Endodontics, Endodontic Retreatment, and Apical Surgery Versus Tooth Extraction and Implant Placement: A Systematic Review

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Abstract

Introduction: The aim of this systematic review was to answer the following clinical question: Which is the best treatment option for a pulpally involved tooth? **Methods:** An electronic search was conducted in the Cochrane, PubMed (MEDLINE), and ScienceDirect databases between December 2015 and February 2016. A manual search was also performed. The inclusion criteria were randomized clinical trials, prospective or retrospective cohort studies, and cross-sectional studies performed on humans with at least 1 year of follow-up and published within the last 10 years. Two researchers independently screened the title and abstract of every article identified in the search in order to establish its eligibility. The selected articles were classified into different levels of evidence by means of the Strength of Recommendation Taxonomy criteria. **Results:** Sixty articles met the inclusion criteria for this systematic review. The survival rate of single-tooth implants was greater than the success rate of the distinct conservative treatments. However, among comparative studies, no important differences between both treatments were observed until at least 8 years later. **Conclusions:** The endodontic treatment and the implant placement are both valid and complementary options for planning oral rehabilitation. Although a level B recommendation can be stated, these results come from retrospective comparative studies because there is a lack of randomized clinical studies comparing both types of therapeutic options. *(J Endod 2017;43:679–686)*

Key Words

Apical surgery, endodontic retreatment, endodontic treatment, outcome, single-tooth implant

Significance

This article evaluates the current scientific literature regarding the preferred treatment option (conservative versus extraction and placement of an implant) for a pulpally involved tooth in terms of survival rates. There is great variability among clinicians in treatment planning for teeth with a questionable prognosis. Current evidence shows no differences between both options although there is a lack of randomized clinical trials.

According to the American Dental Association's *Glossary of Dental Clinical and Administrative Terms*, dentistry is a branch of medicine that is involved in the evaluation, diagnosis, prevention, and/or treatment (nonsurgical, surgical, or related procedures) of diseases, disorders, and/or conditions of the oral cavity, maxillofacial area, and/or the adjacent and associated structures and their impact on the human body. The standard of care of a nonvital tooth is endodontic treatment to preserve the natural tooth (1, 2). There is great variability among clinicians in treatment planning with a pulpally involved tooth with a questionable prognosis (1). Although in some cases this decision may be controversial, it should be based on the remnant tooth structure (3), patient preferences, and cost-effectiveness (2). Nowadays, dental implant placement is a widely accepted treatment option, and it is supported by high survival rates. However, there are many factors that can affect the result of implant treatment like implant position, restoration type, bone quality, and smoking habits (4).

It seems that endodontically treated teeth and single-tooth implants have similar outcomes (1, 2, 4). However, the lack of standardized tools for evaluating the results and the different biological mechanisms make it difficult to directly compare both treatments. Although the success of root canal treatment, retreatment, and apical surgery is defined by complete radiographic healing and the absence of clinical signs and symptoms, the majority of studies on dental implants only refer to survival rates and not to success rates (4–6). The fact that time could affect the treatment prognosis (7, 8) is an interesting issue that could help to make decisions based on the long-term expected results.

The aim of this systematic review was to answer the following clinical question: Which is the best treatment option for a pulpally involved tooth? Then, the following PICO (patient, intervention, comparison, outcome) question was designed: In a patient who has a tooth with pulpitis, necrosis with or without a periapical lesion, in the presence or absence of symptoms, and without a radicular fracture, does the conservative

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treatment (endodontic treatment or retreatment and/or apical surgery) compared with tooth extraction and implant placement achieve higher survival rates?

Materials and Methods

This article follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses declaration (9). An electronic search in the Cochrane Library, PubMed (MEDLINE) and ScienceDirect databases was conducted between December 2015 and February 2016. The designed search strategy was: ((“Root Canal Therapy”[Mesh]) AND (“Dental Implants”[Mesh])) OR (“endodontic treatment”[tw] OR “surgical endodontic treatment”[tw] OR “periapical surgery”[tw] OR “endodontic retreatment”[tw] OR “endodontic surgery”[tw] OR “Dental Implants, Single-Tooth”[Mesh]) AND (“outcome”[tw] OR “Decision Making” [Mesh]). In addition, a manual search was performed in the following journals: *Clinical Oral Implants Research*, *International Endodontic Journal*, *International Journal of Oral and Maxillofacial Implants*, *Journal of Endodontics*, *Journal of Periodontology*, *Journal of Oral and Maxillofacial Surgery*, and *Oral Surgery Oral Medicine Oral Pathology Oral Radiology*.

The last search was performed on February 3, 2016. Two researchers (A.C.R. and A.S.T.) independently screened the title and abstract of every article identified in the search in order to establish its eligibility. A Cohen kappa for each database was calculated to determine the interrater reliability. Afterward, the full text of the selected articles was assessed for a definitive inclusion in the systematic review. A third reviewer (C.G.E.) resolved any discrepancies. The inclusion criteria were randomized clinical trials, prospective or retrospective cohort studies, and cross-sectional studies performed on humans with at least 1 year of follow-up and published within the last 10 years (2006–2016). No language restriction was applied. The exclusion criteria were nonhuman studies, review articles, case series, case reports, and studies based on surveys or expert opinions.

The selected articles were classified into different levels of evidence by means of the Strength of Recommendation Taxonomy criteria (10). The characteristics collected from the studies in order to perform a qualitative analysis were based on the type of intervention, outcome (success, survival, and failure rates), assessment criteria, and follow-up time.

Results

The flowchart according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines is provided in Figure 1. A total of 1229 articles were obtained in the electronic search, and 15 articles were retrieved from the manual search. Sixty articles were selected for full-text assessment. The Cohen kappa was 1 for the Cochrane Library, 0.99 for PubMed, and 0.86 for ScienceDirect. After reading the complete articles, 14 of them were excluded (11–24); the reasons are explained in Figure 2. Unfortunately, the full text of 12 articles could not be obtained. Finally, 45 articles were chosen to

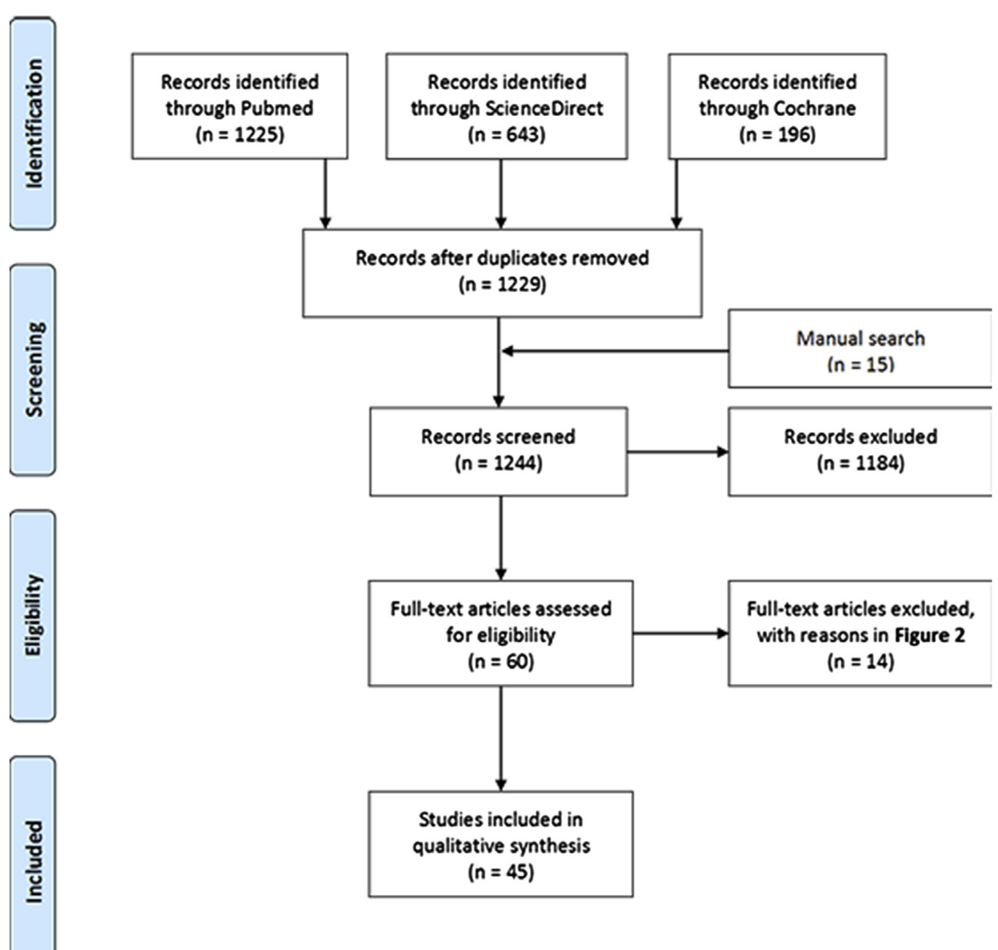

Figure 1. A flowchart of articles according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

AUTHOR	EXCLUSION CRITERIA
von Arx et al. 2007 (11)	Previous article (1 year follow-up) of von Arx et al. (46) publication (5 years follow-up).
Herman 2010 (12)	Editorial.
Friedman 2011 (13)	Letter to the Editor.
Christensen 2006 (14)	Literature review.
Chen et al. 2008 (15)	Subgroup analysis from the article published by Chen et al. (63)
Ng et al. 2011 (16)	Part 1 from article by Ng et al. (51) that assesses prognostic factors without reporting overall treatment outcomes.
Doyle et al. 2007 (17)	This publication evaluates prognostic factors but does not report overall treatment outcomes.
Tsesis et al. 2013 (18)	This publication evaluates prognostic factors but does not report overall treatment outcomes.
Setzer et al. 2011 (19)	This publication evaluates prognostic factors but does not report overall treatment outcomes.
Kurt et al. 2014 (20)	This publication evaluates prognostic factors but does not report overall treatment outcomes.
Kirkevang et al. 2014 (21)	This publication evaluates prognostic factors but does not report overall treatment outcomes.
Simonian et al. 2014 (22)	Literature review.
Moshaverinia et al. 2014 (23)	Literature review.
Song 2013 et al. (24)	This publication evaluates prognostic factors but does not report overall treatment outcomes.

Figure 2. A list of articles excluded and the reasons for exclusion.

be included in this systematic review: 2 randomized clinical trials (25, 26), 22 prospective cohort studies (6, 27–47), 17 retrospective cohort studies (3-5, 48–61), 2 cross-sectional studies (1, 62), and 2 cost-effectiveness analysis studies (63, 64). Concretely, the clinical articles were grouped into distinct tables depending on the type of intervention performed. Table 1 shows the articles on endodontic treatment or retreatment, Table 2 refers to apical surgery, Table 3 includes articles on single-tooth implants, and Table 4 shows studies comparing a conservative technique (endodontic, endodontic retreatment, or apical surgery) versus tooth extraction and implant placement.

As shown in Table 1, the success rate of endodontic treatment varies from 42.1%–86% after 2 to 10 years and from 84.1%–88.6% after 4 to 10 years for endodontic retreatment. The majority of studies do not specify assessment criteria.

The apical surgery success rate ranges from 59.1%–93% after 1 to 10 years, and the most used assessment criteria is based on radiologic criteria, as shown in Table 2.

Table 3 shows the survival rate of dental implants varies from 91.8%–100% after 1 to 10 years. None of the selected articles have assessed the success rates. No apparent differences on survival rates were noted depending on the time of placement.

Among the comparative studies from Table 4, no important differences between both treatments can be observed until after 8 years of follow-up. Only 1 study (1) detected a higher survival rate for implants compared with root canal treatments because survival and survival with intervention rates were grouped in this category. The survival with intervention category included endodontic retreatment or peri-implantitis treatment. The authors found that implants had more postoperative complications requiring intervention.

Discussion

Endodontic treatment and implant placement are both predictable treatment options. The main purpose of the endodontic treatment is to eliminate the pulp so that the periapical tissue can heal. The presence of apical periodontitis is the most important factor influencing treatment outcome. The success rates for teeth without apical periodontitis range from 82.8%–97.3%, whereas teeth with apical periodontitis varies from 75.6%–87.77% (16, 29, 55), as shown in Table 1. In addition, lesions measuring more than 5 mm in size, the presence of a sinus tract (16, 29), and a coronal or middle third root perforation are factors that could complicate treatment results (16, 27).

In a recent study, Craveiro et al (54) showed that the coronal restoration had little impact on the treatment results, whereas the root canal filling quality was a more important factor. However, a randomized clinical trial with a 6-year follow-up period published by Ferrari et al (25) found that the success rate of a tooth restored without a post was 42.1% compared with 76.6% and 61.3% success rates for restorations with a customized or prefabricated post, respectively.

With reference to healing rates, Marquis et al (28) published a prospective cohort study in which it was found that approximately 6% of teeth with apical pathology 10 to 17 years after the initial treatment had completely healed after 10 more years. This suggests that those teeth classified as incomplete or partially healed could have a slower healing rate and could completely heal in the long-term. These results are in accordance with the articles from Fristad et al (65) and Molven et al (66).

Apical surgery aims to treat apical periodontitis in unhealed teeth after nonsurgical endodontic treatment or retreatment (30, 36). In addition, the use of illumination and magnification techniques have been introduced in dentistry to improve and facilitate procedures because they allow us to observe anatomic details, detect microfractures, and minimize the need for ostectomy (34, 35, 52). However, no significant differences were found between the surgical microscope and endoscope in terms of survival and success rates (26).

According to the articles reported in Table 3, the majority of studies on dental implants did not report success rates or complications. Although the survival rates are comparable with conservative treatments,

TABLE 1. Studies on Endodontic Treatment and Retreatment Included in This Systematic Review

Author	*N* (patients/teeth)	Study design	Outcome (%)			Follow-up	Assessment criteria	SORT level
			Success	Incomplete/uncertain	Failure			
Ferrari et al, 2012 (25)	A: Restoration without post 107/120	RCT	42.1	85.9	—	6 y	—	1
	B: Restoration with a customized post 107/120		76.6	99.1	—			
	C: Restoration with a prefabricated post 102/120		61.3	97.2	—			
De Chevigny et al, 2008 (27)	100/126	PC	—	83	17	4–6 y	Radiologic	2
Marquis et al, 2006 (28)	—/132	PC	86	—	14	4–6 y	Radiologic	2
Ricucci et al, 2011 (29)	470/816	PC	88.6	0.5	10.9	5 y	Clinical and radiological	2
Ng et al, 2011 (41)	ET —/759	PC	—	95.4	4.6	4 y	—	2
	Re-ET —/858			95.2	4.8			
Chen et al, 2007 (53)	—/1,557,547	PC	—	92.9	7.1	5 y	—	2
Craveiro et al, 2015 (54)	337/523	RC	85	—	15	2–10 y	Radiologic	2
Fleming et al, 2010 (55)	Classic ET 459/459	RC	—	98.03	1.96	75.73 mo	Radiologic	2
	Contemporary ET 525/525			96	4	34.07 mo		
Fonzar et al, 2009 (56)	411/1175	RC	84.1	8.3 (3.9 [partial success] + 4.4 [partial failure])	5.8	10 y	Clinical and radiological	2
Fransson et al, 2016 (57)	217,047/248,299	RC	—	89.8	10.2	5–6 y	—	2
Skupien et al, 2013 (59)	458/795	RC	85.66	14.34	—	4.48 y	—	2
Salehrabi and Rotstein, 2010 (60)	—/4744	PC	—	89	11	5 y	—	2
Landys-Borén et al, 2015 (61)	330/420	RC	—	81.5	6.8	10 y	—	2
Gomes et al, 2015 (62)	434/1290	CS	—	48.8	51.2	—	—	2

CS, cross-sectional study; ET, endodontic treatment; RC, retrospective cohort; Re-ET, endodontic retreatment; SORT, Strength of Recommendation Taxonomy.

TABLE 2. Apical Surgery Studies Included in This Systematic Review

Author	*N* (patients/teeth)	Study design	Outcome (%) Success	Incomplete/uncertain	Failure	Follow-up	Success criteria	SORT level
Taschieri et al, 2008 (26)	Microscope 36/63	RCT	92	3	5	2 y	Clinical and radiologic	1
	Endoscope 34/50		90.3	2.4	7.3			
Barone et al, 2010 (30)	88/106	PC	—	72	28	4–10 y	Radiologic	2
Çaliskan et al, 2015 (31)	95/90	PC	—	74.4	14.4	2–6 y	Radiologic	2
Kreisler et al, 2013 (32)	255/281	PC	88	—	12	6–12 mo (7.7 mo)	Radiologic	2
Saunders, 2008 (33)	321/276	PC	59.1	21.7 (incomplete) + 8 (uncertain)	11.2	4–72 mo (18 mo)	Radiologic	2
Taschieri et al, 2007 (34)	21/28	PC	93	3.5	3.5	1 y	Radiologic	2
Taschieri and Del Fabbro, 2009 (35)	30/43	PC	90.7	2.3	7	2 y	Radiologic	2
Von Arx et al, 2012 (36)	170/170	PC	70.6	5.9 (incomplete) + 10.6 (uncertain)	12.9	5 y	Global prognosis	2
Wälivaara et al, 2007 (37)	54/55	PC	80 (success and incomplete)	—	20	1 y	Radiologic	2
Song et al, 2014 (42)	—/115	PC	75.7	13.1	11.3	≥4 y	Radiologic	2
Song et al, 2011 (43)	42/42	PC	78.6	16.7	4.8	1 y	Radiologic	2
Peñarrocha et al, 2007 (45)	235/333	PC	71.7	13.9	14.4	12 mo–10 y (27.8 mo)	Global prognosis	2
Walivaara et al, 2011 (47)	IRM —/96	PC	90.6 (success and incomplete)	—	9.4	12–21 mo (13.1 mo)	Radiologic	2
	SuperEBA (Keystone Industries, Gibbstown NJ) —/98		81.6	—	18.4			
Song et al, 2011 (51)	—/441	RC	84.8	—	15.2	1 y	Clinical and radiologic	2
Tortorici et al, 2014 (52)	1: Traditional surgery with handpiece, 45° bevelled apicectomy, and amalgam 393/458	RC	60	7 (incomplete) + 27 (uncertain)	6	5 y	—	2
	2: Modern surgery with microscope, 90° apicectomy, ultrasonic device, and MTA 195/206		71	19 (incomplete) + 7 (uncertain)	3			
	3: Osteotomy and 45° apicectomy with piezosurgery and amalgam 255/273		73	21 (incomplete) + 5 (uncertain)	1			
Lui et al, 2014 (58)	93/93	RC	71	7.5	21.5	1–2 y	Clinical and radiologic	2

MTA, mineral trioxide aggregate; PC, prospective cohort; RC, retrospective cohort; RCT, randomized clinical trial; SORT, Strength of Recommendation Taxonomy.

TABLE 3. Studies on Single-tooth Implants Included in This Systematic Review

Author	*N* (patients/implants)	Study design	Outcome (%) Success	Survival	Failure	Follow-up	Assessment criteria	SORT level
Levin et al, 2006 (5)	1215/1387 Delayed placement	RC	—	93.1	6.9	6 y	—	2
Wennstrom et al, 2005 (6)	36/40 Delayed placement	PC	—	97.4	2.5	5 y	—	2
Covani et al, 2012 (38)	91/159 Immediate placement	PC	—	91.8	8.2	10 y	Buser, 1990	2
Covani et al, 2014 (39)	45/47 Immediate placement	PC	—	95.7	4.3	5 y	Buser, 1990	2
Gotfredsen, 2012 (40)	10/10 Early placement 10/10 Delayed placement	PC	—	100	0	10 y	—	2
Vanlioglu et al, 2014 (44)	47/55 Early placement	PC	—	100	0	2–4 y	—	2
Luongo et al, 2014 (46)	46/57 Immediate and delayed placement	PC	—	98.5	1.5	1 y	—	2
Bonde et al, 2010 (48)	48/52 Delayed placement	RC	—	94	6	10 y (7.5–12 y)	—	2
Cha et al, 2013 (49)	120/136 Delayed placement	RC	—	91.9	8.1	5 y	—	2
Koo et al, 2010 (50)	489/521 Delayed placement	RC	—	95.1	4.9	1–5 y	—	2

PC, prospective cohort; RC, retrospective cohort; SORT, Strength of Recommendation Taxonomy.

the presence of postoperative complications such as peri-implant diseases may require additional procedures according to Doyle et al (1), thus hampering the long-term results and the comfortability of the treatment for the patient. Of course, the presence of periodontal disease has a negative effect on patients with dental implants because it is a well-known risk factor for the development of peri-implant diseases. Before placing dental implants, the periodontal disease should be stabilized, and the residual pockets should be eliminated (6, 40).

Table 4 shows the studies that compare a conservative treatment versus tooth extraction and implant placement, all of them retrospective. A comparative study published by Hannahan and Eleazer (4) obtained an 87.5% success rate for implant treatment and a 90.2% success rate for endodontic treatment. These results are quite similar to those of Doyle et al (1). When more strict success criteria are used, failure rates increase. This can be observed in a study performed by Vozza et al (3) in which implant failure was defined as an implant presenting more than 3 mm of exposed surface and the tooth status was defined by clinical and radiologic parameters including probing pocket depth, apical and coronal seal, and clinical attachment level. It seems that clinical results between endodontic treatment and implant placement are very similar in terms of success, survival, and failure rates (1, 3, 4). However, the main problem is the lack of standardized assessment criteria between the articles and the scarcity of comparative studies.

Regarding studies about endodontics and apical surgery, some authors consider that complete healing of a periapical lesion could require longer time (27, 28, 58, 65, 66). In some cases, the patient could have no clinical signs or symptoms, while the radiographic image could show incomplete bony healing. In the authors' opinion, those cases diagnosed as incomplete or uncertain healing could mean that radiographic and clinical outcome do not evolve at the same time. Accordingly, a study on apical surgery published by Martí-Bowen et al (7) found that the clinical success rate at 6 and 12 months was 92% and 95%, respectively. Interestingly, the radiologic success rate at 6 and 12 months was lower (ie, 58% and 80%, respectively).

On the other hand, although dental implants yield high survival rates, peri-implant diseases constitute a major health problem. More than 50% of patients are affected by mucositis, and 28%–56% have peri-implantitis (8). In a recent systematic review (8), peri-

TABLE 4. Comparative Studies Included in This Systematic Review

Author	*N* (patients/teeth or implants)	Study design	Outcome (%) Success	Survival	Failure	Follow-up	Assessment criteria	SORT level
Doyle et al, 2006 (1)	Implant 171/196	CS	73.5	20.5	6.1	2 y	—	2
	ET 171/196		82.1	11.8	6.1		Radiologic	
Vozza et al, 2013 (3)	Implant 31/47	RC	80.8	—	19.2	8 y	Clinical	2
	ET 31/42		83.3	—	16.7		—	
Hannahan and Eleazer, 2008 (4)	Implant —/129	RC	87.6	10.8	1.6	22 mo	—	2
	ET —/143		90.2	9.1	0.7	36 mo	Radiologic	

CS, cross-sectional study; ET, endodontic treatment; RC, retrospective cohort; SORT, Strength of Recommendation Taxonomy.

implantitis was shown to be related to the time in function of implants. Likewise, a combined retrospective and cross-sectional study that evaluated 588 patients with dental implants after 9 years of follow-up performed by Derks et al (67) observed that periodontitis, ≥4 implants, implants of certain brands, and prosthetic therapy delivered by general practitioners were related to higher odds ratios for moderate/severe peri-implantitis. Before performing this treatment, the patient should be advised for the possible risks because, apart from peri-implant diseases, other complications could appear. As observed by Doyle et al (1), implants have more problems in terms of prosthetic complications compared with endodontically treated teeth.

According to the cost of treatments in the United States, Kim and Solomon (63) found that the best option was to perform an endodontic treatment and, if this failed, apical microsurgery followed by an endodontic retreatment and, ultimately, the placement of a dental implant. However, the need to place a post or a crown during conservative treatment would be more expensive than an implant. On the other hand, Pennington et al (64) found endodontic retreatment to be the most cost-effective option if initial conservative treatments failed in the United Kingdom. The third option should be implant placement because if apical surgery had to be performed, endodontic retreatment should be mandatory, and this would be even more expensive. Unfortunately, there is a lack of cost-effectiveness studies in Spanish dental practices.

In our opinion, the decision to conserve or to extract a tooth must be based on the current scientific literature. However, because the different treatment options are comparable in terms of success and survival rates, the treatment should be agreed upon in accordance with patient preferences and realistic expectations.

Conclusions

The endodontic treatment and the implant placement are both valid and complementary options for planning oral rehabilitation. Although a level B recommendation can be stated, these results come from retrospective comparative studies because there is a lack of randomized clinical studies comparing both types of therapeutic options. Studies on dental implants are less demanding than those studies on endodontics because the majority of them only provide information on survival and not success rates.

Acknowledgments

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

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