Identify the Endodontic Treatment Modalities

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Abstract

Introduction: This paper sought to determine the levels of evidence associated with treatment for specific diagnostic categories and the prognosis of treatment. **Materials and Methods:** A review of the literature was conducted using MEDLINE, PubMed, Google Scholar and the Cochrane Database. The *Journal of Endodontics, International Journal of Endodontics, Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, Endodontic Topics,* and *Dental Traumatology* were also searched. The bibliographies of relevant articles were manually searched. **Conclusion:** The review found a low level of evidence to assess clinical treatment modalities. The development of higher levels of evidence to facilitate the selection of appropriate treatment modalities for each diagnostic category is recommended. *(J Endod 2009;35:1675–1694)*

Key Words

Gaps in knowledge, levels of evidence, treatment modalities

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Executive Summary

The committee sought to determine the levels of evidence associated with treatment for specific diagnostic categories and the prognosis of treatment. Each subquestion was assigned to individual committee members in an effort to provide a broad response to the question. The committee also worked to determine what gaps in knowledge exist in order to identify optimal treatment modalities for different diagnostic categories. The gaps identified could point to specific recommendations for future research. The resulting knowledge would bring us closer to improved evidence-based care, which has been described as the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients.

Ng et al (1) have commented that the quality of evidence for treatment factors affecting primary root canal treatment outcome is suboptimal and that there is substantial variation in the study designs. It would be desirable to standardize aspects of study design, including diagnostic terminology, data recording, operative procedures, and outcome data in future outcome studies. It is essential that we develop higher levels of evidence to facilitate the selection of appropriate treatment modalities for each diagnostic category.

Methodology

Committee members used the same basic methodology in gathering data in order to respond to their subquestions. An extensive search of the literature relevant to each subquestion was conducted electronically using MEDLINE, PubMed, Google Scholar, and the Cochrane Database. The *Journal of Endodontics*, *International Journal of Endodontics*, *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *Endodontic Topics*, and *Dental Traumatology* were also searched. The bibliographies of relevant articles were manually searched. The committee, using the Oxford Centre for Evidence-Based Medicine (CEBM) levels of evidence (May 2001), assigned a level to each paper (2). Responses to subquestions 1, 4, 5, and 6 were written in narrative form, whereas subquestions 2 and 3 used spreadsheet formats.

Results

As an overview, the committee concluded that there was an inadequate high level of evidence available for the determination of appropriate treatment with optimum outcome for each diagnostic category. This was caused in part by substantial variation in study design. It was noted that reported success rates had not improved over the last 4 or 5 decades (1). Specific gaps in knowledge are included in the response.

Recommendations

The committee recommends standardization of diagnostic terminology, study design, data recording, and other aspects of outcome studies. The available information is marked by a lack of standardization among the studies. Specific recommendations are made in the response in section 4.E. Friedman (3) has commented that an "undiscerning review of all the existing studies can be ineffective and even misleading."

The Committee has used the following American Board of Endodontics' Pulpal and Periapical Definitions (4):

Pulpal

Normal pulp. A clinical diagnostic category in which the pulp is symptom free and normally responsive to vitality testing.

Reversible pulpitis. A clinical diagnosis based on subjective and objective findings indicating that the inflammation should resolve and the pulp return to normal.

Irreversible pulpitis. A clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing.

Additional Descriptions

Symptomatic. Lingering thermal pain, spontaneous pain, referred pain.

Asymptomatic. No clinical symptoms, but inflammation produced by caries, caries excavation, trauma, and so on.

Pulp necrosis. A clinical diagnostic category indicating death of the dental pulp. The pulp is nonresponsive to vitality testing.

Previously treated. A clinical diagnostic category indicating that the tooth has been endodontically treated and the canals are obturated with various filling materials other that intracanal medicaments.

Previously initiated therapy. A clinical diagnostic category indicating that the tooth has been previously treated by partial endodontic therapy (eg, pulpotomy or pulpectomy).

Apical (Periapical)

Normal apical tissues. Teeth with normal periradicular tissues that will not be abnormally sensitive to percussion or palpation testing. The lamina dura surrounding the root is intact and the periodontal ligament space in uniform.

Symptomatic apical periodontitis. Inflammation, usually of the apical periodontium, producing clinical symptoms, including painful response to biting and percussion. It may or may not be associated with an apical radiolucent area.

Asymptomatic apical periodontitis. Inflammation and destruction of apical periodontium that is of pulpal origin, appears as an apical radiolucent area, and does not produce clinical symptoms.

Acute apical abscess. An inflammatory reaction to pulpal infection and necrosis characterized by pain onset, spontaneous pain, tenderness of the tooth to pressure, pus formation and swelling of associated tissues.

Chronic apical abscess. An inflammatory reaction to pulpal infection and necrosis characterized by gradual onset, little or no discomfort, and the intermittent discharge of pus through an associated sinus tract.

Subquestion #1: Which Subjective and Objective Data Are Needed to Predict the Outcomes of Various Treatment Modalities?

Literature Review

The literature reviewed included clinical studies that investigated the outcome of primary root canal treatment. A search was conducted electronically (MEDLINE, PubMed, Google Scholar, Cochrane Database) and by manually searching the following journals: *Journal of Endodontics*, *International Endodontic Journal*, *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *Dental Traumatology*, *Endodontic Topics* and bibliographies of relevant articles. The inclusion criteria were:

- Assessment of the outcomes of primary root canal treatment
- Sample size stated
- At least a 6-month, postoperative assessment
- Success criteria clearly stated
- Overall success rates determined

These rather modest inclusion criteria were utilized at the outset to gather a broad base of information in order to determine the level of existing knowledge and identify gaps to be addressed. Our response is directed at evaluating the current level of knowledge using the Oxford CEBM level of evidence, prioritizing questions that should be addressed and planning for future studies.

Most studies reviewed were prospective cohort or retrospective studies. The levels of evidence they provide are levels 2a or 2b based on the criteria provided by the Oxford CEBM. A review of the literature clearly shows that there is a lack of randomized, controlled trials that can be used by a clinician to predictably select clinical treatment modalities that are likely to provide the best outcome. Because of that, there is a need to synthesize an objective overview of the literature based on available evidence.

There are nine published systematic reviews that address the outcomes of primary endodontic treatment. They have used different approaches in the synthesis of information from the literature. Basmadjian-Charles et al (5) and Paik et al (6) used a systematic approach for literature search but a traditional approach for evaluating the variables impacting on the success and failure of the root canal retreatment. Two other reviews calculated the weighted-average success rates by each factor under investigation (7, 8). Neiderman and Theodosopoulou (9) estimated the number of cases needed to treat when comparing two types of treatments. Three reviews (Lewsey et al [10], Kojima et al [11], and Sathorn et al [12]) estimated the size of the effect of individual factors that included presence of preoperative pulpal and periapical status, apical extent of root filling, and number of treatment visits using meta-analysis.

Recent reviews of treatment outcomes were completed by Ng et al (1, 13) and Friedman (14). They considered the influence of clinical factors on the outcome of primary root canal treatment. In Ng's work, 119 articles were identified; 63 studies published from 1922 to 2002 were selected for review. Six were randomized trials, seven were cohort studies, and 48 were retrospective studies. Twenty-four factors (patient and operative) had been investigated in various combinations in the studies reviewed. The influence of preoperative pulpal and periapical status of the teeth on treatment outcome were most frequently explored, but the influence of treatment technique was poorly investigated.

Ng et al's systematic review (1) reported that success rates had not improved over the last 4 or 5 decades. The quality of evidence for treatment factors affecting primary root canal treatment outcome was found to be suboptimal, and there was substantial variation in the study designs. It was concluded that it would be desirable to standardize aspects of study design, data recording, and presentation format of outcome data in future outcome studies (1).

Four conditions (preoperative absence of periapical radiolucency, root filling with no voids, root filling extending to within 2 mm of the radiographic apex, and satisfactory coronal restoration) were found to significantly improve the outcome of primary root canal treatment.

Friedman reviewed 479 references out of which he identified 22 selected studies concerning initial nonsurgical root canal treatment as well as six studies pertaining to nonsurgical retreatment, six studies for surgical treatment, and nine for intentional replantation (14). Friedman makes the point that well-designed cohort studies may be preferred over randomized, controlled studies when considering prognosis, whereas randomized, controlled studies are preferred when comparing the benefits of one procedure over another (3).

Recommendation Position Based on Literature/Levels of Evidence

Based on a review of the literature/levels of evidence, it was concluded that there is a deficiency of high-level evidence for determining treatment factors effect on primary root canal treatment outcome. Randomized, controlled trials and high-quality prospective cohort outcome studies using standardized methodologies should be encouraged.

The following items represent existing gaps in our knowledge concerning optimal treatment modalities for different diagnostic categories:

- The significance of tooth type and number of roots
- The significance of demographic factors (eg, age, sex, and influence of systemic disease)
- Influence of smoking
- Influence of different types of periodontal disease on endodontic outcome
- Influence of intraoperative procedures
- The importance of bacteriologic culturing using modern technology
- Protocol and prognosis for regenerative endodontic procedures
- Predictability of intentional replantation
- Significance of restoration
- Appropriate recall period
- Appropriate standardized criteria and terminology for determining outcome

Rationale for Stated Position

A review of the literature shows a lack of evidence-based studies at the Oxford Center level 1a, the highest level of evidence. The influence of preoperative pulpal and periapical status of teeth on treatment outcomes were most frequently explored, but the influence of treatment technique and demographic factors has been inadequately assessed.

Subquestion #1 References

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Subquestion #2: What Are the Appropriate Treatments for Each of the Pulpal Diagnostic Categories?

Although recognizing it is the combination of pulpal and periapical diagnoses that guide the practitioner towards appropriate treatment, for the purpose of this article, the treatment of pulpal and periapical diagnostic categories will be addressed independently. Endodontic therapy applicable to each of six pulpal diagnoses is categorized in Tables 1 through 6.

Subquestion #3: What Are the Appropriate Treatments for Each of the Periapical Diagnostic Categories?

Using the American Board of Endodontics definitions for periapical pathosis, treatment modalities for periapical diagnoses have been identified. The related literature has been assessed using the Oxford Centre CEBM for their levels of evidence. It is important to recognize that the selection of appropriate treatment is accomplished not only by determining the pulpal and periapical diagnosis but also by reviewing other treatment factors as well.

In Table 7, there is significantly more overlap in the treatment modalities for periapical diagnostic categories than in the pulpal diagnostic categories. There is also an overlap of literature associated with different treatments. Because the overlap of literature is relative to more than one treatment modality, the citations have been segregated based on higher and lower levels of evidence. Articles representing a higher level of evidence are placed adjacent to treatment modalities and appropriately color coded. Articles with lower levels of evidence are found in the reference list.

Subquestion #3 Supplementary References

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TABLE 1. Normal Pulp: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Normal Pulp	1. No Treatment 2. Non-Surgical Root Canal Therapy, only in support of other therapies.	1. No support required	1. No support required
		2. a.Torabinejad M, Kutsenko D, MachnickTK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical endodontic treatment. J Endod 2005;31:637-46.	2.a. Review of 306 Outcome Studies–6 LOE1, 26 LOE2, 274 L0E3 or lower.
		2.b. Orstavik D, Quist V, Stoltze K. A multivariate analysis of the outcome of endodontic treatment. Eur J OralSci2004;112:224-30.	2.b.–LOE3b
		2.c. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod 2005;31:783-90.	2.c.–LOE4
		2.d. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006;32:299-306.	2.d.–LOE4
		2.e. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one- and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007;33:1145-8.	2.e.–LOE4
		2.f. Chugal NM, Clive JM, Spangberg L. Endodontic treatment outcome: effect of the permanent restoration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576-82.	2.f.–LOE4
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		2.h. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/14651858.CD005296.pub2.	2.h.–LOE2a
		2.i. de Chevigny C, DaoTT, Rasrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study - phase 4: initial treatment. J Endod 2008;34:258-63.	2.i.–LOE4
		2.j. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008;34:251-7.	2.j.–LOE2b
		2.k. Ng YL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature- Part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921-39.	2.k & l.–Review of 63 Outcome Studies –6 LOE 1, 7 L0E2, 48 L0E3 or lower
		2.l. NgYL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature- Part 2. Influence of clinical factors. Int Endod J 2008;41:6-31.	
		2.m. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:316-46.	2.m–LOE4
		2.n. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302-9.	2.n.–LOE4

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Sjogren U, Figdor D, Persson S, et al. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with

TABLE 2. Reversible Pulpitis: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Reversible Pulpitis	No Treatment	No support required	No support required
	1. Direct Pulp Capping	1. a. Matsuo T, Nakanishi T, Shimizu H, Ebisu S. A clinical study of direct pulp capping applied to carious-exposed pulps. J Endod 1996;22:551-6.	1.a.–L0E3b
		1.b. Barthel CR, Rosenkranz B, Leuenberg A, Roulet JF. Pulp capping of carious exposures: treatment outcome after 5 and 10 years; a retrospective study. J Endod 2000;26:525-8.	1.b.–L0E4
		1.c. Farsi N, Alamoudi N, Balto K, Al Mushayt A. Clinical assessment of mineral trioxide aggregate (MTA) as direct pulp capping in young permanent teeth. J Clin Pediatr Dent 2006;31:72-6.	1.c.–L0E4
		1.d. Al-Hiyasat AS, Barrieshi-Nusair KM, Al-Omari MA. The radiographic outcomes of direct pulp-capping procedures performed by dental students. A retrospective study. J Am Dent Assoc 2006;137:1699-1705.	1.d.–L0E4
		1.e. Miyashita H, Worthington HV, Qualtrough A, Plasschaert A. Pulp management for caries in adults: maintaining pulp vitality. Cochran Database of Systematic Reviews 2007, Issue 2. Art. No.:CD0044S4. DOI: 10.1002/ 14651S5S.CD0044S4.pub2.	1.e.–LOEla
		1.f. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:297-315.	1.f.–L0E4
		1.g. Bogen G, Kim JS, Bakland, LK. Direct pulp capping with mineral trioxide aggregate: an observational study. JADA 2008;139:305-315	1.g.–L0E4
	2. Indirect Pulp Capping	2. a. Maltz M, Oliveira EF, Fontanella V, Carminatti G. Deep caries lesions after incomplete dentine caries removal: 40-month follow-up study. Caries Res 2007;41:493-6.	2.a.–LOE3b
		2.b. Ricketts DNJ, Kidd EAM, Innes N, Clarkson J. Complete or ultraconservative removal of decayed tissue in unfilled teeth. Cochrane Database of Systematic Reviews 2006, Issue 3. Art. No.: CD003808. DOI: 10.1002/14651858.CD 003808.pub2.	2.b.–L0Ela
		2.c Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:297-315.	2.c.–LOE4
	3. Pulpotomy	3. a. WalyNG. A five-year comparative study of calcium hydroxide-glutaraldehyde pulpotomies versus calcium hydroxide pulpotomies in young permanent molars. Egypt Dent J 1995;41:993-1000.	3.a–LOE3b
		3.b. Witherspoon DE, Small JC, Harris GZ. Mineral trioxide aggregate pulpotomies. A case series outcomes assessment. J Am Dent Assoc 2006;137:610-8.	3.b–LOE3b
		3.c. Qudeimat MA, Barrieshi-Nusair KM, Owais Al. Calcium hydroxide vs mineral trioxide aggregates for partial pulpotomy of permanent molars with deep caries. Eur Arch Paediatr Dent 2007;8:99-104.	3.c–LOE3b
		3.d. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:297-315.	3.d.–LOE4
	4. Non-Surgical Root Canal Therapy, only in support of other therapies.	4.a.Torabinejad M, Kutsenko D, Machnick TK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical endodontic treatment. J Endod 2005;31:637-46.	4.a. Review of 306 Outcome Studies–6 L0E1, 26 LOE2,274 L0E3 or lower.
		4.b. Orstavik D, Quist V, Stoltze K. A multivariate analysis of the outcome of endodontic treatment. Eur J OralSci2004;112:224-30.	4.b.–LOE3b
		4.c. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod 2005;31:783-90.	4.c.–LOE4

(*Continued*)

TABLE 2. (*Continued*)

Pulpal Diagnosis	Treatment	Citations	Level of evidence
		4.d. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006;32:299-306.	4.d.–LOE4
		4.e. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one- and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007;33:1145-8.	4.e.–LOE4
		4.f. Chugal NM, Clive JM, Spangberg L. Endodontic treatment outcome: effect of the permanent restoration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576-82.	4.f.–L0E4
		4.g. Chen S-C, Chueh L-H, Hsiao CK, Tsai M-Y, Ho S-C, Chiang C-P. An epidemiologic study of tooth retention after nonsurgical endodontic treatment in a large population in Taiwan. J Endod 2007;33:226-9.	4.g.–LOE4
		4.h. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/ 14651858.CD005296.pub2.	4.h.–LOE2a
		4.i. de Chevigny C, DaoTT, Rasrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study - phase 4: initial treatment. J Endod 2008;34:258-63.	4 i.–LOE4
		4.j. Penesis VA, Fitzgerald PI, Fayacl MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008;34:251-7.	4.j.–LOE2b
		4.k. Ng YL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature-Part 1. Effects of study characteristics on probability of success. Int Endod J2007;40:921-39.	4.k & l.–Review of 63 Outcome Studies –6 LOE 1, 7 L0E2, 48 L0E3 or lower
		4.l. NgYL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - Part 2. Influence of clinical factors. Int Endod J 200S;41:6-31.	
		4.m. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:316-46.	4.m–LOE4
		4.n. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics- the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302-9.	4.n.–LOE4

apical periodontitis [published erratum appears in Int Endod J 1998 Mar;31:148]. Int Endod J 1997;30:297–306.

Strindberg L. The dependence of the results of pulp therapy on certain factors. Ana analytic study based on radiographic and clinical follow-up examination. Acta Odontol Scand 1956;14(Suppl 21):1-175.

Trope M, Delano EO, Ørstavik D. Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. J Endod 1999;25:345–50.

Weiger R, Rosendahl R, Lost C. Influence of calcium hydroxide intracanal dressings on the prognosis of teeth with endodontically induced periapical lesions. Int Endod J 2000;33:219–26.

Zuolo ML, Ferreira MO, Gutmann JL. Prognosis in periradicular surgery: a clinical prospective study. Int Endod J 2000;33:91–8.

Subquestion #4a: What Are the Pros and Cons of a Postoperative Diagnosis?

Establishing a preoperative pulpal and periapical diagnosis requires the clinician to use information gained from three distinct sources. The first source is the patient's report of the history and current interpretation of the chief complaint. The second source is comprised of the observations obtained from the clinical examination of the patient

TABLE 3. Irreversible Pulpitis: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Irreversible Pulpitis	1. Non-Surgical Root Canal Therapy	1.a.Torabinejad M, Kutsenko D, MachnickTK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical encloclontic treatment. J Enclocl 2005;31:637-46.	1.a. Review of 306 Outcome Studies–6 L0E1, 26 LOE2,274 L0E3 or lower.
		1.b. Orstavik D, Quist V, Stoltze K. A multivariate analysis of the outcome of encloclontic treatment. Eur J OralSci2004;112:224-30.	1.b.–L0E3b
		1.c. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod 2005;31:783-90.	1.c.–LOE4
		1.d. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006;32:299-306.	1.d.–L0E4
		1.e. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one- and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007;33:1145-S.	1.e.–LOE4
		1.f. Chugal NM, Clive JM, Spangberg L. Endodontic treatment outcome: effect of the permanent restoration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576-82.	1.f.–L0E4
		1.g. Chen S-C, Chueh L-H, Hsiao CK, Tsai M-Y, Ho S-C, Chiang C-P. An epidemiologic study of tooth retention after nonsurgical endodontic treatment in a large population in Taiwan. J Endod 2007;33:226-9.	1.g.–L0E4
		1.h. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/14651858.CD005296.pub2.	1.h.–L0E2a
		1.i. de Chevigny C, DaoTT, Rasrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study - phase 4: initial treatment. J Endod 2008;34:258-63.	1.i.–L0E4
		1.j. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008;34:251-7.	1.j.–L0E2b
		1.k. Ng YL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature- Part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921-39.	1.k & l.–Review of 63 Outcome Studies –6 LOE1, 7 L0E2, 48 L0E3 or lower
		1.l. NgYL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - Part 2. Influence of clinical factors. Int Endod J 2008;41:6-31.	
		1.m. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:316-46.	1.m.–LOE4
		1.n. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302-9.	1.n.–LOE4

and the results of commonly used clinical tests, including thermal, electric, percussion, palpation, and mobility. The third source is the interpretation of images produced by a variety of imaging techniques, including conventional and digital periapical or panoramic radiographs, computed tomography scans, cone beam-computed tomography, and micro-CT scans.

Unfortunately, the first two sources of information along with imaging using conventional or digital periapical or panoramic radiography are frequently subject to error. For instance, the accuracy of a variety of pulp vitality tests commonly used by the clinician consistently fall short of the gold standard of 100% (1–4). Petersson et al (4) found that the positive and negative predictive values for the cold test were 0.89 and 0.90, for the heat test 0.48 and 0.83, and for the electric pulp test 0.88 and 0.84, respectively (4). Low et al (5) reported that 34% more endodontic lesions were seen radiographically when limited cone-beam tomography scans were used in maxillary posterior teeth referred for possible endodontic surgery than when conventional periapical radiography was used (5). It is well documented that patient reports

TABLE 4. Pulp Necrosis: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Pulp Necrosis	1. Non-Surgical Root Canal Therapy	1.a.Torabinejad M, Kutsenko D, MachnickTK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical encloclontic treatment. J Enclocl 2005;31:637-46.	1.a. Review of 306 Outcome Studies–6 LOE1, 26 LOE2, 274 L0E3 or lower.
		1.b. Orstavik D, Quist V, Stoltze K. A multivariate analysis of the outcome of encloclontic treatment. Eur J OralSci2004;112:224-30.	1.b.–L0E3b
		1.c. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod 2005;31:783-90.	1.c.–LOE4
		1.d. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006;32:299-306.	1.d.–L0E4
		1.e. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one-and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007;33:1145-8.	1.e.–LOE4
		1.f. Chugal NM, Clive JM, Spangberg L. Endodontic treatment outcome: effect of the permanent restoration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576- 82.	1.f.–L0E4
		1.g. Chen S-C,Chueh L-H, Hsiao CK.Tsai M-Y, Ho S-C, Chiang C-P. An epidemiologic study of tooth retention after nonsurgical endodontic treatment in a large population in Taiwan. J Endod 2007;33:226-9.	1.g.–L0E4
		1.h. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296.DOI: 10.1002/14651858.CD005296.pub2.	1.h.–L0E2a
		1.i. de Chevigny C, DaoTT, Rasrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study- phase 4: initial treatment. J Endod 2008;34:25S-63.	1.i–L0E4
		1.j. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008;34:251-7.	1.j.–L0E2b
		1.k. Ng YL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature-Part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921-39.	1.k & l.–Review of 63 Outcome Studies –6 LOE1, 7 L0E2, 48 L0E3 or lower
		1.l. NgYL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature-Part 2. Influence of clinical factors. Int Endod J 2008;41:6-31.	
		1.m. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:347-80.	1.m.–LOE4
		1.n. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302-9.	1.n.–LOE4
	2. Regenerative/ Revascularization	2.a. Johnson WT, Goodrich JL, James GA. Replantation of avulsed teeth with immature root development. Oral Surg Oral Med Oral Pathol 1985;60:420-7.	2.a–f–All LOE4
		2.b. Kling M, Cvek M, Majare 1. Rate and predictability of pulp revascularization in lOtherapeutically reimplanted permanent incisors. Endod Dent Traumatol 1986;2:83-9.	
		2.c. Iwaya SI, Ikawa M, Kubota M. Revascularization of an immature permanent tooth with apical periodontitis and sin us tract. Dent Traumatol 2001;17:185-7.	

(*Continued*)

TABLE 4. (*Continued*)

Pulpal Diagnosis	Treatment	Citations	Level of evidence
		2.d. Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: new treatment protocol? J Endod 2004;30:196-200. 2.e. Chueh L-H, Huang GT-J. Immature teeth with periradicular periodontitis or abscess undergoing apexogenesis: a paradigm shift. J Endod 2006;32:1205-13. 2.f. Cotti 1, Mereu M, Lusso D. Regenerative treatment of an immature, traumatized tooth with apical periodontitis: report of a case. J Endod 2008;34:611-6. 2.g. Murray PE, BSc, Garcia-Godoy F, Hargreaves KM. Regenerative Endodontics: A Review of Current Status and a Call for Action. J Endod 2007;33:377-390	2.g. Review, summarizing current knowledge

are very subjective and influenced by a multitude of factors ranging from cultural and ethnic background to the category or rank of anxiety-producing stimuli (6).

Because of the inherent error in the information-gathering methods used by clinicians, the preoperative endodontic diagnosis is, in reality, a tentative diagnosis. However, regardless of its tentative nature, initial treatment planning decisions are and will be dependent on this phase of information gathering and interpretation. In some cases, however, it is only after direct macroscopic or microscopic examination of pulpal and periapical tissues or by observing the course of endodontic disease or other disease entity during or after treatment can a definitive diagnosis be made. This is especially true of periapical disease. If the overall objective of establishing a diagnosis is to approach or attain 100% accuracy in the identification of normal or pathologic conditions in order to synthesize an effective treatment plan, then the postoperative diagnosis is essential.

Reliance on the preoperative diagnosis alone can lead to misdiagnosis. In some instances, a misdiagnosis of pulpal disease is inconsequential because the treatment plan or its implementation would have been the same or similar for the real or the erroneously diagnosed disease entity or normal condition. In other instances, the misdiagnosis may result in unnecessary endodontic treatment. For periapical disease, the stakes can be much higher. A misdiagnosis of periapical disease may have far-reaching consequences that may place the patient in jeopardy because of spreading or fulminating infections, neoplastic disease, or other serious conditions (7–9). Because of the serious or even mortal consequences of misdiagnosis, it is compelling to establish an accurate (definitive) postoperative diagnosis.

The consequences for the patient of errors in preoperative diagnosis, which lead to mistakes in treatment selection or omissions, range from minimal to serious to life threatening. In today's litigious society, these errors in diagnosis can and often do result in malpractice suits, large settlements, ruined professional reputations, and irrevocable negative entries in the National Practitioner Data Bank. The reality of the legal ramifications of erroneous preoperative diagnosis clearly speaks for adopting practice behaviors that provide greater accuracy of diagnosis in a timely manner. The more objective methods used to establish a postoperative diagnosis typify those behaviors.

Subquestion #4b: If Different from Preoperative Diagnosis, Should the Postoperative Diagnosis Be the More Definitive Diagnosis in Every Case?

If we accept the premise that a preoperative diagnosis is a tentative diagnosis, albeit an essential one to develop a treatment plan, then it follows that we can confirm an accurate tentative (preoperative) diagnosis postoperatively or discover the inaccuracy of the initial diagnosis. This is achieved during or after the treatment intervention by direct observation of pulpal tissues, microbiological sampling, histopathologic examination of periapical tissues, or recalls of patients to assess the course of healing or nonhealing of diseased tissues. Executing the sequence of actions from preoperative diagnosis to treatment planning to definitive diagnosis postoperatively then becomes the gold standard for clinical practice. Philosophically, because the gold standard represents the very best that can be attained by known means and the best that the clinician can offer the patient, it should be required in every case.

If the postoperative diagnosis is the most accurate because of more objective and direct methods of data collection, then this improved accuracy provides the impetus to change the initial diagnosis if it is wrong. It also follows that if a postoperative diagnosis is different from the preoperative diagnosis, the postoperative diagnosis will be more accurate than the preoperative diagnosis.

From a purist's point of view, a more accurate diagnosis is a more definitive diagnosis. A more definitive diagnosis increases the probability of selecting a better treatment plan for the patient. This, in turn, provides the opportunity for the clinician to provide the patient with a more accurate prediction of treatment outcome. Finally, better treatment leads to better outcomes.

As has been eluded to previously in this article, the implications of failing to make a definitive diagnosis postoperatively when there is an erroneous preoperative diagnosis, especially for periapical disease, can be ominous. It is the clinician's responsibility and obligation to avoid failing to recognize the existence, nature, and importance of disease processes that can lead to patient morbidity or mortality. Thus, a definitive diagnosis, whether it is confirmed after the preoperative diagnosis is made or obtained de novo postoperatively, is mandatory. The definitive diagnosis is central to the timely modification of a treatment plan to best treat the patient when a preoperative (tentative) diagnosis is misleading or inaccurate.

Based on the previously described argument, when the postoperative diagnosis differs from the preoperative diagnosis, the postoperative diagnosis is the more definitive and will be in every case. To believe otherwise tempts the clinician to group clinical situations in which differences in pre- and postoperative diagnoses have no material effect on outcomes together with those in which those differences carry negative consequences for the patient. This creates the situation in which the clinician operates under two different standards of care and exercises two different sets of practice behaviors. This is contrary to and incompatible with the lofty goal of providing all patients with the same opportunity for equal access to and the benefit of the gold standard of care.

TABLE 5. Previously Treated: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Previously Treated	1. Non-Surgical Retreatment	1.a. PaikS, Sechreist C.Torabinejad M. Levels of evidence for the outcome of encloclontic retreatment. J Endod 2004;30:745-50.	1.a. Review of 37 Outcome Studies–0 LOE1, 1 LOE2, 0 LOE3&4, 18 L0E5.
		1.b. Gorni FG, Gagliani MM. The outcome of endodontic retreatment: A 2-yr follow-up. J Endod 2004;30:l-4.	1.b.–L0E3b
		1.c. Yoldas 0, Topuz A, Isci AS, Oztunc H. Postoperative pain after endodontic retreatment: Single-versus two-visit treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98:483-7.	1.c.–L0E3b
		1.d. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:347-80.	1.d.–L0E4
		1.e. Kvist T, Reit C. Results of endodontic retreatment: a randomized clinical study comparing surgical and nonsurgical procedures. J Endod 1999;25:814-17	1.e.–LOE2b
	2. Periradicular Surgery	2.a. Mead C, Javida-Nejad S, Mego ME, Nash B, Torabinejad M. Levels of evidence for the outcome of endodontic surgery. J Endod 2005;31:19-24.	2.a. Review of 79 Outcome Studies -0 LOE1,7 LOE2, 12 LOE3, 60 LOE4.
		2.b. Del Fabbro M, Taschieri S, Testori T, Francetti L, Weinstein RL. Surgical versus non-surgical endodontic retreatment for periradicular lesions. Cochrane Database of Systemic Reviews 2007, Issue 3. Art. No.: CD005511. DOI: 10.1002/14651858.CD005511.publ.	2.b.–L0Ela
		2.c. Gagliani MM, Gorni FG, Strohmenger L. Periapical resurgery versus periapical surgery: a 5-year longitudinal comparison. Int Endod J 2005;38:320-7.	2.c.–LOE2b
		2.d. Friedman S. The prognosis and expected outcome of apical surgery. Endod Topics 2005; 11:219-62.	2.d.–LOE2b
		2.e. Penarrocha M, Marti E, Garcia B, Gay C. Relationship of periapical lesion radiologic size, apical resection, and retrograde filling with the prognosis of periapical surgery. J Oral Max Surg, 2007;65:1526-9.	2.e.–LOE3b
		2.f. von Arx T.Jensen SS, Hanni S. Clinical and radiographic assessment of various predictors for healing outcome 1 year after periapical surgery. J Endod 2007;33:123-8.	2.f.–LOE3b
		2.g. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:381-407.	2.g.–LOE4
		2.h. Kvist T, Reit C. Results of endodontic retreatment: a randomized clinical study comparing surgical and nonsurgical procedures. J Endod 1999;25:814-17	2.h.–LOE2b
		2.i. Wang N, Knight K, Dao T, Friedman S. Treatment outcome in endodontics - the toronto study: phases 1 and II: apical surgery. J Endod 2004;30:751-761.	2.i.–LOE4
		2.j. Lindeboom JA, Frenken JW, Kroon FH, van den Akker HP. A comparative prospective radomized clinical study of MTA and IRM as root-end filling materials in single-rooted teeth in endodontic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:495-500.	2.j.–LOE2a
	3. Intentional Replantation	3.a. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:452-4.	3.a.–LOE4
		3.b. Koenig KH, Nguyen NT, Barkhordar RA. Intentional replantation: a report of 192 cases. Gen Dent 1988;36:327-31.	3.b.–LOE4

(*Continued*)

TABLE 5. (*Continued*)

Pulpal Diagnosis	Treatment	Citations	Level of evidence
		3.c. Keller U. A new method of tooth replantation and auto-transplantation: aluminum oxide ceramic for extraoral retrograde filling. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1990;70:341-4.	3.c.–LOE4
		3.d. Bender IB, Rossman LE. Intentional replantation of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1993;76:623-30.	3.d.–LOE4

Subquestion #4 References

1. Hyman JJ, Cohen ME. The predictive value of endodontic diagnostic test. Oral Surg Oral Med Oral Pathol 1984;58:343–6.

2. Fuss Z, Trowbridge H, Bender IB, et al. Assessment of reliability of electrical and thermal pulp testing agents. J Endod 1986;12:301–5.

3. Peters DD, Baumgartner JC, Lorton L. Adult pulpal diagnosis. I. Evaluation of the positive and negative responses to cold and electrical pulp test. J Endod 1994;20:506–11.

4. Petersson K, Soderstrom C, Kiani-Anaraki M, et al. Evaluation of the ability of thermal and electrical tests to register pulp vitality. Endod Dent Traumatol 1999;15:127–31.

5. Low KM, Dula K, Bürgin W, et al. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. J Endod 2008;34:557–62.

6. Eitner S, Wichmann M, Paulsen A, Holst S. Dental anxiety—an epidemiological study on its clinical correlation and effects on oral health. J Oral Rehabil 2006;33:588–593.

7. Garlock JA, Pringle GA, Hicks ML. The odontogenic keratocyst. A potential endodontic misdiagnosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;85:452–6.

8. Dahlkemper P, Wolcott JF, Pringle GA, et al. Periapical central giant cell granuloma: a potential endodontic misdiagnosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:739–45.

9. Kuc I, Peters E. Comparison of clinical and histologic diagnoses in periapical lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:333–7.

Subquestion #5: What Are the Indications, Contraindications, and Prognoses for These Treatments?

In this review of the literature, the current endodontic diagnostic terminology derived by the American Board of Endodontics is used. Possible treatments relative to those diagnostic categories are pulp capping, pulpotomy, pulpectomy (nonsurgical or orthograde root canal therapy), apicoectomy, and replantation; these appear as MeSH terms under "endodontics." These terms were searched through PubMed with the additional MeSH terms "prognosis" or "contraindications." Limits applied to these searches included "English" along with either "randomized controlled trial," "meta-analysis," or "review." General searches using the same search terms, but without limits, were also performed. The intention was to find relevant literature on prognosis of these treatments in adult permanent teeth. Controlled trials as well as many systematic reviews have been a focused topic of investigation.

Pulp Capping/Pulpotomy

Most investigative work on the outcomes of pulp-capping procedures has been performed on younger patients and on primary teeth. Investigations of these procedures on permanent teeth in adults are exceedingly limited. There is a consistent criterion in these studies that only teeth with deep caries, possibly even carious pulp exposure, but without spontaneous symptoms be included in the experimental groups. Teeth with spontaneous symptoms are assumed to be committed to pulpectomy and complete root canal therapy. This concept itself, although widely accepted and broadly applied, is drawn by inference from histopathologic studies of the dental pulp. No study could be located that directly tested this concept, and it may be warranted to investigate this very fundamental clinical paradigm.

Successful outcome with indirect pulp capping of adult permanent teeth is reported to be on the order of 80% to 90% (1); direct pulp capping is reported to be 50% to 80% (2) or as high as 100% (3). At 3 years, 33% of carious exposures were radiographically successful, whereas mechanical exposure had 92% success (4). An overall clinical and radiographic success of 82% was observed for calcium hydroxide direct pulp caps up to 40 years of age (5) with decreasing success beyond that age.

Whitworth et al (6) found that the odds ratio of pulp breakdown in teeth with pulp exposure versus those without was 28.4. The deterioration over time of the prognosis of pulp-capping carious exposures in adult permanent teeth seems to indicate this procedure is contraindicated as a long-term treatment. Observations made by Matsuo et al (5) refute this conclusion. In assessing the outcomes of direct pulp capping (carious exposure) of adult teeth, they found an impressive success rate of 88.6% when there was slight bleeding versus 55.6% with conspicuous bleeding. There is a significant drop off in the number of participants because the study was performed for 36 months so absolute success is speculative, but, of those who returned for follow-up, success rates remained at 80% to 92%.

Nyborg (7) observed a difference between clinical outcome, based on signs and symptoms, and histopathologic healing. Fifty-six percent (41/73) of adult teeth with carious pulp exposure but no prior symptoms were clinically "successful" after pulp capping. On histopathologic examination of 19 of those cases, only 8 (44%) were considered histopathologically "successful." Nyborg also makes the observation that histopathologic and clinical success is more likely in permanent teeth in children (74% clinical and 68% histopathologic) than in adults.

A case series (LOE 4) reported by Bogen et al (8) included 18 adult patients aged 16 to 47 years and with 1 to 7 years follow-up. All pulp-capping procedures followed a meticulous treatment protocol, and MTA was used as the capping material. Thirteen of the 18 teeth (72%) had radiographically detectable dentin bridges and showed normal clinical pulp responses at final follow-up. The information from Hodosh, Shovelton, and Whitworth is extracted from a Cochrane Review focusing on pulp management in adult teeth (9) with an LOE of 2.

Sixty-five percent of teeth in a case series of mostly adult patients receiving pulpotomy procedures instead of extraction were present and functioning at last recall (up to 88 months) (10). Up to 30 days, 98% of pulpotomized teeth may remain symptom free whether a liquid sedative dressing is used or not (11). For up to 6 months, a hard-setting eugenol

TABLE 6. Previously Initiated therapy: Treatment, Citations, Level of Evidence

Pulpal Diagnosis	Treatment	Citations	Level of evidence
Previously Initiated Therapy	1. Non-Surgical Root Canal Therapy	1.a.Torabinejad M, Kutsenko D, MachnickTK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical encloclontic treatment. J Enclocl 2005;31:637-46.	1.a. Review of 306 Outcome Studies- 6 LOE1, 26 LOE2, 274 L0E3 or lower.
		1.b. Orstavik D, Quist V, Stoltze K. A multivariate analysis of the outcome of encloclontic treatment. Eur J OralSci2004;112:224-30.	1.b.–L0E3
		1.c. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: a 10-year retrospective study. J Endod 2005;31:783-90.	1.c.–LOE4
		1.d. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006;32:299-306.	1.d.–L0E4
		1.e. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one- and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007;33:1145-S.	1.e.–LOE4
		1.f. Chugal NM, Clive JM, Spangberg L. Endodontic treatment outcome: effect of the permanent restoration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576-82.	1.f.–L0E4
		1.g. Chen S-C, Chueh L-H, Hsiao CK, Tsai M-Y, Ho S-C, Chiang C-P. An epidemiologic study of tooth retention after nonsurgical endodontic treatment in a large population in Taiwan. J Endod 2007;33:226-9.	1.g.–L0E4
		1.h. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/ 14651858.CD005296.pub2.	1.h.–L0E2
		1.i. de Chevigny C, DaoTT, Rasrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study-phase 4: initial treatment. J Endod 200S;34:25S-63.	1.i–L0E4
		1.j. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation. J Endod 2008;34:251-7.	1.j.–L0E2
		1.k. Ng YL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature-Part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921-39.	1.k & l.–Review of 63 Outcome Studies–6 LOE1, 7 L0E2, 48 L0E3 or lower
		1.l. NgYL, Mann V, Rahbaran S, LewseyJ, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature-Part 2. Influence of clinical factors. Int Endod J 200S;41:6-31.	
		1.m. Orstavik D, Pitt Ford T. Essential Endodontology. 2nd ed. Oxford UK: Blackwell, 2008:347-80.	1.m.–LOE4
		1.n. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302-9.	1.n.–LOE4

dressing allowed symptom-free retention of 90% of teeth in adults; however, 51% of those teeth had radiographic changes in that time period (12). Pulpotomy with or without a sedative dressing may be an effective temporary palliative treatment for adult permanent teeth. As with pulp capping of carious exposures, the prognosis of long-term pulpotomy treatment in adult permanent teeth has been assumed to be contraindicated but has not been thoroughly investigated with current materials.

TABLE 7. Normal: Treatment, Citations, Level of Evidence

Periapical Diagnosis	Treatment	Citations		Level of Evidence
Normal	Dependent only on pulpal status	Not applicable	l. Torabinejad M, Kutsenko D, MachnickTK, Ismail A, Newton CW. Levels of evidenceforthe outcome of nonsurgicalendodontic treatment.] Endod 2005;31:637-46.	L0E2a
Symptomatic apical periodontitis	Non-Surgical Root Canal Therapy	Studies #1-8	2. Marquis VL, DaoT, Farzaheh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phase III: initial treatment. J Endod 2006:32:299-306.	L0E4
	Surgical Root Canal Therapy	Studies #9-16	3. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. Cochran Database of Systematic Reviews 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/ 14651858.CD005296.pub2.	L0E2a
Asymptomatic apical periodontitis	Non-Surgical Root Canal Therapy	Studies #1-8	4. de Chevigny C, DaoTT, Basrani BR, Varquis V, Farzaheh M, Abithol S, Friedman S. Treatment outcome in endodontics: the Toronto study- phase 4: initial treatment. J Endod 2008;34:258-63.	L0E4
	Surgical Root Canal Therapy	Studies #9-16	5. Penesis VA, Fitzgerald PI, Fayad MI, WenckusCS, BeGole EA, Johnson BR. Outcome of one-visit and two-visit endodontic treatment of necrotic teeth with apical periodontitis: a randomized controlled trial with one-year evaluation.] Endod 2008:34:251-7.	L0E2b
Acute apical abscess	Non-Surgical Root Canal Therapy	Studies #1-8	6. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - Part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921-39.	L0E2a
	Surgical Root Canal Therapy	Studies #9-16	7. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature - Part 2. Influence of clinical factors. Int Endod J 2008;41:6-31.	LOE2a
	Incision and Drainage	Study #17	8. Farzaneh M. Abitbol S. Lawrence HP, Friedman S. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004:30:302-9.	LOE4
Chronic apical abscess	Non-Surgical Root Canal Therapy	Studies #1-8	9. Mead C, Javida-Nejad S, Mego ME, Nash B, Torabinejad M. Levels of evidence forthe outcome of endodontic surgery. J Endod 2005:31:19-24.	LOE2a
	Surgical Root Canal Therapy	Studies #9-16	10. Del Fabbro M.TaschieriS,Testori T, Francetti L, Weinstein RL Surgical versus non-surgical endodontic retreatment for periradicular lesions. Cochrane Database of Systemic Reviews 2007, Issue 3. Art. No.: CD005511. DOI:10.1002/14651858.CD005511.publ.	LOE1a
			11. Gagliani MM, Gorni FG, Strohmenger L Periapical resurgery versus periapical surgery: a 5-year longitudinal comparison. Int Endod J 2005;38:320-7.	LOE2b
			12. Friedman S. The prognosis and expected outcome of apical surgery. Endod Topics 2005;11:219-62.	LOE2b
			13. KvistT, Reit C. Results of endodontic retreatment: a randomized clinical study comparing surgical and nonsurgical procedures. J Endod 1999;25:814-17	LOE2b

(*Continued*)

TABLE 7. (*Continued*)

Periapical Diagnosis	Treatment	Citations		Level of Evidence
			14. Wang N, Knight K, DaoT, Friedman S. Treatment outcome in endodontics the to ronto study: phases land II: apical surgery. J Endod 2004;30:751-761.	LOE4
			15. Lindeboom JA, Frenken JW, Kroon FH, van den Akker HP. Acomparative prospective radomized clinical study of MTAand IRM as root-end filling materials in single-rooted teeth in endodontic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:495-500.	LOE2a
			16. von Arx T, Jensen SS, HanniS. Clinical and radiographic assessment of various predictors for healing outcome 1 year after periapical surgery. J Endod 2007:33:123-8.	LOE2a
			17. Matthews DC, Sutherland S, Basrani B. Emergency management of acute apical abscesses in the permanent dentition: a systematic review of the literature. Journal (Canadian Dental Association) 2003;69(10):660	LOE2a

Pulpectomy/Surgery/Intentional Replantation

Two recent publications arguably represent the most thorough, insightful, and complete evaluations of endodontic treatment outcomes. In chapter 14 of the second edition of *Essential Endodontology* (13), Friedman reviewed 479 references out of which he identified 22 selected studies concerning initial nonsurgical root canal treatment: six selected studies pertaining to nonsurgical retreatment, seven studies for surgical treatment, and 13 for intentional replantation (Friedman's complete bibliography is not replicated in this article; however the selected studies are included in the references with Subquestion #5). Within the set of 22 initial treatment studies were 4 assessed by Torabinejad et al (14) to be at LOE 1 and 7 at LOE 2. Of the retreatment studies, Paik et al (15) assessed two to be at LOE 2 and three at LOE 3. The surgery series included two LOE 2, one LOE 3, and one LOE 4 study according to Mead et al (16). No studies on intentional replantation meet the criteria of LOE 1 or 2.

In ranking levels of evidence, the Oxford Centre for Evidence-Based Medicine indicates that well-designed cohort studies and particularly good systematic reviews of such studies are of equal or perhaps even greater value than randomized, controlled studies when evaluating prognosis (17). This distinction seems to have been applied by Friedman in his selection of articles to be included in his evaluation of endodontic outcome studies, which includes many cohort studies. Friedman also makes the observation that the rate of healing is not consistent from case to case and that a certain period of time, on the order of years, is necessary for the ultimate outcome of a particular case to be manifest. Taking into consideration these two thoughts, a third concept is applied; positive treatment outcome includes both healed and healing cases, recognizing the dynamic nature of healing after endodontic therapy. These categories are combined into a "functional" category by Friedman. Not all studies have been presented in these terms, but where available, Friedman has identified the "healed," "healing," and "functional" values. Even within Friedman's select groups, there are few studies that fulfill all criteria of a top-quality study with appropriate duration of follow-up and thorough description of cohort, treatment, method of healing assessment, and analysis of data.

A brief summary of Friedman's material follows:

Initial root canal treatment
- Healed
  - Preop without AP 88%–97%
  - Preop with AP 74%–91%
- Functional 90%–97%

("Functional" includes the sum of AP and no AP). A study with 91% (18) evaluated only teeth without initial AP; three studies with 97% evaluated either cases with AP only (19) or cases with and without AP [20, 21].)

Nonsurgical retreatment
- Healed
  - Preop withoutAP 93%–97%
  - Preop with AP 58%–84%
- Functional 93%

("Functional" includes the sum of AP and no AP). Data from only one study could be interpreted with a value for "functional" (22).

Surgical treatment
- Healed 37%–91%
- Functional 80%–96%

Thirty-seven percent healed and 80% functional are the same study (23).

Intentional replantation
- Success 34%–93%
- Survival 71%–100%

A study with 34% success had 80% survival at 1 to 13 years (24).

The second publication is a two-part systematic review written by Ng et al and published in 2007 and 2008 (25, 26) (LOE 2). They limited their review to outcomes of initial root canal treatment; 54 studies met their inclusion criteria. The authors considered two sets of parameters: those that defined the structure of the study (when and where it was conducted, duration of recall, the strictness of outcome assessment, and experience of operators) and those that defined the patient and clinical factors (age and sex, general health, tooth, pulp and periradicular status, procedures, materials used, quality of treatment, and number of visits). Interestingly, they found no significant difference in outcome

rates based on the decade of the study or the geographic region in which the treatment was rendered. In other words, by this assessment, modern techniques appear to have not rendered improved outcomes. As with many other outcomes studies, a lack of homogeneity regarding recall rates and duration of follow-up must be kept in mind when interpreting summarized data. A major contribution of these articles is the emphasis on distinguishing between "strict" and "loose" outcome criteria. Echoing the actuality stated by Friedman (13) that healing after endodontic therapy is a dynamic, ongoing process for months to years; the amount of time that has passed since treatment will have direct bearing on the radiographic appearance. After a shorter time, "looser" healing criteria are still valid, whereas "strict" healing criteria will be valid only after sufficient passage of time. The authors state, "From a research perspective and based on this review, the cases should be reviewed for a minimum of 1 year and preferably for at least 3 years, after completion of treatment" and perhaps even a stronger standard might be applied aiming for the 4- to 5-year recall encouraged by the American Association of Endodontists and the European Society of Endodontology.

A brief summary of Ng et al (25) follows:

Initial root canal treatment

Strict ("healed")

Preop without AP	72.7%–91.6%
Preop with AP	61.1%–78.1%

Loose ("functional")

Preop without AP	86.9%–93.3%
Preop with AP	76.2%–86.6%

The most recent journal articles reviewed by Friedman (13) and Ng et al (25) were from 2002. A thorough search was conducted for this consensus project to include applicable references dated 2002 to present to ensure a complete representation of the literature. In the Ng review, there were 17 studies identified ranging from case series to randomized, controlled trials. One study was a Cochrane Review and another study a CONSORT trial, both of single- versus multiple-visit treatment. The outcome percentages identified in these studies were similar to the ranges in Friedman's work. Not included in Friedman's inclusion list for surgical treatment was a systematic review by Peterson and Gutmann (27), although it is included in the discussion. The authors reviewed the literature for outcomes of repeat surgery and found an average healed rate of 36%, a distinctly low positive outcome implying that resurgery is not an indicated procedure. It should be noted, however, that seven of the eight included studies were performed between 1970 and 1987, and so techniques and materials were very different from current techniques and materials. Wang et al (28) in the Toronto Study on endodontic surgery using current surgical principles found 63% of eight resurgery cases healed, so it may be imprudent to assume that resurgery is an absolutely contraindicated procedure. No additional studies of intentional replantation were identified.

The second of the two articles by Ng et al (26) is a systematic review of the literature concerning the outcome of secondary root canal treatment (ie, retreatment). The aims of the study were to investigate the effects of study characteristics on the reported success rates of root canal retreatment and to investigate the effects of clinical factors on the success of retreatment. Of the 40 articles identified, 17 studies published between 1961 and 2005 were included. The majority of studies were retrospective ($n = 12$), and only five were prospective. The pooled estimated success rate of root canal retreatment was 77%. The presence of a preoperative periapical lesion, apical extent of root filling, and quality of coronal restoration proved significant prognostic factors with concurrence between all three strands of evidence, whereas the effects of primary treatment history and retreatment protocol have been poorly investigated.

It was evident that teeth without periapical lesions had 6.32 times higher odds of success than teeth with periapical lesions. Teeth with short root fillings had significantly higher success rates than those with long fillings. Teeth that had been restored or permanently restored were associated with significantly higher success rates than their counterpart. The type of restoration (29, 30) was found to have no significant influence on the outcome of secondary root canal treatment.

It has been argued that had dropouts been included in outcome studies the ultimate results would be skewed in the unfavorable direction. Probably the most challenging aspect of endodontic outcome studies is following the cohort for an appropriate length of time (4 years) and maintaining a meaningful percentage of the original cohort over that time span; the Oxford Centre requires $\geq$80% follow-up retention for a LOE 1 cohort study. This describes a principle gap in knowledge in understanding the prognosis of endodontic therapy—studies with well-defined cohorts, treatments, methods of healing assessment, and analyses of healing assessment coupled with appropriate follow-up periods and retention of the original cohort to fairly assess stabilized healing outcomes. It is suggested that a template for outcome studies be formulated, perhaps by a consensus group, which meets appropriate follow-up and design characteristics to further develop our knowledge of endodontic treatment prognosis. Parameters to be established include standardized outcome metrics, minimum recall period, and guidelines for the definition of cohort and treatment data. Correlation of histopathologic conditions with clinical healing interpretations is critical to validation of outcome assessment. Revisiting Brynolf's intent of 1967 and developing acceptable investigative models to relate histopathologic and clinical appearances are warranted to validate our outcomes assessments.

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Subquestion #6: What Gaps in Knowledge Remain for Identifying the Optimal Treatment Modalities for the Different Diagnostic Categories?

Significant gaps in knowledge remain for identifying optimal treatment modalities for the different diagnostic categories. With each new significant development in endodontic technique, equipment, or materials, a new subset of questions become important. For example, what is the effect of microscopy, rotary instruments, or MTA on endodontic outcome? There is a gap in knowledge concerning their effect on the outcome of treatment with respect to the new variables.

Although there exists a commonly referenced, classic study suggesting that systemic health may not play a role in healing ability (1), there are recent studies suggesting it is an important factor (2, 3).

The same is true for age and sex, with studies both supporting (4) and negating (5, 6) its influence. There are also conflicting studies indicating either better healing in single-rooted teeth (7, 8) or better healing in multirooted teeth (1, 9).

The effect of a positive culture on the outcome of endodontics remains an area of debate. As an example, there are the results of Sjogren et al (10) and conflicting findings of Peters and Wesselink (11). There is an existing body of evidence concerning intentional replantation procedures that are primarily case reports or case series. However, there are no related studies representing a level of evidence higher than LOE 3 (12). Regenerative procedures will require outcome studies characterized by a high level of evidence in order to determine the procedures' clinical applicability (13).

Subquestion #6 References

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