Impact of the Quality of Coronal Restoration versus the Quality of Root Canal Fillings on Success of Root Canal Treatment: A Systematic Review and Meta-analysis

Brian M. Gillen, DDS, Stephen W. Looney, PhD,† Li-Sha Gu, DDS, MS, PhD,‡ Bethany A. Loushine, DMD,* Roger N. Weller, DMD, MS,* Robert J. Loushine, DDS,* David H. Pashley, DMD, PhD,§ and Franklin R. Tay, BDSc (Hons), PhD*§*

Abstract

Introduction: Thorough cleaning and shaping of root canals are essential for periapical healing. Restoration of endodontically treated teeth is also required for them to function and prevent coronal leakage. This study compared the impact of the quality of root canal treatment versus the quality of coronal restoration in treatment outcomes. **Methods:** Literature search was conducted using the search terms "coronal restoration," "root canal," "periapical status," and "quality." Articles that evaluated the effect of the quality of root filling and coronal restoration or both on the success of root canal treatment were selected. Nine articles were identified and were reviewed by 3 investigators. Data were collected based on predetermined criteria. Percentages of teeth without apical periodontitis were recorded for each category: adequate root canal treatment (AE), inadequate root canal treatment (IE), adequate restoration (AR), and inadequate restoration (IR). Data were analyzed using meta-analysis for odds ratios (ORs). **Results:** After adjusting for significant covariates to reduce heterogeneity, the results were combined to obtain pooled estimates of the common OR for the comparison of AR/AE versus AR/IE (OR = 2.734; 95% confidence interval [CI], 2.61–2.88; $P < .001$) and AR/AE versus IR/AE (OR = 2.808; 95% CI, 2.64–2.97; $P < .001$). **Conclusions:** On the basis of the current best available evidence, the odds for healing of apical periodontitis increase with both adequate root canal treatment and adequate restorative treatment. Although poorer clinical outcomes may be expected with adequate root filling–inadequate coronal restoration and inadequate root filling–adequate coronal restoration, there is no significant difference in the odds of healing between these 2 combinations. *(J Endod 2011;37:895–902)*

Key Words

Coronal restoration, meta-analysis, obturation, periapical status, quality, root canal treatment, systematic review

It is generally accepted that the outcome of root canal treatment is positively correlated with the technical quality of the root filling. Well-filled root canals are expected to provide a 3-dimensional seal against bacteria ingress (1–5). Under controlled clinical conditions, the potential for a favorable outcome for primary root canal treatment can be well above 90% in the absence of preoperative apical periodontitis (6–8) and in the range of 75% to 80% in the presence of preoperative apical periodontitis (8–12). Nevertheless, epidemiological studies of root canal treatment performed in various cohorts outside a university-supported clinical setting revealed less favorable treatment outcomes, with high rates of inadequate root fillings and apical periodontitis (40%–65%) associated with endodontically treated teeth (13–26). These studies highlighted the need to provide a coronal seal for these lesions to heal (27–29).

Although a coronal seal may be produced by a well-filled root filling, a coronal restoration with margins that prevent bacteria penetration, or both, data derived from a retrospective clinical study (30) suggest that a favorable endodontic treatment outcome may be achieved even in poorly filled root canals when the quality of the coronal restoration is adequate. Those results appear to be supported by epidemiologic data showing that inadequately filled root canals can remain in a normal state of periapical health (31). The data produced by Ray and Trope (30) overtly challenged the rationale of endodontics and had stimulated intense discussions over the past 15 years on whether the quality of the coronal restoration is more significant than the quality of root canal treatment in eliminating apical periodontitis (32–44). The conclusion from that study (30) also motivated clinicians to reconsider their clinical decision making, whether it is more preferable to place a high-quality permanent restoration immediately after root canal treatment or to insert a provisional restoration that has a greater chance to leak while waiting for the resolution of apical periodontitis (45–48).

From the Departments of *Endodontics, †Biostatistics, and §Oral Biology, Georgia Health Sciences University, Augusta, Georgia; and ‡Department of Operative Dentistry and Endodontics, Sun Yat-sen University, Guangzhou, China.

Drs Gillen and Looney contributed equally to this work.

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Address requests for reprints to Dr Franklin R. Tay, Department of Endodontics, School of Dentistry, Georgia Health Sciences University, Augusta, GA 30912-1129. E-mail address: ftay@georgiahealth.edu

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Since the study by Ray and Trope (30), similar clinical studies have been conducted to confirm the validity of their results by correlating the qualities of both the filled root canals and the coronal restorations to the resolution of apical periodontitis. Most of these studies were retrospective in nature, using radiographic examination alone. However, a few were prospective studies that used both clinical and radiographic examination as the evaluation criteria. Despite these efforts, the question of whether it is the root filling or the coronal restoration that contributes more significantly to endodontic success remains equivocal (49).

Thus, the aim of this systematic review and meta-analysis was to determine whether the quality of a coronal restoration or the quality of a root canal filling has a greater impact on the outcome of root canal treatment. The clinical question to be answered in this systematic review (a problem, intervention, comparison and outcome [PICO] question) may be framed as follows: in adult patients who have had nonsurgical root canal treatment, does the presence of an adequate root filling and an inadequate coronal restoration compared with the presence of an inadequate root filling and an adequate coronal restoration result in a worse clinical outcome?

Materials and Methods

Literature Search

A search was undertaken to identify all clinical studies that reported coassociation of the quality of root canal treatment and the quality of coronal restoration with endodontic treatment outcome. The MEDLINE (Ovid) database was searched for retrospective studies published between 1966 and 2010 (last accessed November 2, 2010) using key words “root filling” OR “coronal restoration” OR “quality” OR “periapical status.” A Cochrane Library search was also conducted. A similar search was also conducted using Pubmed, EMBASE, and the Wiley Online Database. Four journals (*Journal of Endodontics*, *International Endodontic Journal*, *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*, and *Endodontics and Dental Traumatology*) and the bibliography of all relevant articles and review articles were manual searched. No language restriction was applied to the search. This resulted in the identification of 132 studies for preliminary analysis. Titles and abstracts, where available, were scanned, and the relevance of each study to the PICO question was determined. When the title and abstract of a study were inadequate for determining its relevance, the study was automatically included in subsequent analysis. This resulted in the exclusion of 101 articles from the list, and the remaining 31 articles were subjected to stricter inclusion and exclusion criteria.

Study Selection and Data Extraction

The full texts of the remaining 31 articles were obtained and reviewed independently by 3 reviewers (B.M.G., S.W.L., and L.-S.G.) based on the following inclusion criteria:

1. Clinical study
2. Sample size given
3. Success based on radiographic and/or clinical criteria
4. Evaluated quality of root filling
5. Evaluated quality of coronal restoration (fillings, crowns, and/or posts)
6. Evaluated periapical status (absence or reduction in size of apical radiolucency)
7. Evaluation conducted at least 1 year after root canal treatment
8. Overall success rate given or could be calculated from the raw data

Exclusion criteria included the following:

1. Evaluation of nonendodontically treated teeth or when stratified information (ie, dividing a sample or population into subgroups by race, sex, and so on) on endodontically treated teeth was unavailable
2. Association of the treatment outcome with a particular disease (eg, diabetes or periodontal disease)
3. Coronal restorations reported only as present/absent or permanent/temporary
4. No association of the quality of the coronal restoration with endodontic treatment outcome
5. Overall poor quality of the endodontic treatment outcome
6. Could not establish whether the treatment outcome was contributed by a coronal restoration alone or the combined effects of a coronal restoration and an intracanal post

The reasons for study rejection at this stage or later were recorded. Data collection included publication date, location of study, sample size, statistical analysis methods, clinical and or radiographic evaluation of treatment, recall interval, and study outcome. To identify the potential sources of statistical heterogeneity among the selected studies, data were also collected on 4 dichotomous characteristics of those studies (covariates) that were thought to be potential confounders of the association between root canal treatment and absence of apical periodontitis:

1. Type of evaluation (root canals were evaluated radiographically vs root canals were evaluated radiographically and clinically)
2. Calibration (evaluators were calibrated vs evaluators were not calibrated)
3. A 5-point periapical index (50) was used for radiographic assessment of periapical status (yes vs no)
4. Seal and length (both the quality of lateral seal and the length of root filling were evaluated vs only length was evaluated)

Any disagreements on study inclusion were resolved by discussion.

Percentages of teeth without apical periodontitis were calculated and recorded for each category of root canal treatment including adequate restoration (AR), inadequate restoration (IR), adequate root canal treatment (AE), and inadequate root canal treatment (IE). Of the 6 possible comparisons, only AR/AE versus AR/IE, AR/AE versus

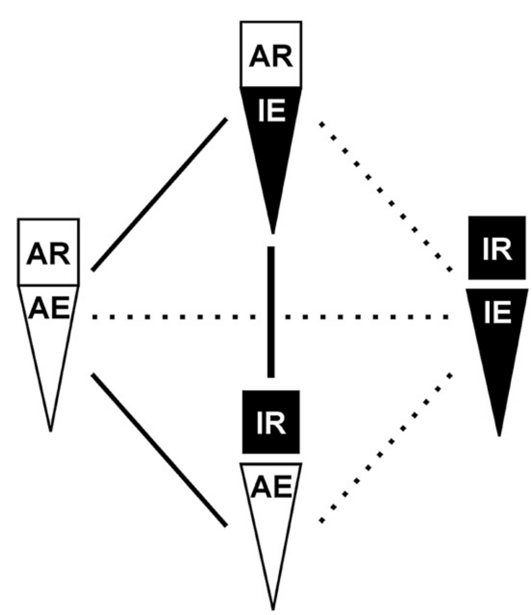

Figure 1. A schematic of the comparisons made in the meta-analysis. *Solid connection line*, comparison performed; *dotted line*, comparison not performed because of expected results.

IR/AE, and IR/AE versus AR/IE were subjected to further analysis (Fig. 1).

Statistical Analysis

Data for 3 comparisons (AR/AE vs AR/IE, AR/AE vs IR/AE, and IR/AE vs AR/IE) were analyzed using meta-analysis for odds ratios (ORs). For each comparison (eg, AR/AE vs AR/IE), the Breslow–Day–Tarone (BDT) test was used to test for heterogeneity among the ORs calculated from the data extracted from the selected studies. Logistic regression was used to reduce heterogeneity by adjusting for significant covariates that defined homogeneous subsets among the studies being compared. Once the heterogeneity among studies was reduced sufficiently using logistic regression (as indicated by a nonsignificant BDT test result), the results from the selected studies were combined using the Mantel–Haenszel method to obtain a pooled estimate of the overall OR, along with a 95% confidence interval (CI). For each treatment group comparison, a forest plot (51) was used to display the OR results for each study, along with the Mantel–Haenszel pooled estimate. L'Abbé plots (52) were used to shows the heterogeneity. The method proposed by Orwin (53) was used to ascertain if publication bias was present. A significance level of 0.05 was used for all statistical tests. Statistical analyses were performed using SAS 9.2 (SAS Institute Inc, Cary, NC) and R 2.11.1 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the 31 articles examined, 20 studies containing information on some aspects of coronal restorations (31, 45, 54–71) were excluded for various reasons (Table 1). Two studies were further excluded from the remaining 11 studies, yielding 9 (30, 72–79) for meta-analysis. One study was excluded based on comments by the authors that the quality of root canal treatment was very poor in the region in which the study was conducted (80), and the other was excluded because the identity of treatment outcomes contributed by a coronal restoration alone or the combined effects of a coronal restoration and an intracanal post could not be established (81). A summary of the 4 dichotomous characteristics used for identifying statistical heterogeneity for each of the 9 studies retained for meta-analysis is included in Supplementary Table 1 (supplemental Table 1 is available online at www.jendodon.com). Those 9 studies were designated as study 1 to study 9 (arranged in chronological order) as follows:

1. Ray and Trope (1995) (30)
2. Tronstad et al (2000) (72)
3. Kirkevang et al (2000) (73)
4. Hommez et al (2002) (74)
5. Dugas et al (2003) (75)
6. Segura-Egea et al (2004) (76)
7. Siqueira et al (2005) (77)
8. Georgopoulou et al (2008) (78)
9. Tavares et al (2009) (79)

Data extracted for the 3 comparisons (AR/AE vs AR/IE, AR/AE vs IR/AE, and IR/AE vs AR/IE) are listed in Supplementary Table 2 (supplemental Table 2 is available online at www.jendodon.com). Odds ratios greater than 1 indicate that patients in the first treatment group (eg, AR/AE) had lower odds of apical periodontitis; ORs less than 1 indicate that patients in the second treatment group (eg, AR/IE) had lower odds.

For the comparison of AR/AE versus AR/IE (Fig. 1), significant heterogeneity among ORs was detected using the BDT test (χ^2_8 = 32.96, P < .001) and was evident from the L'Abbé plot (supplemental Figure 1*A* is available online at www.jendodon.com). Three covariates were statistically significant when included with AR/AE in the logistic regression model: type of evaluation, calibration, and seal and length (supplemental Table 3*A* is available online at www.jendodon.com). The 9 studies were divided into 4 homogeneous subsets based on their pattern of values for these covariates:

1. Radiographic evaluation only + no calibration + length only (study 1)
2. Radiographic evaluation only + calibration + seal and length evaluation (studies 3 and 6)
3. Radiographic and clinical evaluation + calibration + length only (studies 4 and 5)
4. Radiographic evaluation only + calibration + length only (studies 2, 7, 8, and 9).

After estimating a common OR for each of these homogeneous subsets (supplemental Table 3*B* is available online at www.jendodon.com), the BDT test was applied and indicated no significant heterogeneity among the adjusted ORs (χ^2_3 = 5.53, P = .137). A L'Abbé plot for the adjusted ORs for each study is shown in Supplementary Figure 1*B* (supplemental Figure 1*B* is available online at www.jendodon.com). The adjusted ORs were then combined to obtain an estimate of the overall OR for the comparison of AR/AE versus AR/IE (OR = 2.73; 95% CI, 2.40–3.11; P < .001). A forest plot showing the unadjusted OR and CI for each of the 9 studies, along with the overall OR estimate obtained from the meta-analysis is given in Figure 2.

For the comparison of AR/AE versus IR/AE (Fig. 1), significant heterogeneity among ORs was detected using the BDT test (χ^2_8 = 76.05, P < .001) and was evident from the L'Abbé plot (supplemental Figure 2*A* is available online at www.jendodon.com). Three covariates were statistically significant when included with AR/AE in the logistic regression model: calibration, use of the 5-point periapical index, and seal and length (supplemental Table 4*A* is available online at www.jendodon.com). The 9 studies were divided into 4 homogeneous subsets based on their pattern of values

TABLE 1. Reasons for Exclusion of Studies from the Meta-analysis

Excluded studies	Exclusion criteria
Heling and Tamshe (1970) (54)	4
Heling and Tamshe (1971) (55)	1, 4
Heling and Shapira (1978) (56)	1
Heling and Kischinovsky (1979) (57)	1, 3 ,4
Swartz et al (1983) (58)	1
Safavi et al (1987) (45)	1
Friedman et al (1995) (59)	4
Lilly et al (1998) (60)	3
Sidaravicius et al (1999) (31)	1
Ricucci et al (2000) (61)	4
Heling et al (2001) (62)	5
Hoskinson et al (2002) (63)	1
Peters and Wesselink (2002) (64)	5
Boucher et al (2002) (65)	3
Cheung (2002) (66)	5
Farzaneh et al (2004) (67)	4
Stassen et al (2006) (68)	3
Kirkevang et al (2007) (69)	2
Imura et al (2007) (70)	4
Touré et al (71)	4
Kayahan et al (2008) (80)	5
Estrela et al (2008) (81)	6

1: Evaluation of nonendodontically treated teeth or when stratified information on endodontically treated teeth was unavailable. 2: Association of the treatment outcome with a particular disease. 3: Coronal restorations reported only as present/absent or permanent/temporary. 4: No association of the quality of the coronal restoration with endodontic treatment outcome. 5: Overall poor quality of the endodontic treatment outcome. 6: Could not establish whether the treatment outcome was contributed by a coronal restoration alone or the combined effects of a coronal restoration and an intracanal post.

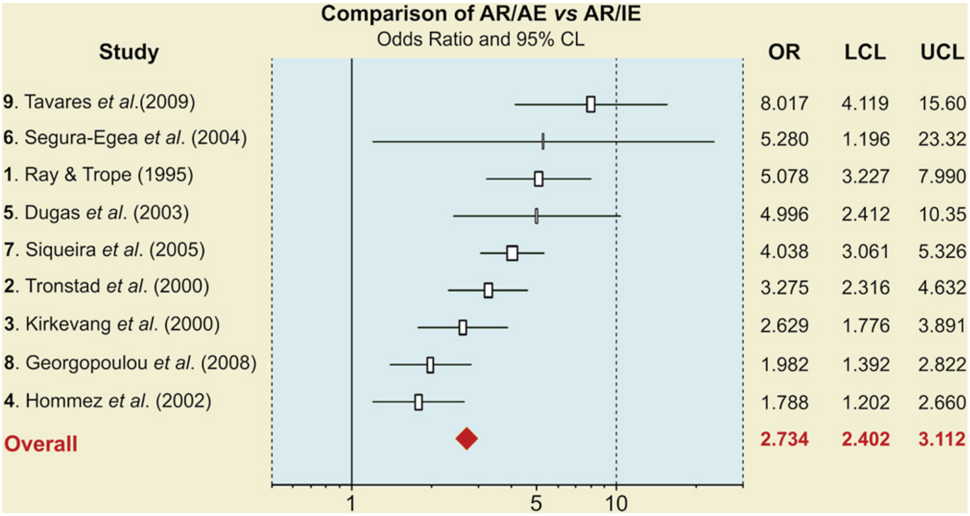

Figure 2. A forest plot of ORs and 95% confidence limits based on data from 9 studies for the comparison of AR/AE versus AR/IE with regard to absence of apical periodontitis. Overall estimate is based on combined data from the 9 studies. The size of each rectangle is proportional to the total sample size for the AR/AE versus AR/IE comparison in that study. The size of the *diamond* is proportional to the combined sample size for the 9 AR/AE versus AR/IE comparisons. The *solid line* indicates an OR of 1.0, and the *dashed lines* indicate ORs of 0.5, 10.0, and 30.0, respectively. LCL, lower confidence level; UCL, upper confidence level.

for these covariates: (1) no calibration + periapical index not used + length only (study 1), (2) calibration + periapical index used + seal and length evaluation (studies 3 and 65), (3) calibration + periapical index not used + length only (studies 2, 4, 7, and 8), and (4) calibration + periapical index used + length only (studies 5 and 9). After estimating a common OR for each of these homogeneous subsets (supplemental Table 4*B* is available online at www.jendodon.com), the BDT test was applied and indicated no significant heterogeneity among the ORs (χ^2_3 = 3.80, P = .284). A L'Abbé plot for the adjusted ORs for each study is shown in Supplementary Figure 2*B* (supplemental Figure 2*B* is available online at www.jendodon.com). The adjusted ORs were then combined to obtain an estimate of the overall OR for the comparison of AR/AE versus IR/AE (OR = 2.81; 95% CI, 2.40–3.29; P < .001). A forest plot showing the unadjusted OR and CI for each of the 9 studies, along with the overall OR estimate obtained from the meta-analysis is given in Figure 3.

For the comparison of IR/AE versus AR/IE (Fig. 1), significant heterogeneity among ORs was detected using the BDT test (χ^2_8 = 94.65, P < .001) and was evident from the L'Abbé plot (supplemental Figure 3*A* is available online at www.jendodon.com). Note that 6 of the studies (2, 3, 5–7, 9) found that IR/AE yielded greater odds of no apical periodontitis, whereas 3 of the studies (1, 4, 8) found that AR/IE yielded greater odds of no apical periodontitis. Two covariates were statistically significant when included with AR/IE in the logistic regression model: type of evaluation and seal and length (supplemental Table 5*A* is available online at jendodon.com). The 9 studies were divided into 3 homogeneous subsets based on their pattern of values for these covariates:

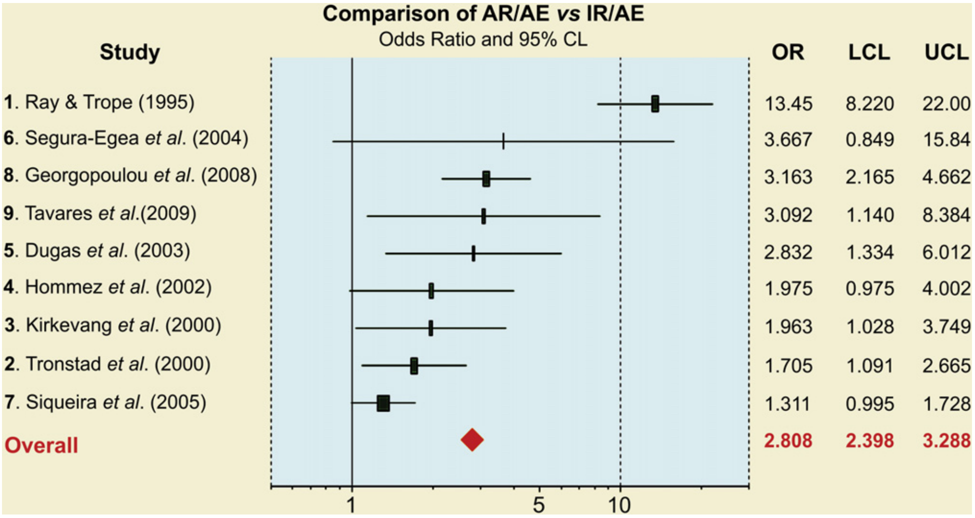

Figure 3. A forest plot of ORs and 95% confidence limits based on data from 9 studies for the comparison of AR/AE versus IR/AE with regard to the absence of apical periodontitis. Overall estimate based on combined data from the 9 studies. The size of each rectangle is proportional to the total sample size for the AR/AE versus IR/AE comparison in that study. The size of the *diamond* is proportional to the combined sample size for the 9 AR/AE versus IR/AE comparisons. The *solid line* indicates an OR of 1.0, and the *dashed lines* indicate ORs of 0.5, 10.0, and 30.0, respectively. LCL, lower confidence level; UCL, upper confidence level.

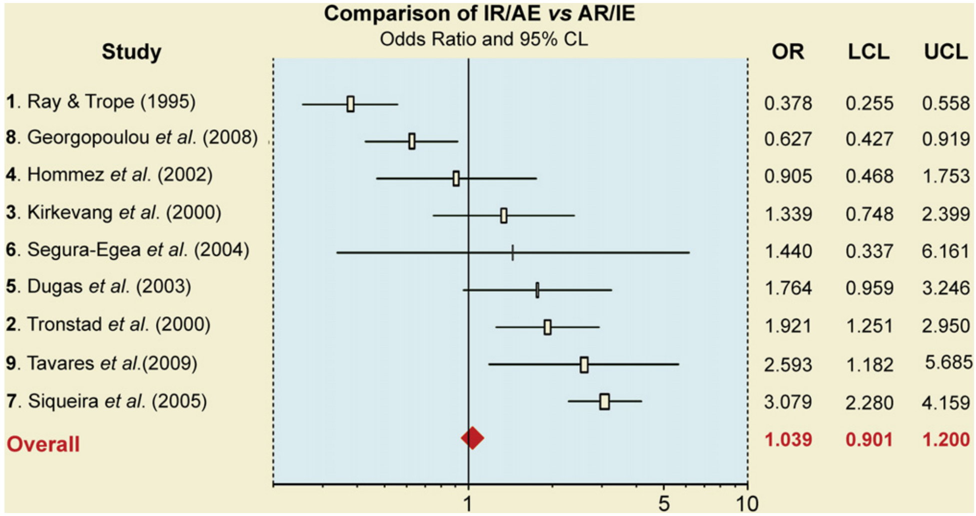

Figure 4. A forest plot of ORs and 95% confidence limits based on data from 9 studies for the comparison of IR/AE versus AR/IE with regard to the absence of apical periodontitis. Overall estimate based on combined data from the 9 studies. The size of each rectangle is proportional to the total sample size for the IR/AE versus AR/IE comparison in that study. The size of the *diamond* is proportional to the combined sample size for the 9 IR/AE versus AR/IE comparisons. The *solid line* indicates an OR of 1.0, and the *dashed lines* indicate ORs of 0.2 and 10.0, respectively. LCL, lower confidence level; UCL, upper confidence level.

1. Radiographic evaluation only + length only (studies 1, 2, 7, 8, and 9)
2. Radiographic evaluation only + seal and length evaluation (studies 3 and 6)
3. Radiographic and clinical evaluation + length only (studies 4 and 5)

After estimating a common OR for each of these homogeneous subsets (supplemental Table 5*B* is available online at www.jendodon.com), the BDT test was applied and indicated no significant heterogeneity among the ORs of the 3 subsets (χ^2_2 = 0.0001, *P* = .9999). A L'Abbé plot for the adjusted ORs for each study is shown in Supplementary Figure 3*B* (supplemental Figure 3*B* is available online at www.jendodon.com). The adjusted ORs were then combined to obtain an estimate of the overall OR for the comparison of IR/AE versus AR/IE (OR = 1.04; 95% CI, 0.90−1.20; *P* = .598). A forest plot showing the unadjusted OR and CI for each of the 9 studies, along with the overall OR estimate obtained from the meta-analysis is given in Figure 4.

To address the issue of publication bias, the method of Orwin (53) was used, after converting each of the adjusted ORs to an effect size using the method reported by Chinn (82). To apply this method, one calculates the number of negative studies not included in the meta-analysis (the "fail-safe" number) that would be required to reduce the estimated overall OR to a negligible value. In the present meta-analysis, 2 of the comparisons yielded a statistically significant overall OR: AR/AE versus AR/IE (OR = 2.73) and AR/AE versus IR/AE (OR = 2.81). Using OR = 1.44 (corresponding to Cohen's value of 0.2 for a "small" effect size) (83) as our definition of "negligible," Orwin's method indicates that 17 negative "file drawer" studies would be required to reduce the estimated overall OR for the AR/AE versus AR/IE comparison from OR = 2.73 to OR = 1.44 and to reduce the estimated overall OR for the AR/AE versus IR/AE comparison from OR = 2.81 to OR = 1.44. It is highly unlikely that 17 negative studies examining the effect of the qualities of root filling and coronal restoration on the success of endodontic treatment were overlooked in our meta-analysis. The odds that these studies have been done but not published is further decreased by our observation that negative results do not necessarily preclude publication of a study evaluating the success of root canal treatment (6, 8, 84, 85). Of the 9 studies included in this meta-analysis, 5 of them yielded results that were nonsignificant for at least 1 of the comparisons: Hommez et al (74), Segura-Egea et al (76), and Siqueira et al (77) for AR/AE vs IR/AE and Kirkevang et al (73), Hommez et al (74), Dugas et al (75), and Segura-Egea et al (76) for IR/AE vs AR/IE.

Discussion

Endodontic treatment outcome has been the subject of investigation for many years with studies examining success rates using different protocols. The lack of standardization of study protocols and endpoints for determining success make comparisons difficult. Despite the presence of a host of factors that contribute to success or failure of root canal treatment, the fundamental biologic principle that determines clinical success remains unchanged. Kakahashi et al (86) showed that apical periodontitis will develop if the canal system is contaminated with bacteria. Multiple *in vitro* studies have shown that even the best root canal treatment can allow leakage of bacteria and their byproducts through an apparently well-filled canal system. Yet, other studies have shown that even in the presence of obvious contamination, periapical disease does not necessarily develop in all patients (61, 87, 88). The work of Ray and Trope (30) provided important insight into what may be conceived as a paradigm shift in endodontic treatment philosophy in their quest to determine which aspect of treatment had a greater impact on the outcome of root canal treatment. Their study found that the coronal restoration had a greater impact on success than the quality of root canal treatment. Naturally, as endodontists, we would like to think that a well-performed root canal treatment is more important. However, as research scientists, we welcomed and admired the candidness of these clinical scientists in alerting our profession to the potential impact of previously less-emphasized aspect of coronal contamination on the maintenance of periapical health (45, 89). Thus, it is not surprising that other studies have been performed worldwide seeking to generate a larger body of evidence to either support or refute this paradigm shift.

Because most of the studies examined in the present systematic review were "outcomes" research derived from observational cohort studies, the level of evidence is level 2 based on the criteria given by the Oxford Centre for Evidence-based Medicine (90). Meta-analysis of observational studies is as common as meta-analysis of controlled trials (91), and guidelines for "Meta-analysis of Observational Studies in Epidemiology" have been issued since 2000 (92). Data from observational studies provide an important source of information when randomized controlled trials cannot or should not be undertaken, provided that the data are analyzed and interpreted with special attention to bias (93). Evidence-based endodontics stresses the examination of evidence from high-level clinical trials, in contrast to intuition, nonsystematic clinical experience, and anecdotal case reports. Although the importance of randomized trials is based on the concept of the hierarchy of clinical evidence, much of the outcomes research generated in endodontics to date remains observational in nature (94).

Reports on observational research are often not as detailed and clearly defined as those in RCTs, which hamper the assessment of their strengths and weaknesses and the universality of the results (92). Thus, progress and innovations in health care are measured by systematic reviews and meta-analyses. A systematic review may be defined as the application of scientific strategies that limit bias by the systematic assembly, clinical appraisal, and synthesis of all relevant studies on a specific topic. Meta-analysis usually is the final step in a systematic review, provided that heterogeneity among the selected studies can be sufficiently controlled by the identification of covariates that are potential confounders in the analysis (95, 96).

In the present systematic review, comparison of previous studies is difficult because of the wide variability of criteria evaluated. The potential sources of heterogeneity originated from variations of the participants and interventions (clinical heterogeneity), variations in study design and evaluation techniques (methodological heterogeneity), and variations in the analysis of the data derived from each study (statistical heterogeneity) (97). Although many criteria are similar, none of the studies is exactly alike. This resulted in the highly significant heterogeneities identified for each of the 3 comparisons (supplemental Figures 1*A*, 2*A*, and 3*A* are available online at www.jendodon.com). Nevertheless, with the use of logistic regression, we were able to identify the potential sources of heterogeneity in each comparison and adjust for significant covariates among the studies by grouping the respective studies into homogeneous subsets. This enabled us to combine the data and calculate an overall OR for each comparison. Standardization of study criteria would make future analysis more manageable and produce a stronger impact.

For comparison of AR/AE versus IR/AE, the original study by Ray and Trope (30) presented with an unadjusted OR of 13.45, which is much higher than the other 8 studies (1.311–3.667, Fig. 3). In nonstatistical terms, this means that in Ray and Trope's study, patients with both adequate restoration and root canal treatment (AR/AE) had odds of no persistent apical periodontitis that were 13.5 times as large as the odds for patients with inadequate restoration and adequate root canal treatment (IR/AE). Conversely, the odds of no apical periodontitis were only 1.3 to 3.7 times greater in patients with both adequate restoration and adequate root canal treatment in the other 8 studies. After reduction of heterogeneity, results of the meta-analysis indicate that the overall odds of having no apical periodontitis for patients with both adequate restoration and root canal treatment is 2.8 times greater than patients with inadequate restoration and adequate root canal treatment (IR/AE). A similar trend can be seen for the comparison of AR/AE versus AR/IE (supplemental Figure 1 is available online at jendodon.com). After reduction of heterogeneity, results of the meta-analysis indicate that the overall odds of having no apical periodontitis for patients with both adequate restoration and root canal treatment is 2.7 times greater than patients with adequate restoration and inadequate root canal treatment. Results from both comparisons clearly indicate that a better treatment outcome may be expected from patients receiving both high-quality root canal treatment and restoration. The corollary to that statement is that one cannot simply place a good restoration over a poorly obturated root canal or vice versa and expect the high degree of success that associated with performing both procedures adequately. Although one may be successful with individual cases (ie, case studies, level of evidence 4 or case reports, and level of evidence 5), one is unlikely to be successful in achieving consistently positive results for every patient in the long run.

Because the aforementioned 2 comparisons do not completely answer the PICO question, meta-analysis was performed on the third comparison (IR/AE vs AR/IE). Data extracted from the Ray and Trope study (unadjusted OR = 0.378) indicate that patients with adequate restoration and inadequate root canal treatment (AR/IE) have higher odds of preserving periapical health (ie, no radiographic evidence of apical periodontitis) as compared with patients with inadequate restoration and adequate root canal treatment (IR/AE) (Fig. 4). Although a similar trend was supported by 2 additional studies (OR = 0.627–0.905) (74, 78), data from the other 6 studies indicated opposite results (OR = 1.339–3.079). After the reduction of heterogeneity among the 9 studies, the results of the corresponding meta-analysis indicate that the presence of an adequate root filling and an inadequate restoration has equal odds of association with a suboptimal clinical outcome as the presence of an inadequate root filling and an adequate restoration. On the basis of the current best available evidence, one may answer the PICO question by stating that placing an inadequate coronal restoration over an adequately root-treated tooth does not produce a worse treatment outcome than placing an adequate coronal restoration over an inadequately root-treated tooth. In nonstatistical terms, this means that trying to salvage a poorly performed root canal treatment by placing a well-sealed coronal restoration is as futile as placing an inadequate restoration over well-filled root canals in anticipating the resolution of apical periodontitis for every patient in the long run.

The most common methods for determining outcomes of root canal treatment are clinical and radiographic examinations. It must be stressed that data extracted from the majority of the studies examined were based on radiographic examinations. Radiographic interpretation is highly subjective (98) and can be influenced by a variety of factors, including changes in beam angulation. In a cross-sectional study, the preoperative diagnosis of each case was often unknown, and the presence of apical periodontitis per se may be indicative of either healing or failure (99). It is well known that endodontic treatment outcomes are highly dependent on the presence of preoperative apical periodontitis (9–12). Moreover, the time between the completion of root canal treatment and the placement of the restoration were unknown. There are also no clinical data to support that the assessment of restoration quality can be adequately achieved based on examination of periapical radiographs alone. In a stratified study of the effect of permanent restorations on periapical health, the authors concluded that the presence of permanent restorations contributes minimally to the success of root canal treatment (48). These clinical results appeared to be supported by a case-control study of matched tooth pairs with identical periapical status, with 1 filled root exposed to the oral environment and the other protected by a permanent restoration (100). Taken together, these studies appeared to indicate that coronal leakage may not be of as much clinical significance as implicated by *in vitro* leakage examination. Despite the limitations of a meta-analysis based predominantly on radiographic interpretation, the unanimous result from the 9 studies that examined root-filled teeth with adequate restorations and root canal treatment produced better treatment outcomes reinforces the fundamental biologic principle of preventing bacteria ingress via the concerted efforts of the endodontist and the restorative dentist in providing the highest quality of care in saving functional teeth.

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The authors deny any conflicts of interest related to this study.

Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jendodon.com (doi:10.1016/j.joen.2011.04.002).

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