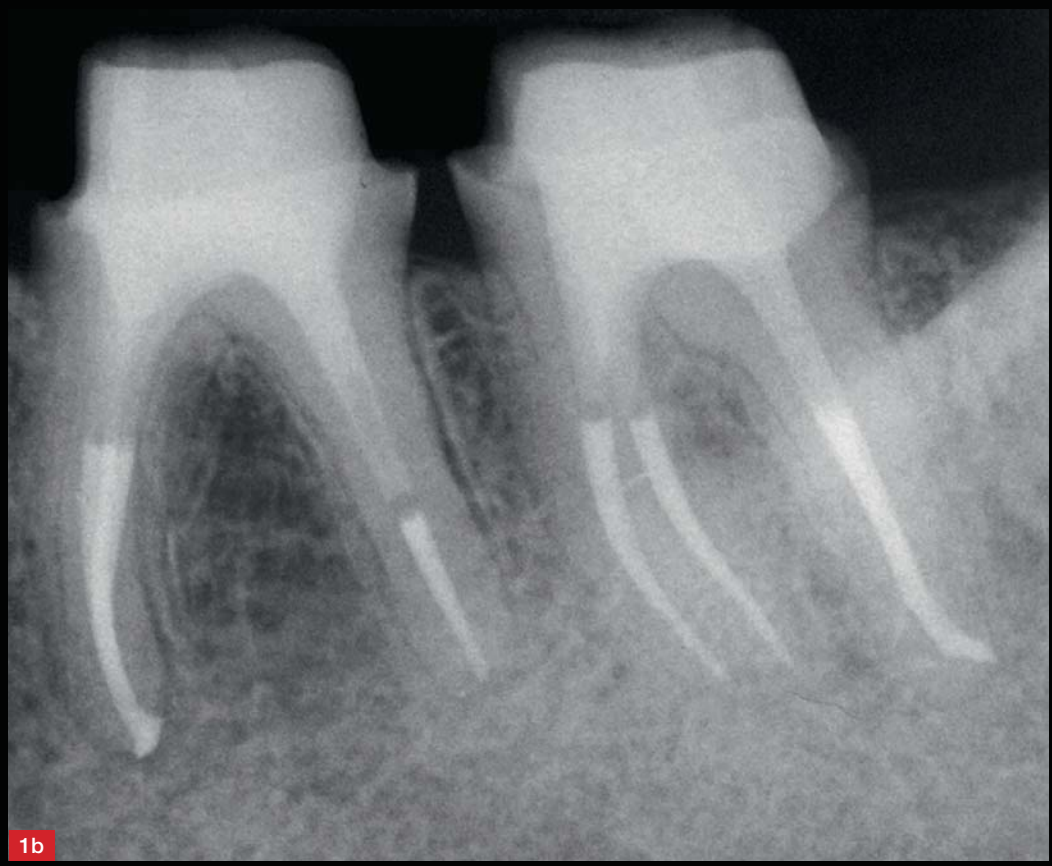


Figure 1b: Resolution after 1 year, the patient still has temporary restorations.

Figure 2: Radiographic view of the lower molar with periapical disease; note the inadequate length of the treatment.

Figure 3: Coronal access and an adequate apical shape have made it possible to retrace the entire endodontic space, to seal it properly and to design a correct reconstruction with adhesive techniques.

Figure 4: The scenario at the end of the reconstruction with fiber root canal posts.

Figure 5: A 10-year X-ray reveals complete reconstruction of the periapical bone and excellent integration of the restoration.

The epidemiology of periapical disease

Chronic inflammatory diseases of endodontic origin in the maxillary bones are a far from negligible event; recent findings indicate that approximately 10% of the population has at least one tooth with endodontic problems[30]. The epidemiological data on periapical disease vary significantly depending on the approach to dental care, resulting in a low prevalence in some countries, and a higher prevalence in others (Table 1.1). In Italy, few related findings have been published; however, on the basis of the studies conducted in the last decade, the observations reported in Box 1.1 have been highlighted. Many of these studies are based on observations performed on panoramic x-rays (Figs. 1.25-1.26) whereas, others use different imaging techniques, including Cone-Beam Computed Tomography (CBCT)[31], a description of which is provided in the next chapter (Figs. 1.27-1.30).

Recent studies have been carried out using this technique, which is more sensitive in detecting periapical disease of endodontic origin. The results are provided below.

Paes da Silva et al.[32] selected a sample of about 300 images and reported a 35% prevalence of periapical rarefactions related to inadequate endodontic treatments.

Table 1.1 **EPIDEMIOLOGICAL DATA ON THE PREVALENCE OF PERIAPICAL DISEASES IN VARIOUS POPULATIONS WORLDWIDE**

	Year	Imaging technique employed	Patients	Teeth analyzed	Treated teeth present and examined	% apical periodontitis out of all teeth	% of treated teeth out of all examined teeth	% of correctly treated teeth with periapical lesions	% of incorrectly treated teeth with periapical lesions	Country
Jimenez-Pinzon et al.	2004	OPT*	180	4453		4.2	2.1		64.5	Spain
Kabak et al.	2005	OPT	1423	8632		12			45	Belarus
Siqueira et al.	2005	OPT		2051	2051		100	18	71	Brazil
Tercas et al.	2006	OPT	200	5008	553	5.9	11		42.5	Brazil
Estrela et al.	2008	OPT		1372	1372		100	12.1	71.7	Brazil
Frisk et al.	2008	OPT	490				23	36	24.5	Sweden
Georgopoulou et al.	2008	OPT						39.2	67.6	Greece
Tavares et al.	2009	OPT		1035	1035		100	19	93.5	France
Peters L.B. et al.	2010	OPT	178	4594		7	4.8	24.1	55.8	Netherlands
Kim S.	2010	OPT			896	22.8			29.3	Korea
Santos et al.	2010	OPT			291		100	11	19	Brazil
Al-Omari et al.	2011	OPT	294	7390	4655	11.6	5.7		87	Jordan
Chala et al.	2011	OPT				63.79			39.5	Morocco
Kamberi et al.	2011	OPT	193	4131	95	12.3	2.3		46.3	Kosovo
Lopez-Lopez et al.	2012	OPT	397			34	59	23	42	Spain
Kalender et al.	2013	Periapical OPT and Rx	1006	24730	7986	7.01	9.4		62	Cyprus
Jersa et al.	2013	OPT	312	7065		7	18		78	Lithuania
Berlinck et al.	2015	Rx periapicali	1126	25292		7			16.7	Brazil
Huumonen et al.	2017	OPT	5335	120635	32571	4.42	5.3		15.3	Finland
Kielbassa et al.	2017	OPT	1000	22586	2504	6.4	11.1		42.6	Austria

*OPT: orthopantomographic radiogram.

Box 1.1 PREVALENCE OF CHRONIC INFLAMMATORY DISEASES OF ENDODONTIC ORIGIN IN ITALY

Few epidemiological studies have been carried out in Italy (Table 1.2). Generali et al. reported that the prevalence of apical periodontitis was equal to 6.6% of the teeth involved; 10.8% of all the elements presented evidence of endodontic treatment. In 45.8% of the latter, a periapical lesion was observed. Hence, the percentage of apical periodontitis was higher in endodontically treated teeth than in untreated teeth, and no close correlation was observed between the quality of canal fillings and the prevalence of apical periodontitis. In the same year, Cotti et al. analyzed 318 patients and found that periapical pathologies were attributable to endodontium infections in 7.9% of the teeth examined; of which, more than 50% were found in endodontically treated teeth. Similar findings were confirmed by Covello et al. In a study on 214 subjects using digital panoramic x-rays, the authors observed that almost half of endodontically treated teeth had a radiologically visible periapical inflammatory reaction.
More recently, in a preliminary study conducted in 2014 in the Milan area, Fini et al. reported similar results. Dolci et al. described a more optimistic scenario using similar methods but with a more significant sample.

Table 1.2 ITALIAN EPIDEMIOLOGICAL DATA

	Year	Imaging technique employed	Patients	Teeth examined	Treated teeth present and examined	% of apical periodontitis out of all teeth	% of treated teeth out of all the teeth analyzed	% of teeth correctly treated with periapical lesions	% of incorrectly treated teeth with periapical lesions	Country
Generali et al.	2007	OPT*	214	4707	226	6.6	10.8	29.3	71.7	Italy
Cotti et al.	2007	OPT	318	7287	293	7.8	4.1	50.8	62.3	Italy
Covello et al.	2010	OPT	384	9423	1081	8.3	11.4	-	41.6	Italy
Fini et al.	2014	OPT	108	1284	318	9.4	24.8	19	47	Italy
Dolci et al.	2016	Periapical Rx	312	8101	534	1.3	6.6	-	17	

*OPT: orthopantomographic radiogram.

Cotti E, Lusso D, Baroni C, Dettori C. *Valutazione sullo stato di salute periapicale di un campione di popolazione sarda*. G It Endo. 2007;21(1):1-8.

Covello F et al. *Prevalence of apical periodontitis and quality of endodontic treatment in an Italian adult population*. Oral Implantol. 2010 Oct-Dec; 3(4):9-14.

Dolci M et al. *Prevalence and distribution of endodontic treatments and apical periodontitis in an Italian population sample*. European Journal of Inflammation. 2016;(14)1:48-53.

Fini M and Grassi M .*Prevalence of* periapical pathologies in a sample of adults in the Milan area. In Cardinali F, Fornara R, Gorni F, Gagliani M. La risoluzione delle complessità nei ritrattamenti. Dental Cadmos. 2014;(10)2-24.

Generali P et al. *Prevalenza di parodontiti apicali croniche e qualità dei trattamenti endodontici in una popolazione adulta italiana*. G It Endo. 2007;21(1):35-40.

Van der Veken et al.[33] conducted the most extensive study with CBCT tests in a large sample of patients (631). In this study, the prevalence of periapical diseases is approximately 6%, which is in line with the results of other studi conducted in neighboring countries. More than half of all endodontically treated teeth had inadequate canal filling, a result that is consistent with recent studies (Table 1.3). One of the most important findings is the prevalence of periapical lesions in endodontically treated teeth; almost half of the treatments had problems, suggesting that this treatment is not performed using the correct criteria by most dentists worldwide. In short, post-treatment endodontic disease – or that with a persistent aetiology involving a periapical lesion of endodontic origin – does not look set to decrease over time and, despite the fact that, in percentage terms, it involves a limited number of dental elements, it affects a large part of the population. Indeed, although, on the one hand, the number of affected teeth per individual are

Fig. 1.25: Orthopantomographic scenario in patients suffering from various periapical pathologies; the degree of definition of individual lesions is barely noticeable.


1.25

Fig. 1.26: Similar scenario to the previous but with manifestations of more evident periapical lesions; notice on the upper canine left the apical overfilling.

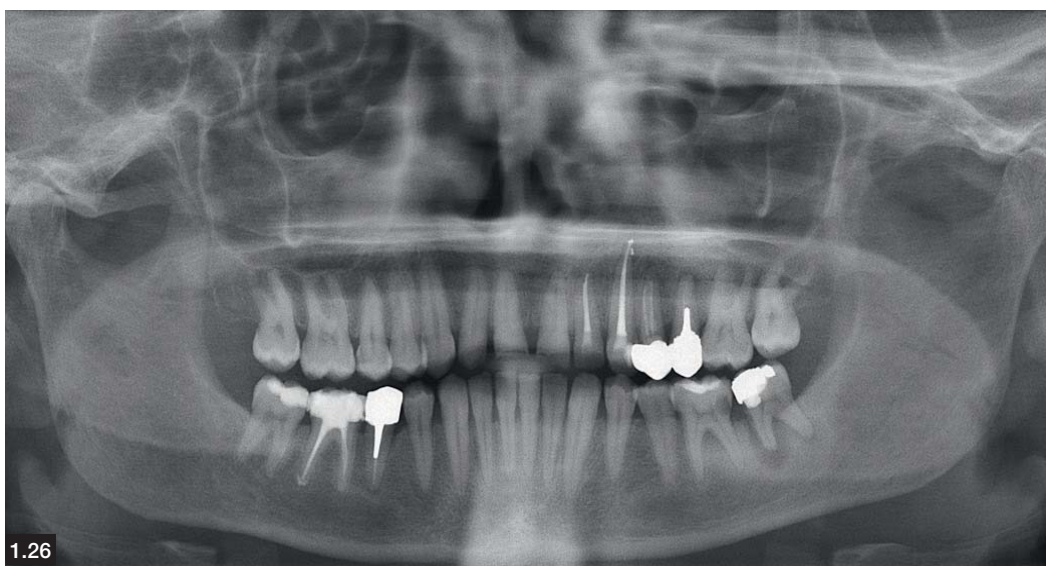

1.26

Fig. 1.27: Intraoral x-ray presenting an area of radiotransparency at the mesial root of tooth 16 and a suspected lesion on tooth 15.


1.27

Fig. 1.28: A three-dimensional image (Cone-Beam Computed Tomography, CBCT) makes it possible to obtain an optimum view of the periapical tissues.

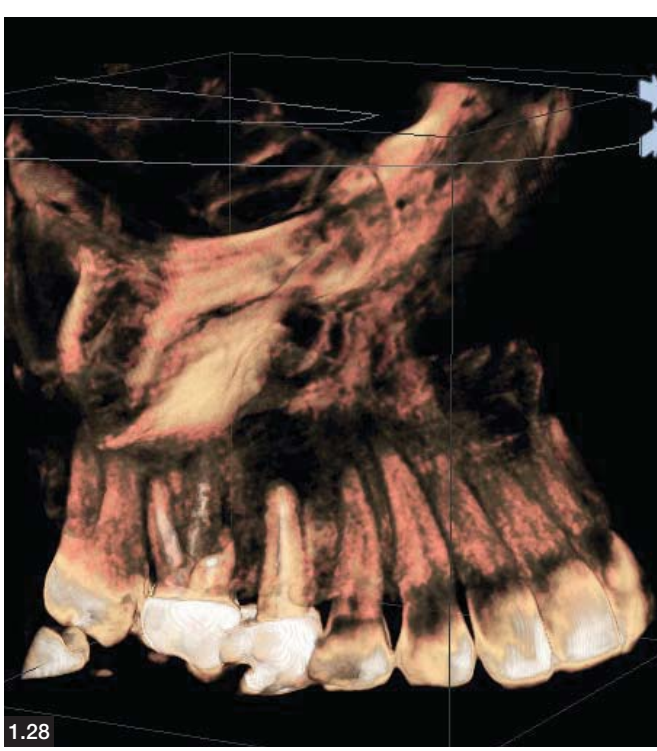

1.28

Table 1.3 **EPIDEMIOLOGICAL DATA COLLECTED BY CONE-BEAM COMPUTERIZED TOMOGRAPHY (CBCT)**

	Year	Imaging technique used for analysis	Patients	Teeth examined	Treated teeth present and examined	% of apical periodontitis out of all teeth	% of treated teeth out of all analyzed teeth	% of teeth correctly treated teeth with periapical lesions	% of incorrectly treated teeth with periapical lesions	Country
Paes da Silva et al.	2013	CBCT	300	5585	-	7	8.9	-	35.4	Brazil
Dutta et al.	2014	CBCT	245	3595	-	5.8	4.8	-	47.4	UK
Lemagner et al.	2015	CBCT	100	2368	431	8.6	8.6	-	40.8	France
Karabucak et al.*	2016	CBCT	1397	1137	1137	59.5	-	-	82.8	-
Van der Veken et al.	2017	CBCT	804	11117	1357	5.9	12.2	22.8	46.6	Belgium

* The Authors examine only the teeth affected by periapical disease and check for the presence of unidentified canals (consequently, untreated): among the teeth with lesion, those with unidentified canals-not treated were found to be 23.04%.

Paes da Silva Ramos Fernandes LM et al. *Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation*. Dentomaxillofac Radiol. 2013;42(1): 80179163.

Dutta A et al. *Prevalence of periradicular periodontitis in a Scottish subpopulation found on CBCT images*.Int Endod J. 2014 Sep;47(9):854-63.

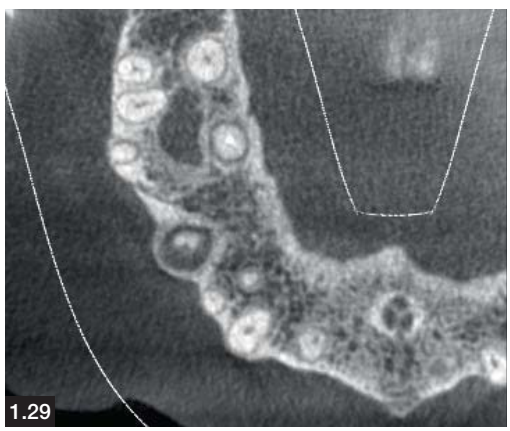
Lemagner F et al. *Prevalence of Apical Bone Defects and Evaluation of Associated Factors Detected with Cone-beam Computed Tomographic Images*. J Endod. 2015 Jul;41(7):1043-7.

Karabucak B et al. *Prevalence of Apical Periodontitis in Endodontically Treated Premolars and Molars with Untreated Canal: A Cone-beam Computed Tomography Study*. J Endod. 2016 Apr;42(4):538-41.

Van der Veken D et al. *Prevalence of apical periodontitis and root filled teeth in a Belgian subpopulation found on CBCT images*. Int Endod J. 2017;50(4):317-29.

Burklein S, Schafer E, Johren HP, Donnermeyer D. Quality of root canal fillings and prevalence of apical radiolucencies in a German population: a CBCT analysis. Clin Oral Investig 2019 (on-line pre-press).

few; on the other, the epidemiological evidence available suggests that this problem may affect millions of people.
Pak et al.[34] conducted a very thorough study that moved in this direction; they clarified through the joint analysis of several community studies, they clarified that about 5% of the teeth presented endodontic periapical disease.
About 10% of the teeth had received nonsurgical endodontic treatments; of the 30,000 treated teeth incorporated in the systematic review, about 36% of them had a periapical lesion of endodontic relevance. Almost all of the patients involved in the study had a periapical lesion associated with unsuccessful root canal therapy. The most worrying fact is that, instead of being eradicated, the disease persists, even in settings where the quality level of dental care is presumed to be high, as reported by a number of authors[35-37];


1.29

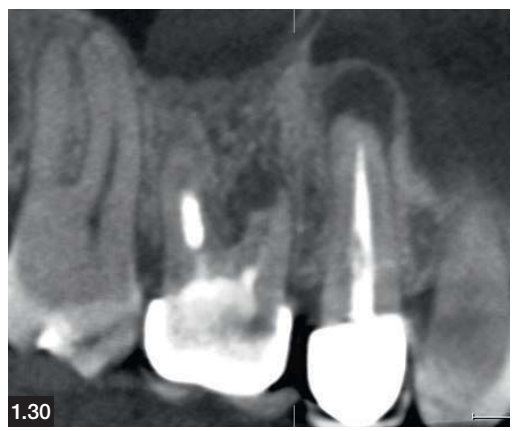

1.30

Fig. 1.29: Axial image providing the best possible view of the two lesions.

Fig. 1.30: Sectional lateral vision showing the extent of the disease (the case is presented in an aesthetic way in Chapter 2 on page 101).

Box 1.2 PREVALENCE OF PERIAPICAL DISEASE OF ENDODONTIC ORIGIN

The periapical disease of endodontic origin appears to be of little relevance in percentage terms considering the teeth involved (on average less than 10%), but is of far greater importance if we consider the number of patients involved (more than 60% of the population attending dental appointments).

certain paradoxical situations have been highlighted. In studies comparing groups of patients who underwent endodontic treatment 20 years ago and those treated in more recent times, there was little difference in the percentage of subjects with periapical diseases of endodontic origin and the quality of the treatments administered, suggesting that although the techniques available to practitioners have changed, the variable associated with the practitioner and his/her expertise in this setting is still a key factor for the achievement of an optimal result. New and old techniques do not appear to differ greatly in terms of the achievement of satisfactory clinical and radiological results. Kirkevang et al.[38] compared two groups of Danish patients undergoing endodontic treatments at different times and observed that patients trends were similar with regard to both the periapical lesions and the therapies used to treat them. The authors deduced that the advent of *new surgical technologies* had not helped them to reach significantly better results. Similar conclusions were reported by another study conducted in a Dutch population reported the same conclusions by comparing groups of patients about 20 years apart[37]. Based on a recent study in a German population, a limited improvement was observed over a timespan of 20 years, but data were insufficient to affirming that new technologies might radically improve the outcomes of the root canal treatment (D). Therefore, the prevalence of periapical inflammatory diseases of endodontic origin is not decreasing, and new technologies are unable to address clinicians-related issues and the objective difficulties in the eradication of bacteria proliferating in biofilm within the endodontium.

EVOLUTION

New techniques have no clear advantages in terms of success of endodontic therapies.

Periapical diseases and systemic diseases

As discussed in the previous paragraphs, the percentage of endodontically treated teeth affected by periapical problems is not very high; however, if we consider the prevalence of the condition in population terms, it affects millions of people. This fact has always attracted the interest of researchers not only because of the local effects but also the potential systemic effects. A number of studies[39, 40] have attempted to establish potential relationships between systemic disease and chronic periapical infection problems[41, 42]. As the population continues to age[43-45], the likelihood that these jaw bone conditions may affect other body tissues does not seem remote[46]. In a systematic review[43] of studies on a population over 65 years of age, the percentages of periapical lesions (Fig. 1.31) and endodontically treated teeth were high; given that the latter was less affected by inflammatory periradicular conditions, age did not affect the likelihood of a successful endodontic retreatment. In other words, a periapical disease is equally likely to heal once the endodontic bacterial component has been eliminated in both young and old individuals; indeed, several studies have confirmed that the prognosis is not influenced by the age variable[47, 48]. Treatment of endodontic periapical diseases is therefore possible at all ages, provided thorough patient assessments are performed. Diagnostic work-up and treatment plan assessments will be discussed later in this chapter. With regard to the correlations between systemic and periapical disease, a number of situations of a general nature can be associated with periapical diseases of endodontic origin; for example,

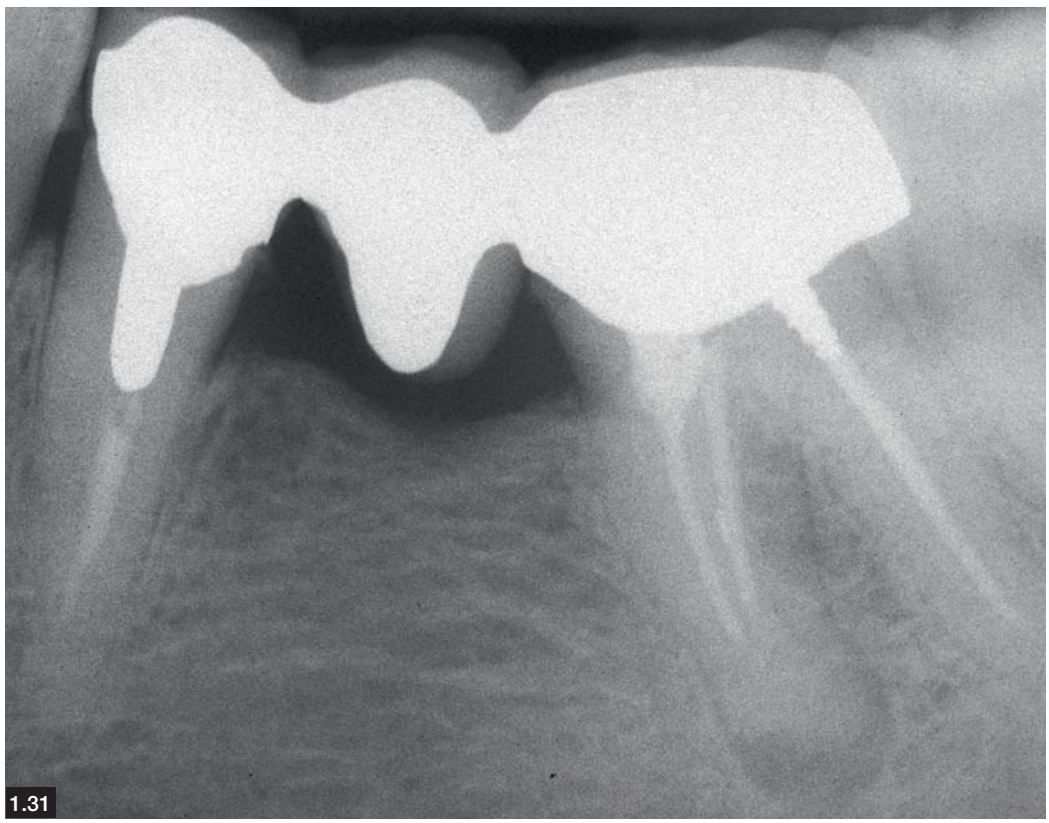


Fig. 1.31: Radiographic scenario in a patients of more than 80 years of age. The lesion is not symptomatic; given the general situation, the patient should have an annual x-ray to monitor the progress of the lesion.

Fig. 1.32: In a patient with juvenile diabetes, nuanced symptoms are present at tooth 21; the radiographic scenario suggests a recrudescence of the periapical lesion, but the CBCT study shows a fracture. The therapeutic treatment option is not practical because of the patient's general health.

patients with insulin-dependent diabetes mellitus have an increased risk of developing endodontic disease[49, 50] (E-F-G) (Fig. 1.32). Hypertension, on the other hand, does not play a fundamental role in the development of periapical diseases[51]. Other chronic diseases, such as rheumatoid arthritis[39, 52], have not shown any significant correlation with periapical endodontic lesions. Undoubtedly, certain health conditions or overt diseases are unfavorable factors in the success of an endodontic treatment (Table 1.4); however, this fact alone does not allow a definitive decision in favor of the most radical solution, i.e. extraction, and numerous viable alternatives are available.

Table 1.4 **MEDICAL AND SYSTEMIC FACTORS CONDITIONING THE SUCCESS OF ENDODONTIC TREATMENT**

• NUTRITIONAL DEFICIENCIES	• HORMONAL IMBALANCES
• DIABETES	• AUTOIMMUNE DISEASES
• KIDNEY DISEASE	• OPPORTUNISTIC INFECTIONS
• BLOOD DISORDERS	• STEROID THERAPY

Correlation between periapical disease and cardiovascular diseases

Cardiovascular conditions and periapical inflammations of endodontic origin deserve serious evaluation. In a recent study, Virtanen et al.[53] reported the correlation between *cardiovascular diseases* and the presence of periapical lesions linked or not to unsuccessfull endodontic treatments. The findings appeared to be noteworthy and thus should be considered particularly in adult patients.
A systematic review of literature[54] on this subject revealed that cardiovascular diseases can coincide with periapical lesions of endodontic origin; by examining a number of studies, the authors found positive correlations, but of mild evidence, in more than 70% of the works analyzed. This opinion is shared by Cotti and coll.[55] who examined the issue several times, not merely from a cardiological point of view. Pasqualini et al.[56] highlighted the positive correlation between cardiovascular disease and the number of missing teeth or teeth with periradicular inflammatory diseases. Hence, inflammatory situations in dental elements must be considered (Fig. 1.33a-d) not only with regard to the local issues but also to the systemic implications. These implications are indicative of a complex setting to which due attention must be dedicated; once again we are aware of the need to integrate our observations as dental surgeons with those of the general practitioners responsible for the patient's general health.

CARDIOVASCULAR DISEASES

The relationship between cardiovascular diseases and periapical lesions of endodontic origin has been supported by preliminary clinical evidence.

Pharmacological therapies and retreatments

In addition to nondental disease, pharmacological therapies can also play a decisive role in the development or nonresolution of periapical lesions of endodontic origin because they interfere with bone metabolism to some extent.


1.33a


1.33b


1.33c


1.33d

Fig. 1.33a-d: A cardiopathic patient who came in for observation with pain in tooth 47. The x-ray (a) shows a periapical lesion and poor-quality endodontic treatment. Once the previous filling had been removed, the tooth was resealed (b-c). The 5-year follow-up (d) showed a perfect reintegration of the periapical tissues of the tooth.

Table 1.5 **EXAMPLES OF COMMERCIALLY AVAILABLE BISPHOSPHONATES**

Active substance	Trade name	Nitrogen content	Route of administration	Relative potency	Common use
Alendronate	Fosamax®	Yes	Oral	700	Osteoporosis
Clodronate	Bonefos® Clasteon®	No	Oral	10	Hypercalcemia secondary to neoplastic diseases
Ethylated	Didronel®	No	Oral and IV	1	Paget's disease
Ibandronate	Boniva®	Yes	Oral and IV	4000	Osteoporosis
Pamidronate	Aredia®	Yes	Oral and IV	325	Cancer
Risedronato	Actonel®	Yes	Ora	2000	Osteoporosis
Tiludronate	Skelid®	No	Oral	10	Hypercalcemia secondary to neoplastic diseases
Zoledronate	Zometa®	Yes	IV	700	Cancer
Zoledronate	Reclast®	Yes	IV (once/year)	700	Osteoporosis

Source: AAE POSITION STATEMENT – Endodontic Implications of Bisphosphonate-Associated Osteonecrosis of the Jaws. https://www.aae.org/specialty/wpcontent/uploads/sites/2/2017/07/bisphosonatesstatement.pdf

In addition, the need to carry out treatment in elderly subjects with concomitant health problems must always be a cause for concern for the clinician, who is faced with the prospect of a clinical session that frequently neither easy nor short). We will take a closer look at certain pharmacological aspects of general interest:

1. endodontic treatments in patients on bisphosphonate therapy;
2. which patients require prophylactic antibiotic treatment;
3. analgesic strategies prior to root canal therapy and the use of anesthetics in retreatments.

Basic rules, supported by scientific evidence, will be provided on these issues, which are increasingly frequently observed in patients, especially the elderly.

The use of antibiotics can also contribute to the exacerbation of periapical diseases immediately after the retreatment. Segura-Egea et al.[57] stress that antibiotics should only be used when necessary and at the lowest effective dose during the postoperative period.

This aspect should therefore be carefully pondered in terms of the patient's general condition, concomitant medication, and potential interactions.

Bisphosphonates and endodontic retreatments

Patients who are receiving treatment or have been treated with bisphosphonates are increasingly frequent.

In recent times, bisphosphonates have been used in myriad ways for the short- or long-term treatment of many conditions affecting the bone and bone marrow and for breast and prostate cancer[58].

Bisphosphonates can be classified according to whether they are administered orally or intravenously, and their dosage and the duration of therapy depend on the method of administration.

Tables 1.5 and 1.6 show the conditions for which *bisphosphonates* are used on a continuous basis and clarify the boundaries within which the highest level of attention is required.

BISPHOSPHONATES

The clinical situations that should be focused on are those that develop in patients who received high-dose IV therapies.

Table 1.6 **PATIENTS RECEIVING TREATMENT WITH BISPHOSPHONATES: DEGREE OF RISK FOR RELEVANT ENDODONTIC PROCEDURES**

Patients at risk		
High	**Medium**	**Low**
Prolonged intravenous therapies for neoplasms (multiple myeloma, prostate or breast cancer, lymphomas, leukemia) or Paget's disease	Intensive care for the treatment of osteoporosis lasting more than three years, both intravenously and intraorally	Oral therapies for the treatment of osteoporosis

Source: AAE POSITION STATEMENT – Endodontic Implications of Bisphosphonate-Associated Osteonecrosis of the Jaws. https://www.aae.org/specialty/wpcontent/uploads/sites/2/2017/07/bisphosonatesstatement.pdf

Bisphosphonate therapy is considered to be responsible for osteonecrosis of the jaws, as first reported by Ruggiero and Marx[58-61].
In other studies[62, 63], maxillary osteonecrosis is more common in the mandible than in the maxilla and is associated with prolonged, high-dose use of these medicinal products.
This posology is associated with a number of diseases such as multiple myeloma, metastatic forms of prostate and breast cancer, and certain forms of leukemia and/or lymphomas, Paget's disease, and severe osteoporosis.
As intravenous administration is common, the anamnestic finding is already in itself decisive with regard to the potential development of osteonecrosis of the jaws, despite its extremely low prevalence, which varies according to the source consulted and is less than one in ten thousand in the most favorable situations, and never more than 2% of treated cases in situations of greater severity.
Osteonecrosis of the maxilla is frequently associated with traumatic events, first and foremost dental extractions, particularly for those in whom the anamnestic risk, i.e., use of high-dose intravenous bisphosphonates, was not considered or was overlooked.
In the endodontic field, Moinzadeh et al.[64] reported that the potential development of osteonecrosis, following contingent canal treatment maneuvers, can be related to two main factors: lesions of the marginal periodontium during the positioning of the clasp for the fixation of the rubber dam and the extrusion of the infected material beyond the root apex during the maneuvers involving the shaping and cleansing of the endodontic space.
The use of anesthetics without vasoconstrictors is also recommended.
For example, in a patient who has received or is currently receiving bisphosphonates therapy for cancer (Table 1.6), the osteonecrosis issue should be addressed with the utmost caution. In other cases, the normal precautions will be more than sufficient for preventing undesirable side effects.
No clear consensus has been reached with regard to the possible effectiveness of antibiotic prophylaxis.
Considering inconsequential problems related to bacterial resistance that could develop in conjunction with the prophylactic regimen, conventional antibiotic prophylaxis (Table 1.7) is recommended for all subjects undergoing root canal treatment, especially in those cases in which the disease has already progressed at periapical level.
The above authors[64] recommend, in particularly severe cases, performing root canal therapy and permanently sealing the canal lumen, even in teeth that should logically be extracted.
This approach would result in a lower risk than that of an extraction.
Endodontic surgery deserves separate consideration.
Despite not being without its risks, the procedure can be performed with relative peace of mind in patients with a limited risk, provided adequate antibiotic prophylaxis is prescribed and the therapy is continued according to conventional regimens, where necessary.
It should only be performed when strictly required in subjects with a high or medium risk, in whom, as mentioned previously, duly-controlled orthograde therapies can be considered[65] instead of surgery,

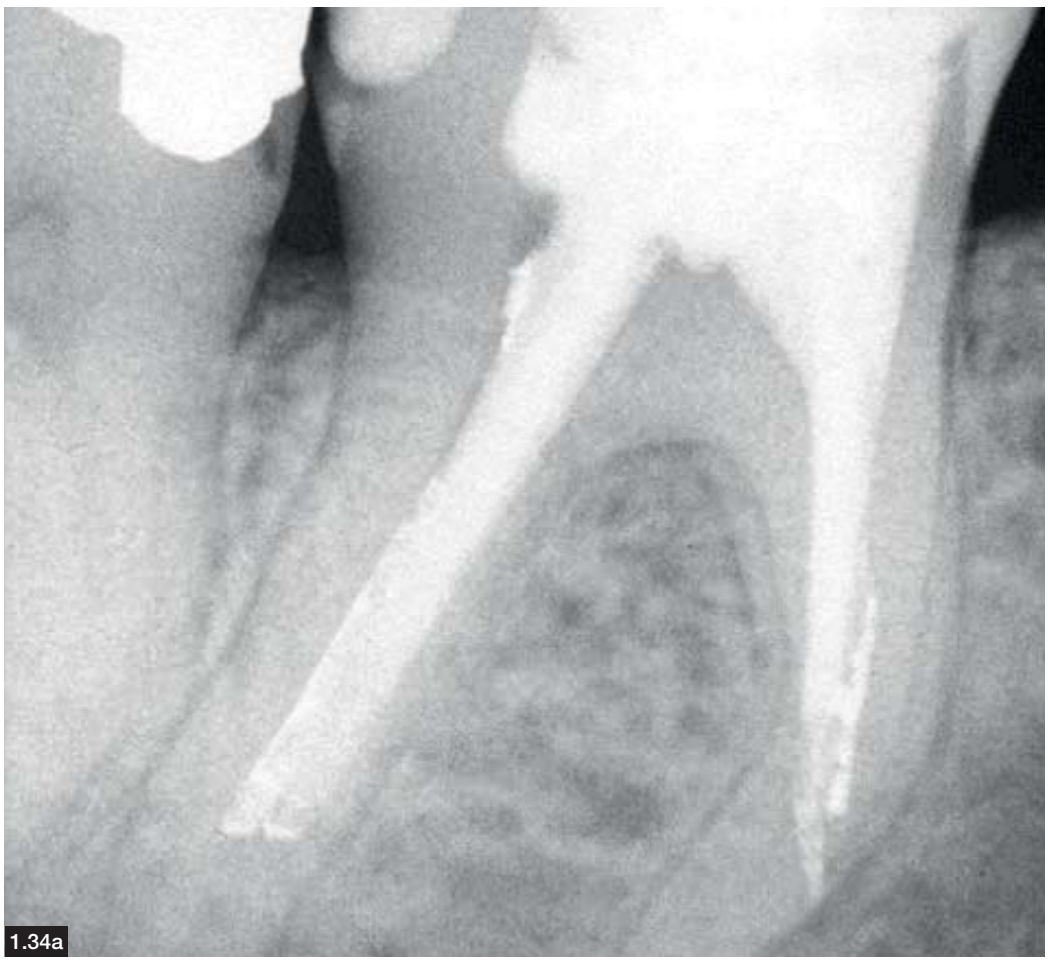


Fig. 1.34a-b: A lower molar with a number of problems associated with inappropriate treatment of the apical third is reviewed and resealed. The response of the periradicular tissues confirms success of the therapy.

precisely to avoid tooth extraction, which is reported by several authors[66, 67] as being one of the main sources of osteonecrosis of the jaws.
In any case, endodontic surgery – provided the early stages are performed correctly by sculpting a flap to obtain effective final suture without mucous dehiscence – would be preferable to extraction, which, as mentioned previously, is one of the main sources of jaw osteonecrosis.

Antibiotic prophylaxis

As retreatment is a surgical procedure that, to a greater or lesser extent, can transfer bacteria into the periapical tissues and, consequently, into the bloodstream, antibiotic prophylaxis must always be considered.
The need to administer it is specifically expressed for certain well-defined groups of patients (Box 1.3).

Attempts to use antibiotic prophylaxis to improve the success rate, however, have not proved ineffective because success is the result of a series of factors of which the spread of bacteria beyond the root apex is thought to be one of the least important[68].
Antibiotic therapy should, in any case, be considered an option in the postoperative phase in the case of infective exacerbations (which do not exceed 6%-7% of the cases treated) in the lifetime of individuals undergoing treatment, despite the presence, in almost half of all cases, of mild or moderate pain not warranting the use of a medicinal product (Chapter 6).
We also refer the reader to Chapter 6 on the use of antibiotics in pre-or postendodontic retreatment period, stressing the percentage of events that deserve this kind of therapy should not exceed 6% of the total number of cases[69].

Box 1.3 **ANTIBIOTIC PROPHYLAXIS**

The European Society of Endodontology (ESE) "Position statement": "the use of antibiotics in endodontics with regard to the use of antibiotic prophylaxis"

Antibiotic prophylaxis should be seriously considered in all patients who may develop bacterial endocarditis as a result of particularly bloody oral interventions.

These include, subjects who have:

- **congenital heart defects**
- **natural and mechanical heart valves**
- **previous history of bacterial endocarditis.**

The general definition of invasive dental procedure is yet to be established. This category may include all clinical procedures that lead to the violation of the gingival margin and surgeries performed to solve periapical diseases of endodontic origin.
All of the following may be added to these conditions leading to perforation of the alveolar mucosa. For example, this category should include all patients who have undergone orthopedic surgery with prosthetic replacement, i.e., hip or knee prostheses. Antibiotic prophylaxis should be considered in patients who have had radiation therapy on the maxillary bones and undergone treatment with bisphosphonates at the recommended doses for cancer (see paragraph *Bisphosphonates and endodontic retreatment*).

TYPES OF PATIENTS	INDICATIONS
Decompensated immune function (leukemia, HIV/AIDS, irreversible renal dysfunction, dialysis, uncontrollable diabetes, chemotherapy, treatment with corticosteroids or immunosuppressive drugs post-transplantation, genetic defects)	Absolute both in endodontic surgery and in orthodontic endodontic treatments taking into account: a) general health of the patient b) related risk of further infection c) risk of cross-reactions with other drugs or side effects
Subjects at risk for the development of bacterial endocarditis (patients with congenital heart defects, heart valves, heart defects and a history of past endocarditis)	Orthograde endodontics and surgery
Patients with hip or knee prostheses	Orthograde and surgical endodontic treatment if within three months of treatment
Exposed to high-dose radiation therapies, especially to the maxillary bones	Orthograde endodontics and surgical treatment
Exposed to high IV doses of bisphosphonates	Endodontic surgery

Montefusco V, Gay F, Spina F, et al. (2008) *Antibiotic prophylaxis before dental procedures may reduce the incidence of osteonecrosis of the jaw in patients with multiple myeloma treated with bisphosphonates*. Leukemia and Lymphoma 49, 2156-2162.

European Society of Endodontology developed by: Segura-Egea JJ, Gould K, , Hakan-Sen B, Jonasson P, Cotti E, Mazzoni A, Sunay H, Tjäderhane L, Dummer PMH.

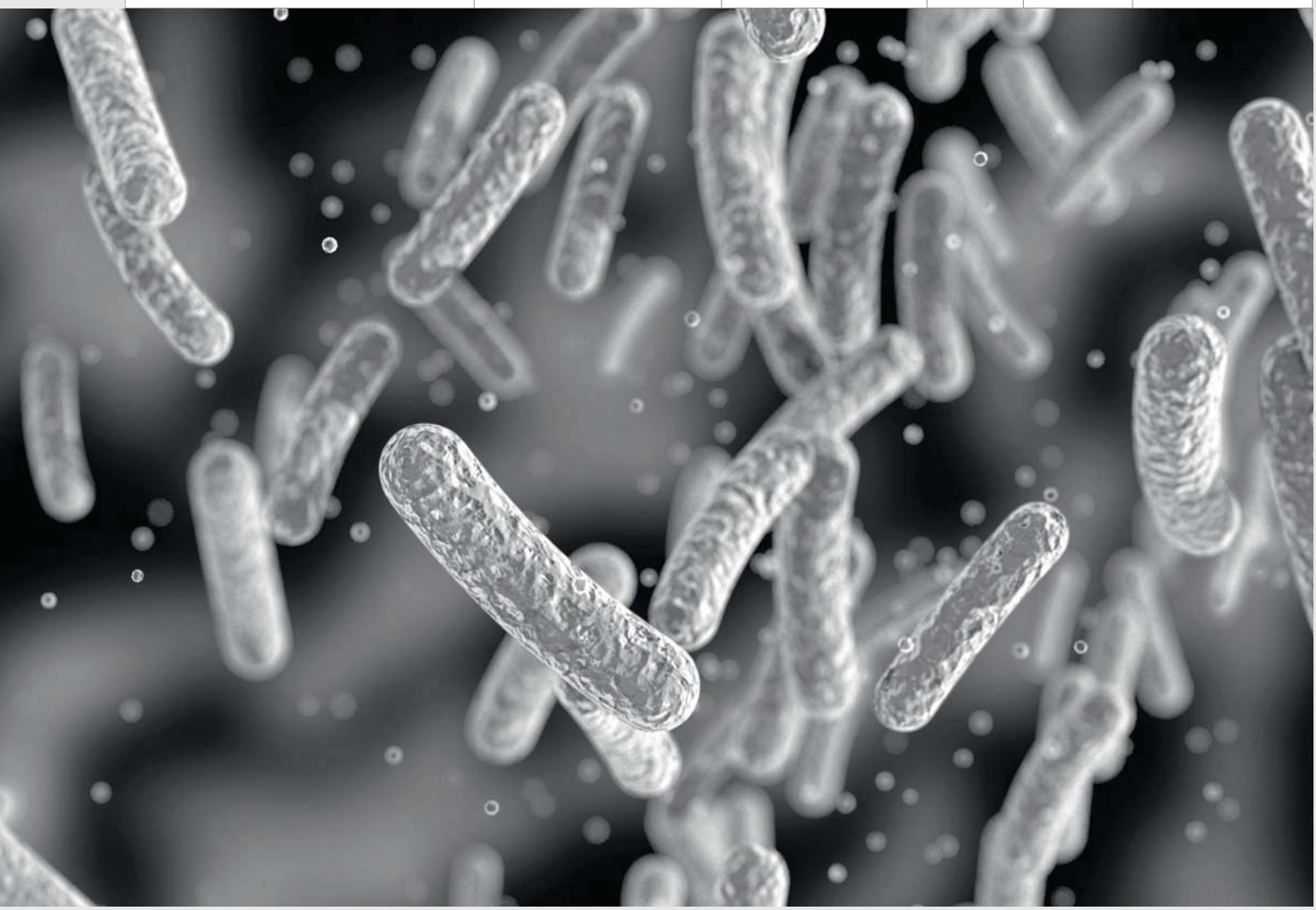
European Society of Endodontology position statement: the use of antibiotics in endodontics. International Endodontic Journal, 51, 20-25, 2018.

* Segura-Egea JJ, Gould K, Hakan-Sen B et al. (2017) *Antibiotics in Endodontics:* a review. International Endodontic Journal 50, 1169-1184.

Sollecito TP, Abt E, Lockhart PB, et al. (2015) *The use of prophylactic antibiotics prior to dental procedures in patients with prosthetic joints: evidence-based clinical practice guideline for dental practitioners–a report of the American Dental Association Council on Scientific Affairs*. Journal of the American Dental Association 146, 11-16.e8.

Table 1.7 **RECOMMENDED ANTIBIOTIC PROPHYLAXIS REGIME IN ENDODONTICS***

Patient group	Antibiotic	Route of administration	Dosage		Time before the procedure
			Adults	**Children**	
Standard general prophylaxis	Amoxicillin	Oral	2 g	50 mg kg^{-1}	1 h
Unable to take oral medications	Ampicillin	IV or IM	2 g	50 mg kg^{-1}	Within 30 min
Allergic to penicillins	Clindamycin Cefalexin or cefadroxil Azithromycin or clarithromycin	Oral Oral Oral	600 mg 2 g 500 mg	20 mg kg^{-1} 50 mg kg^{-1} 15 mg kg^{-1}	1 h 1 h 1 h
Allergic to penicillins/amoxicillins/ampicillin and unable to take oral medications	Clindamycin Cefazolin	IV IV	600 mg 1 g	20 mg kg^{-1} 25 mg kg^{-1}	Within 30 min Within 30 min



Box 1.4 ASSESSMENT OF CANAL TREATMENT OUTCOMES ACCORDING TO THE EUROPEAN SOCIETY OF ENDODONTOLOGY (ESE)

Root canal treatment should be evaluated at least after 1 year and subsequently if necessary. The following results indicate favorable outcomes: absence of pain, swelling, and other symptoms; absence of fistula; no loss of function; and radiological evidence of normal periodontal ligament space around the root.
The root canal treatment has an uncertain outcome if the radiographs reveal that a radiotransparent lesion remains, that is, has the same size or has decreased but it has not disappeared completely. In this case, the lesion should be further evaluated for a minimum of 4 years until it resolves. If a lesion persists after 4 years, then the root canal treatment is considered responsible for the endodontic post-treatment disease; whether it precedes the treatment itself and therefore is not resolved, or it is the result of it, in any case, it has not achieved the desired results.

The canal treatment has unfavorable outcomes when the following occurs:

1. The tooth shows signs and symptoms of infection.
2. A radiologically visible radiolucent lesion appears after treatment or a pre-existing lesion has increased in size.
3. A lesion has remained the same size or only decreases in size during the 4-year follow-up.
4. Signs of root resorption are present.
   In this case, additional treatments should be carried out.

Source: European Society of Endodontology. Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. International Endodontic Journal, 2006;39,921-930.

Endodontic pretreatment analgesic strategies and anesthesia

Although true anesthesia is not necessary during retreatment, as the dental pulp is no longer present in the root canal, the patient should be placed in a state of absolute relaxation during the procedure, which can be long and complex. This type of treatment causes anxiety especially in females[70].
Cho et al.[71] reported that in particularly anxious patients, the mere application of an anesthetic ointment can be effective in establishing a good state of analgesia due to the infiltration of articaine as anesthetic[72].
In cases where surgery is required, submucosal administration of tramadol (50 mg) may be sufficient, since the analgesic effect generated by the anesthetic, especially in the lower arch, is likely to be potent[73].
This drug also increases the effect of anesthetics, which are particularly effective when used synergistically in many instances.
In conclusion, the use of anesthetics seems advisable in these cases, despite the absence of dental pulp in most cases.
The use of specific analgesics or anesthetics is recommended for patients who are in pain.

Success and failure: what clinical and radiographic parameters?

We come now to the core of this chapter, that is, how to judge, with sufficient precision, the success or failure of endodontic therapy and how to assess whether a tooth should be retreated.
In previous paragraphs of this chapter, we have dealt with general issues.
In subsequent chapters, we will perform a thorough examination of the clinically relevant factors that result in the development of chronic periapical inflammatory diseases or failure to resolve them.
A sufficiently approximative approach should therefore be adopted when establishing a cut-off between success and failure.
This is no mean feat, given the existence of a vast range of intermediate situations that should be better defined and outlined.
Defining success and failure is the key to approaching this problem.

Box 1.5 ASSESSMENT OF TREATMENT OUTCOME ACCORDING TO THE AMERICAN ASSOCIATION OF ENDODONTISTS (AAE)

To further confirm the data in Box 1.4, numerous detailed and exhaustive documents are available from the website of the American Association of Endodontists, the results of which can be summarized with a series of clinical and radiological considerations that do not differ greatly from those expressed by the European Society of Endodontology. These considerations include correct procedures for the isolation and disinfection of the endodontic space, correct filling within 2 mm of the radiological apical limit, and appropriate posttreatment reconstruction. For detailed reading, please refer to the sitemap below.

https://www.aae.org/specialty/wpcontent/uploads/sites/2/2018/04/TreatmentStandards_Whitepaper.pdf
https://www.aae.org/specialty/wpcontent/uploads/sites/2/2017/06/2014treatmentoptionsguidefinalweb.pdf

Fig. 1.35: An upper premolar and an upper molar with prosthetic reconstructions both present poor endodontic treatments that have caused significant periapical damage.

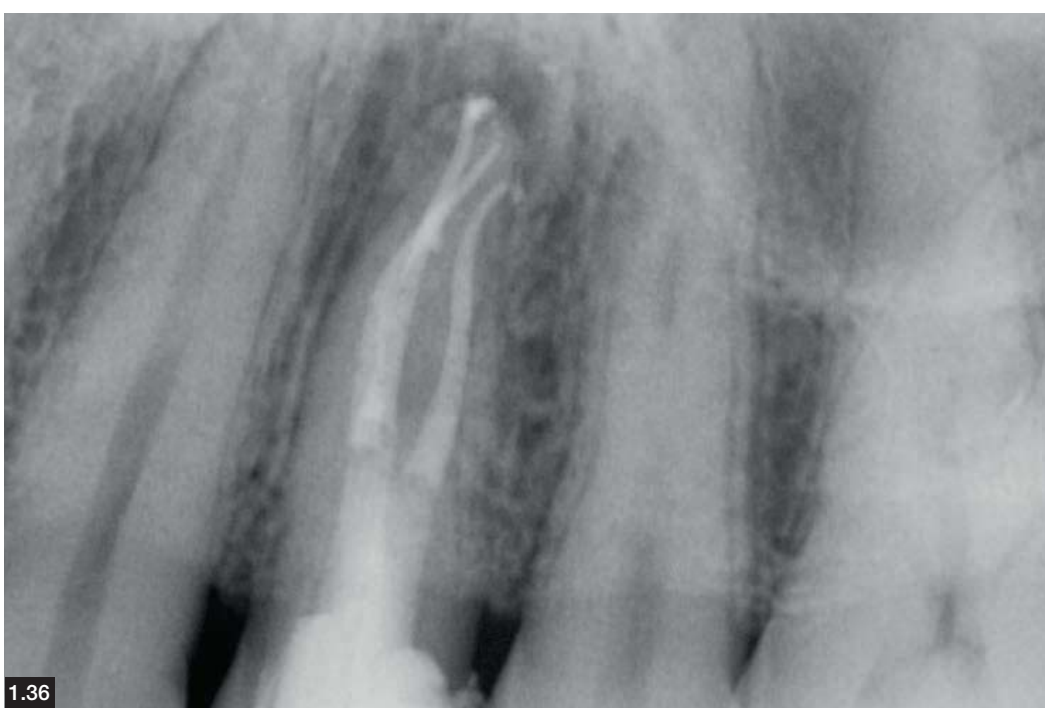


Fig. 1.36: An upper premolar with a complex anatomy (three canals) has been correctly shaped and blocked; the continuous black line surrounding the apical portion of the tooth confirms the success of treatment.

Some authors[74] have minimized the radiological aspect, while others have emphasized the clinical aspect[75]. The need for the two scenarios to be concordant would lead to further subdivision into four categories: from clinical and radiological success to failure for both categories, passing through the two intermediate scenarios in which the clinical and radiological aspect present two different scenarios. The function of the tooth has been proposed as a central element for evaluation; however, not all scholars agree that a clinically asymptomatic tooth should be considered in any case free of post-treatment diseases[2, 4]. To solve this question, the only viable solution is to adopt the guidelines of the European Society of Endodontology (ESE, reported in Box 1.4) and the American Association of Endodontists (AAE, reported in Box 1.5). By summarizing the guidelines of the major international scientific societies and drawing on other studies, can we realistically define the cut-offs between health and disease? When faced with a patient who has received poorly-managed endodontic therapy, would we have all the information needed to make the right decisions? The answer, it would seem, is no; indeed, there is a large body of evidence confirming the substantial discordance of therapeutic choices depending on the level of the respondents' professional expertise[76-80]. Clinical factors that are relevant to the absolute indication for retreatment include impossibility of chewing or onset of acute events, such as abscess.

As regards the reconstruction of deficient treatments, in the presence of secondary caries or fractures on previously treated teeth, the signs of periapical suffering, from a radiological point of view, urge the clinician to consider endodontic retreatment as the first step toward tooth restoration. The following phase involves a thorough discussion with the patient regarding the different therapeutic options in reconstructive settings and the possible consequences associated with the procedures listed. If it is well-designed, this therapeutic agreement will protect each of its parties from any possible misunderstanding. Numerous elements of judgment come into play, moving away from the tooth in the stricter sense towards the broader context of patient care and guidelines for the therapeutic decision-making, primarily in relation to those local factors that, in the final analysis, we will consider to in order to decide whether to address the retreatment procedure or whether to start the operational choice in other surgical fields, not least the tooth extraction.

Box 1.6 **CLINICAL AND RADIOLOGICAL NORMALITY**

NORMAL FRAMEWORK TO CLINICS

Absence of:

- spontaneous pain;
- pain caused by chewing or percussion;
- mobility;
- redness or swelling in the adherent mucosa;
- localized periradicular periodontalfistulas orprobes.

Dental structure without dyschromia or of the normal tooth-restoration whole, in a mucous context also free from suspicious chromaticisms.

NORMAL FRAMEWORK TO RADIOLOGICAL

- Uniform periradicular margin.
- Periodontal ligament space not exceeding one millimeter.
- Hard foil circumscribing and clearly delimits the periodontal space.
- Absence of:
  - root resorption;
  - radiotransparent areas periradicular in contiguity with the roots themselves.

Box 1.7 **WHAT TO LOOK FOR ON AN X-RAY**

Coronal

1 Coronal seal

2 Reconstruction material

Radicular

Presence of obstacles inside the canal:

3 Tools

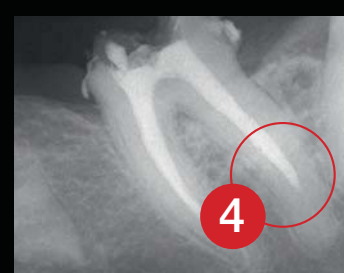
4 Blocks

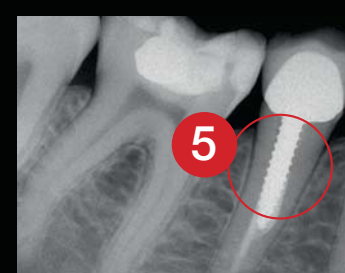
5 Pins

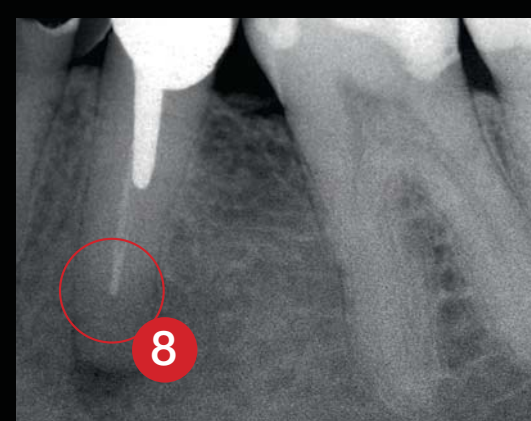
6 Voids

7 Trunk-taper

8 Length of the filling







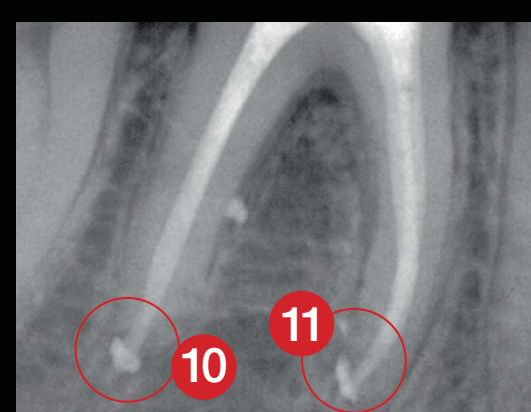
Periradicular

9 Extension along the root of the radiolucent area

9 Amplitude of the radiotransparent area

10 Overfill

11 Appearance of the periradicular ligament



CASE REPORT 3

Suspected periapical lesion in the case of endodontic retreatment

The information provided by two-dimensional X-ray images is often very limited and the pathological state of the tooth must be investigated with three-dimensional X-ray studies. Three-dimensional radiographic x-ray techniques are essential for formulating a diagnosis of chronic apical periodontitis with maxillary sinus involvement.

Figure 1: The two-dimensional x-ray view does not show a very large lesion in the same tooth, the endodontic treatment appears correct, although it shows a modest overfilling.

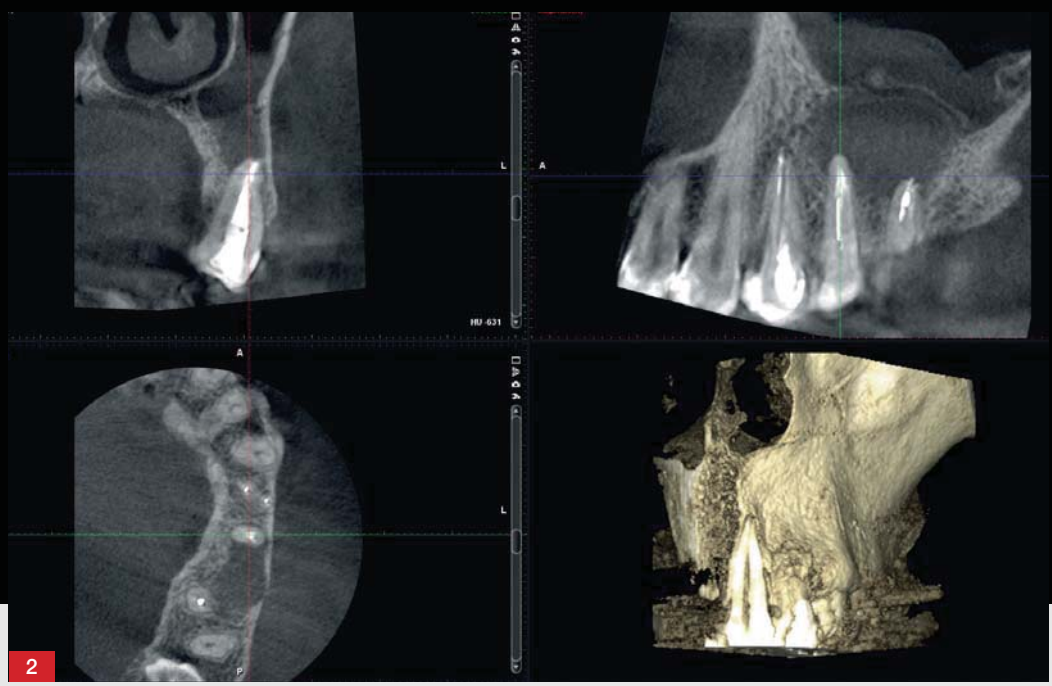


Figure 2: The CBCT image highlights a very large lesion affecting both the premolar and the molar and extends to the floor of the upper sinus.

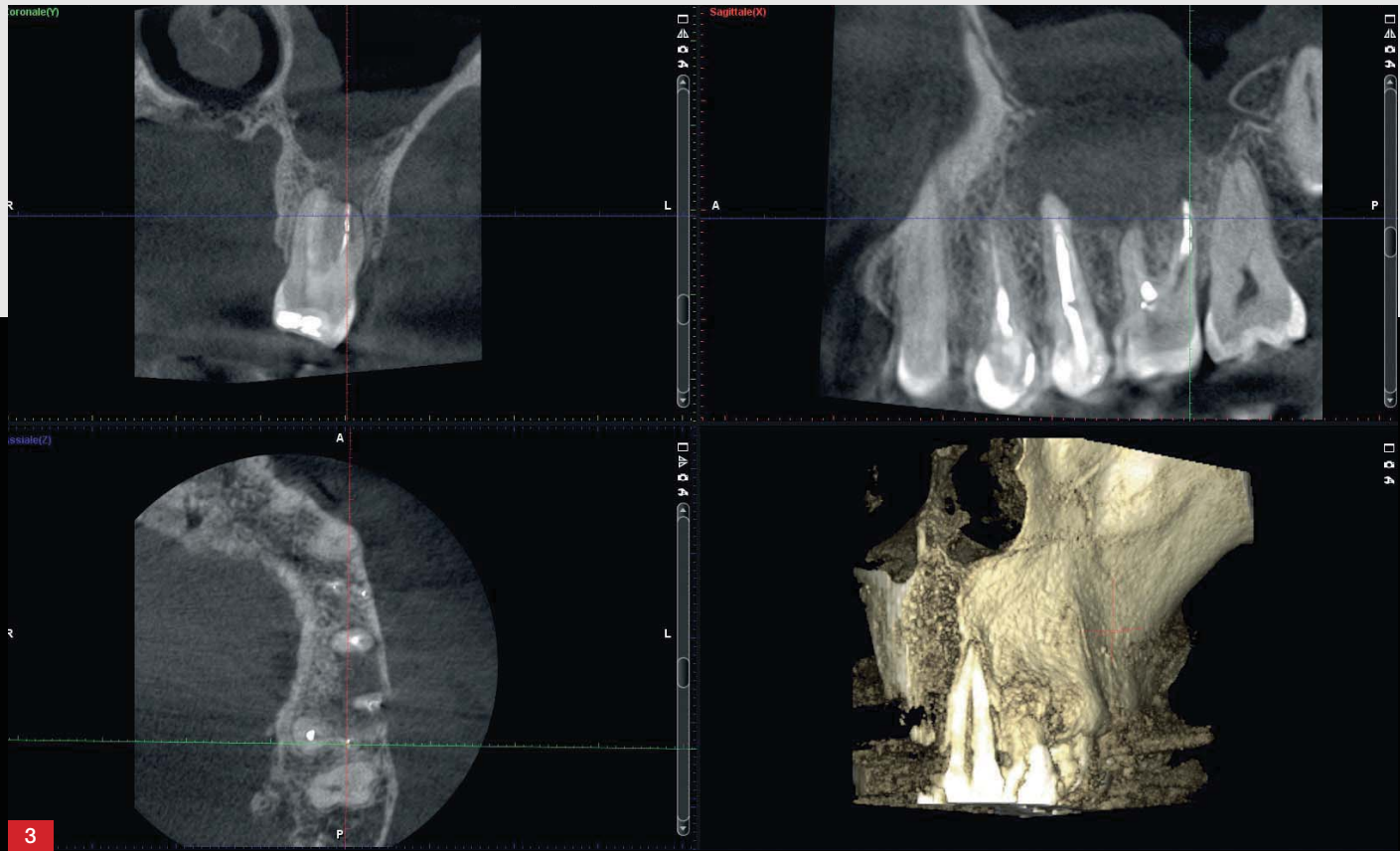


Figure 3: The same scenario seen from a different angle.

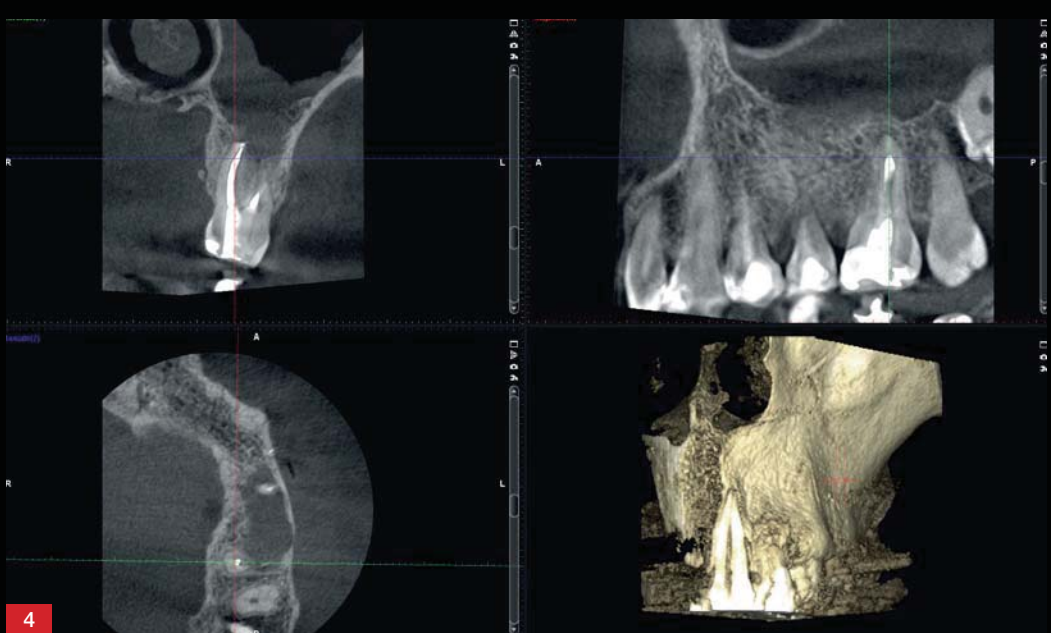


Figure 4: These images clearly show the massive involvement of the maxillary sinus, which could underlie the very severe symptoms reported by the patient. An extra-radicular infection (see next section) could be hypothesized, given the excellent congruence between the canal lumen and the filling material.

CASE REPORT 4

Upper premolar with prosthetic reconstruction: integrated endodontic-orthodontic-prosthetic treatment

The second upper premolar presents clinically and radiologically evident infiltration (Fig. 1); the prosthetic restoration will lead to a reduction in root size and the need to place a root canal post.


1

Figure 1: Second upper premolar with clinically and radiologically evident infiltration.


2

Figure 2: The case before retreatment.


3

Figure 3: After retreatment.


4

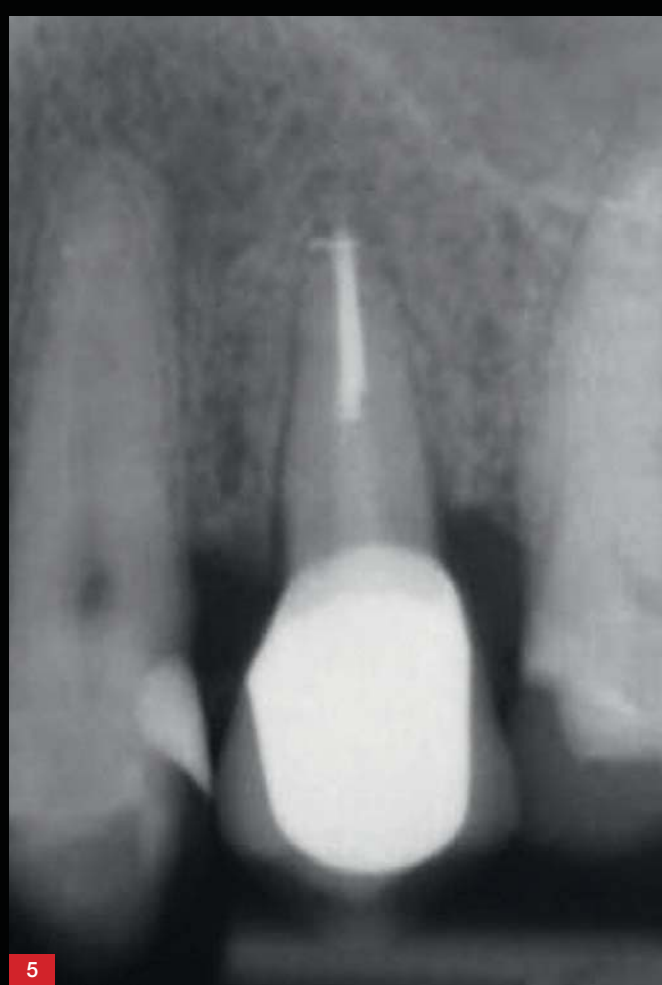

5

Figure 4 and 5: The newly inserted orthodontic appliance and the final result one year later.

In addition, the reduced amount of supporting tissues and the root size encouraged the practitioner, when formulating the treatment plan, to perform retreatment and a root extrusion procedure (Figs. 2-5).
The violation of the coronal seal and of the previous filling bode in favor of the retreatment procedure even in the presence of a periradicular aspect that, despite not being overtly pathological, considering the underestimation of the 2D x-ray, seems increasingly advisable in clinical settings such as those represented in this case (Figs. 6-7).

Figure 6: The abutment on the day of cementation: note the good condition of periodontal tissues.

Figure 7: The 1-year follow-up shows perfect integration with the supporting tissues and neighboring teeth.

Periapical disease classification systems based on x-ray and CBCT images

Based on their analysis of x-rays, a number of scholars have attempted to classify the pathological aspects and the damages caused by previous endodontic treatments to the tooth and/or the supporting tissues, using numerical indices. These include the periapical index, commonly known as the PAI[81] (Box 1.8), which primarily classifies the periapical state of teeth affected by diseases of that district, and the classification proposed by Elyas et al.[82] (Box 1.9). The former index has a significant historical value, whereas the latter reconciles the dental problems and those regarding the supporting tissues to quantify the complexity of any retreatment procedure. The content of this classification system proposed for the analysis of pathological scenarios using CBCT (Box 1.10) is different. The possibility of obtaining a better radiographic detail leads to a redefinition of classification systems; three of those discussed in current literature are reviewed here.

Box 1.8 **PERIAPICAL INDEX SCORE (PAI)**

Developed by Ørstavik et al. the periapical index (often abbreviated to PAI) is a system for radiologically classifying the apical and periapical situation of a tooth affected by inflammatory reactions of endodontic origin using 2D x-rays. The figure below provides a brief description of the classification system that has been used in endodontics to classify the initial conditions as well as the results after endodontic treatment in teeth that are affected or not affected by periapical problems.

Ørstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endodontics & Dental Traumatology 1986;2:20-34.*

1

Apical and periapical structures in normal conditions, periodontal ligaments surrounded by the lamina dura

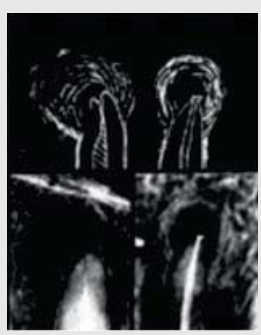
2

Very slight alterations in the bone structure with limited radiotransparency at the periodontal ligament

3

Alterations in the bone structure with slight radiotransparency

4



Well-defined area of radiotransparency, indicating overt periodontitis

5

Very severe periodontitis with very well-defined radiotransparency

In clinical studies, conditions 1 and 2 are often associated with normal scenarios; cases with such a radiographic appearance are classified as healthy.

In clinical studies, conditions with an index greater than or equal to 3 are considered to be abnormal and are incorporated into the groups of cases that are either overtly pathological (usually at the beginning of longitudinal studies) or that do not achieve the desired effect if treated during a longitudinal study.

Box 1.9 X-RAY STUDY: IDENTIFICATION OF THE TEETH AND RATING OF TREATMENT ADEQUACY

X-ray studies play a key role whenever the success of root canal therapy is to be judged. The practitioner must be perfectly aware of the aspects to be examined and considered and forming connections between these findings is not an easy exercise. This makes it essential to establish a sequence of aspects on which to base the analysis, which, in this particular case, consists in assigning a score to each of the elements examined.
This was the aim of the study conducted by Elyas et al., who attributed a dichotomous value to each single item in the list below (1 point if the item is present, 0 if the item is not present) to obtain numerical score. The scores obtained indicate the quality of the treatment, i.e., the higher the score, the poorer the quality of treatment.

The items considered are:

1. Shaping errors

- wrong access;
- steps or hourglass morphologies;
- perforations or erosion of the root wall;
- root canal blocking;
- fractured instruments;
- undetected root canals.

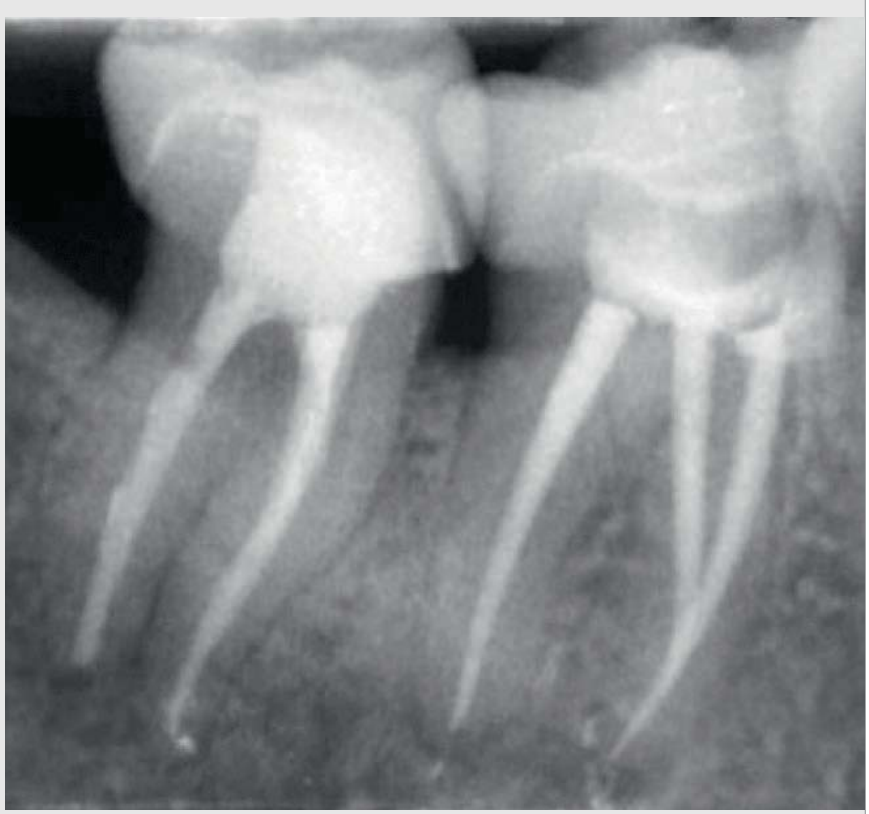
2. Filling errors

- morphological discontinuity and poor-conicity;
- presence of voids;
- presence of bubbles;
- filling limit, short (if more than 2 mm from the radiological apex) or long (if clearly oversized).

Despite the limitations of abstract classifications, this method provides a rough guide for judging the quality of treatment; if the quality is poor, then the tooth should be retreated. Otherwise, in the presence of an endodontic periapical lesion in a well-treated tooth, alternative therapeutic procedures, such as endodontic surgery, should be initiated.

Using the same scoring system, the x-ray does not score any points for the first part; in the filling errors part, one point can be attributed for the presence of clinically irrelevant voids in the distal root. The total score is 1 out of 10, which confirms the correctness of the treatment.

Using on the indices considered, the case has four points for procedural errors in shaping and as many points for errors in the filling phase (a total of 8 out of 10 points).



Eliyas et al. Technical skills in Endodontics. International Endodontic Journal 2017;50;652-66.

Box 1.10 **CBCT-BASED ANALYSIS**

The progress achieved in two-dimensional digital radiological techniques (digital subtraction) (L) and, in particular, the introduction of the CBCT technique in the endodontic field, have called for new indices for evaluating the initial pathological situation (Table 1.8) and parameters for analyzing the success or failure of treatment.
Through analysis with CBCT before and after retreatment therapy, Davies et al.[99] highlighted the sensitivity of this technique in identifying pathological radiotransparency at periapical level; the classification of successful or unsuccessful measures proposed by the authors provides an optimum classification of periapical disease that is otherwise impossible with two-dimensional x-rays. Two cases are given as examples.

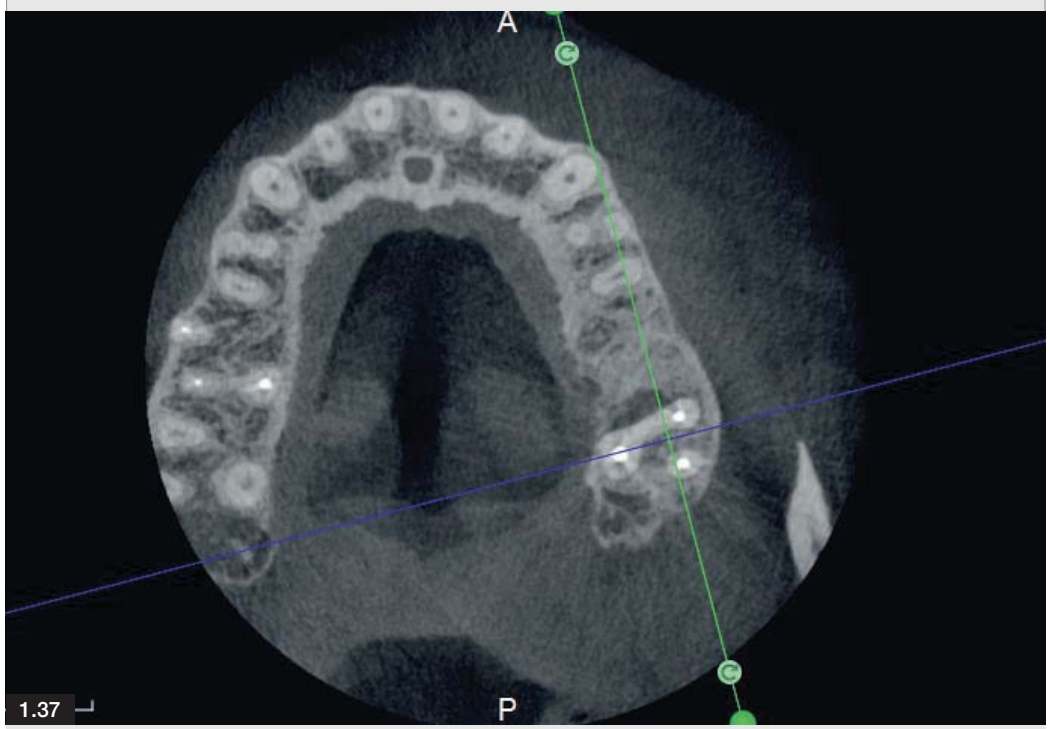


Fig.1.37: Typical CBCT image for dental use, an indispensable tool for making a detailed diagnosis of the problems afflicting the apical periodontium of endodontically treated teeth.

Table 1.8 **CBCT-BASED IMAGING SYSTEMS**

Score	Estrela et al.[1]	Torabinejad et al. (Eri Score)[2]
	Periapical radiotransparency	**Periapical radiotransparency**
0	Absent	Absent
1	0.5-1 mm	< 0.5 mm
2	1-2 mm	0.5-1.0 mm
3	2-4 mm	1.0-1.5 mm
4	4-8 mm	1.5-2.0 mm
5	> 8 mm	2.0-2.5 mm
6		> 2.5 mm
E	Expansion of the periapical cortical bone	
D	Destruction of the periapical cortical bone	

[1] Index to classify periapical diseases identified by CBCT. C. Estrela et al., A New Periapical Index Based on Cone-Beam Computed Tomography. J Endod 2008;34:1325-1331.

[2] ERI (Endodontic Radiolucency Index) for CBCT analysis. M.Torabinejad et al., Incidence and Size of Periapical Radiolucencies Using Cone-beam Computed Tomography in Teeth without Apparent Intraoral Radiographic Lesions: A New Periapical Index with a Clinical Recommendation. J Endod 2018;44:389-394.

CASE REPORT 5

Radiological doubt solved with 3D x-ray

Despite effective retreatment, an upper molar presents a nuanced but persistent symptoms; combined use of multiple investigation techniques alone will lead to the desired diagnostic result.

Figure 1: The intraoral x-ray shows good closure of the root canals; however, the clinical symptoms remain abnormal.

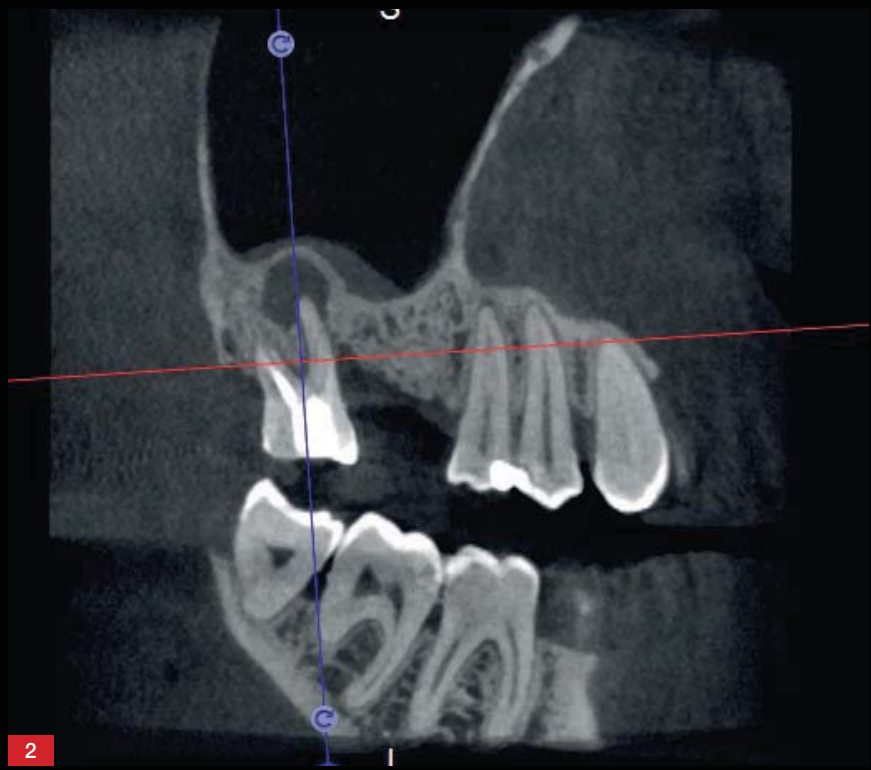


Figure 2: The two images show overt periapical disease that can most likely be attributed, to an extra-radicular infection (see next section).

Figure 3: The same situation with a posteroanterior view.

CASE REPORT 6

Severe periapical lesion with perforation on lateral incisor

The patient, a 26-year-old female, had undergone root canal treatment on tooth 12 as a result of a traumatic event; after about 2 years after treatment, a narrow vestibular fistula was observed on the same tooth.

Figure 1: The fistula in the vestibular area tooth 12.

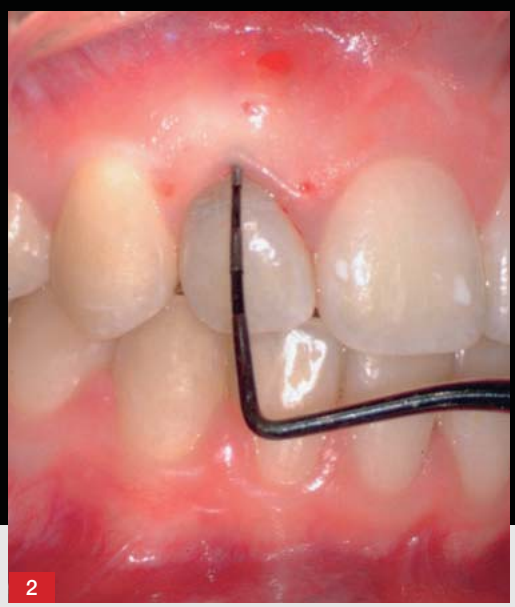


Figure 2: The radiographic study shows a very extensive lesion secondary to a non-exceptional but acceptable endodontic treatment.

This kind of evolution must always lead to a suspicion of periodontal impairment and, in this specific case, must attract the attention of the clinician who, in such cases, with young patients, has double responsibilities, be they diagnostic or therapeutic.

Figure 3a: The CBCT image brings to light a radically different scenario, because it is the result of a perforation of the middle third with extrusion of the filling material.

Figure 3b: CBCT image, the occlusal view does not appear to reveal further impairment; a consistent lack of vestibular cortical bone tissue at tooth no. 12 is also evident.

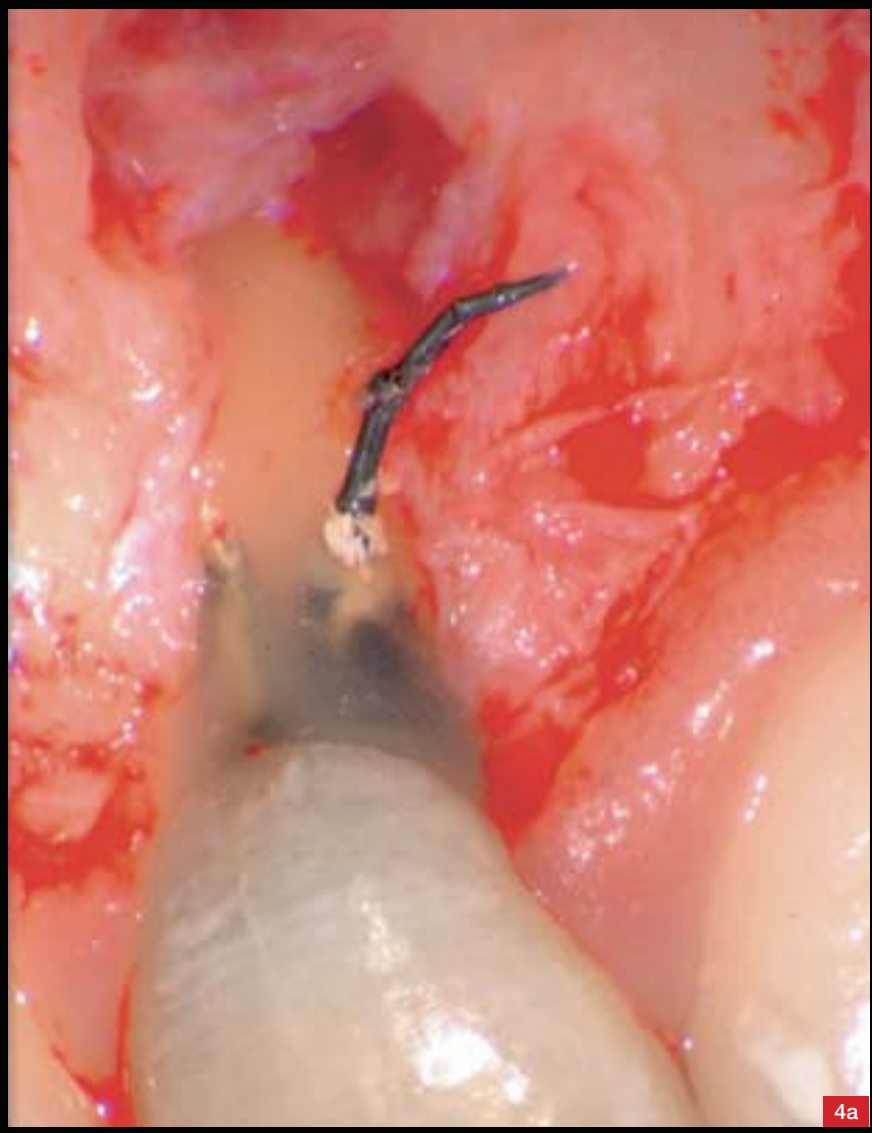
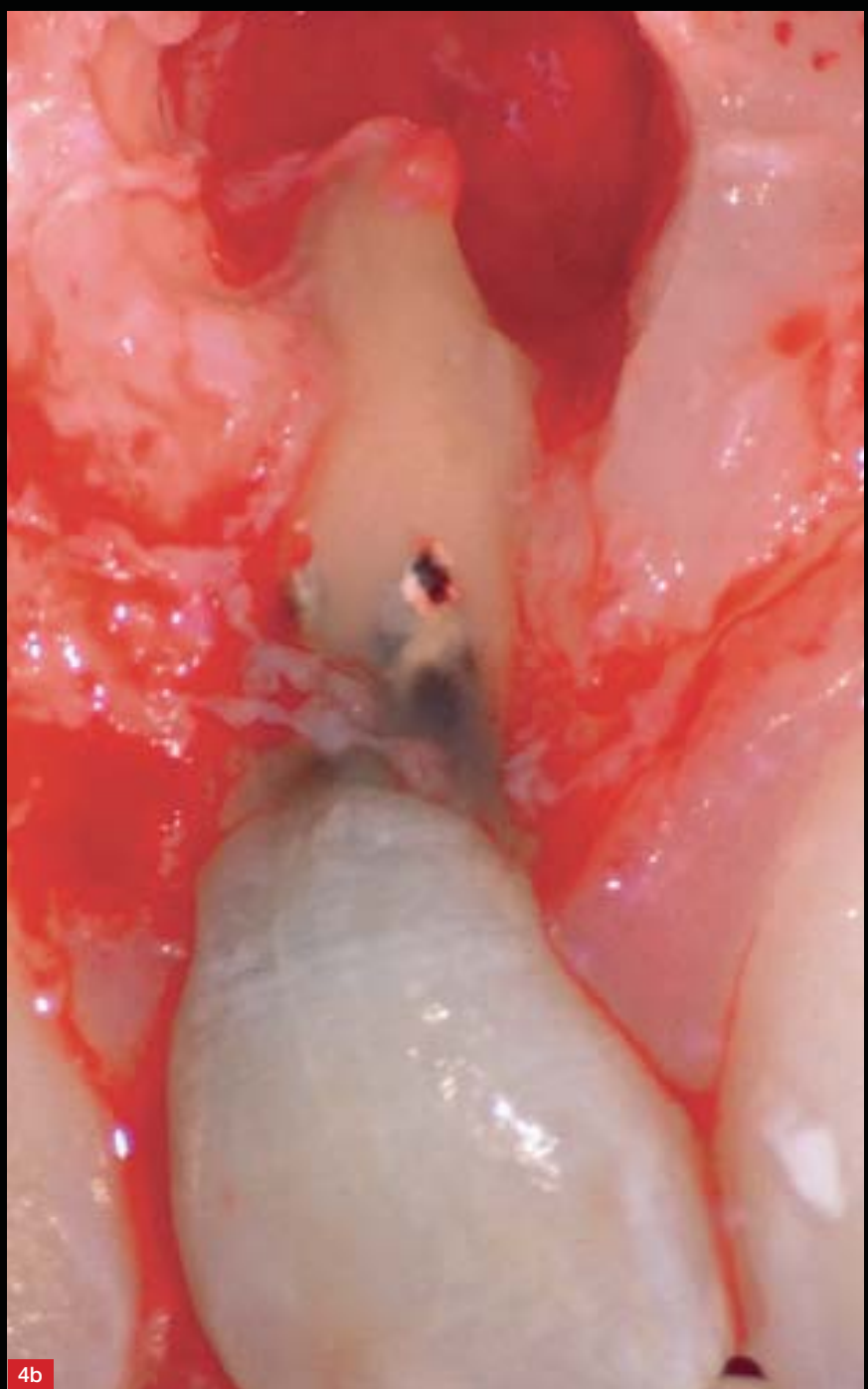
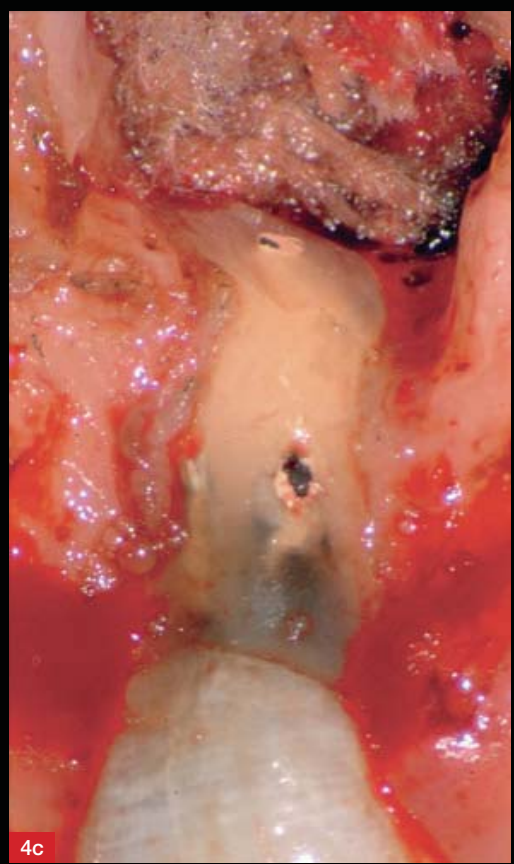
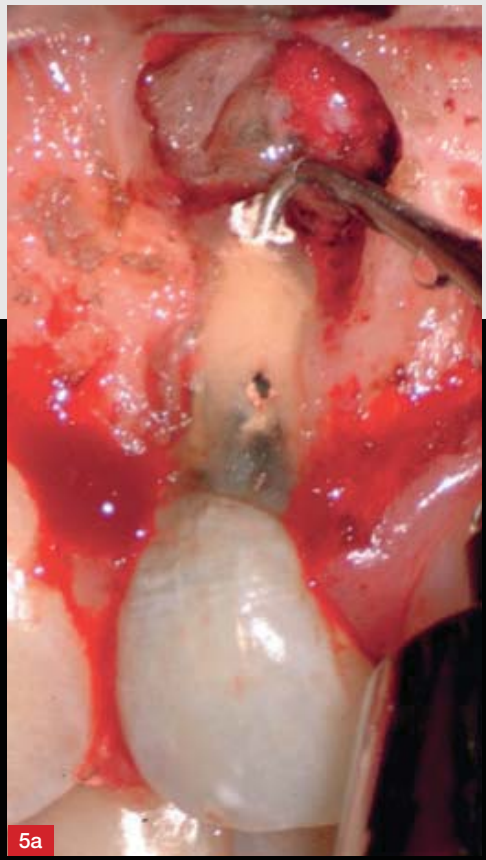


Figure 4a: The three-dimensional images confirmed the clinically observed pathological condition.

Figure 4b-c: Two initial phases of the intervention, the gutta-percha in the perforation was cut and revealed further perforations.


4b


4c



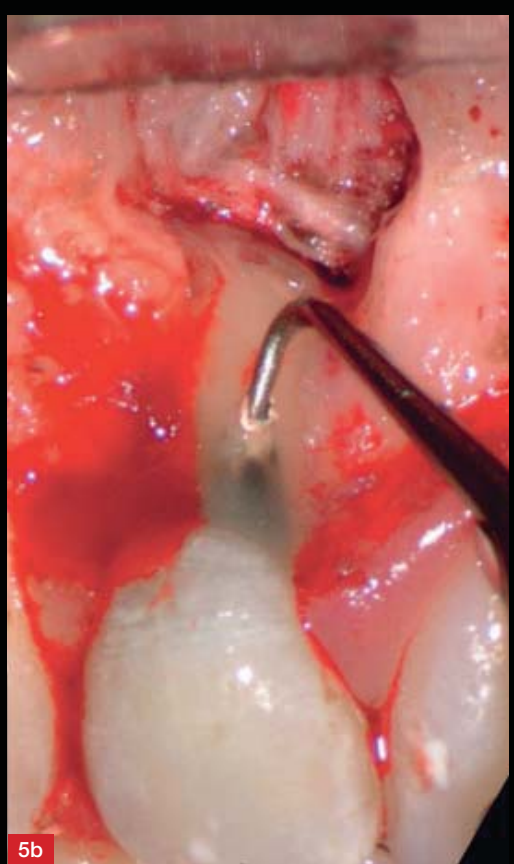


Figure 5a-c: Some phases of endodontic and periodontal surgery aimed at sealing the perforations.

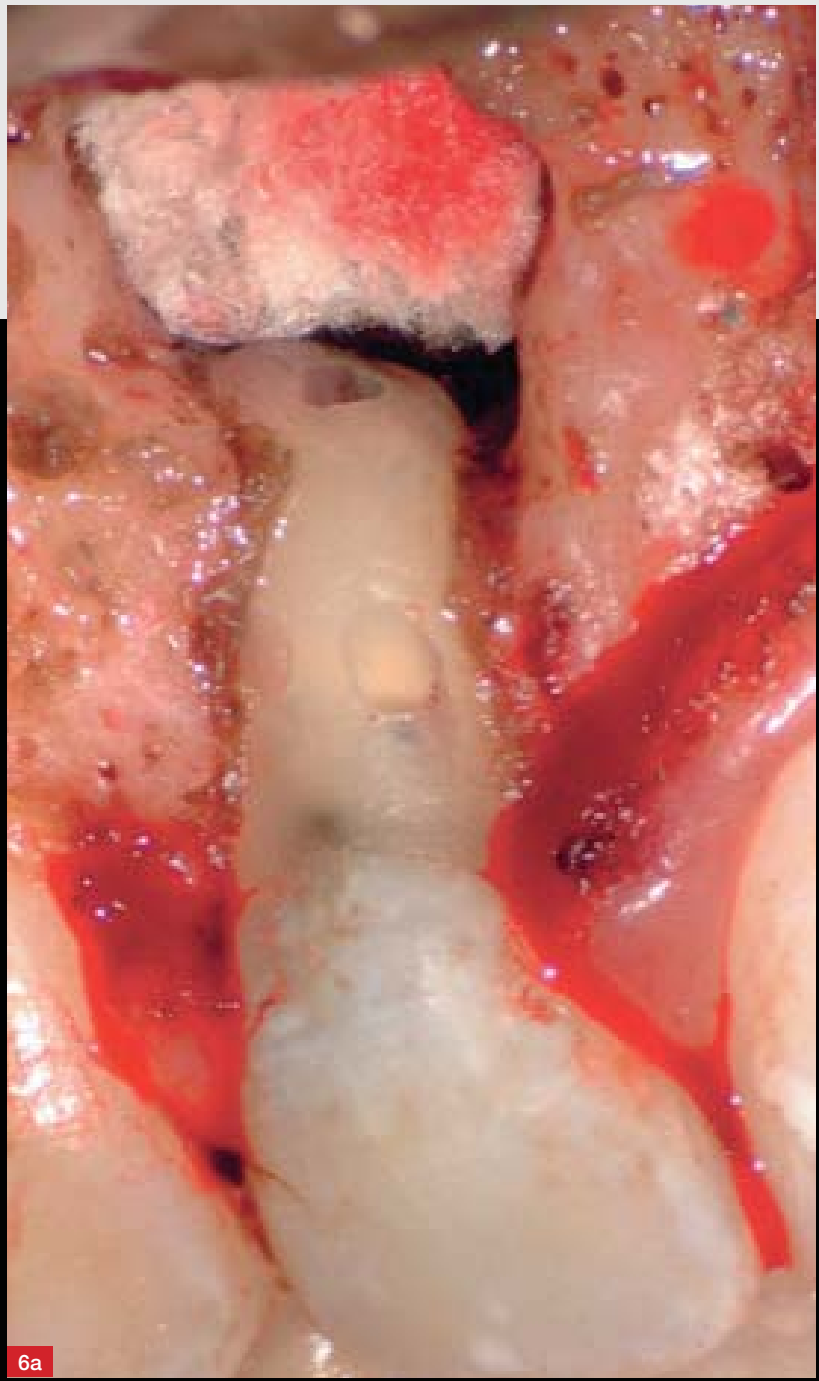
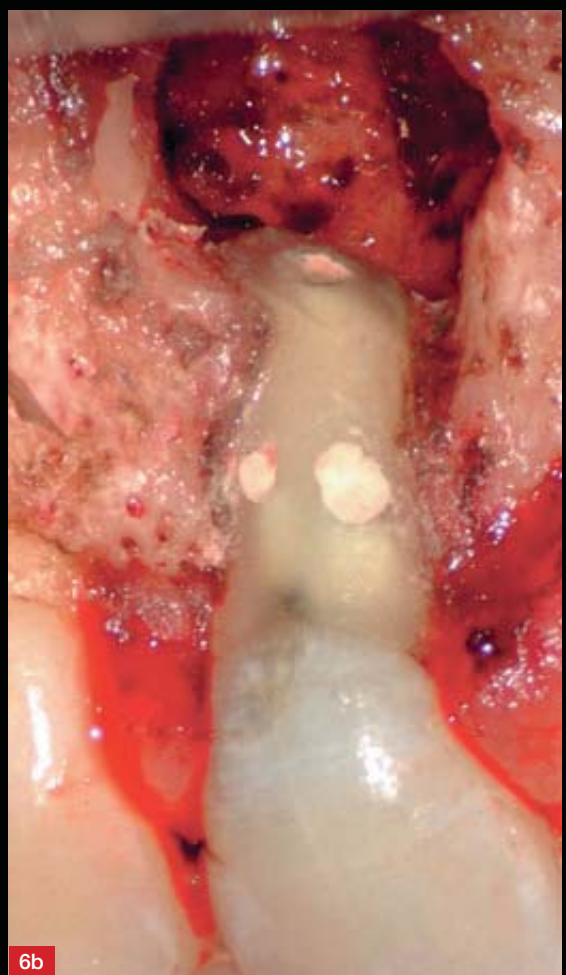


Figure 6a-b: The perforations are perfectly sealed with biocompatible material and the retrograde cavity is finished to the limit of the apical lesion.




7a


7b


7c

Figure 7a-c: Two- and three-dimensional images confirming the full success of the intervention. The dyschromia remains, but the cosmetic problem can be brilliantly solved at a later time.

Fig. 1.38a: Injury to the mesial root of the lower molar, in which the periapical disease developed suddenly, suggesting a concomitant root lesion.

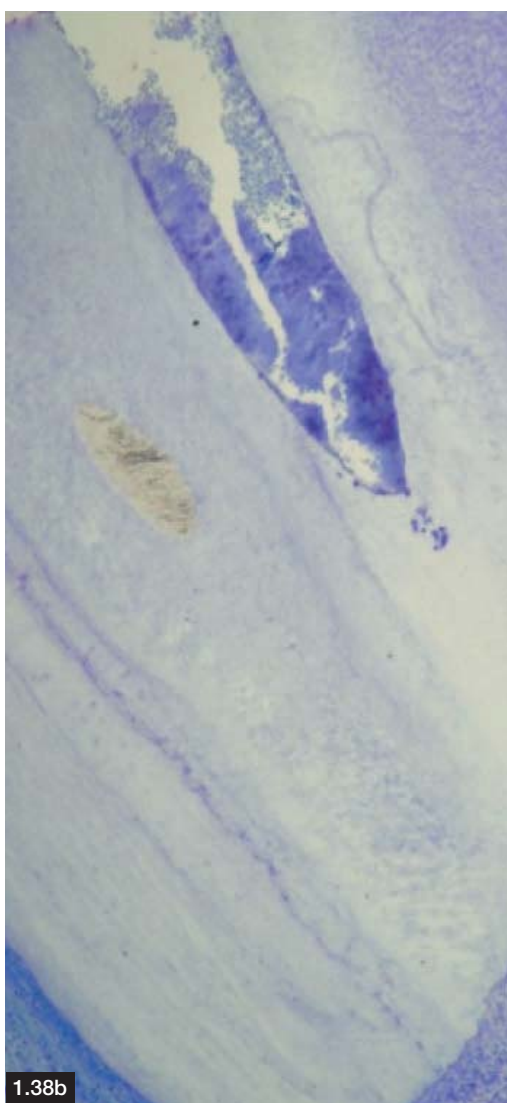


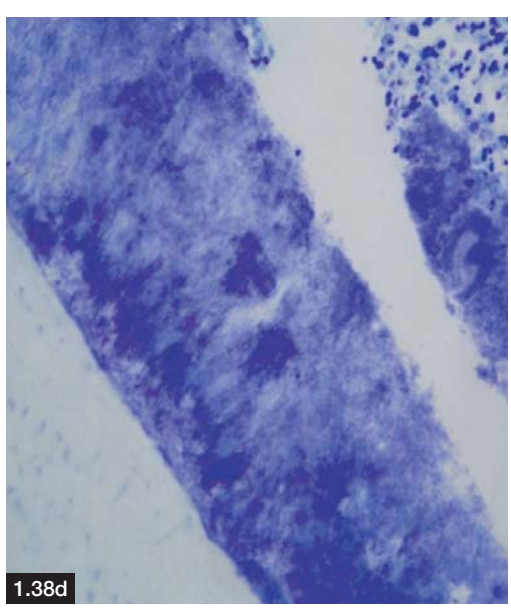
Fig. 1.38b-d: Intracanal bacterial aggregation in the form of biofilm.

Fig. 1.38c: Lower molar with partial root canal therapy and poor coronal reconstruction: the essential prerequisite for failure of the treatment.

Failures: which determinants?

Four factors are responsible for endodontic periapical diseases:

1. intraradicular infections (Fig. 1.38a-d);
2. extraradicular infections (Fig. 1.39);
3. foreign bodyreactions (Fig. 1.40);
4. cyst with cholesterol crystals (Fig. 1.41).



Considering cases 3 and 4 as marginal in percentage terms and easy to identify, practitioners must focus on the microbiological aspect, as the first two causes are, by definition, infectious. From a microbiological point of view, the bacterial colonization of the endodontic space is carried out by microorganisms organized in biofilms (Box 1.11). These entities are represented by bacterial cells immersed in an extracellular matrix that protects them from external agents and makes them extremely resistant to interventions aimed at eradicating the infection. This result is very difficult to achieve in tissues with a complex structure, such as dentin, which is rich in collagen fibers deeply embricated into the characteristic tubular structure.

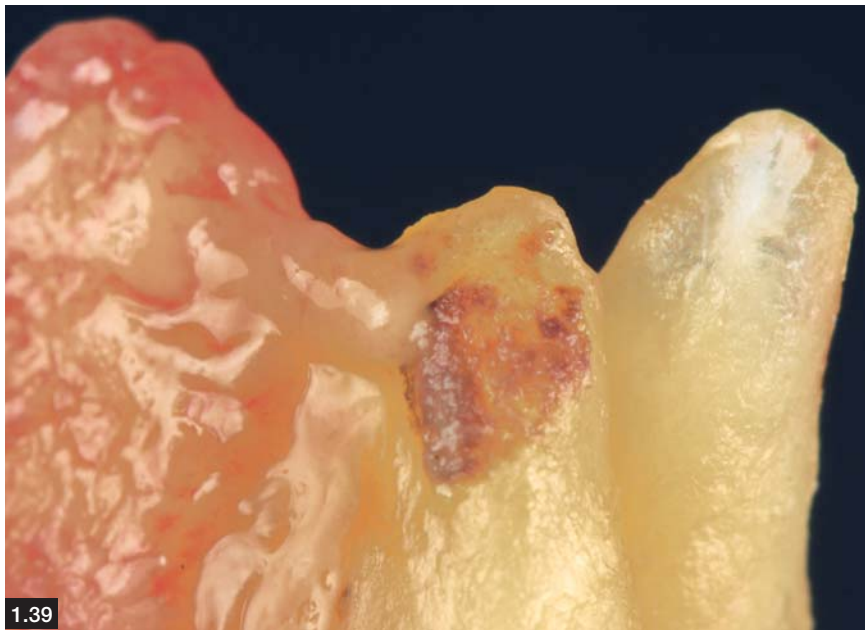


Fig. 1.39: Extraradicular calcifications exemplifying lesions generated by extraradicular infections.

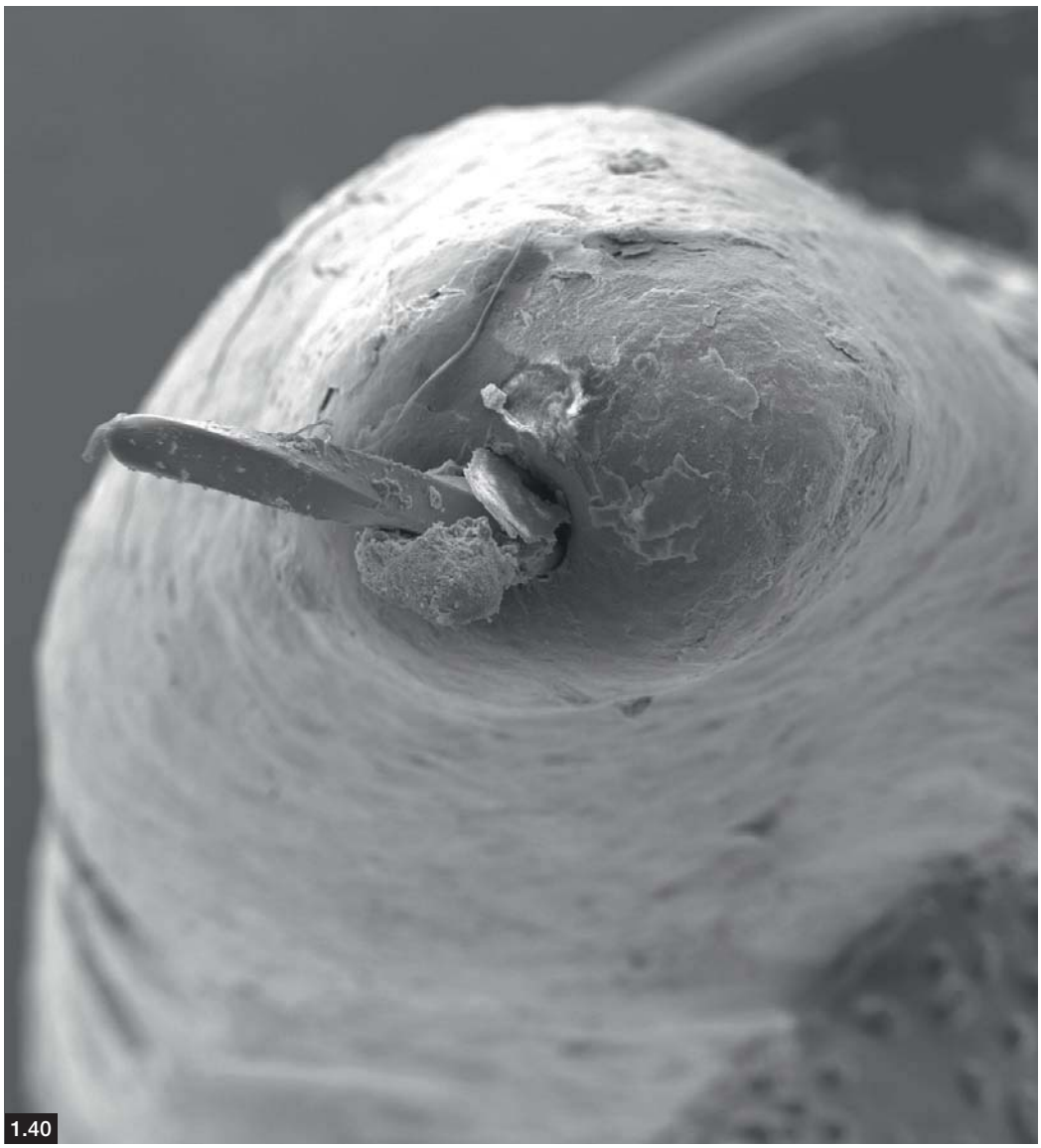


Fig. 1.40: An instrument extruded beyond the apical limit generated a foreign body granuloma and led to the avulsion of the tooth.

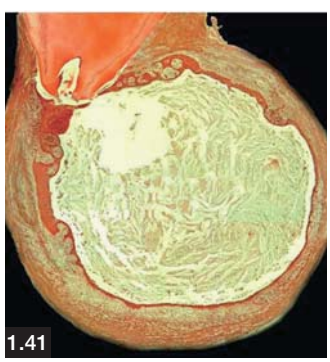
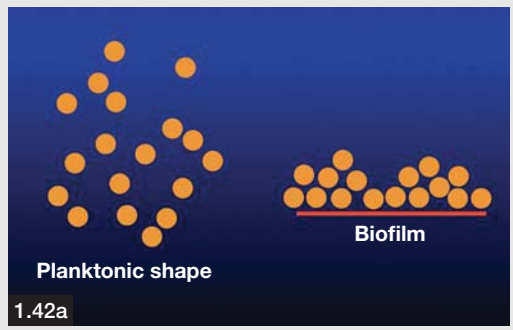


Fig. 1.41: Typical appearance of root cysts filled with cholesterol crystals.

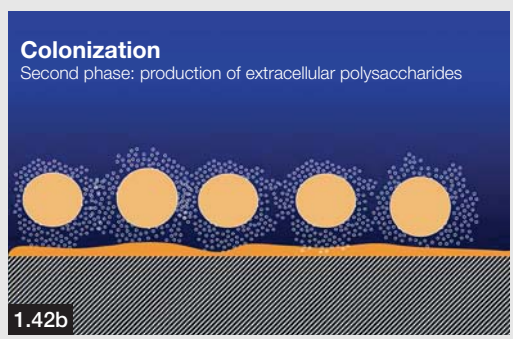
Box 1.11 **ENDODONTIC MICROBIOLOGY**

DETERMINANTS OF PERIAPICAL DISEASE: BACTERIA

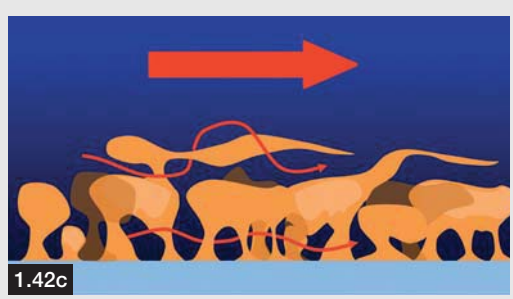
In a purely clinical context, including too much material regarding endodontic microbiology seems inappropriate given the many bacterial species are involved in this process[83].
Some studies[84] have established the need to thoroughly investigate the specific composition of the flora and its structural aspects in order to identify strategies for eliminating, limiting, and controlling the bacterial colonization of the endodontium[85].
As has been extensively demonstrated, certain bacterial species have a representative role due to their ability to withstand long periods of low nutrient availability and colonize unfavorable environments, such as previously treated root canals[86].
This aggregation leads to the formation of a biofilm, which is very difficult to violate using root canal cleansing procedures (Figs. 1.42a-e).
The endodontic space cannot be sterilized and sealed without involving the presence of bacterial cells, albeit with a far lower load.
Likewise, in many clinical situations, it is impossible to obtain a perfectly durable coronal seal.
The bacterial species involved (most of which are Gram positive) are able to grow in environments that are almost completely devoid of oxygen[87].
Yeast findings are frequent, and, according to very specific literature, viruses[88, 89] are not given adequate consideration.
The bacteria present in infections of previously treated dental elements are mainly Gram positive, and only a minority are Gram negative[90].
Peptostreptococcus and *Streptococcus* would appear to be prevalent. *Porphyromonas* is found in unsuccessfully treated canals. *Enterococcus faecali*, *S. sanguis*, *S. salivarius*, *P. endodontalis* together with *A. odontolyticus*, and *Peptostreptococcus* are present in treated and untreated teeth.
Despite the lack of universal agreement, *Enterococcus faecalis* is the most commonly observed bacterial species[91] in the endodontium of endodontically treated teeth and generates periapical distress. This process is due to the intrinsic ability of this bacterium to resist depleted nutrient supplies and to the ability to deeply colonize the dentinal tubules, thereby ensuring protection from the irrigation agents used to disinfect the root canal.

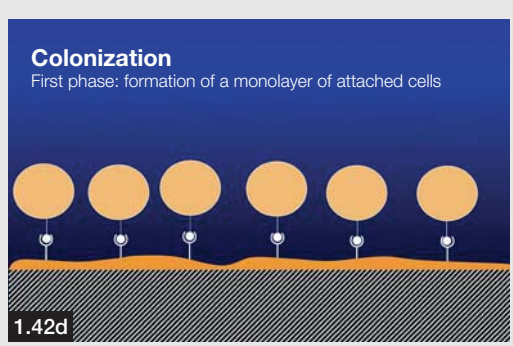


1.42a

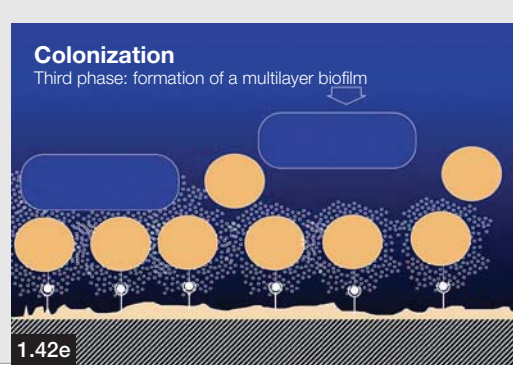


1.42b


1.42c



1.42d



1.42e

Viruses and yeasts in periapical diseases

Although it is yet to be clarified, the presence of *Candida albicans* in teeth with previously treated periapical lesions could represent a cofactor in the development of the disease, as suggested by a number of studies reporting an association with *E. faecalis*. However, this finding is yet to be clarified. In other cases, herpes and cytomegalo viruses have been assumed to be involved in the development of acute periapical diseases secondary to failed endodontic treatments. However, their role within the pathogenetic mechanism is unclear, confirming the fact that although the evolution of periapical problems secondary to infections of endodontic origin is clear in terms of its general contours, the finer details remain somewhat hazy.

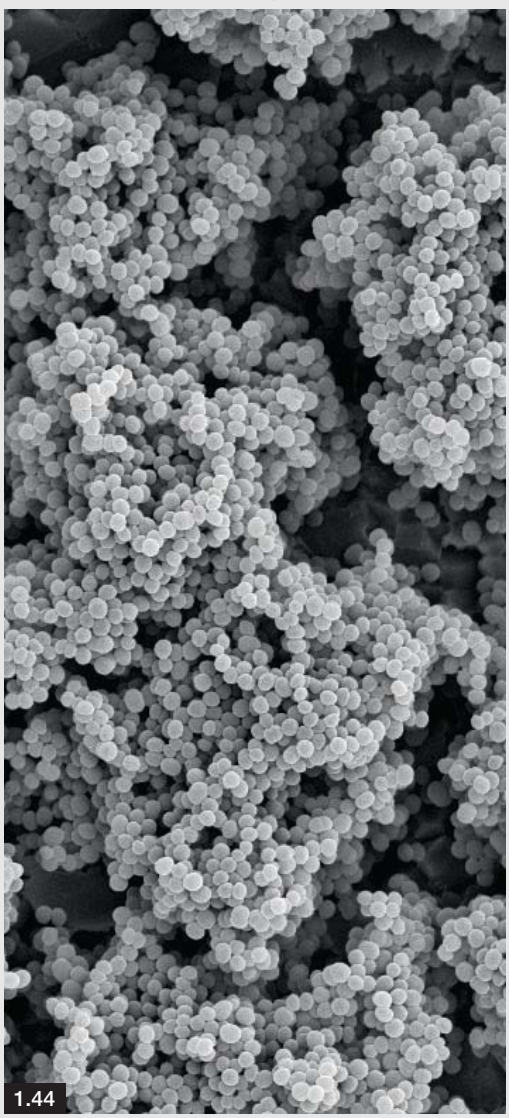


Fig. 1.44: Biofilm of *E. faecalis* in necrotic root canal (2000x).

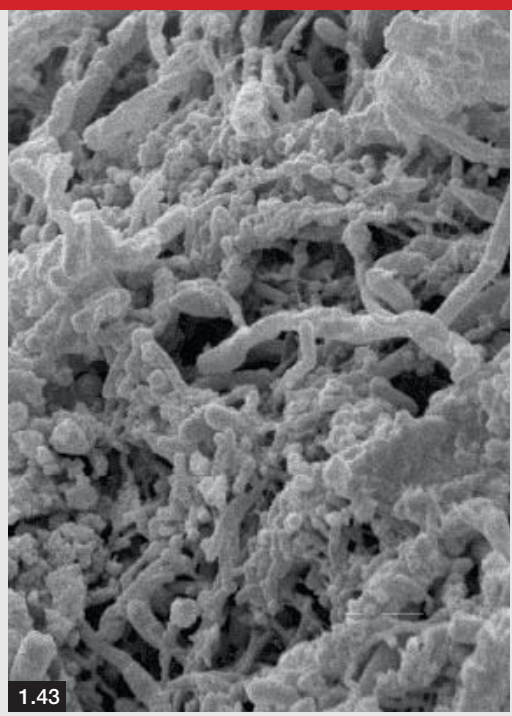


Fig. 1.43: Bacterial biofilm inside the root canal (1800x).

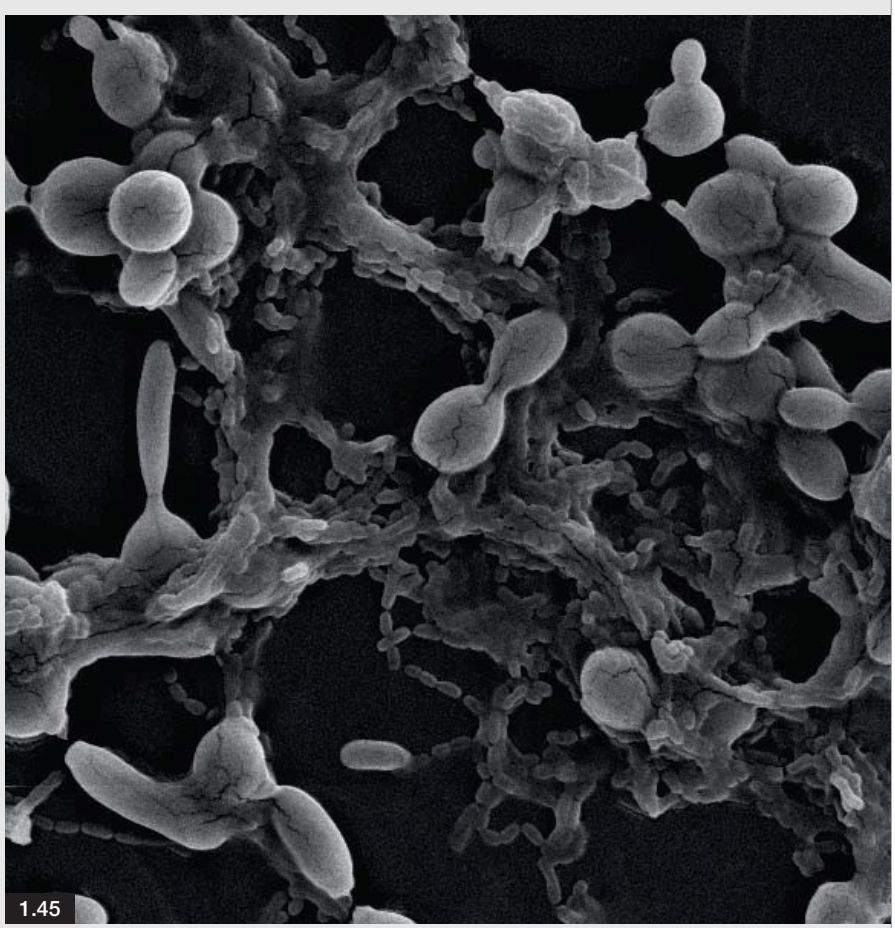


Fig. 1.45: Coaggregation of *C. albicans* and *Enterococcus faecalis* (2000x).

Extraradicular infections

Extraradicular infection, as was well described by Ricucci et al.[7, 20], deserves separate consideration.
Although the identification of an extraradicular infection can only be assumed[92], there are a number of clinical and radiological signs that suggest such involvement. One such parameter is the presence of a suppurating fistula, which is very often associated with the bacterial colonization of the apical root surface[21].
The microorganisms that are most commonly isolated in this type of infection are *Actinomyces israelii* and *P. propionicum*. These microorganisms invade the root surface and aggregate to form well-organized biofilms, making their elimination by the immune system very unlikely.

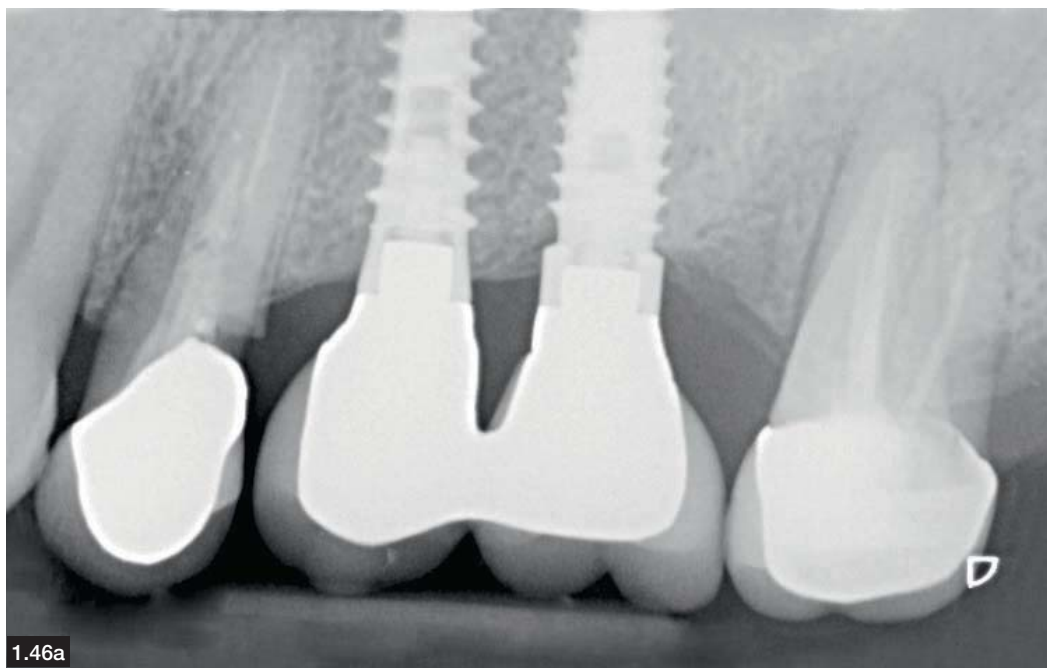


Fig. 1.46a: The second upper molar still causes pain when chewing, although the radiographic scenario is reassuring, except for a clear ectasia of the mesial canal. Subsequent periodontal evaluations lead to tooth extraction.

Fig. 1.46b: X-ray investigation shows an ineffective endodontium filling.

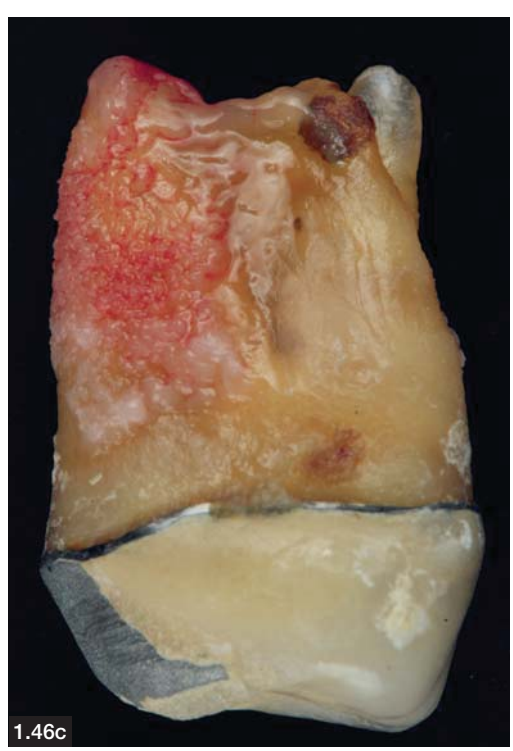


Fig. 1.46c: Anatomical finding reveals an obvious calcific aggregation on the surface of the entire root of the molar, thereby justifying the clinical scenario.

Prognosis of retreatments

The likelihood of successful retreatment depends to a large extent on the initial condition of the tooth concerned and a myriad of factors that can often not be precisely quantified.
As pointed out by Farzaneh et al.[93] and De Chevigny et al.[94], periapical health, the degree of canal filling, and the presence of transformations in canal anatomy, such as perforations, play a crucial role in the success of retreatment.
Referring to the well-consolidated systematic literature reviews conducted by Ng et al.[95-97] (Table 1.9), it can be said that the success rate of retreatment, be it judged by selective or less specific criteria, is greater than 80% of the dental elements considered.
The variables that affect the success rate are as follows:

- the presence or absence of an area of radiographic periapical radiotransparency visible on 2D x-rays;
- the size of this area, which coincides with the size of the inflamed periapical lesion;
- the extent of the canal filling, regardless of whether it respects the apical limit.

Among the cofactors, the lack of a correct coronal seal was seen to be one of the most relevant elements in this section.
Conversely, the following were seen to be elements that favored tooth survival:

- the reconstruction with a crown after treatment;
- the presence of elements that were mesial and distal to the treated tooth;
- the absence of fixed or removable prosthetic devices;
- the type of tooth, molars having the highest risk of failure.

These results are consistent with the findings of Torabinejad et al.[98], who reported a success rate of 77.8% in all the works examined.
More recently, Davies et al.[99] used CBCT as an investigation technique, i.e., an imaging method that can accurately identify inflammatory periapical lesions of endodontic origin; the results showed that the one-year success rate was approximately 93% when analyzed with normal endodontic x-rays, but dropped to 77% in cases in which CBCT was used.
He et al.[75] showed that the success rate can increase considerably when retreatment is tackled using more modern technologies, a finding that partly contradicts many epidemiological studies.
However, this last fact must make us think, as this evidence brings to light a number of non-negligible facts, not least that concerning the study in question, exist. The authors used rather lax criteria to judge the final result and the so-called complete healings at two years did not exceed 75%. This finding once again shows the difficulty in obtaining a realistic estimation of the likelihood of success that can be achieved in cases in which retreatment is performed.
In the early 2000s, Gorni and Gagliani[100] examined a sample of more than 400 retreated teeth and concluded that the success rate was around 68% (Box 1.12).
Recent studies have emphasized the prognostic value of the preoperative status of the tooth, which can be divided into two separate categories: clinical and radiographic.
With regard to the radiographic status, Kirkevang et al.[74] used a previously defined radiographic scoring system, namely the PAI (Box 1.8), and correlated its initial score with the 5-year result.

Table 1.9 **PROGNOSIS FOR ENDODONTICALLY TREATED TEETH**

Survival (years)	Percentage	95% confidence interval
2-3	86%	75-98
4-5	93%	92-94
8-10	87%	82-92

Box 1.12 ANALYSIS OF SUCCESS IN THE RETREATMENT OF TEETH WITH DIFFERENT MORPHOLOGICAL ALTERATIONS OF THE EN

In a sample of 425 patients, more than 250 molars,100 premolars and 91 front teeth were retreated. Depending on the type of retreatment, they were classified into two broad categories:

A. dental elements, in which the anatomy of the root canal was respected by the previous treatment;

B. teeth in which the previous treatment modified the structure of the endodontium.

Group A.
Canal morphology respected by the previous treatment

This group, an example of which is given in case 1, includes the following categories:

A.1 APICAL CALCIFICATIONS OR STOPS

A.2 FRACTURE OF ENDODONTIC INSTRUMENTS

A.3 ROOT CANALS NOT FILLED IN TERMS OF VOLUME AND LENGTH

A.1

Apical calcifications and obliterations (stops) are most likely two sides of the same coin; indeed, they represent two canal configurations, in which the root canal is not visible as far as the radiological apex. This may be due to the closure of the canal by the root pulp of the canal lumen and the proliferation of the root cement; both are signs of a reaction to bacterial infection, which is probably mild in its virulent component, and causes a sufficient or self-limiting defensive response for itself. In such cases, disinfection and closure of the residual endodontic space, in which the microorganisms responsible for the periapical inflammatory reaction are located, may be sufficient to ensure a favorable end result.

A.2

One chapter of great interest is that regarding fractured endodontic instruments, an area that is almost always represented by dental elements, in which root canal treatment was started but had to be discontinued when the instrument broke. Consequently, the endodontic anatomy of these teeth is rarely modified because instrument fractures often occur in the early stages of the treatment.
With sophisticated systems, such as ultrasonic tips and special excavators (Chapter 3), fractured instruments can be extracted from root canals, which can be shaped in the most appropriate way.

A.3

Root canals that are inadequately filled in terms of volume and length are extremely common and constitute the majority of referred cases because they are prone to periapical disease of endodontic origin.
In these cases, shaping did not change the size and shape of the canal, because the reaming work was not adequately extensive; sub-instrumentation, as shaping that does not include the entire root canal is known, is also a finding with recently-proposed instrumentation techniques, as reported in the studies published by Peters[37]. Not infrequently in these teeth, the second canal of the mesial root of the upper molars and the middle canal of the mesial root of the lower molars are not considered in the treatment.
Lingual canals should not be overlooked in the lower incisors.

NDODONTIC SPACE

Group B.
Canal morphology not respected by the previous treatment

This second group (an example of which is given in case 2) includes the following

B.1 EXTERNAL OR INTERNAL APEX TRANSPORT

B.2 DRILLING AND/OR STRIPPING

B.3 INTERNAL ROOT RESORPTION

B.1

Canal anatomy transport is one of the major causes of endodontic treatment failure. Transport means an outwards or inwards deviation of the curvature; it is often due to an incorrect opening of the pulp chamber and insufficient reaming of the coronal third of the root canal and results in an action of the instruments at apical level that does not respect this nerve area of the root canal.
Even when flexible, endodontic instruments are unable to properly interpret the curvatures of this area and, inevitably, tend to "rest" against the outer side of the curvature, thereby shaping, at apical limit level, that side of the canal without intervening on the inner part.
This leads to the creation of an so-called "hourglass morphology", which makes mechanical cleansing ineffective, leaves debris in the inner part of the canal's curvature and creates a final shape that cannot be effectively sealed using any technique. Moreover, this type of shaping has a traumatic effect on the periapical tissues.

B.2

Drilling and stripping are two events of iatrogenic origin caused by incorrect canal maneuvers inside the root canal that lead to undesirable endoparodontal communications.
There is an evident alteration in the anatomy of the root canal, whose perforation, as clearly illustrated in Chapter 7, may occur at various levels within the canal.

B.3

Apical root resorption is a common finding in teeth with severe periapical disease (clinical case 8, page 54); in other cases, chronic pulp disease has resulted in an uneven enlargement of the root canal to create a space in the middle of the canal itself (Chapter 2, clinical case 8).

Conclusion

Once these subdivisions had been established, all cases were subjected to orthograde treatment. The results are summarized in Table 1.10. The best results were found in dental elements with unaltered canal morphology and without radiologically visible periapical lesions. In general terms, the best results were obtained in teeth with preserved root canal morphology, with a successful rate close to 90% in group A and with a consistent difference from that obtained in teeth attributed to group B.

Gorni F & Gagliani The Outcome of Endodontic Retreatment: A 2-yr Follow-up; Journal of Endodontics 2004;30(1):1-4.

Table 1.10 **CASE STUDY PROPOSED BY GORNI AND GAGLIANI**

	Controlled patients	Mean age	Males	Females	Teeth included in the study	Duration of follow-up	
	425	40.5 (11.6)	211	214	452	24 months	
		No. of teeth	**Healed**	**Recovering**	**Failures**	**Success rate**	**Failure rate**
Teeth with preserved root canal morphology	Undamaged	83	76	0	7	91.6	8.4
	Damaged	167	136	4	27	83.8	16.2
Teeth with unrestored root canal morphology	Undamaged	32	27	0	5	84.4	15.6
	Damaged	170	56	12	102	40	60

Source: Gorni e Gagliani, 2004.

CASE REPORT 7

Retreatment on a tooth with preserved canal anatomy

The lower molar being retreated has an almost normal anatomy; following the fracture of an instrument in both the mesial and distal roots, the clinician referred the case to a specialist.

Figure 1: Initial situation.

Figure 2a-b: Opening and extraction of instruments using ultrasonic tips and a surgical microscope.

Figure 3a-b: The two broken instruments were extracted and the canal was closed with an apical cap in MTA on the distal root.

Figure 4: Case completed.

Figure 5: Follow-up at 1 year.

CASE REPORT 8

Retreatment of a tooth with unpreserved root canal anatomy

The anatomy of the lower molar being retreated is greatly altered; the apical lesion is very large and the clinically detectable fistulous path provides another reason to proceed with retreatment. Although the retreatment was performed despite the poorly preserved anatomy of the root canal, unfortunately, it did not show good results at subsequent follow-up.

Figure 1: The initial situation. Note the extent of periapical radiotransparency and the inconsistency of the canal filling.

Figure 2: The filling, due to a large erosion of the distal root apex, is not perfectly contained within the endodontium.

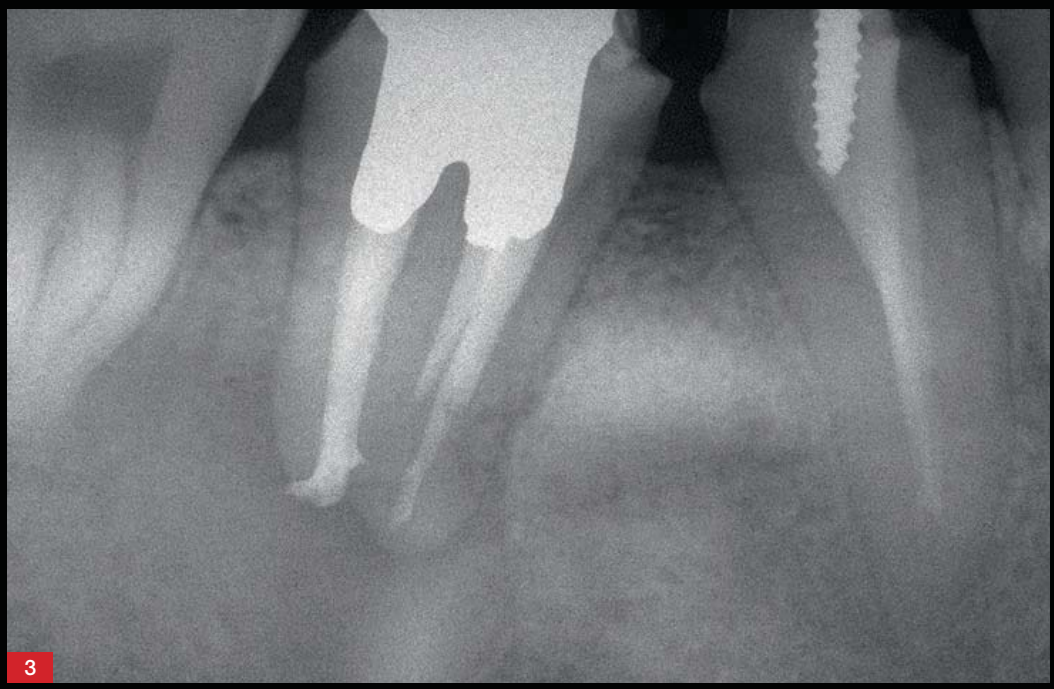
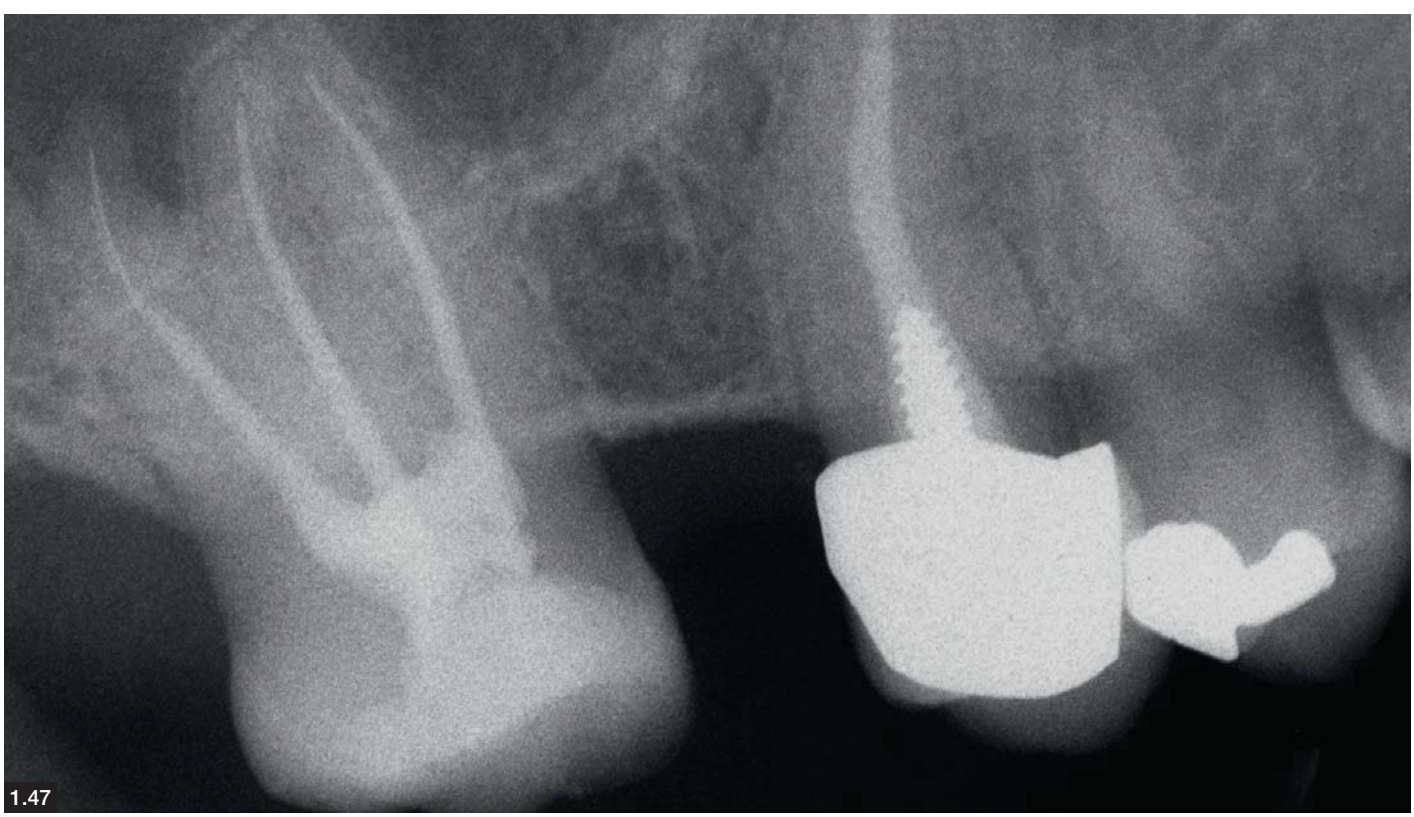


Figure 3: At 6 months, although the excess cement has been reabsorbed, the lesion remains.

Figure 4: One year later, the appearance of a supportive fistula leads us to consider this case as a failure; the case is referred for endodontic surgery.

On the basis of the findings on 143 patients, the authors concluded that each initial PAI score could result in a largely corresponding PAI score at the end of the 5-years observation period; i.e., a given initial score was prognostically more or less favorable.
From a clinical point of view, Al-Nuaimi et al.[101, 102] analyzed 137 posterior teeth using CBCT to accurately assess the extent of the periapical problem, as well as intraoral scanners to quantify the volume of the residual dental crown; they concluded that a residual dental structure of less than 30% was a highly unfavorable prognostic factor for retreatment success.
The success rates 1 year after the treatment were 82% with CBCT imaging and 88% with two-dimensional x-rays, confirming that the latter tends to overestimate healing.
As highlighted by the excellent study conducted by Ricucci et al.[7, 103], the presence of suppurative fistulae suggests the presence of extraradicular bacterial arborescence, which is difficult to control with normal orthograde retreatment procedures.
Fonzar et al.[104] performed a study on almost 500 patients (a total of 1175 teeth) treated by a group of highly qualified specialists; a 10-year success rate of 94% was observed for retreatment, equivalent to approximately 40% of the sample examined.
Preoperative symptoms and the presence of a considerable radiologically-evident lesion emerged as the two main factors for failure. In a 5-year cohort study conducted in Korea, a success rate of 88.4% was observed for retreatment, whereas the treatment outcome in previously untreated teeth was 90.8%. (H) Pirani et al. (I) used a different filling technique and achieved a slightly lower rate.
To conclude, the success rate is – according to the data discussed above – approximately 80% and the influencing factors are the degree of involvement of the periapical tissue, followed by canal morphology and the entity of the residual crown. Seen with a broader treatment perspective, this percentage can be increased by adopting the endodontic surgery solution.
A combination of the two therapeutic techniques, which are closely related to the skill of the operator (see below), will lead to excellent results.

Fig. 1.47: Upper molar with endodontic treatment that seems to be correct in the two vestibular roots but has a different conicity in the palatine root. In such cases, frank symptoms can lead to retreatment; otherwise, the watchful waiting is the best choice.



Why to perform or not perform a retreatment: Preliminary considerations

The discovery of endodontic periapical disease is often an incidental finding. This issue is far from irrelevant, particularly when we consider that the finding of asymptomatic disease that may or may not generate local or systemic disease presents the clinician with the dilemma of whether or not to perform retreatment.

As pointed out by Wesselink[105], it is not uncommon for an endodontical x-ray or an orthopantomographic x-ray – for reasons others than those for which the patient was referred – to present a radiolucent area near a root apex of a previously treated tooth. As indicated in the behavior patterns (page 64), the main factor on which retreatment decision-making is based is a negative transformation of the lesion. In the study conducted by Yu et al.[69], less than 6% of the lesions

Fig. 1.48: Typical case of a self-limiting periapical reaction, caused by an enormous proliferation of root cement; the canal lumens are obliterated. Retreatment is strongly discouraged.

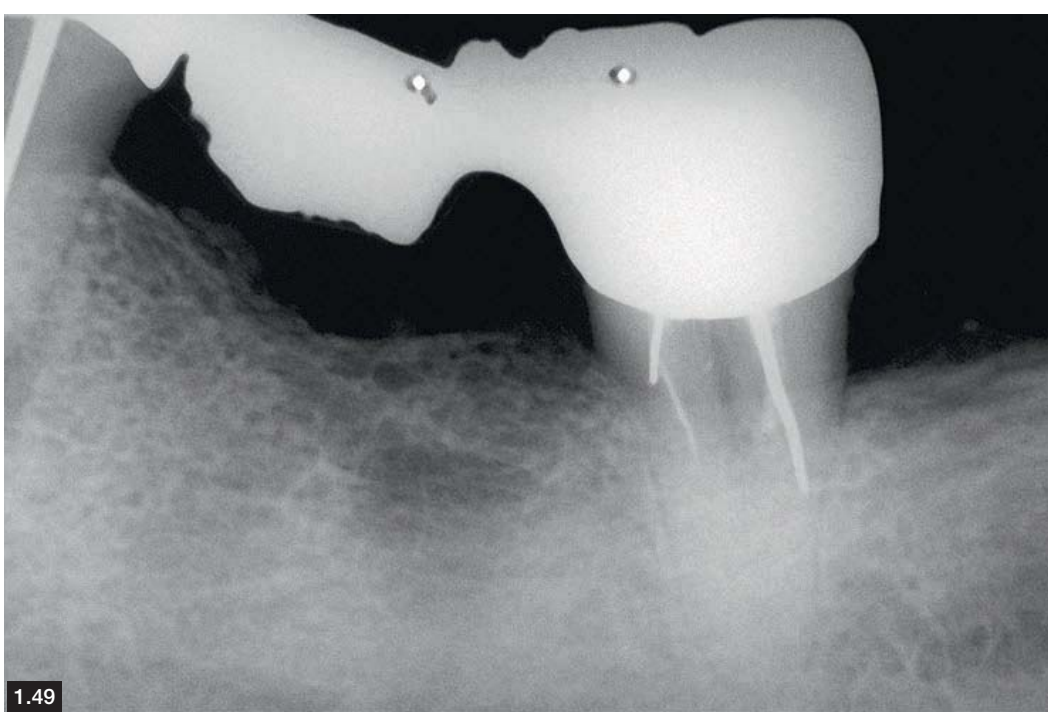
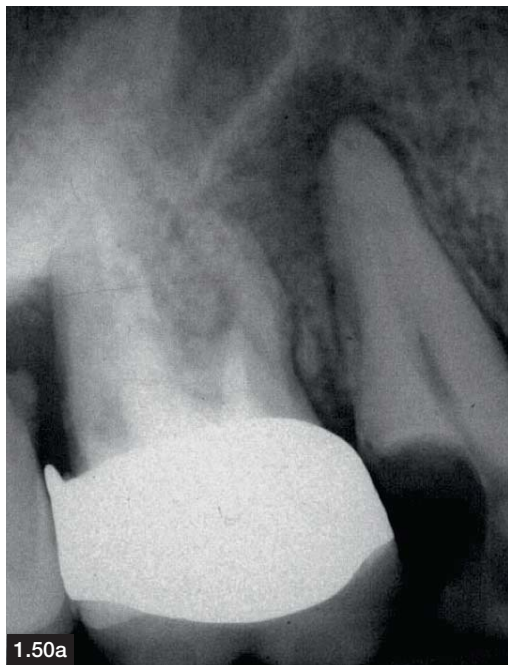


Fig. 1.49: Similar case with a treatment that did not cause a periapical lesion but that totally occluded the canal lumen: retreatment would be impossible.

Fig. 1.50a: Inappropriate endodontic treatment at the expense of tooth 16 and a frank periapical lesion on tooth 15 determine the need for endodontic surgery.

Fig. 1.50b: Reconstructions that ineffective in terms of sealing and are worn.


1.50a


1.50b

Fig. 1.51a: Two reconstructions made of ceramic-metallic material.

Fig. 1.51b: After 6 months, the treatment of tooth 15 had already achieved the expected result, whereas tooth 16 was examined but was not considered to be retreatable.

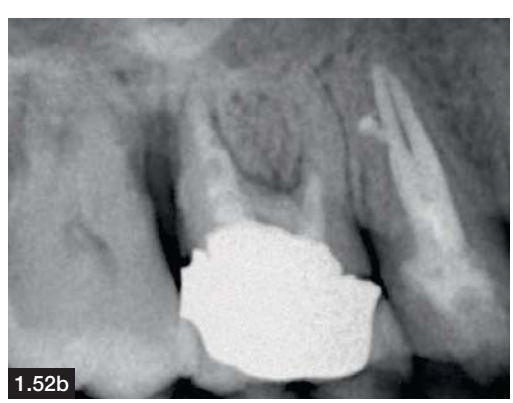

1.51a


1.51b

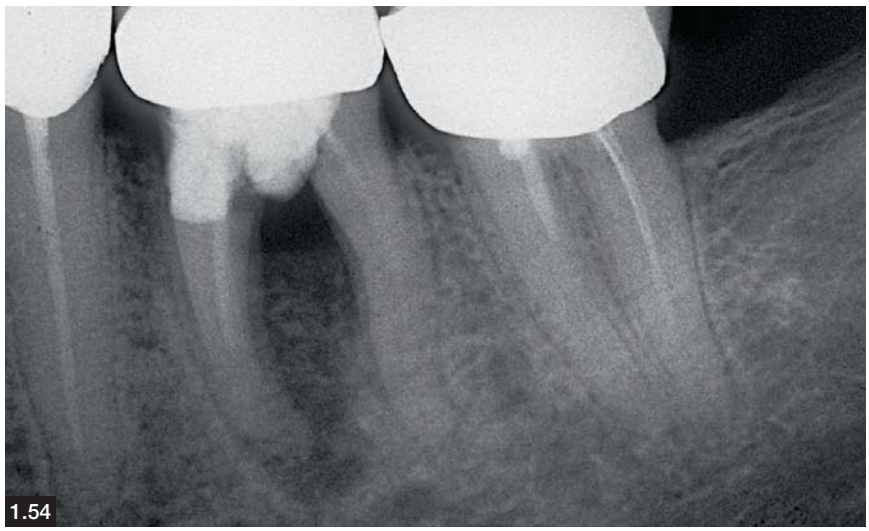
Fig. 1.52a: Follow-up x-ray after 22 years, confirming the appropriateness of the therapeutic choice, that is, watchful waiting on the tooth 16 and intervention on tooth 15.

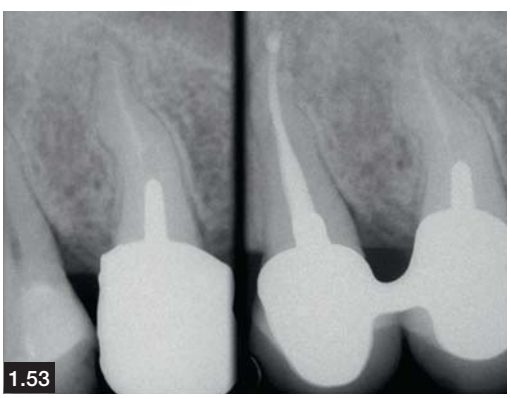
Fig. 1.52b: Same images from different angles.


1.52a


1.52b

over a 20-year period, become more acute, i.e., they cause significant infection that requires an emergency dental and stomatological procedure. However, almost one in two teeth present pain over the same period, without impacting the patient's quality of life. It was therefore decided to deal with this topic in a separate chapter because, although it refers to other procedures already described or to others described later, this allows us to make a number of specific considerations. Some of these have been taken from contributions from literature that we consider worthy of note; one non-negligible aspect is that relating to costs. A study conducted by Schwendicke & Stolpe[106], focuses on the economic aspect that this kind of consideration involves. The authors used an economic model employed in healthcare cost-effectiveness analyses to evaluate the various types of retreatment; they compared all these settings (reconstruction with filling, with a prosthetic crown or with a root canal post and a prosthetic crown) by simulating the results that could be obtained without retreatment and after performing the retreatment. The complications and problems were classified according to data available in the literature, and the results at a distance were recorded. The results of the study would appear to be discouraging, as performing a reconstruction on a failed root canal treatment even in the presence of a periapical lesion, in the absence of clinical symptoms, causes - from an economic point of view - far fewer problems than would have to be faced if it were decided to perform a retreatment before performing a restoration or a direct filling. Although it is not entirely satisfactory, as it is based on a virtual simulation that does not consider natural circumstances, such as poor root canal treatment associated with a periapical radiographic lesion; the study deserves great consideration because it deals with an aspect of clinical practice that is particularly relevant today. This aspect, which textbooks and literature in general often mystify, can represent a significant decision-making factor, not only for the patient but also for the dentist: the cost of managing the inconveniences generated by complications typical of retreatment.


1.54


1.53

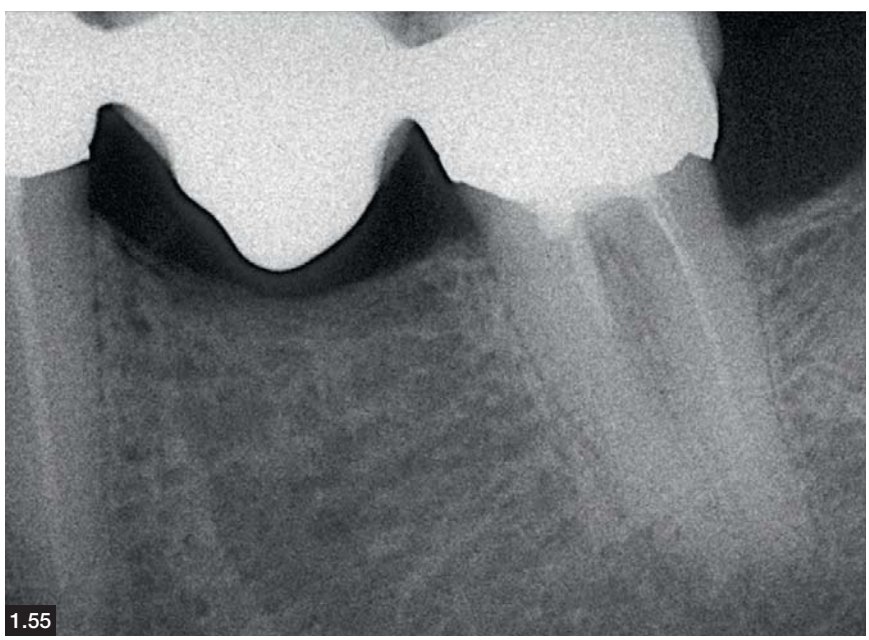

1.55

Fig. 1.53: Premolar with a complicated canal anatomy kept under observation (second follow-up at 5 years); retreatment would be poorly indicated given the operational complexity.

Fig. 1.54: Lost tooth leads to the decision of extraction; the neighboring teeth, although not well treated were not retreated.

Fig. 1.55: Follow-up at 5 years, confirming the validity of the choice.


1.56


1.57

Figs. 1.56-1.57: Pair of lower molars with an inappropriate treatment. In 47, the vision of the root canal beyond the previous filling suggests an easier retreatment; on the other hand, 46 is characterized by the obliteration of the remaining part of the canal, which advises against retreatment.

Endodontic periapical diseases could affect the general health of patients and, therefore, any further reasoning in this regard would largely take second place.
However, the economic aspect also emphasizes on the treatment alternatives, i.e., endodontic surgery extraction, and implants, even if it is granted that the "wait and see" approach is the best solution provided there is no clear evidence that periapical disease can play a very different role to that currently attributed to them.
Therefore, at the preliminary examination, purely as a learning exercise, we considered it useful to explore all the alternatives that treatment decision-making may present not only for the dentist, but also for the patient.
Tifooni et al. (x) proposed a more sophisticated prognostic index, which supported the idea that a score-based decision-making process might be useful in predicting favorable or negative outcomes.
To conclude, we believe that providing the patient with full knowledge of the facts is a further aspect required to foster a solid bond of trust, the essential basis for establishing a relationship that refers to the "therapeutic alliance," of which there is much talk but which, in situations like this, is often relegated to a few words that only regard the practitioners' duties toward their patients.
The patient should be informed that an infection, albeit asymptomatic, has been found. Intervention is required for the reasons described above, but it is equally true that non-intervention can be the solution in certain cases. The costs of the therapy will not be negligible, because of the need for further reconstructions.
Complications may arise, and, whilst they are almost always manageable, they are still unpleasant. Undesirable alternatives, such as extraction, should not be overlooked, although this should be seen as an extreme solution. One possible alternative is watchful waiting, or identifying the most appropriate time for intervention, when it is required, such as when it is necessary to replace an obsolete restoration or provide more extensive rehabilitation. The main risk associated with waiting is that of a violent exacerbation, which often makes it impossible to carry out a retreatment and calls for solutions that are more radical and destructive and involves the need for more expensive rehabilitation. It is important to remember that intervening with reconstructive or prosthetic solutions on a previously-treated tooth involves the assumption of full responsibility by the last operator.

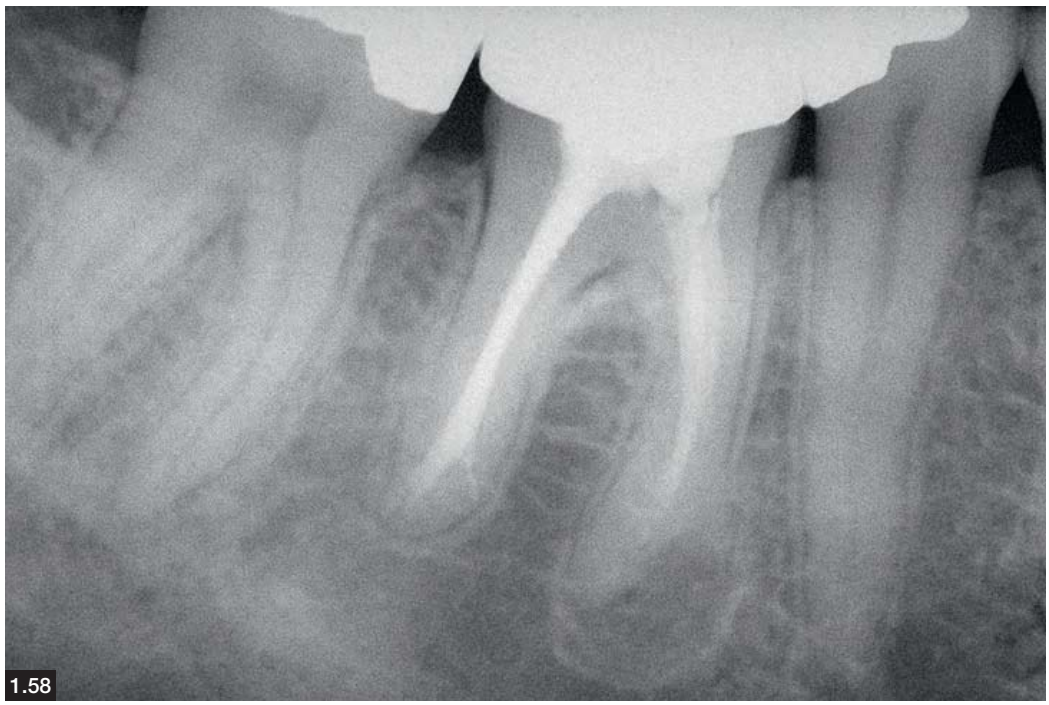
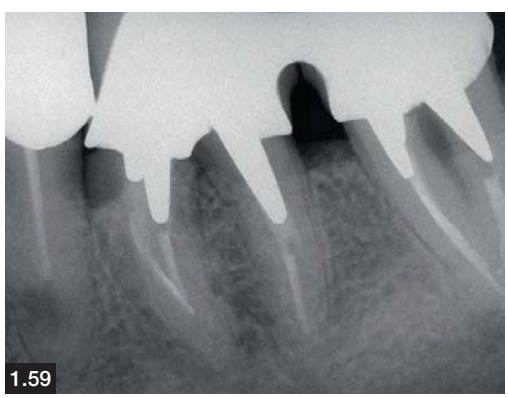
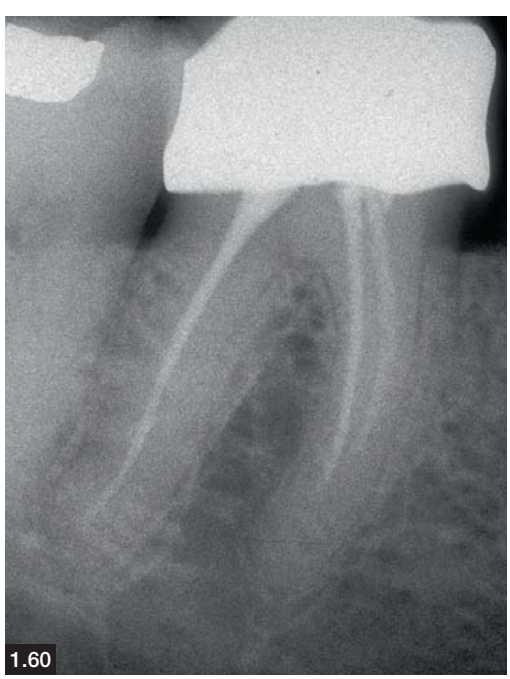

1.58

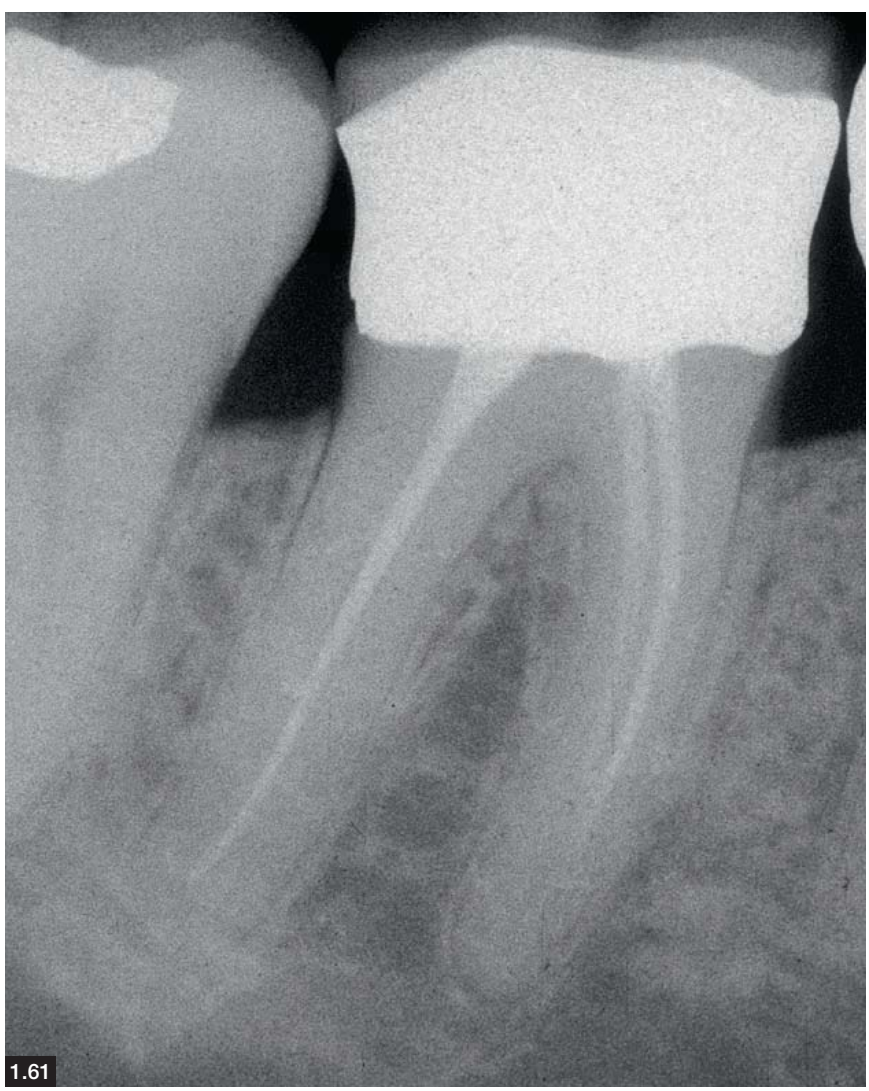
Fig. 1.58: The large lesion on the lower molar cannot be eliminated unless with endodontic surgery; the patient asked to postpone the treatment.

Fig. 1.59: The presence of root canal posts discourages a retreatment.

Figs. 1.60-1.61: Replacement of a crown on a previously treated tooth without periapical lesions.


1.59


1.60


1.61

Retreatment: the role of the specialist

As discusssed in these opening paragraphs, retreatment is an extremely demanding clinical procedure that must be performed by a experienced clinician[107].
This makes it essential for the practitioner to have a full awareness, from the outset, of his/her technical limits as well as the availability of the tools needed to solve all the problems imposed by retreatment that may occur once the procedure is under way.
As reported by the American Association of Endodontists (AAE) (Box 1.5), a long list of clinical situations, previously considered unapproachable by less experienced clinicians, can now be contemplated.
Consequently, once a correct diagnosis has been established, deciding to conduct complex endodontic treatment becomes much easier; at this stage, careful consideration by the dentist will lead to the decision as to whether to carry out the procedure personally or to refer the matter to a colleague with greater experience in the field and who is likely to have more refined instrumentation that is suitable for solving the case in the best possible way.

In a study of treatments performed by endodontic specialists and general dentists, the former achieved better results than the latter on molar teeth[108]. Many scholars[109-113] have reiterated that the use of a surgical microscope could be an important aid for achieving the desired clinical results[114-117]. Lee et al.[118] compared practitioners belonging to institutional associations and general practitioners and found a higher success rate amongst the former; this finding indicates the contribution that the number of cases treated in environments with a high workflow can have in maintaining a high quality
Ramey et al.[119] performed a retrospective study on more than 2000 treatments and reported a close correlation between endodontic success and the quality of the operator's training; the treatments carried out by colleagues with postgraduate training from courses or in specialization programs had better results. Savani et al.[120] emphasized that the younger generations are more sensitive to the use of new technologies, but that the degree of attention to endodontics cannot be measured on the basis of the training courses attended.
Ultimately, the clinician's level of expertise would appear to be a significant factor in the success of root canal treatment and retreatment and this factor could also affect the final result of complex procedures.


Leica

BEHAVIOR PATTERNS

The following is a sequence of the four phases that precede the performance of retreatment and represent key moments of analysis that the clinician must perform before formulating a prognosis and starting treatment.

1

ASPECTS TO BE CONSIDERED IN A RETREATMENT

Factors influencing the prognosis

Preoperative status of periapical tissues
Size of periradicular lesion
Canal anatomy
Coronal or root fractures
Iatrogenic factors (see below)
Quality of the post-endodontic restoration
Time elapsed since first treatment
Microbiology
Observation period

Iatrogenic errors leading to retreatment

Fractured instruments
Blocked canals - steps or plugs
Perforations
Incomplete root canal fillings in terms of extent and quality
Overlooked canals
Extent of filling beyond the apical limit

General factors to be considered in retreatment

General patient health
Operator experience
Available instruments
Diagnosis and treatment plan
Radiographic interpretation
Canal anatomy
Quality and extension of the canal seal
Quality of endodontic post-retreatment restoration

Contraindications for retreatment

Endodontic retreatment inevitably leads to a weakening of the tooth root, a fact that must be considered in the diagnostic phase; practitioners must also consider that root warming caused by the use of drills or ultrasound can cause damage to and weaken the surrounding periodontium, particularly the structure that supports the tooth.

2

CASE SELECTION

The following issues may contraindicate retreatment and make endodontic surgery a preferable option:

Patient reluctancy
Clinical history of of recurrent infections
Presence of extensive periodontal lesion
Presence of adjacent erupting teeth
Occlusal trauma
Unfavorable root-to-crown ratio
Complex canal anatomies
External root resorption
Root fractures
Quality of filling
Relationship between the size of the lesion and the quality of the filling
Overfilling or overextension of root canal fillings

3

SEQUENCE OF ANALYSIS BEFORE PERFORMING RETREATMENT

1. Patient **2.** Oral cavity **3.** Quadrant **4.** Tooth

PRETREATMENT CONSIDERATIONS

Elements to consider when evaluating the need for a new endodontic treatment procedure

Asymptomatic patient
Strategic importance of the element in question
Real effectiveness of retreatment

SEAT TIME AND RELATED COSTS

Removal and new fabrication of prosthetic restorations
Technical difficulties
Hypothetical quality of the future result

4

SUCCESS OR FAILURE OF A RETREATMENT: THE DETERMINANTS

Elements that do not determine the failure of retreatment

Type and position of the tooth
Age and sex of the patient
Number of appointments for therapy
Type of filling material
Pre- or postoperative-operative pain

Elements leading to the failure of retreatment

Persistence of infection
Incorrect shaping - canal transport (hemorrhage)
Irritation of periapical tissues with chemical agents
Minor and major iatrogenic errors (blocks and/or perforations)

References

1. Cardinali F, et al., *La risoluzione delle complessitè nei ritrattamenti.* Dental Cadmos, 2014. 82(10): p. 690-712.
2. Friedman S, *Considerations and concepts of case selection in the management of post-treatment endodontic disease (treatment failure).* Endodontic Topics, 2002. 5(1): p. 54-78.
3. Haapasalo MSY, Ricucci D, *Reasons for persistent and emerging post-treatment endodontic disease.* Endodontic Topics, 2011. 18(1): p. 31-50.
4. Abbott P, *Diagnosis and management planning for root-filled teeth with persisting or new apical pathosis.* Endodontic Topics, 2008. 19(1): p. 1-21.
5. Dofour DL, V Leung, Levesque, CM, *Bacterial biofilm: structure, function, and antimicrobial resistance.* Endodontic Topics, 2010. 22(1): p. 2-16.
6. Ricucci D and G Bergenholtz, *Bacterial status in root-filled teeth exposed to the oral environment by loss of restoration and fracture or caries-a histobacteriological study of treated cases.* Int Endod J, 2003. 36(11): p. 787-802.
7. Ricucci D, et al., *Extraradicular infection as the cause of persistent symptoms: a case series.* J Endod, 2015. 41(2): p. 265-273.
8. Kakehashi S, HR Stanley, and R Fitzgerald, *The exposed germ-free pulp: effects of topical corticosteroid medication and restoration.* Oral Surg Oral Med Oral Pathol, 1969. 27(1): p. 60-67.
9. Kakehashi S, HR Stanley, and RJ Fitzgerald, *The Effects of Surgical Exposures of Dental Pulps in Germ-Free and Conventional Laboratory Rats.* Oral Surg Oral Med Oral Pathol, 1965. 20: p. 340-349.
10. Sjogren U, et al., *Factors affecting the long-term results of endodontic treatment.* J Endod, 1990. 16(10): p. 498-504.
11. Sundqvist G, *Ecology of the root canal flora.* J Endod, 1992. 18(9): p. 427-430.
12. Sundqvist G, *Taxonomy, ecology, and pathogenicity of the root canal flora.* Oral Surg Oral Med Oral Pathol, 1994. 78(4): p. 522-530.
13. Sundqvist G and D Figdor, *Life as an endodontic pathogen. Ecological differences between untreated and root-filled root canals.* Endodontic Topics, 2003. 6: p. 3-28.
14. Moller AJ, et al., *Influence on periapical tissues of indigenous oral bacteria and necrotic pulp tissue in monkeys.* Scand J Dent Res, 1981. 89(6): p. 475-484.
15. Nair PN, *Pathogenesis of apical periodontitis and the causes of endodontic failures.* Crit Rev Oral Biol Med, 2004. 15(6): p. 348-381.
16. Nair PN, *Pathobiology of Apical Periodontitis*, in *Essential Endodontology*, D. Orstavik and T.R. Pitt Ford, Editors. 2008, Blackwell Munksgaard Ltd: Oxford, UK. p. 81-123.
17. Siqueira JF, Jr., *Endodontic infections: concepts, paradigms, and perspectives.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2002. 94(3): p. 281-293.
18. Siqueira Jr, JFR, IN Rôças, Ricucci D, *Biofilms in endodontic infection.* Endodontic Topics, 2010. 22(1): p. 33-49.
19. Siqueira Jr, JFR, IN Rôças, *Present status and future directions in endodontic microbiology.* Endodontic Topics, 2014. 30(1): p. 3-22.
20. Ricucci D and JF Siqueira, Jr., *Apical actinomycosis as a continuum of intraradicular and extraradicular infection: case report and critical review on its involvement with treatment failure.* J Endod, 2008. 34(9): p. 1124-1129.
21. Ricucci D and JF Siqueira, Jr., *Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings.* J Endod, 2010. 36(8): p. 1277-1288.
22. Sabeti M, et al., *Cytomegalovirus and Epstein-Barr virus active infection in periapical lesions of teeth with intact crowns.* J Endod, 2003. 29(5): p. 321-323.
23. Sabeti M and J Slots, *Herpesviral-bacterial coinfection in periapical pathosis.* J Endod, 2004. 30(2): p. 69-72.
24. Egan MW, et al., *Prevalence of yeasts in saliva and root canals of teeth associated with apical periodontitis.* Int Endod J, 2002. 35(4): p. 321-329.
25. Siqueira JF, Jr. and BH Sen, *Fungi in endodontic infections.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2004. 97(5): p. 632-641.
26. Waltimo TM, et al., *Yeasts in apical periodontitis.* Crit Rev Oral Biol Med, 2003. 14(2): p. 128-37.
27. Nair PN, *On the causes of persistent apical periodontitis: a review.* Int Endod J, 2006. 39(4): p. 249-281.
28. Aminoshariae A, Kulild JC. *The impact of sealer extrusion on endodontic outcome: A systematic review with meta-analysis*. Aust Endod J, 2019 (in-press).
29. Mello, F. W., et al., *The influence of apical extent of root canal obturation on endodontic therapy outcome: a systematic review*. Clin Oral Investig, 2019. 23(5).
30. Sakamoto M, et al., *Molecular analysis of bacteria in asymptomatic and symptomatic endodontic infections.* Oral Microbiol Immunol, 2006. 21(2): p. 112-122.
31. Lang MLZ, Zhu L, Kreth J, *Keeping the bad bacteria in check: interactions of the host immune system with oral cavity biofilms* Endodontic Topics, 2010. 22(1): p. 17-32.
32. Hülsmann M, *Epidemiology of post-treatment disease.* Endodontic Topics, 2016. 34(1): p. 42-63.
33. Tsai P, et al., *Accuracy of cone-beam computed tomography and periapical radiography in detecting small periapical lesions.* J Endod, 2012. 38(7): p. 965-970.
34. Paes da Silva Ramos Fernandes LM, et al., *Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation.* Dentomaxillofac Radiol, 2013. 42(1): 80179163.
35. Van der Veken D, et al., *Prevalence of apical periodontitis and root filled teeth in a Belgian subpopulation found on CBCT images.* Int Endod J, 2017. 50(4): p. 317-329.

36. Burklein S, Schafer E, Johren HP, Donnermeyer D. *Quality of root canal fillings and prevalence of apical radiolucencies in a German population: a CBCT analysis*. Clin Oral Investig, 2019 (on-line pre-press).
37. Pak JG, S Fayazi, and SN White, *Prevalence of periapical radiolucency and root canal treatment: a systematic review of cross-sectional studies.* J Endod, 2012. 38(9): p. 1170-1176.
38. Kirkevang L, *Root canal treatment and apical periodontitis: What can be learned from observational studies?* Endodontic Topics, 2011. 18(1): p. 51-61.
39. Kirkevang LL, M Vaeth, and A Wenzel, *Ten-year follow-up of root filled teeth: a radiographic study of a Danish population.* Int Endod J, 2014. 47(10): p. 980-988.
40. Peters LB, et al., *Prevalence of apical periodontitis relative to endodontic treatment in an adult Dutch population: a repeated cross-sectional study.* Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2011. 111(4): p. 523-528.
41. Kirkevang LL, M Vaeth, and A Wenzel, *Ten-year follow-up observations of periapical and endodontic status in a Danish population.* Int Endod J, 2012. 45(9): p. 829-839.
42. Connert, T., et al, *Changes in periapical status, quality of root fillings and estimated endodontic treatment need in a similar urban German population 20 years later*. Clin Oral Investig, 2019. 23(3): p. 1373-1382.
43. Murray CA and WP Saunders, *Root canal treatment and general health: a review of the literature.* Int Endod J, 2000. 33(1): p. 1-18.
44. Cotti E, et al., *An overview on biologic medications and their possible role in apical periodontitis.* J Endod, 2014. 40(12): p. 1902-1911.
45. Aminoshariae A, et al., *Association between Systemic Diseases and Endodontic Outcome: A Systematic Review.* J Endod, 2017. 43(4): p. 514-519.
46. Aminoshariae A, JC Kulild, and AF Fouad, *The Impact of Endodontic Infections on the Pathogenesis of Cardiovascular Disease(s): A Systematic Review with Meta-analysis Using GRADE.* J Endod, 2018. 44(9): p. 1361-1366 e3.
47. Hamedy R, et al., *Prevalence of root canal treatment and periapical radiolucency in elders: a systematic review.* Gerodontology, 2016. 33(1): p. 116-127.
48. Hamedy R, B Shakiba, and SN White, *Essential elder endodontics.* Gerodontology, 2016. 33(4): p. 433.
49. Shakiba B, et al., *Influence of increased patient age on longitudinal outcomes of root canal treatment: a systematic review.* Gerodontology, 2017. 34(1): p. 101-109.
50. Segura-Egea, JJ, J. Martin-Gonzalez, and L Castellanos-Cosano, *Endodontic medicine: connections between apical periodontitis and systemic diseases.* Int Endod J, 2015. 48(10): p. 933-951.
51. Allen PF, JM Whitworth, *Endodontic considerations in the elderly.* Gerodontology, 2004. 21: p. 185-194.
52. Rutz da Silva F, et al., *Relationship between quality of root canal obturation and periapical lesion in elderly patients: a systematic review.* Gerodontology, 2016. 33(3): p. 290-298.
53. Lopez-Lopez J, et al., *Periapical and endodontic status of type 2 diabetic patients in Catalonia, Spain: a cross-sectional study.* J Endod, 2011. 37(5): p. 598-601.
54. Segura-Egea JJ, et al., *High prevalence of apical periodontitis amongst type 2 diabetic patients.* Int Endod J, 2005. 38(8): p. 564-569.
55. Cabanillas-Balsera, D., et al., *Association between diabetes and non-retention of root filled teeth: a systematic review and meta-analysis*. Int Endod J, 2019. 52(3): p. 297-306.
56. Laukkanen, E., et al,. *Impact of systemic diseases and tooth-based factors on outcome of root canal treatment*. Int Endod J, 2019. 52(10): p. 1417-1426.
57. Nagendrababu, V., et al., *Association between diabetes and the outcome of root canal treatment in adults: An umbrella review*. Int Endod J, 2019. (in press)
58. Segura-Egea JJ, et al., *Hypertension and dental periapical condition.* J Endod, 2010. 36(11): p. 1800-1804.
59. Jalali P, et al., *Prevalence of Periapical Rarefying Osteitis in Patients with Rheumatoid Arthritis.* J Endod, 2017. 43(7): p. 1093-1096.
60. Virtanen E, et al., *Apical periodontitis associates with cardiovascular diseases: a cross-sectional study from Sweden.* BMC Oral Health, 2017. 17(1): p. 107.
61. Berlin-Broner Y, M Febbraio and L Levin, *Association between apical periodontitis and cardiovascular diseases: a systematic review of the literature.* Int Endod J, 2017. 50(9): p. 847-859.
62. Cotti E, et al., *Association of endodontic infection with detection of an initial lesion to the cardiovascular system.* J Endod, 2011. 37(12): p. 1624-1629.
63. Pasqualini D, et al., *Association among oral health, apical periodontitis, CD14 polymorphisms, and coronary heart disease in middle-aged adults.* J Endod, 2012. 38(12): p. 1570-1577.
64. Segura-Egea JJ, et al., *Antibiotics in Endodontics: a review.* Int Endod J, 2017. 50(12): p. 1169-1184.
65. Marx RE, JE Cillo Jr, and JJ Ulloa, *Oral bisphosphonate-induced osteonecrosis: risk factors, prediction of risk using serum CTX testing, prevention, and treatment.* J Oral Maxillofac Surg, 2007. 65(12): p. 2397-2410.
66. Price N, et al., *Prevention and management of osteonecrosis of the jaw associated with bisphosphonate therapy.* Support Cancer Ther, 2004. 2(1): p. 14-17.
67. Ruggiero SL, et al., *Osteonecrosis of the jaws associated with the use of bisphosphonates: a review of 63 cases.* J Oral Maxillofac Surg, 2004. 62(5): p. 527-534.
68. Sawatari Y and RE Marx, *Bisphosphonates and bisphosphonate induced osteonecrosis.* Oral Maxillofac Surg Clin North Am, 2007. 19(4): p. 487-498, v-vi.
69. Assael LA, *Oral Bisphosphonates as a Cause of Bisphosphonate-Related Osteonecrosis of the Jaws: Clinical Findings, Assessment of Risks, and Preventive Strategies.* Journal of Oral Maxillofacial Surgery, 2009. 67: p. 35-43.

70. Fantasia JE, *Bisphosphonates - What the Dentist Needs to Know: Practical Considerations.* Journal of Oral Maxillofacial Surgery, 2009. 67: p. 53-60.
71. Moinzadeh AT, et al., *Bisphosphonates and their clinical implications in endodontic therapy.* Int Endod J, 2013. 46(5): p. 391-398.
72. Hsiao A, G Glickman and J He, *A retrospective clinical and radiographic study on healing of periradicular lesions in patients taking oral bisphosphonates.* J Endod, 2009. 35(11): p. 1525-1528.
73. Alsalleeh F, et al., *Bisphosphonate-associated osteonecrosis of jaw reoccurrence after methotrexate therapy: a case report.* J Endod, 2014. 40(9): p. 1505-1507.
74. Ruggiero SLC, ER Carlson, LA Assael, *Comprehensive Review of Bisphosphonate Therapy: Implications for the Oral and Maxillofacial Surgery Patient.* Journal of Oral Maxillofacial Surgery, 2009. 67: p. 1.
75. Segura-Egea JJ, et al., *European Society of Endodontology position statement: the use of antibiotics in endodontics.* Int Endod J, 2018. 51(1): p. 20-25.
76. Yu VS, et al., *Incidence and impact of painful exacerbations in a cohort with post-treatment persistent endodontic lesions.* J Endod, 2012. 38(1): p. 41-46.
77. Carter AE, G Carter, and R George, *Pathways of fear and anxiety in endodontic patients.* Int Endod J, 2015. 48(6): p. 528-532.
78. Cho SY, et al., *Effect of Topical Anesthesia on Pain from Needle Insertion and Injection and Its Relationship with Anxiety in Patients Awaiting Apical Surgery: A Randomized Double-blind Clinical Trial.* J Endod, 2017. 43(3): p. 364-369.
79. Monteiro MR, et al., *4% articaine buccal infiltration versus 2% lidocaine inferior alveolar nerve block for emergency root canal treatment in mandibular molars with irreversible pulpits: a randomized clinical study.* Int Endod J, 2015. 48(2): p. 145-152.
80. De Pedro-Munoz A and J Mena-Alvarez, *The effect of preoperative submucosal administration of tramadol on the success rate of inferior alveolar nerve block on mandibular molars with symptomatic irreversible pulpitis: a randomized, double-blind placebo-controlled clinical trial.* Int Endod J, 2017. 50(12): p. 1134-1142.
81. Kirkevang LL, et al., *Prediction of periapical status and tooth extraction.* Int Endod J, 2017. 50(1): p. 5-14.
82. He J, et al., *Clinical and Patient-centered Outcomes of Nonsurgical Root Canal Retreatment in First Molars Using Contemporary Techniques.* J Endod, 2017. 43(2): p. 231-237.
83. Burns LE, et al., *Long-term Evaluation of Treatment Planning Decisions for Nonhealing Endodontic Cases by Different Groups of Practitioners.* J Endod, 2018. 44(2): p. 226-232.
84. Foltyn P, *Ethical decision making in aged care.* Gerodontology, 2017. 34: p. 289-290.
85. Alani A, K Bishop, and S Djemal, *The influence of specialty training, experience, discussion and reflection on decision making in modern restorative treatment planning.* Br Dent J, 2011. 210(4): p. E4.
86. Re D, et al., *Natural tooth preservation versus extraction and implant placement: patient preferences and analysis of the willingness to pay.* Br Dent J, 2017. 222(6): p. 467-471.
87. Mounce R and JD Moody, *The decision fork in the road; When to treat, when to refer, and when it's time for titanium.* Dent Today, 2013. 32(11): p. 98-103.
88. Orstavik D, K Kerekes and HM Eriksen, *The periapical index: a scoring system for radiographic assessment of apical periodontitis.* Endod Dent Traumatol, 1986. 2(1): p. 20-34.
89. Eliyas S, et al., *Development of quality measurement instruments for root canal treatment.* Int Endod J, 2017. 50(7): p. 652-666.
90. Del Fabbro M, et al., *Analysis of the secondary endodontic lesions focusing on the extraradicular microorganisms: an overview.* J Investig Clin Dent, 2014. 5(4): p. 245-254.
91. Rocas IN and JF Siqueira Jr, *Characterization of microbiota of root canal-treated teeth with posttreatment disease.* J Clin Microbiol, 2012. 50(5): p. 1721-1724.
92. Zhu X, et al., *Prevalence, phenotype, and genotype of Enterococcus faecalis isolated from saliva and root canals in patients with persistent apical periodontitis.* J Endod, 2010. 36(12): p. 1950-1955.
93. Rocas IN, M. Hulsmann, and J.F. Siqueira, Jr., *Microorganisms in root canal-treated teeth from a German population.* J Endod, 2008. 34(8): p. 926-931.
94. Siqueira JF, Jr. and IN Rocas, *Bacterial pathogenesis and mediators in apical periodontitis.* Braz Dent J, 2007. 18(4): p. 267-280.
95. Li H, et al., *Herpesviruses in endodontic pathoses: association of Epstein-Barr virus with irreversible pulpitis and apical periodontitis.* J Endod, 2009. 35(1): p. 23-29.
96. Chen V, et al., *Herpesviruses in abscesses and cellulitis of endodontic origin.* J Endod, 2009. 35(2): p. 182-188.
97. Schirrmeister JF, et al., *New bacterial compositions in root-filled teeth with periradicular lesions.* J Endod, 2009. 35(2): p. 169-174.
98. Wang QQ, et al., *Prevalence of Enterococcus faecalis in saliva and filled root canals of teeth associated with apical periodontitis.* Int J Oral Sci, 2012. 4(1): p. 19-23.
99. Signoretti FG, et al., *Persistent extraradicular infection in root-filled asymptomatic human tooth: scanning electron microscopic analysis and microbial investigation after apical microsurgery.* J Endod, 2011. 37(12): p. 1696-1700.
100. Farzaneh M, S Abitbol, and S Friedman, *Treatment outcome in endodontics: the Toronto study. Phases I and II: Orthograde retreatment.* J Endod, 2004. 30(9): p. 627-633.
101. De Chevigny C, et al., *Treatment outcome in endodontics: the Toronto study--phases 3 and 4: orthograde retreatment.* J Endod, 2008. 34(2): p. 131-137.

102. Ng YG K, et al.;, *Outcome of non-surgical re-treatment.* Endodontic Topics, 2008. 18(1): p. 3-30.
103. Ng YL, V Mann and K. Gulabivala, *Outcome of secondary root canal treatment: a systematic review of the literature.* Int Endod J, 2008. 41(12): p. 1026-1046.
104. Ng YL, V Mann and K. Gulabivala, *Tooth survival following non-surgical root canal treatment: a systematic review of the literature.* Int Endod J, 2010. 43(3): p. 171-189.
105. Torabinejad M, et al., *Outcomes of nonsurgical retreatment and endodontic surgery: a systematic review.* J Endod, 2009. 35(7): p. 930-937.
106. Davies A, et al., *The detection of periapical pathoses using digital periapical radiography and cone beam computed tomography in endodontically retreated teeth - part 2: a 1 year post-treatment follow-up.* Int Endod J, 2016. 49(7): p. 623-635.
107. Gorni FG and MM Gagliani, *The outcome of endodontic retreatment: a 2-yr follow-up.* J Endod, 2004. 30(1): p. 1-4.
108. Al-Nuaimi N, et al., *A prospective study assessing the effect of coronal tooth structure loss on the outcome of root canal retreatment.* Int Endod J, 2017. 50(12): p. 1143-1157.
109. Al-Nuaimi N, et al., *Pooled analysis of 1-year recall data from three root canal treatment outcome studies undertaken using cone beam computed tomography.* Int Endod J, 2018. 51 Suppl 3: p. e216-e226.
110. Ricucci DG, D et al.;, *The compromised tooth: conservative treatment or extraction?* Endodontic Topics, 2006. 13(1): p. 108-122.
111. Fonzar F, et al., *The prognosis of root canal therapy: a 10-year retrospective cohort study on 411 patients with 1175 endodontically treated teeth.* Eur J Oral Implantol., 2009. 2(3): p. 201-208.
112. Kwak, Y., et al., *The 5-Year Survival Rate of Nonsurgical Endodontic Treatment: A Population-based Cohort Study in Korea*. J Endod, 2019. 45(10): pp. 1192-1199.
113. Pirani, C., et al., *Outcome of secondary root canal treatment filled with Thermafil: a 5-year follow-up of retrospective cohort study*. Clin Oral Investig, 2018. 22(3): pp. 1363-1373.
114. Wesselink PR, *The incidental discovery of apical periodontitis.* Endodontic Topics, 2014. 30(1): p. 23-28.
115. Schwendicke F and M Stolpe, *Secondary Treatment for Asymptomatic Root Canal Treated Teeth: A Cost-effectiveness Analysis.* J Endod, 2015. 41(6): p. 812-816.
116. Tifooni, A., et al.,*Validation of the effectiveness of the Dental Practicality Index in predicting the outcome of root canal retreatments*. Int Endod J, 2019.52(10): pp. 1403-1409.
117. Torabinejad M, et al., *Levels of evidence for the outcome of nonsurgical endodontic treatment.* J Endod, 2005. 31(9): p. 637-646.
118. Burry, J.C., et al., *Outcomes of Primary Endodontic Therapy Provided by Endodontic Specialists Compared with Other Providers.* J Endod, 2016. 42(5): p. 702-705.
119. Iandolo A, et al., *Modern technologies in Endodontics.* Giornale Italiano di Endodonzia, 2016. 30(1): p. 2-9.
120. Lababidi EA, *Discuss the impact technological advances in equipment and materials have made on the delivery and outcome of endodontic treatment.* Aust Endod J, 2013. 39(3): p. 92-97.
121. Rampado ME, et al., *The benefit of the operating microscope for access cavity preparation by undergraduate students.* J Endod, 2004. 30(12): p. 863-867.
122. Rapani M, et al., *Influenza del microscopio operatorio nella diagnosi intraoperatoria e nel ritrattamento chirurgico endodontico: studio clinico e radiografico con follow-up a un anno.* Dental Cadmos, 2011. 79(8): p. 533-543.
123. Riccitiello F, et al., *Microscopio operatorio: diffusione e limiti.* Giornale Italiano di Endodonzia, 2012. 26(2): p. 67-72.
124. Del Fabbro M and S Taschieri, *Endodontic therapy using magnification devices: a systematic review.* J Dent, 2010. 38(4): p. 269-275.
125. Del Fabbro M, et al., *Magnification devices for endodontic therapy.* Cochrane Database Syst Rev, 2009(3): p. CD005969.
126. Taschieri S, et al., *Magnification in modern endodontic practice.* Refuat Hapeh Vehashinayim (1993), 2010. 27(3): p. 18-22, 61.
127. Taschieri S, et al., *Magnifying loupes versus surgical microscope in endodontic surgery: a four-year retrospective study.* Aust Endod J, 2013. 39(2): p. 78-80.
128. Lee CB, et al., *Association of Failed Root Canal Treatment with Dentist and Institutional Volumes: A Population-based Cohort Study in Taiwan.* J Endod, 2017. 43(10): p. 1628-1634.
129. Ramey K, J Yaccino, and J Wealleans, *A Retrospective, Radiographic Outcomes Assessment of 1960 Initial Posterior Root Canal Treatments Performed by Endodontists and Dentists.* J Endod, 2017. 43(8): p. 1250-1254.
130. Savani GM, et al., *Current trends in endodontic treatment by general dental practitioners: report of a United States national survey.* J Endod, 2014. 40(5): p. 618-624.

Sitography

[1a] https://www.aae.org/specialty/wp-con-tent/uploads/sites/2/2017/06/2006casedifficultyassessmentformb_edited2010.pdf
[1b] American Association of Endodontists (2005) Endodontic Case Difficulty Assessment and Referral. https:// www.aae.org/uploadedfiles/dental_professionals/endodontic_case_assessment/2006casedifficultyassessmentformb_edited 2010.pdf. [accessed on 24 April 2016].
[1c] https://www.endodonzia.it/articoli-scientifici/cose-un-granuloma/
[1d] https://www.e-s-e.eu/publications/index.html