The success of endodontic therapy - healing and functionality

Shimon Friedman and Chaim Mor

Abstract

Current, relevant knowledge on the outcome of endodontic therapy is key to clinical decision-making, particularly when endodontic treatment is weighed against tooth extraction and replacement. Inherent to reviewing the outcome is a definition of 'success' in relation to the goals of therapy. As the specific goal set out by the individual patient may either be healing/prevention of disease (apical periodontitis) or just functional retention of the tooth, the potential for both healing and functionality is reviewed. Based on selected follow-up studies that offer the best evidence, the chance of teeth without apical periodontitis to remain free of disease after initial treatment or orthograde retreatment is 92% to 98%. The chance of teeth with apical periodontitis to completely heal after initial treatment or retreatment is 74% to 86%, and their chance to be functional over time is approximately 91% to 97%. Thus there does not appear to be a systematic difference in outcome between initial treatment and orthograde retreatment. The outcome of apical surgery is less consistent than that of the non-surgical treatment. The chance of teeth with apical periodontitis healing completely after apical surgery is 37% to 85%, with a weighted average of approximately 70%. However, even with the lower chance of complete healing, the chance for the teeth to be functional over time is 86% to 92%. Considering the favorable outcome, conservative endodontic therapy, both non-surgical and surgical, is justified and should be attempted when a good restorative and periodontal prognosis is projected,unless the patient is not motivated to retain the tooth.

Imagine the following scenario. Mrs LK suffered a complicated fracture of her left wrist. After receiving emergency care, she consulted with an orthopedic surgeon who offered her two treatment options, each with its specific benefits and risks. The first option was to treat the broken wrist, with an 80% chance of 'success' (complete healing of the fracture) but with the possibility of sporadic discomfort and some movement restriction, and the risk of re-fracture upon another impact. The second was to amputate the hand and replace it with a state-of-the-art prosthesis, with 97% chance of 'success' (complete integration and functionality of the prosthesis) without discomfort or movement restriction. Although impressed by the prosthetic device's functionality and hand-like appearance, Mrs LK selected the first treatment option without any hesitation.

The analogy of this scenario applies to recent articles (Curtis DA et al, 2002; Matosian GS, 2003; Somborac M, 2003) debating endodontic therapy of teeth versus implant-supported single tooth replacement, and comparing the success rates of both procedures. The main argument in that debate is the success rate of endodontic therapy – initial treatment, orthograde retreatment and apical surgery. Often the quoted success rates are irrelevant to the debate, because they are outdated or derived from articles providing a low level of evidence. Importantly, the debate itself is often irrelevant, comparing a functional organ with an artificial prosthetic device, however perfect. While the latter problem concerns the balancing of ethics against pragmatism, the former is a matter of possessing the relevant knowledge regarding endodontic therapy and single-tooth implants, based on current information.

The objective of this article is to provide current, relevant review of the success of endodontic treatment procedures, and thus the knowledge basis for case selection regarding options of endodontic therapy.

What is success?

The non-specific term 'success' is ambiguous – it has a different meaning when referring to different dental treatment procedures, such as endodontic therapy, periodontal therapy or implants (Friedamn S, 2002). Undiscerning use of the term 'success' confuses communication within the profession and it may misguide patients contemplating alternative treatments, particularly endodontic therapy versus extraction and tooth replacement. The definition of success and the related rates differ considerably for the various procedures in dentistry. The uninformed patient weighing one success rate against the other may erroneously assume their definitions are comparable and select the treatment alternative that offers the 'higher number' and thus appears to suggest a better chance of success (Friedamn S, 2002).

Even for endodontic therapy, the definition of success has

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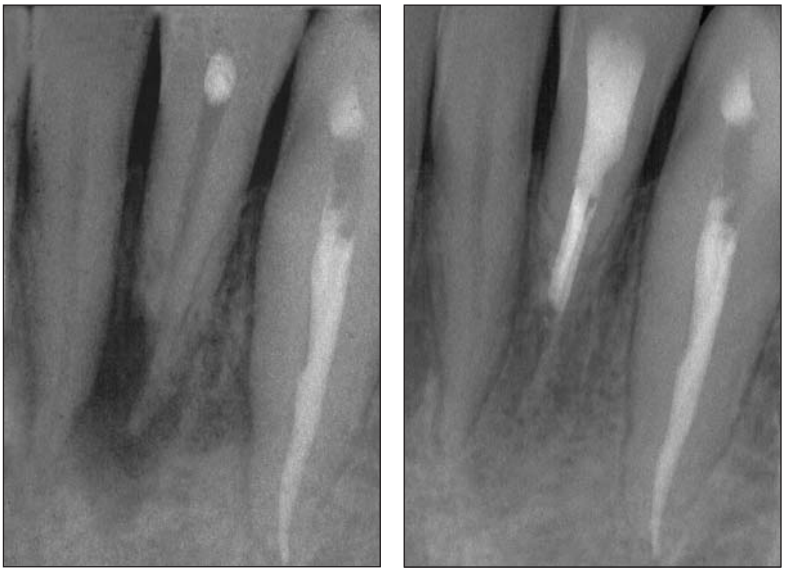


Figures 1a and 1b: Outcome classified as 'healed'. (a) Pre-operative radiograph of a mandibular lateral incisor with apical periodontitis and associated apical external resorption. (b) Follow-up radiograph at 1 year; the radiolucency has completely resolved and the tooth is asymptomatic, indicating it has healed

Figures 2a and 2b: Outcome classified as 'healed'. (a) Pre-operative radiograph of a maxillary second molar with apical periodontitis extending along the mesial root surface and associated sinus tract (traced with a gutta percha cone). (b) Follow-up radiograph at 1 year; the radiolucency has completely resolved and the tooth is asymptomatic, indicating it has healed

been ambiguous, with requirements ranging from stringent (radiographic and clinical normalcy) to lenient (only clinical normalcy) (Friedamn S, 2002; Friedamn S, 1998). Clearly, the more lenient definition increases the success rate in comparison with the more stringent one. For example, in a follow-up study after endodontic initial treatment and retreatment, Friedman et al (1995) report 78% complete healing (radiographic and clinical normalcy) and 16% incomplete healing (clinical normalcy combined with reduced radiolucency). Their success rate can be interpreted as 78% using the stringent definition, or 94% using the more lenient definition.

To resolve this long-lasting dilemma, one should remember that success is invariably defined by the goal(s) established to be achieved. To use another analogy, one can reflect on two athletes preparing for the Olympic games – the first's goal is to attend the games, while the second's goal is to win. For the first athlete, just participating in the Olympics is a success, irrespective of placement on the scoreboard. For the second athlete, only winning the gold medal is a success – winning a silver medal may feel like a failure. Just like in this analogy, the confusion resulting from the ambiguity of the term success with regard to endodontic therapy can be easily avoided by defining the specific goals and expected outcomes of treatment (Friedamn S, 2002).

The usual goal of endodontic therapy is to prevent or heal the disease, apical periodontitis (Ørstavik D, Pitt Ford TR, 1998). Accordingly, endodontic treatment outcomes should be defined in reference to healing and disease (Friedman S, 1998; Byström A et, 1987; Ørstavik D, 1996), as follows:

- Healed: Both the clinical and radiographic presentations are normal (Figures 1 and 2)
- Healing: Because healing is a dynamic process, reduced radiolucency combined with normal clinical presentation can be interpreted as healing in progress (Figure 3)
- Disease: Radiolucency has emerged or persisted without change, even when the clinical presentation is normal (Figure 4), or clinical sign or symptoms are present, even if the radiographic presentation is normal.

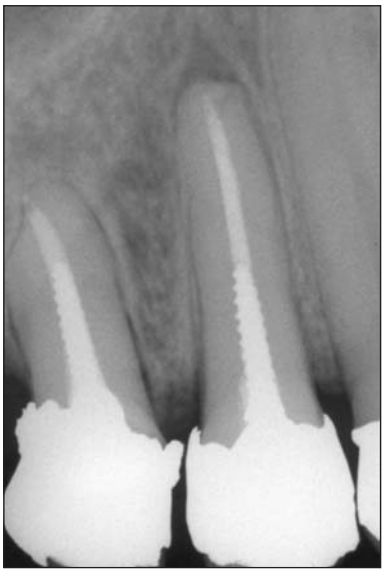
Although curing of disease is the ultimate goal of therapy, patients are autonomous to set less demanding goals for therapy, such as prevention or elimination of symptoms, or retention of the tooth. The latter is particularly applicable when the patient is motivated to attempt therapy even though the projected prognosis is unfavorable because of complicating factors. Accordingly, the endodontic treatment outcome can be defined as tooth retention (Friedman S, 2002), as follows:

- Functional retention: The clinical presentation is normal, while radiolucency may be absent or present newly emerged or persisting (Figures 5 and 6).

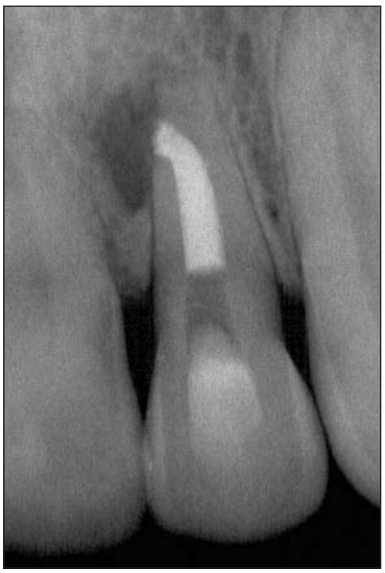
Considering the above, the outcome of endodontic therapy, or its success, is usually defined as the healing of disease unless it is specifically defined as tooth retention in asymptomatic function (Friedman S, 2002).

Relevant information on endodontic treatment outcomes

The potential for healing and functional retention of endodontically treated teeth can be gleaned from numerous



Figures 3a and 3b: Outcome classification as 'healed' versus 'healing'. (a) Immediate post-operative radiograph of maxillary first and second premolars with apical periodontitis. (b) Follow-up radiograph at 1 year; both teeth are asymptomatic. While the second premolar is classified as healed (see Figures 1 and 2), the reduction of the radiolucency in the first premolar is indicative of healing in progress (see also Figures 4 and 5). Regrettably, both the restorations are inadequate



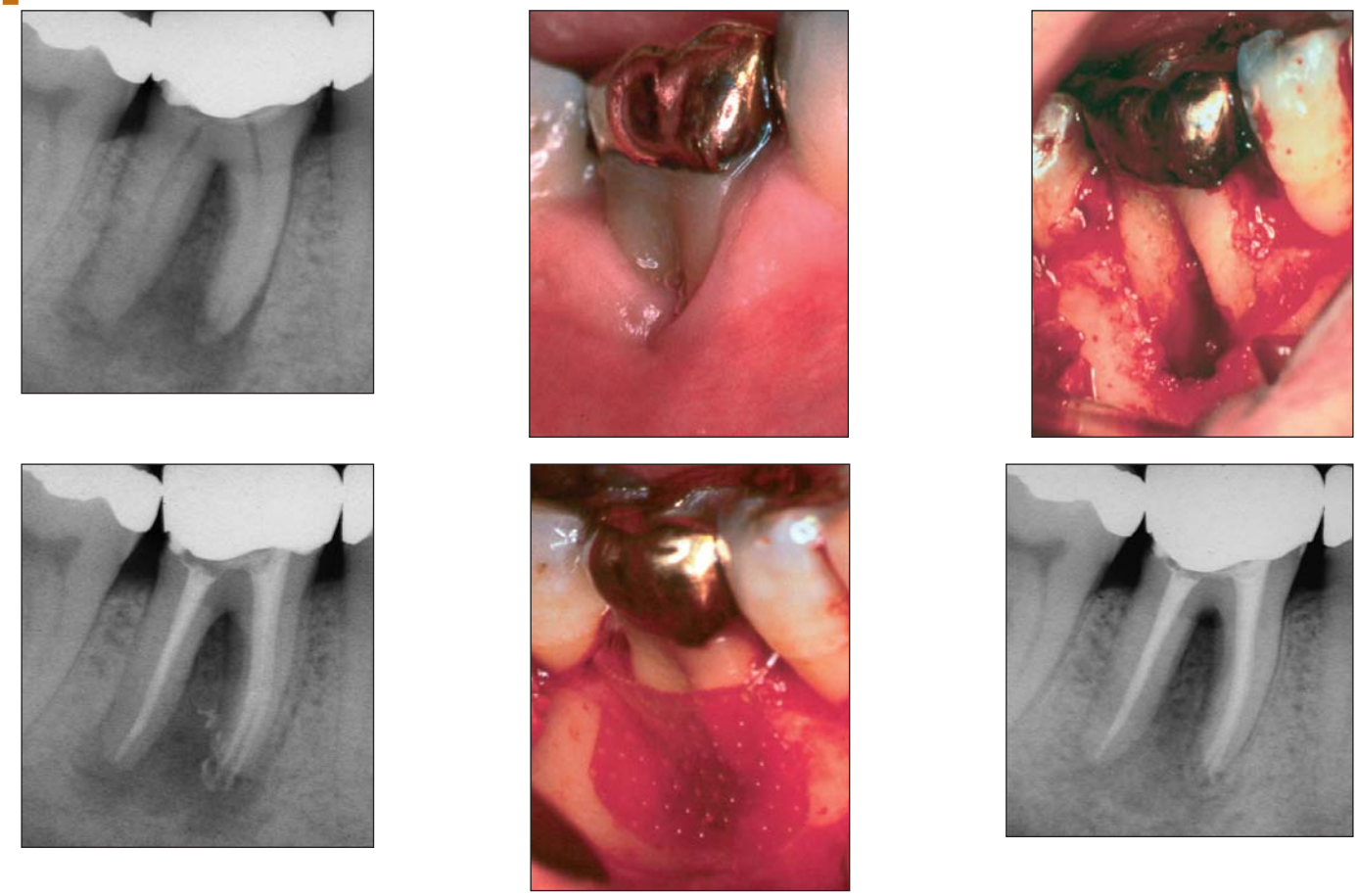
Figures 4a, 4b and 4c: Outcome classified as 'disease'. (a) Pre-operative radiograph of a maxillary lateral incisor with apical periodontitis. (b) Immediate post-operative radiograph. (c) Follow-up radiograph at 1 year; the tooth is asymptomatic but the radiolucency has not been reduced, indicating persistence of the disease

follow-up studies of selected populations exposed to initial treatment (Figure 7), orthograde retreatment (Figure 8) and apical surgery (Figure 9). Cumulatively, those studies include data from thousands of treated cases. Comprehensive reviews of those studies (Friedman S, 2002; Friedman S, 1998) reveal inconsistencies and large variability in the reported outcomes, resulting from diversity in material composition, treatment procedures and methodology. Because of that diversity, not all published studies are equally valuable as a source of valid and clinically relevant information. As suggested by one review (Friedman S, 2002): 'Undiscerning review of all the existing studies can be ineffective and even misleading'.

The fact that clinical studies vary with regards to the level of evidence they provide is well recognized in the current concept of evidence-based health care (Sackett DL et al, 1997). Reviewed studies, therefore, must be appraised according to well-defined criteria to differentiate them according to the level of evidence (Anderson JD, 2000). Such appraisal criteria can also be applied to select those endodontic outcome studies that provide the best evidence.

In a review article on the prognosis of initial treatment of apical periodontitis, Friedman (2002) used the accepted guidelines for appraisal of studies (Department of Clinical Epidemiology and Biostatistics, 1981). The appraisal criteria were grouped into four general parameters, comprising the following: cohort at inception and end-point of study, exposure (treatment), outcome assessment, and analysis/reporting of data. Studies conforming to three out the four parameters were selected for review, while others were excluded. A similar approach was subsequently used to review studies on orthograde retreatment (Farzaneh et al, in press; Wang NC et al, in press) and apical surgery (Wang NC et al, in press).

Tables 1-3 at the end of this article list the studies that were selected in the reviews as described above, for initial treatment (Byström A et al, 1987; Ørstavik D, 1996; Strindberg LZ, 1956; Engström Bet al, 1964; Kerekes K, Tronstad L, 1979; Ørstavik D, Kerekes K, Eriksen HM, 1987; Eriksen HM, Ørstavik D, Kerekes K, 1988; Sjögren U, Hägglund B, Sundqvist G, Wing K, 1990; Sjögren U, Figdor D, Persson S, Sundqvist G, 1997; Trope M, Delano O, Ørstavik D, 1999; Weiger R, Rosendahl R, Löst C, 2000; Peters LB, Wesselink PR, 2002; Hoskinson SE, Ng Y-L, Hoskinson AE, Moles DR, Gulabivala K,



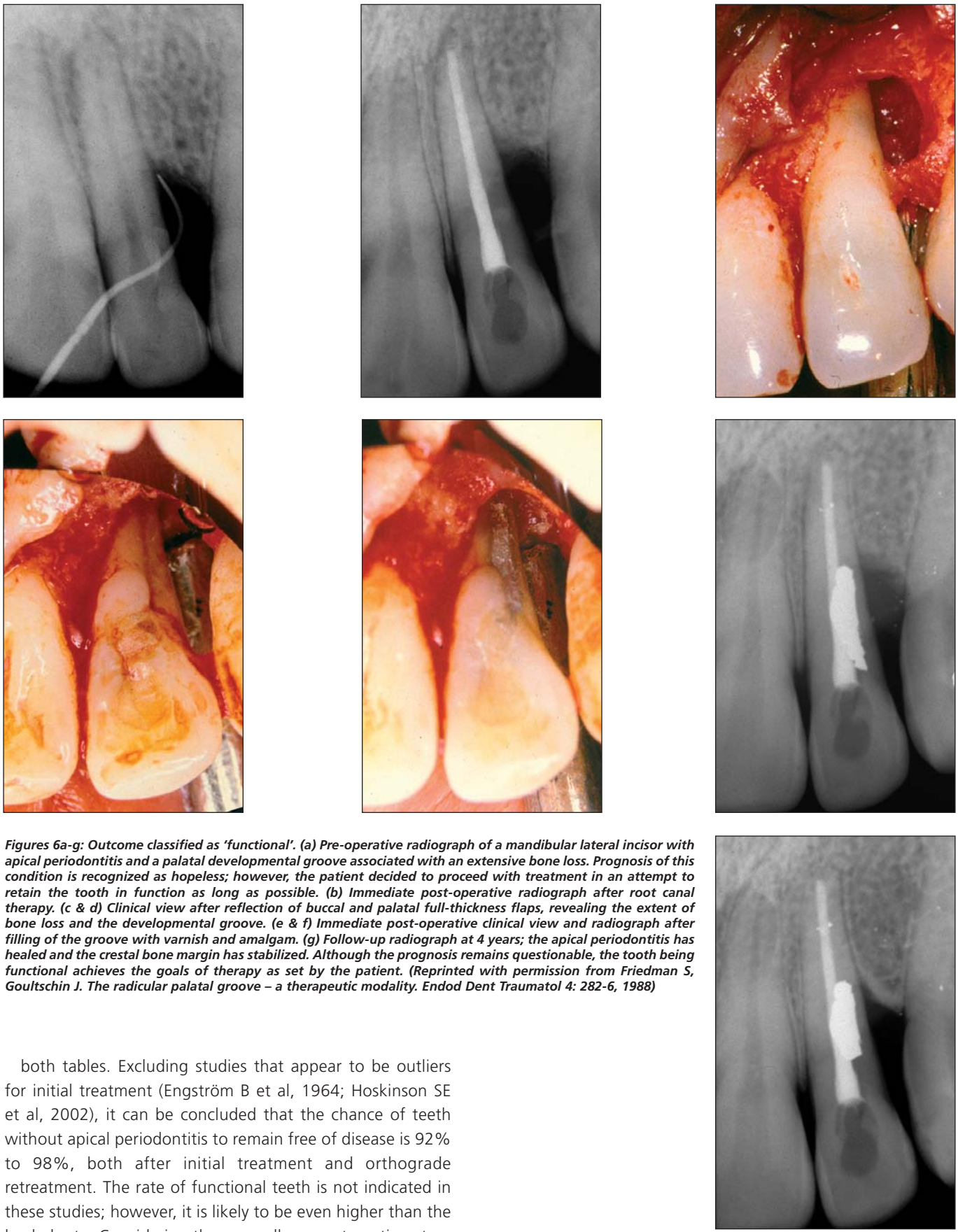
Figures 5a-g. Outcome classified as 'functional'. (a) Pre-operative radiograph of a mandibular first molar with extensive apical periodontitis. (b) Clinical view of the gingival recession on the buccal aspect of the tooth, coupled with probing depth apical to the root tips, suggests total loss of the buccal bone plate. The projected prognosis is poor. (c) Clinical view after reflection of a full-thickness flap reveals the extent of bone loss on the buccal aspect of the tooth. Advised of the poor prognosis, the patient decided to proceed with treatment in an attempt to retain the tooth in function as long as possible. (d & e) Immediate post-operative radiograph after root canal therapy (root filling with vertical compaction of warm gutta percha), followed by placement of a resorbable guided tissue regeneration membrane. (f & g) Follow-up radiograph and clinical view at 6 months; the radiolucency is considerably reduced and the gingival tissue appears to be healed. Although the prognosis remains poor, the tooth being functional achieves the goals of therapy as set by the patient, and should be considered as success

2002; Friedman S, Abitbol S, Lawrence HP, 2003; Farzaneh S, Abitbol S, Lawrence HP, Friedman S, 2004), orthograde retreatment (Farzaneh M, Abitol S, Friedman S, 2004; Strindberg LZ, 1956; Engström Bet al, 1964; Sjögren U, Hägglund B, Sundqvist G, Wing K, 1990; Sundqvist G, 1998; Kvist T, Reit C, 1999) and apical surgery (Wang NC, Knight K, Dao TT, Friedman S, 2004; Kvist T, Reit C, 1999; Molven O, Halse A, Grung B, 1991; Jansson L, Sandstedt P, Låftman A-C, Skoglund A, 1997; Zuolo ML, Ferreira MOF, Gutmann JL, 2000; Rahbaran S, Gilthorpe MS, Harrison SD, Gulabivala K, 2001), respectively.

The outcomes in the tables are interpreted from those reported by the original authors, as follows: (i) combined clinical and radiographic normalcy is classified as 'healed'; (ii) reduced radiolucency combined with clinical normalcy is classified as 'healing'; and (iii) the rate of teeth with no signs and symptoms is classified as 'functional' – for several studies this is simply the sum of 'healed' and 'healing' (when both are available), while for others it includes also teeth where the radiolucency remained unchanged.

Treatment outcome in teeth presenting without apical periodontitis

Teeth that present without apical periodontitis may have irreversible pulpitis, pulp necrosis or a dubious root filling (Friedman S, 2002). Accordingly, they undergo initial treatment or orthograde retreatment with the goal of preventing emergence of apical periodontitis. The outcomes of initial treatment and retreatment are presented separately in Tables 1 and 2, respectively. Consistently high percentages of teeth that remained healed after follow-up of up to 10 years can be seen in



Figures 6a-g: Outcome classified as 'functional'. (a) Pre-operative radiograph of a mandibular lateral incisor with apical periodontitis and a palatal developmental groove associated with an extensive bone loss. Prognosis of this condition is recognized as hopeless; however, the patient decided to proceed with treatment in an attempt to retain the tooth in function as long as possible. (b) Immediate post-operative radiograph after root canal therapy. (c & d) Clinical view after reflection of buccal and palatal full-thickness flaps, revealing the extent of bone loss and the developmental groove. (e & f) Immediate post-operative clinical view and radiograph after filling of the groove with varnish and amalgam. (g) Follow-up radiograph at 4 years; the apical periodontitis has healed and the crestal bone margin has stabilized. Although the prognosis remains questionable, the tooth being functional achieves the goals of therapy as set by the patient. (Reprinted with permission from Friedman S, Goultschin J. The radicular palatal groove – a therapeutic modality. Endod Dent Traumatol 4: 282-6, 1988)

both tables. Excluding studies that appear to be outliers for initial treatment (Engström B et al, 1964; Hoskinson SE et al, 2002), it can be concluded that the chance of teeth without apical periodontitis to remain free of disease is 92% to 98%, both after initial treatment and orthograde retreatment. The rate of functional teeth is not indicated in these studies; however, it is likely to be even higher than the healed rate. Considering the generally asymptomatic nature of apical periodontitis (Farzaneh M, Abitbol S, Friedman S, 2004; Wang NC, Knight K, Dao TT, Friedman S, 2004; Friedman S, Abitbol S, Lawrence HP 2003; Farzaneh M, Abitbol S, Lawrence HP, Friedman S, 2004), it can be assumed that only a few of the teeth with emerged disease are symptomatic.

Treatment outcome in teeth presenting with apical periodontitis

Teeth that present with apical periodontitis may have a primary infection of the root canal system or a residual or

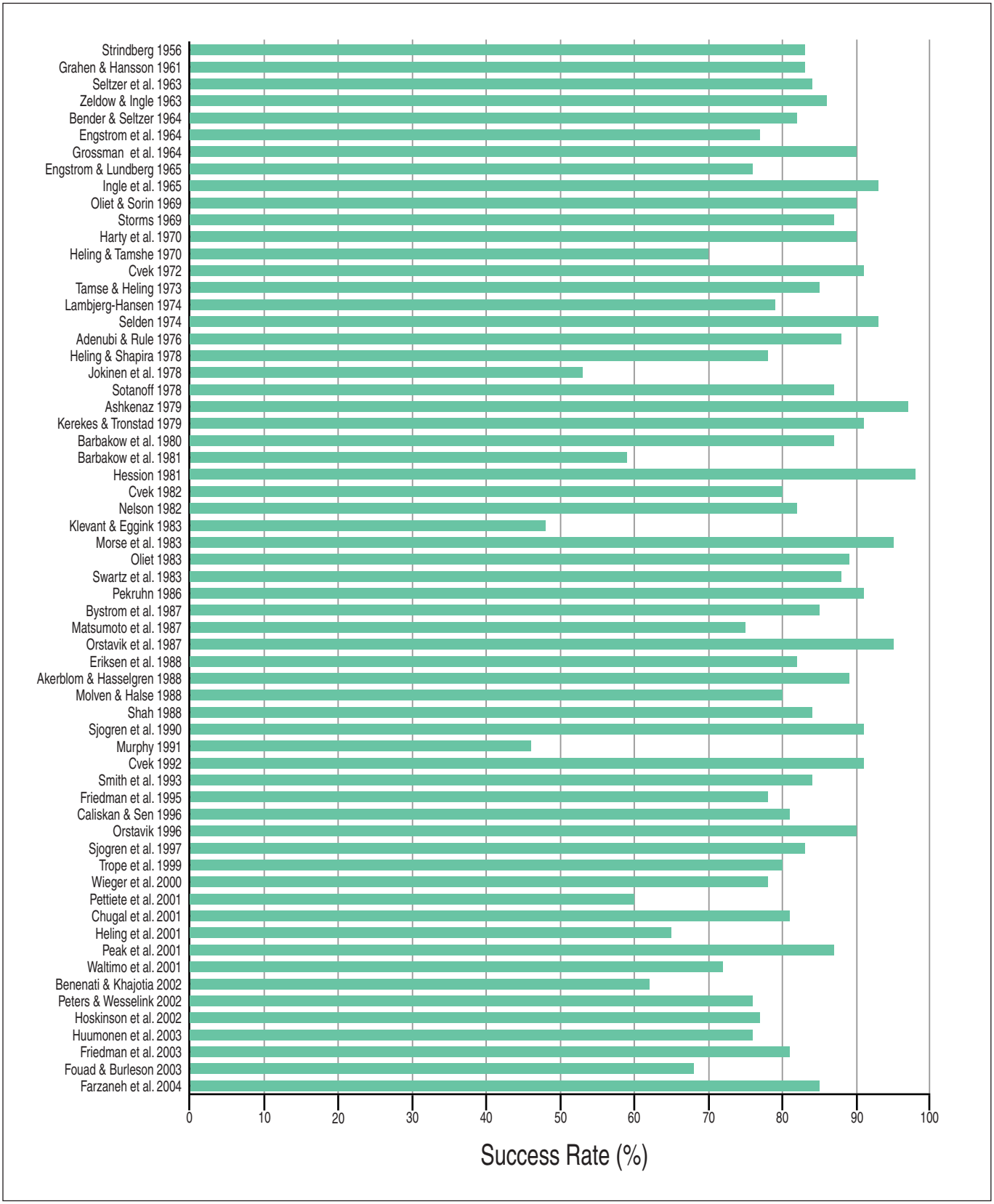


Figure 7: Graphic representation of the reported success rates in follow-up studies after endodontic initial treatment, from 1956 to 2004

Accordingly, they undergo initial treatment, orthograde retreatment, or apical surgery with the goal of healing of apical periodontitis. The outcomes of those treatment procedures are presented separately in Tables 1, 2 and 3, respectively.

Even among the selected studies on the outcome of initial treatment (Table 1) and orthograde retreatment (Table 2), there is some variability in the reported results. The 'healed' rates up to 10 years after therapy range from 73% (Engström et al, 1964) to 90% (Kerekes K, Tronstad L, 1979) for initial treatment, and from 74% (28) to 86% (Farzaneh M, Abitbol S, Friedman S, 2004) for orthograde retreatment. This disparity is considerably smaller than that observed across all studies for initial treatment (46% to 91%) (Figure

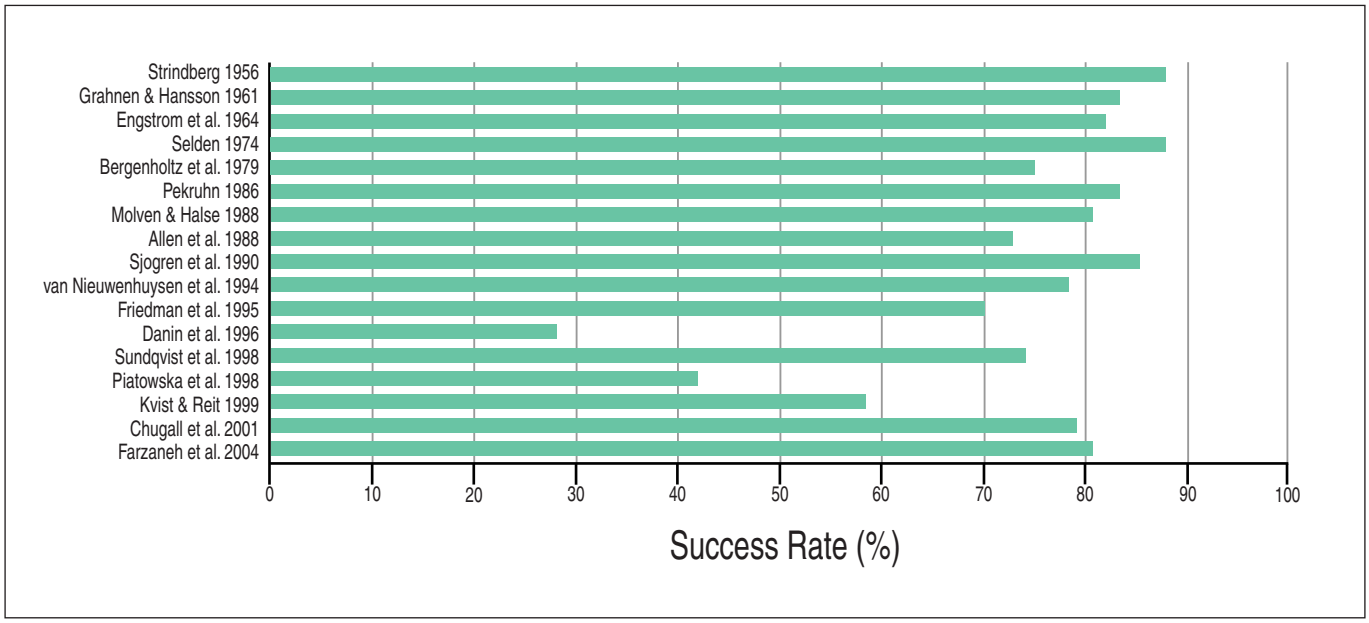


Figure 8: Graphic representation of the reported success rates in follow-up studies after endodontic orthograde retreatment, from 1956 to 2004

7) and retreatment (43% to 86%) (Figure 8). Because the selected studies are rather uniform in outcome assessment, this variability may be related to differences in case selection, in requiring a negative bacterial culture before root filling and in restoration after treatment (Friedman S, 2002). Excluding studies that appear to be outliers, on initial treatment (Kerekes K, Tronstad L, 1979) and on orthograde retreatment (Sjörgen U et al, 1990; Kvist T, Reit C, 1999), as well as teeth with perforations before retreatment (Farzaneh M, Abitbol S, Friedman S, 2004), it can be concluded that the chance of teeth with apical periodontitis to completely heal is 74% to 86%, after both initial treatment and orthograde retreatment. The fact that apical periodontitis has a similar potential to heal after initial treatment and orthograde retreatment challenges the historic perception of the latter having a poorer prognosis than the former.

Seven of the studies on initial treatment (Table 1) and one study on retreatment (Table 2) reveal that over 88% of the teeth are 'functional', with the disease mostly healed or healing. It can be assumed that in additional teeth disease persists without symptoms, as in 5% of the teeth included in the study by Friedman et al (2003); thus the rate of functional teeth probably approaches or even exceeds 95% (Peters LB, Wesselink PR, 2002; Friedman S, Abitbol S, Lawrence HP, 2003; Farzaneh S, Abitbol S, Lawrence HP, Friedman S, 2004). Excluding one study on initial treatment that appears to be an outlier (Ørstavik D, 1996), it can be concluded that the chance of teeth with apical periodontitis to remain in asymptomatic function is 91% to 97%, after both initial treatment and orthograde retreatment. These figures are certainly on a par with the success rate reported for single-tooth implant-supported replacement (Creugers NHJ, 2000). Clearly, then, in teeth with apical periodontitis, a good restorative and periodontal prognosis and no pre-operative perforation, conservative endodontic therapy is justified and should be attempted; tooth extraction and replacement should not be considered unless the patient is not motivated to retain the tooth.

Among the selected studies on the outcome of apical surgery (Table 3), the variability in the reported results remains large. The healed rates, up to eight years after surgery, range from 31% (Jansson L et al, 1997) to 91% (Zuolo ML, Ferreira MOG, Gutmann JL, 2000). This disparity is comparable to that observed across all studies for apical surgery (31% to 97%, Figure 9). In regard to apical surgery, this variability may be related to differences in case selection, in percentage of teeth undergoing repeat surgery (Peterson J, Gutmann JL, 2001), in type (initial or retreatment) and quality of the previous endodontic treatment (Friedman S, 1998; Wang NC, Knight K, Dao TT, Friedman S, 2004), and, possibly, also in root-end preparation and filling techniques. Excluding two studies that appear to be outliers (Jansson L, 1997; Zuolo ML, Ferreira MOF, Gutmann JL, 2000), the chance of teeth with apical periodontitis to heal completely after apical surgery appears to be 37% to 85%. To overcome this wide range and draw more definitive conclusions from the selected studies, a weighted average can be calculated (Hepworth MJ, Friedman S, 1997). Including the outlier studies (Jansson L et al 1997; Zuolo ML, Ferreira MOF, Gutmann JL, 2000) the average is 66%, and excluding these studies the average is 69%. It can be concluded, therefore, that the surgical treatment is less predictable than the non-surgical treatment, with an approximate 70% chance for teeth to heal.

Three of the studies reveal that 70% to 92% of the teeth show the disease to be healed or healing (Table 3). Because in additional teeth disease most likely persists without symptoms, the rate of 'functional' teeth after apical surgery

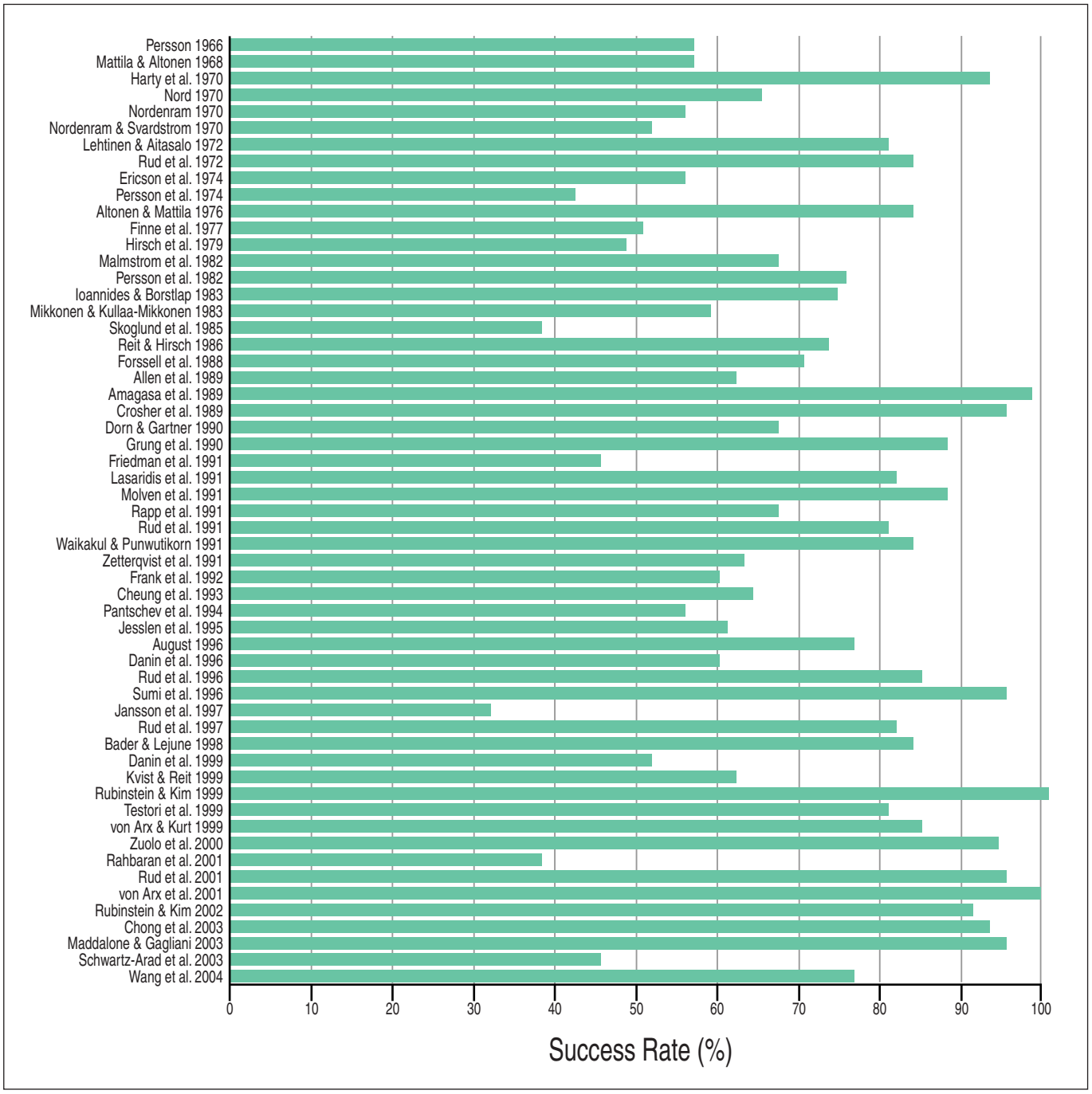


Figure 9: Graphic representation of the reported success rates in follow-up studies after apical surgery, from 1966 to 2004

approximates 90% (Table 3). Excluding one study that appears to be an outlier (Rahbaran S et al, 2001), it can be concluded that the chance of teeth with apical periodontitis to remain in asymptomatic function after apical surgery is 86% (Jansson L et al, 1997) to 92% (Molven O, Halse A, Grung B, 1991). These figures may be considered lower than those for non-surgical endodontic therapy. Nevertheless, they suggest that, for teeth with apical perio-dontitis and a good periodontal prognosis, even apical surgery is justified and should be attempted rather than contemplating tooth extraction and replacement, unless the patient is not motivated to retain the tooth.

Case selection

Selection of cases for endodontic therapy takes into consideration the prognosis of the endodontic, restorative and periodontal procedures, but also health and socio-economic factors. Contraindications to treatment include non-restorable and periodontally hopeless teeth, patients with extensive dental problems and restricted resources (that have to be utilized so as to benefit as many teeth as possible), and medically compromised patients at high-risk for infection. Criteria used for case selection can influence the outcome of endodontic therapy. It can be generalized, however, that in teeth presenting without apical periodontitis, the chance to prevent disease in the long-term is excellent. Even in teeth presenting with apical

Table 1: Selected follow-up studies on the outcome of endodontic initial treatment

STUDY			Teeth without apical periodontitis	Teeth with apical periodontitis		
	Follow-up (years)	Cases observed (%)	Healed (%)	Healed (%)	Healing (%)	Functional* (%)
Strindberg 1956	0.5-10	258	93	80	-	-
Engtröm et al. 1964	4-5	221	88	73	-	-
Kerekes & Tronstad 1979	3-5	491	97	90	-	-
Byström et al. 1987	2-5	79	-	85	9	94
Ørstavik et al. 1987	1-4	543	95	-	-	-
Eriksen et al. 1988	3	121	-	82	9	91
Sjögren et al. 1990	8-10	471	96	86	-	-
Ørstavik 1996	4	599	94	75	13	88
Sjögren et al. 1997	<5	53	-	83	-	-
Trope et al. 1999	1	76	-	80	-	-
Weiger et al. 2000	1-5	67	-	78	16	94
Hoskinson et al. 2002	4-5	200	88	74	-	97
Peters & Wesselink 2002	1-4.5	38	-	76	21	97
Friedman et al. 2003	4-6	120	92	74	18	97
Farzaneh et al. 2004	4-6	242	94	79	-	95

* Proportion of all teeth, with and without apical periodontitis

Table 2: Selected follow-up studies on the outcome of endodontic orthograde treatment

STUDY			Teeth without apical periodontitis	Teeth with apical periodontitis		
	Follow-up (years)	Cases observed (%)	Healed (%)	Healed (%)	Healing (%)	Functional* (%)
Strindberg 1956	0.5-10	187	95	84	-	-
Engtröm et al. 1964	4-5	153	93	74	-	-
Sjögren et al. 1990	8-10	266	98	62	-	-
Sundqvist et al. 1998	4	54	-	74	-	-
Kvist & Reit 1999	4	47	-	58	-	-
Farzaneh et al. 2004	4	103	97	86b	6	93

a Proportion of all teeth, with and without apical periodontitis

b Excluding teeth with pre-operative perforations (78% healed with perforated teeth included)

Table 3: Selected follow-up studies on the outcome of apical surgery

STUDY	Follow-up (years)	Cases observed (%)	Healed (%)	Healing (%)	Functional (%)
Molven et al. 1991	1-8	222	85	17	92
Jansson et al. 1997	1-1.3	62	31	55	86
Kvist & Reit 1999	4	45	60	-	-
Zuolo et al. 2000	1-4	102	91	-	-
Rahbaran et al. 2001	≥4	129	37	33	70
Wang et al. 2004	4-8	94	74	-	91

periodontitis, the prognosis is good whether they are exposed to initial treatment, orthograde retreatment or apical surgery – the chance of complete healing is reasonably high, and the chance for the tooth remaining asymptomatic and functional over time is truly excellent, provided that the tooth is promptly and well restored. An asymptomatic functional state, although not a measure of healing, allows the tooth to be retained without necessitating extraction. This clear, even if not optimal, benefit should be routinely communicated to patients when endodontic therapy is weighed against tooth extraction and replacement with a prosthetic device.

Summary

In summary, the concerns regarding the success of endodontic therapy are unsupported and misguided. The success of endodontic therapy, in terms of healing and functionality, is very good for teeth without both and with apical periodontitis. Therefore, the most appropriate form of endodontic therapy should be attempted whenever feasible, and generally preferred over tooth extraction and replacement.

This article first appeared in the Journal of the California Dental Association and is reprinted with the permission of Endodontic Practice.

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