Retrospective Cross Sectional Comparison of Initial Nonsurgical Endodontic Treatment and Single-Tooth Implants

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Abstract

Initial root canal treatment and the replacement of a single tooth with implants are both viable treatment options, but various success rates have been reported for each treatment modality. This study compared 196 implant restorations and 196 matched initial nonsurgical root canal treatment (NSRCT) teeth in patients for four possible outcomes- success, survival, survival with subsequent treatment intervention and failure. Cross classifications/tabulations were analyzed using Pearson's χ^2 test for association of the two classifications (endo vs. implant and outcome). Polytomous regression with likelihood ratio tests were used in testing association with tooth location and outcome. Outcomes were as follows for implants and NSRCT outcomes, respectively: success 73.5% and 82.1%; survival with no intervention 2.6% and 8.2%; survival with intervention 17.9% and 3.6%; and failure 6.1% and 6.1%. Location of the restoration in the mouth did not affect outcome. This study suggests that restored endodontically treated teeth and single-tooth implant restorations have similar failure rates, although the implant group showed a longer average and median time to function and a higher incidence of postoperative complications requiring subsequent treatment intervention. *(J Endod 2006;32:822–827)*

Key Words

Endodontic, implant, outcomes, time-to-function

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One of the main objectives in dentistry is prevention of oral disease and the preservation of natural dentition, frequently achieved utilizing root canal treatment (1). When this is not possible, osseointegrated implants play a significant role in the rehabilitation of patients who have lost their teeth or have hopeless teeth because of periodontal or restorative concerns (2). Implants are increasingly being used to replace missing teeth in a variety of situations including the missing single tooth.

There is, however, considerable variation in treatment planning philosophy among clinicians when encountering patients with pulpally involved teeth and a questionable prognosis (3–7). The decision between retention of endodontically involved teeth as opposed to extraction and implant treatment is a clinical decision that requires a careful evaluation of the pre-, intra-, and postoperative factors that may influence the outcome of the proposed treatment (8, 9). Tooth variables (periodontal status, restorative status, endodontic status), implant variables (site, bone quality/quantity) and patient variables (systemic health status, economics, compliance and motivation) must also be considered in the development of a predictably successful long-term treatment plan (8, 9). Determining the most appropriate treatment for a patient that is cost-effective and offers the best long-term prognosis can be difficult, and the decision should be based on good clinical judgment and an understanding of the risks involved with either choice (8).

Initial nonsurgical root canal treatment (NSRCT) and the replacement of a single tooth with an implant are both viable treatment options. Favorable, yet variable, success rates have been reported for each treatment modality in multiple outcome studies (10–13). A primary reason for the variability of reported outcomes is the inconsistent definition of success in evaluation criteria. The replacement of a tooth with an implant has a definition of success-failure that is quite different from that used in endodontics, and is more consistent with the outcome category survival. Another concern is the restoration of the endodontically treated tooth. Teeth that are not restored after root canal treatment were significantly more likely (>4-fold) to undergo extraction than restored teeth (14). The loss of the endodontically treated tooth is because of multiple types of failure, including prosthetic failure (59.4%), periodontal failure (32%) and endodontic failure (8.6%) (15). In addition to the success rate, one must also consider time to adequate clinical function, expenses, and any complications that may occur. While the reported success rates of implants are high, they are not without potential failure or complications. The purpose of this investigation was to compare retrospectively the outcomes of single tooth implant restorations with matched teeth receiving initial NSRCT and restoration.

Methods and Materials

Data for this study were obtained from patients of record treated at the University of Minnesota School of Dentistry from January 1, 1993 through December 31, 2002. Expedited IRB approval was obtained from the University of Minnesota's Academic Health Center's Institutional Review Board. A database was used to identify all patients treated with single-tooth implant restorations during this time period. From this group, a subset of patient charts was collected, consisting of restored implants with 1-year recall or those that had an untoward event before restoration. The charts were consecutively evaluated and categorized by tooth number. Each restored implant that met

TABLE 1. Summary of endodontic outcomes

Outcome	Location: Group I maxillary anterior	Group III maxillary posterior	Group IV mandibular posterior
Success	58	48	55
Survival	8	4	4
(cause)	1 uncertain 7 healing	2 uncertain 2 healing	4 uncertain
Survival with intervention (cause)	3 retreatment 1 AP 1 symptoms 1 swelling	1 retreatment 1 sinus tract	3 retreatment 2 AP 1 symptoms
Failure (cause)	4 extractions 1 VRF 2 coronal fractures 1 periodontal	4 extractions 1 caries 1 coronal fracture 2 periodontal	4 extractions 2 caries 1 VRF 1 periodontal

inclusion criteria had a matched endodontically treated tooth chosen as follows. For an implant restoring tooth area number X (using the universal system 1-32), three potential matches were randomly chosen by a database according to ADA codes from among charts where tooth X was endodontically treated. These three endodontic charts were consecutively evaluated until a subject met inclusion criteria, at which time information from the chart was accumulated.

Inclusion criteria for the implant group included patients 18 years of age or older that had single tooth implant surgery and subsequent restoration at the University of Minnesota. All implants were surgically placed by staff or resident oral surgeons or periodontists, and restored by staff or resident prosthodontists. The treatment consisted primarily of two-stage treatment, but one-stage and immediate placement procedures were also included. Each implant had to consist of a single-tooth restoration supported by a single implant. Multi-unit restorations were excluded. Additionally, the implants had to have at least one adjacent natural tooth. The 1-year recall period was defined from the time of function, i.e. the time from placement of the final coronal restoration. Untoward events requiring subsequent treatment intervention, including prosthetic complications, adjunctive surgical procedures or removal of the implant, that occurred before the 1-year recall were recorded for analysis.

Inclusion criteria for the endodontic group included patients 18 years of age or older that had initial nonsurgical root canal treatment followed by subsequent coronal restoration at the University of Minnesota. Dental students, graduate residents, or staff clinicians performed all endodontic treatment. Each endodontically treated tooth had to have at least one adjacent natural tooth. The 1-year recall period was defined from the time of function, i.e. at the completion of root canal treatment. Untoward events requiring subsequent treatment intervention, including retreatment and extraction, that occurred before the 1-year recall were also recorded for analysis. Cases of uncertain or incomplete healing were documented and classified in the survival outcome.

All treatment was recorded including unaccounted for patients that did not return for recall. From this total, the data was further refined into the subsets to be analyzed that included only initial procedures with greater than 1 year follow-up or those that had an adjunctive procedure initiated before the 1-year recall period. Recorded clinical and radiographic data were interpreted by a single investigator to form an assessment outcome of success, survival with and without subsequent treatment intervention, or failure.

Implants were considered successful if radiographic and recorded clinical data demonstrated that the implant is functional and present in mouth at the time of recall without definite signs of absolute failure, such as peri-implant radiolucency or implant mobility. Implants were considered to be surviving if present in the mouth with subsequent posttreatment intervention or adjunctive procedures. Failure was assumed if the implant was removed or planned for removal.

Endodontically treated teeth were considered successful if radiographic and recorded clinical data demonstrated that the tooth was present in the mouth without the presence of apical periodontitis or symptoms. A Periapical Index (PAI) was used to evaluate the presence or absence of apical periodontitis following treatment. The system provides an ordinal scale of five scores ranging from 1 (healthy) to 5

TABLE 2. Summary of implant outcomes

Outcome	Location: Group I maxillary anterior	Group III maxillary posterior	Group IV mandibular posterior
Success	52	44	48
Survival (cause)	1 planned crown remake, esthetics	0	4 considered for removal, pending
Survival with intervention (cause)	17 3 CT grafts 4 peri-implant sx 7 crown remakes 1 crown fx 1 abutment fx 1 abutment dislodgement	8 4 crown remakes 1 crown mobility 2 screw loosening 1 abutment fx	10 2 peri-implant sx 4 screw loosening 1 screw fx 1 abutment loosening 2 crown fx
Failure	3	5	4

fx, fracture; CT, connective tissue graft required following restoration; sx, surgery following restoration; VRF, vertical root fracture; AP, persistent apical periodontitis.

TABLE 3. Outcome by group

Outcome	Group	
	Endo	Implant
Success	82.1%	73.5%
Survival	8.2%	2.6%
Survival with intervention	3.6%	17.9%
Failure	6.1%	6.1%
	196 total	196 total

(severe apical periodontitis with exacerbating features). The presence of apical periodontitis was considered absent or minimal by a low score (1-2), while higher scores were determined to have greater severity of apical periodontitis (16). The PAI is an accurate and reproducible method that minimizes variability and bias and has been designed for and used in clinical trials (17–20) and in epidemiological surveys (21). Endodontically treated teeth were considered to be surviving if present in the mouth, including those with uncertain healing (score of ≤3) or evidence of healing since treatment, and those that had subsequent posttreatment intervention. Failure was assumed if the tooth was extracted or planned for extraction.

The endodontically treated teeth and implant restorations were subdivided into groups based on the location in the mouth using the universal numbering system (1-32). All third molars were excluded. Group I: maxillary anterior (6-11); group II: mandibular anterior (22-27); group III: maxillary posterior (2-5 and 12-15); and group IV: mandibular posterior (18-21 and 28-31).

Statistical Methods

Cross classifications/tabulations were analyzed using Pearson's χ^2 test for association of the two classifications (e.g. endodontic vs. implants is one classification, outcome is the other classification). In the time-to-failure analysis, Kaplan-Meier was used to estimate the percentage not failing at each recall time. The groups were compared using the log-rank test. The *t* test was used when comparing endodontic vs. implants for a continuous dependent variable (e.g. recall time). When simultaneously testing the association of the group (endodontic vs. implant) and another variable (e.g. location) with outcome, polytomous regression (like logistic regression except the dependent variable has more than two categories) with likelihood ratio tests was used.

Results

From a total of approximately 2,000 charts derived from an electronic database of patients receiving implant therapy, 405 fit the preliminary inclusion criteria. From this group, a subset was collected, consisting of restored implants with 1-year recall or those that had an untoward event before restoration.

For the first implant group (group I: maxillary anterior), 172 total implants were evaluated. Five subjects with restored implants were deleted from analysis because their age was less than 18. A total of 73 implants fit the inclusion criteria. For the second implant group (group II: mandibular anterior), nine total implants were evaluated. Of these, none fit the inclusion criteria, so a comparison with the endodontic group was not made for this group. For the third implant group (group III: maxillary posterior), 113 total implants were evaluated. Five subjects with restored implants were deleted from analysis because their age was less than 18. A total of 57 implants fit the inclusion criteria. For the fourth implant group (group IV: mandibular posterior), 111 total implants were evaluated. Two subjects with restored implants had age less than 18 and were deleted. A total of 66 implants fit the inclusion criteria.

Patient identification numbers were assigned to implant patients to account for clustering of implants by subject. There were 196 different endodontic subjects and 171 different implant subjects, and among those 171 distinct implant subjects, only 20 had more than one implant. The effect of clustering on the final analysis would be negligible so clustering was ignored to allow for a less complicated analysis.

Tables 1 and 2 are summaries of the outcomes (and causes for classification) for the endodontic and implant groups by location. Table 3 describes all four possible outcomes for both the endodontic and implant groups (success, survival, survival with intervention, failure), ignoring both location and exposure time for the moment. The two groups differ ($p < 0.0001$). The groups had identical numbers of failures, but the implant group had fewer successes, fewer survivals and more survivals with treatment intervention. Specifically, a test comparing the groups (according to the fraction requiring subsequent treatment intervention) is significant ($p < 0.0001$).

Figure 1 illustrates how the groups differed in the *timing* of their failures after restoration of function (recall times). These curves do not differ significantly by the log-rank test ($p = 0.21$). Implants (green line) tend to fail sooner than endodontically treated teeth (red line), indicated by the green line being below the red line. The horizontal axis is the recall time in days and the vertical axis is the fraction that have not failed as of that recall time. Tables 4 and 5 are the estimates of fractions that have not failed as of each recall time; Fig. 1 shows the column headed "Nonfailure." The column "At risk" is the number of patients who had not had failures and whose recall times are at least as large as the time in the left-most column.

To determine and compare the outcomes of initial nonsurgical root canal treatment and single tooth implant restorations according to location, data are presented in Tables 6 and 7. The columns correspond to locations and the percentages are of the column (location) total. For the endodontic group, the locations do not differ in outcomes ($p = 0.91$). For the implant group, the locations do not differ in outcomes ($p = 0.22$). A combined analysis was also done comparing locations and groups simultaneously (using polytomous regression with likelihood ratio tests). Table 8 shows the results. The first line in Table 8, "Group", shows that the endodontic and implant groups differ in their fractions of the four different outcomes, ignoring locations ($p < 0.0001$). The second line, "Location", shows that the locations do not differ, ignoring groups ($p = 0.43$). The third line, "Group*location", shows that (a) the difference between endodontic and implant groups does not depend on the location and (b) the difference (or lack thereof) between loca-

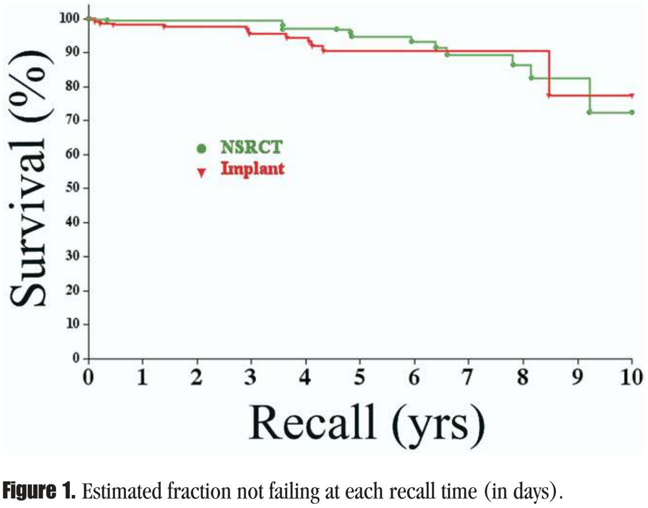

Figure 1. Estimated fraction not failing at each recall time (in days).

TABLE 4. Estimates of the fraction failing and not failing (endodontic)

Recall (days)	Nonfailure	Failure	STD Err	N Failed	At risk
0	1.0000	0.0000	0.0000	0	196
126	0.9949	0.0051	0.0051	1	196
1304	0.9872	0.0128	0.0092	1	129
1305	0.9795	0.0205	0.0119	1	128
1666	0.9698	0.0302	0.0152	1	101
1760	0.9590	0.0410	0.0185	1	90
1766	0.9482	0.0518	0.0212	1	89
2173	0.9324	0.0676	0.0261	1	60
2334	0.9141	0.0859	0.0313	1	51
2407	0.8947	0.1053	0.0362	1	47
2852	0.8649	0.1351	0.0457	1	30
2976	0.8256	0.1744	0.0581	1	22
3366	0.7224	0.2776	0.1091	1	8

tions does not depend on whether the subject is in the endodontic or implant group ($p = 0.37$).

To determine and compare the time to function for initial nonsurgical root canal treatment with single tooth implant restorations, data are presented in Fig. 2 below. Implants tend to have longer time-to-function, with a higher average (284 vs. 187, $p < 0.0001$) and a higher median (250 vs. 67, $p < 0.0001$ in the median test [not shown]). However, the endodontic group has the longer upper tail, as the 90th percentile is higher for endodontics than for implants (528 vs. 464). The results are nearly identical if failures are excluded.

Summary

The results of this study show that the endodontic and implant therapies resulted in an identical number of failures, but the implant group had fewer successes and survivals, independent of location. The implants had a significantly higher fraction of patients classified as surviving with the requirement for subsequent treatment, equivalent to clinical complications. Additionally, the implant group had a longer time-to-function than the endodontic group. The location of the restorative treatment was not a significant factor when comparing the two treatment groups.

Discussion

This study compared implants placed in varying locations (except mandibular anterior area; group II) to a matched group of endodontic restorations. The location of the treatment did not affect the outcome for either group (Table 8). This result is consistent with many reported in the endodontic literature (17, 22–24). The implant literature differs, with many studies demonstrating lower outcomes in specific locations, specifically the maxillary posterior, implant group III in this study (25–30).

The failure rates for both groups were low, or inversely the functional survival rates were high, consistent with previous reports both in the endodontic literature (13, 31, 32), as well as in the implant literature (11, 30, 33, 34).

The analysis becomes more difficult when determining the other outcomes. There is great variability in both the endodontic and implant literature regarding the definition of both success and survival (13, 35, 36). The nature of the definitions becomes even more important when weighing one treatment alternative with another. It can be argued that the criteria are much more stringent in endodontics. In an attempt to make comparisons objective, a variation in the traditional definition of success for endodontic treatment was made.

The endodontic outcome category for survival in this study can be related to a healing or uncertain category in other endodontic studies. This category refers to incompletely healed lesions or to uncertainty and technical inadequacy of the radiograph that precludes interpretation. Combining the healed and healing category may elevate the reported healed rate compared to studies that do not use this category. Healed lesions were considered successful, and uncertain or healing were classified as survival, which does not preclude the possibility for success if certainly healed at a subsequent recall. To be included in the survival with intervention, the complication had to have the potential to affect the prognosis. This excluded endodontic flare-ups and posttreatment pain and infection following implant placement. Although some consider endodontic retreatment as failure of initial treatment, because the tooth is still functional it was not determined to be successful but rather assessed to be surviving with subsequent intervention. A similar argument could be made for the treatment of peri-implantitis after implant restoration.

TABLE 5. Estimates of the fraction failing and not failing (implant)

Recall (days)	Nonfailure	Failure	STD Err	N Failed	At Risk
0	1.0000	0.0000	0.0000	0	196
35	0.9949	0.0051	0.0051	1	196
45	0.9898	0.0102	0.0072	1	195
81	0.9846	0.0154	0.0088	1	192
166	0.9794	0.0206	0.0102	1	189
510	0.9734	0.0266	0.0118	1	162
1066	0.9644	0.0356	0.0147	1	108
1080	0.9552	0.0448	0.0172	1	105
1332	0.9431	0.0569	0.0208	1	79
1480	0.9300	0.0700	0.0243	1	72
1503	0.9165	0.0835	0.0274	1	69
1578	0.9020	0.0980	0.0306	1	63
3088	0.7731	0.2269	0.1221	1	7

TABLE 6. Outcome related to location, ignoring recall times (endodontic)

Outcome	Location		
	I maxillary anterior	III maxillary posterior	IV mandibular posterior
Success	79.5%	84.2%	83.3%
Survival	11.0%	7.0%	6.1%
Survival with intervention	4.1%	1.8%	4.6%
Failure	5.5%	7.0%	6.1%
	73 total	57 total	66 total

TABLE 7. Outcome related to location, ignoring recall times (implant)

Outcome	Location		
	I maxillary anterior	III maxillary posterior	IV mandibular posterior
Success	71.2%	77.2%	72.7%
Survival	1.4%	0%	6.1%
Survival with intervention	23.3%	14.0%	15.2%
Failure	4.1%	8.8%	6.1%
	73 total	57 total	66 total

One of the greatest challenges in determining the outcome of a nonsurgical root canal treatment procedure is the fact that nonendodontic factors, such as the quality of the subsequent restoration often are major contributors to the long-term retention and function of teeth after root canal treatment (15, 37). Extraction after root canal treatment is a composite measure of multiple types of failure (4). Therefore this study only evaluated endodontically treated teeth that were restored following treatment. The results show that of the failures, very few were of true endodontic factors. In order for the implant to be included for analysis, it also had to have a functional restoration. Most implant studies consider the functionality of the restored implant, yet many endodontic studies fail to address restoration. An adequate definitive seal over the root canal space, which would protect against recontamination, seems critical because an inadequate restoration would expose the tooth to ingress of bacteria, thereby increasing the risk of future disease. Furthermore, an adequate restoration protects the tooth from fracture, while maintaining tooth function. Inadequate or inappropriate restoration places the tooth at a risk of fracture, and may result in failure of overall treatment. It is probable that a higher success outcome may be demonstrated for endodontically treated teeth when restoration is considered.

Patients frequently inquire about the total financial cost of proposed treatment procedures, the length of time required to complete treatment, potential complications and the projected outcome. Unfortunately, a comparison of the financial cost of treatment was not possible in this study. The costs in an academic setting may not necessarily be extrapolated to the private practice setting. Additionally, several of the implant patients were involved in independent studies that subsidized the financial costs to the patient.

The time for completion of treatment was evaluated as the time from initiation of treatment until time to function. The implant group had a longer time-to-function than the endodontic group (Fig. 2). Although this may not be a fair comparison because of the requirement for osseointegration for the implant group, it is something that patients should be informed of. Time to function for implants is being extensively studied and with the introduction of osteo-conductive surfaces there is a decrease in the time to function being advocated for many implant systems. The design of this study probably biased the time to function in favor of the endodontic treatment, yet this is still a valid piece of information to offer patients. Knowledge of the clinical complications that can occur with treatment facilitates the communication of realistic expectations to patients and aids in planning time intervals needed for posttreatment care. This study found more postrestoration complications, such as prosthetic complications, requiring subsequent treatment intervention with the implant group (Table 3). Implant reviews have stated that prosthetic complications are quite frequent (11, 30). Patients should be made aware of the potential complications when deciding between treatment alternatives.

TABLE 8. Simultaneous analysis of locations and groups

Source	DF	L-R Chi-square	p-value
Group	3	28.7	<0.0001
Location	6	5.9	0.4295
Group*location	6	6.5	0.3688

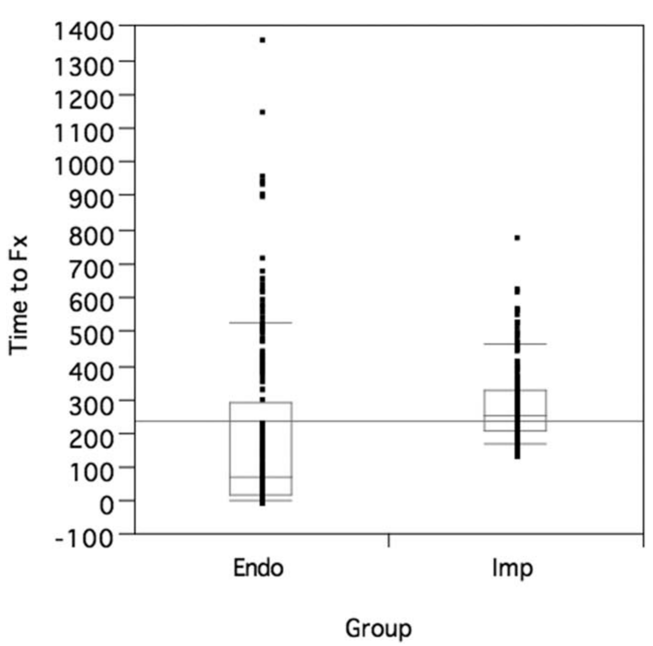

Figure 2. Time to function by group.

References

1. DeVan MM. The nature of the partial denture foundation: suggestions for its preservation. J Prosthet Dent 1952;2:210–8.
2. Torabinejad M. Apples and oranges. J Endod 2003;29:541–2.
3. Henry PJ. Tooth loss and implant replacement. Aust Dent J 2000;45:150–72.
4. Lewis S. Treatment planning: teeth versus implants. Int J Periodontics Restorative Dent 1996;16:366–77.
5. Rose LF, Weisgold AS. Teeth or implants: a 1990s dilemma. Compend Contin Educ Dent 1996;17:1151–9.
6. Davarpanah M, Martinez H, Tecucianu JF, Fromentin O, Celletti R. To conserve or implant: which choice of therapy? Int J Periodontics Restorative Dent 2000;20:412–22.
7. Spear F. When to restore, when to remove: the single debilitated tooth. Compend Contin Educ Dent 1999;20:316–8.
8. Bader HI. Treatment planning for implants versus root canal therapy: a contemporary dilemma. Implant Dent 2002;11:217–23.
9. Caplan DJ, Weintraub JA. Factors related to loss of root canal filled teeth. J Public Health Dent 1997;57:31–9.
10. Artzi Z, Carmeli G, Kozlovsky A. distinguishable observation between survival and success rate outcome of hydroxyapatite-coated implants in 5–10 years in function. Clin Oral Implants Res 2006;17:85–93.
11. Creugers NH, Kreulen CM, Snoek PA, de Kanter RJ. A systematic review of single-tooth restorations supported by implants. J Dent 2000;28:209–17.
12. Friedman S. Treatment outcome and prognosis of endodontic therapy. In: Orstavik D, Pitt FordTR, eds. In: Essential endodontology: prevention and treatment of apical periodontitis. Oxford: Blackwell Science; 1998.
13. Friedman S. Prognosis of initial endodontic therapy. Endod Topics 2002b;2:59–88.
14. Lazarski MP, Walker WA 3rd, Flores CM, Schindler WG, Hargreaves KM. Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. J Endod 2001;27:791–6.
15. Vire DE. Failure of endodontically treated teeth: classification and evaluation. J Endod 1991;17:338–42.
16. Orstavik D, Kerekes K, Eriksen HM. The periapical index: A scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 1986;2:20–34.
17. Orstavik D, Horsted-Bindslev P. A comparison of endodontic treatment results at two dental schools. Int Endod J 1993;26:348–54.
18. Trope M, Delano EO, Orstavik D. Endodontic treatment of teeth with apical periodontitis: Single vs. multivisit treatment. J Endod 1999;25:345–50.
19. Delano EO, Ludlow JB, Orstavik D, Tyndall D, Trope M. Comparison between PAI and quantitative digital radiographic assessment of apical healing after endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:108–15.
20. Waltimo TM, Boiesen J, Eriksen HM, Orstavik D. Clinical performance of 3 endodontic sealers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:89–92.
21. Eriksen HM, Bjertness E, Orstavik D. Prevalence and quality of endodontic treatment in an urban adult population in Norway. Endod Dent Traumatol 1998;4:122–6.
22. Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. J Endod 1979;5:83–90.
23. Swartz DB, Skidmore AE, Griffin JA Jr. Twenty years of endodontic success and failure. J Endod 1983;9:198–202.
24. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16:498–504.
25. Fugazzotto PA, Gulbransen HJ, Wheeler SL, Lindsay JA. The use of IMZ osseointegrated implants in partially and completely edentulous patients: success and failure rates of 2023 implant cylinders up to 60+ months in function. Int J Oral Maxillofac Implants 1993;8:617–21.
26. Esposito M, Hirsch JM, Lekholm U, Thompsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998a;106:527–51.
27. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants (II). Etiopathogenesis. Eur J Oral Sci 1998b;106:721–64.
28. Cochran DL. A comparison of endosseous dental implant surfaces. J Periodontol 1999;70:1523–39.
29. Noack N, Willer J, Hoffman J. Long-term results after placement of dental implants: longitudinal study of 1,964 implants over 16 years. Int J Oral Maxillofac Implants 1999;14:748–55.
30. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. J Prosthet Dent 2003a;90:121–32.
31. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: the Toronto Study. Phase 1: initial treatment. J Endod 2003;29:787–93.
32. Farzaneh M, Abitbol S, Lawrence HP, Friedman S. Toronto Study. Treatment outcome in endodontics-the Toronto Study. Phase II: initial treatment. J Endod 2004;30:302–9.
33. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. Clin Oral Implants Res 1998;9:80–90.
34. ADA Council on Scientific Affairs. Dental endosseous implants: an update. J Am Dent Assoc 2004;135:92–7.
35. Zarb GA, Albrektsson T. Towards optimized treatment outcomes for dental implants. J Prosthet Dent 1998;80:639–40.
36. Friedman S. Considerations and concepts of case selection in the management of post-treatment endodontic disease (treatment failure). Endod Topics 2002a;1:54–78.
37. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995;28:12–8.