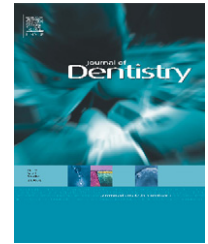


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Review

A systematic review of single crowns on endodontically treated teeth

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ABSTRACT

Objectives: To test the hypothesis that the placement of a crown is associated with improved (long term) survival of root canal treated teeth, using a systematic review process of clinical studies.

Data sources: Papers referring to single crowns on endodontically treated teeth were located by a MEDLINE search and hand searching. One thousand six hundred and nine references were found, and they were subjected to a systematic review procedure.

Study selection: A three-step inclusion–exclusion procedure was applied to identify papers that represented; good scientific practice (GSP), reported results of all patients, restorations on root canal treated teeth (RCT) for more than 2 years and had sufficient data to generate life table analyses. The outcomes were ‘survival of RCT restored with crowns’ and ‘survival of RCT with direct restorations’. Ten studies survived. These data showed an overall mean GSP of 0.605 with a 10-year survival of 81% for crowned RCT and a 10-year survival of 63% for RCT with direct restorations (resin composites, amalgam, cements).

Conclusion: RCTs restored with crowns show an acceptable long-term survival of 10 years, while direct restorations have a satisfactory survival only for a short period.

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1. Introduction

Reported success rates for conventional root canal treatment range from 40% to 97% depending on differences in study design, clinical procedures, criteria for evaluation and length of postoperative observation period.^{1–6} These results are promising for the long-term function of root canal treated teeth (RCT), as long as the coronal restoration succeeding the endodontic therapy ensures longevity. Many prosthetic treatment modalities have been suggested after the completion of the root canal therapy. Most of them involve either crowns or direct restorations such as resin composites, amalgam or cements.

RCT are structurally compromised teeth. Preservation of sound tooth structure is regarded as one of the most important aspects in the increasing survival rate of endodontically treated teeth.^{7–9} From this perspective direct restorations seem to have an advantage over crowns, since preparation of a crown weakens the tooth exposing it to more likely failure. On the other hand, the need for a full coverage crown to prevent root fracture in endodontically treated posterior teeth has been supported by *in vitro* studies^{10,11} and by retrospective clinical studies.^{12,13} Another study showed that coronal coverage did not significantly improve the rate of clinical success for anterior teeth, whereas it improved success for premolars and molars.¹³

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The systematic review process enables the aggregation of results from different studies and has proved to lead to reproducible estimates of the survival of treatment modalities. This study aims to systematically review clinical studies on the performance of crowns and restorations, such as composites, amalgam and cements in root-treated teeth.

2. Materials and methods

The method used in this study was similar to the one described by Kreulen et al.¹⁴ There are four steps which are followed in order to complete a systematic review and these steps are: literature search and selection, inclusion/exclusion of papers, quality assessment, and statistical processing.

The literature search was conducted using both MEDLINE and hand searching on a campus library. Searching the network involved the years from 1960 to 2006, while studies that could not be traced using MEDLINE were identified by hand searching indexes existing in the library's collection. Keywords were 'restorations', 'crown', 'endodontic' and 'success'. Abstract texts were not included, since such texts cannot provide the necessary information for a systematic review to be undertaken. Systematic reviews demand a thorough description of study set-up and data analysis is not likely to be expressed within an abstract.

The literature search was carried out by two researchers and was based on a written protocol. There are three steps in the selection procedure to be distinguished. An initial selection of the relevant references found was made on the basis of Table 1 and involved the 'first selection' (Table 1). A second selection, using a standard form including the criteria as described in the second part of Table 1 followed the first. The criteria in Table 1 marked with (a) were binary assessed, while no attention was paid to the actual content of each item. The item 'type of restoration' was assessed on a four-point scale, while the items 'foundation type' and 'tooth type' were assessed on a two- and three-point scale, respectively. In this study RCTR is defined as a restoration supported by a single root canal treated tooth. A third step in the selection procedure was carried out in order to aggregate survival data into a common mean outcome. Studies that had no identifications available on the individual survival periods were excluded. Studies that survived this three-step selection procedure were evaluated in order to estimate their quality. The quality assessment of the papers was necessary to obtain a description of the sample of the studies survived and the total of quality scores.

There were only 10 papers to survive after the third selection. Of these papers the sections 'Materials and methods' and 'Results' were duplicated (without referential data). These sections were separately evaluated by two observers (A.F.S., P.T.K.) using a formal procedure. For this purpose, a modification of the quality scoring system as described by Antczac et al.^{15,16} and Kreulen et al.¹⁴ was used. The studies were evaluated according to items that were considered to represent good scientific practice (GSP) in clinical studies.¹⁴ To arrive at a standard form that reflects GSP, criteria formulation and calibration sessions for the two observers were conducted. Items can be classified into four

Table 1 – Selection criteria regarding papers on the restoration of root canal treated teeth (RCT)

Step	Include	Exclude
First selection	RCTR ^a reported Clinical study	Non-clinical study Description of technique Review No RCTRs Case report
	Follow-up study	
Second selection	Paper in English ^b	One of the criteria is not met in order of appearance
	Follow-up 2 years or more ^b	
	Study outcome shown as failures of RCTRs ^b	
	Study outcome shown as failures of RCT ^b	
	Type of restoration ^c	
	No. of patients stated ^b	
	No. of teeth stated ^b	
Foundation type stated ^d		
	Tooth type stated ^e	

^a RCTR: root canal treated teeth restorations.
^b Binary assessment, 0: not stated/not applicable.
^c Assessment on four-point scale, 0: crown; 1: resin; 2: amalgam; 3: combination 0/1/2.
^d Assessment on two-point scale, 0: no post; 1: post.
^e Assessment on three-point scale, 0: anterior teeth; 1: posterior teeth; 2: anterior and posterior teeth.

main fields, i.e. 'study methodology', 'dental methodology', 'evaluation methodology' and 'statistical methodology'. The item 'aim of the study' was added to illustrate whether the paper addressed the research question. Each item was regarded 'full-', 'partial-' or 'no credit' by the criteria as shown in Table 2. The proportional weight of an item was (subjectively) balanced to the influence compared with the other items of the particular field. Scores 3, 2 and 1 were attached to the credit qualifications (except for 'aim', see Table 2) and scores were summed. The total score of each main field was weighted by a factor that was expected to reveal the importance of that field regarding the performance of clinical studies (Table 2). The total score of the studies was transferred to a 0–1 scale by the formula: (mean score – min. score) × weight / (max. total score – min. total score). The resulting value is referred to as the 'GSP-score'.

The selected studies used different identifications of failures. In this systematic review 'failure of the RCTRs' is defined as: fracture of the tooth, fracture of the restoration, post fracture, post decementation, dislodgment of the restoration, marginal leakage of the restoration and tooth loss. The outcome of the study was chosen to be 'success of RCTRs' and none of the above failure criteria should exist for the restoration to be considered successful.

Overall cumulative life table survival curves were constructed by pooling the data included in the studies to new data sets. To test homogeneity of the data, the percentage of 2-year survival (and confidence interval) of each study was compared with respect to the overall survival at the 2-year follow-up.¹⁷

Table 2 – Criteria used for quality assessment of the included studies

Item	Full credit (3 points)	Partial credit (2 points)	No credit (1 point)	Weight factor	Maximum weighted points
Aim of the study ^a	Purpose clearly described, results related to the aim	Not clearly described or results not related to the aim	Not described	1	2
Study methodology					
Type of study	Comparative clinical trial	Indications for prospective study	Indications for cross-sectional or retrospective study	2	6
Conditions	Treatment allocation procedure described, homogeneity test for co variables, evaluation planning, of 4	Two conditions described	Less than one condition described	2	6
Representativity of the sample	Selection procedure described and patient characteristics (age, sex, dentition, social/financial status described)	Selection procedure or patient characteristics described	Not described	2	6
Follow-up period	Age (s) of the restorations clearly described (distribution and variability)	Age (s) of the restorations given by intervals	Age (s) of the restorations unclear	2	6
Dental methodology					
Treatment protocol	Clinical procedures (endodontical and prosthetical) step by step described	Roughly described or one out of both described	Not described	1	3
Compounds of restoration described	Type of crown/composite/amalgam, foundation type, post type	Two out of three items described	Less than two items described	1	3
Materials stated and described	All materials used for fixation of the post, fixation of the crown, amalgam/resin core built-up	Main materials described	Not described	1	3
Operators indicated	More than one operator, number and skills	More than one operator, no description/one operator indicated	Not described	1	3
Remaining tooth structure	Type of cavities described (MO/MOD), min-max tooth structure	Roughly described	Not described	1	3
Evaluation methodology					
Description major endpoints/failure	Criteria described and validated frequencies given	Failure criteria described but not validated, failures reported, reference for criteria	Not described	2	6
Other evaluation criteria	Periapical lesions, marginal leakage, color stability, surface staining described and reported; validated method	One or two items described or reported; validated or reference given	Not described or not reported	2	6

Table 2 (Continued)

Item	Full credit (3 points)	Partial credit (2 points)	No credit (1 point)	Weight factor	Maximum weighted points
Observers indicated	Calibrated observer(s), agreement indicated, procedure described	Calibrated observer(s) but no agreement indicated, procedure described	Procedure not described	2	6
Statistical methodology					
Numbers	Numbers of patients, restorations (crowns, amalgam/resin composite cores) presented, including success, failure and lost to follow up	Numbers not clearly presented but interpretation for R.C.T teeth survival possible	Only sample size and number of failures, interpretation no possible	1.5	4.5
Origin of percentage success/failure	Stated	Not shown but traceable	Just percentage or numbers	1.5	4.5
Statistical procedures	Explained, data handling described	Partially described	Not described	1.5	4.5
Reliability	Confidence limits, covariables analyzed, power estimate, justified method	Two items	Less than two items	1.5	4.5
Total					77

^a Aim of the study received a different score, full credit: 2; partial credit: 1; no credit: 0.

Table 3 – Papers selected after first selection (in alphabetical order; n = 18) (remaining papers after second selection are presented in italics (n = 13))

Aquilino and Caplan¹⁸
 Caplan et al.²⁹
 Chen et al.³⁴
 Creugers et al.²²
 Ellner et al.²¹
 Glazer³¹
 Grandini et al.²⁴
 Hansen²⁵
 Hansen et al.²⁶
 Hansen and Asmussen²⁷
 Lewis and Smith²³
 Linde³⁰
 Manocci et al.¹⁹
 Nagasiri and Chitmongkolsuk²⁰
 Sorensen and Martinoff^{12,13}
 Wallerstedt et al.²⁸
 Wegner et al.³³
 Willerhausen et al.³²

3. Results

The MEDLINE and INDEX literature search resulted in 1609 hits. After the first selection, 1591 papers were excluded and the 18 papers that remained were entered in the second selection. These 18 remaining papers are shown in Table 3.^{13,18-34} Of the remaining 18 studies, three were excluded as they were not referring to single teeth and one was excluded for being in a language other than English. Next, one paper was excluded since the follow-up period appeared to be less than 2 years. As a result, 13 studies were included for further analysis after the second selection. The remaining 13 studies after the second selection are shown in Table 3 (presented in italics). The third selection revealed three studies with insufficient data for life table statistics. These studies are listed in Table 4. Thus, 10 studies remained. The results of the quality assessment of these studies are shown in Table 5. It can be observed that the main field with the most credits was 'dental methodology' (mean total score = 10). The lowest mean score was found for the field 'evaluation methodology' (mean total score = 5.8). The overall mean GSP score was 0.605.

Data from the 10 studies that remained after the third selection, were assessed to construct two survival curves; data from five studies^{18,19,21,22,29} were analyzed for the construction of the survival curve referring to RCT covered with crowns, while data from eight studies^{18-20,24-27,29} were analyzed for the construction of the curve referring to RCT without crown coverage. The combined survival curve for RCT with crowns shows a survival of 81 ± 12 after 10 years (Fig. 1), while the

Table 4 – Studies excluded by third selection step due to insufficient data for construction of life table survival curves

Lewis and Smith²³
 Sorensen and Martinoff¹³
 Wallerstedt et al.²⁸

Table 5 – Assessment scores of the 10 studies included, in accordance to the fields and criteria used in the quality assessment form (Table 2)

Item	Mean score	Mean GSP score per item
Aim of the study	1.7	0.33
Study methodology		
Type of study	1.4	0.015
Conditions	2.7	0.066
Representativity of the sample	2.6	0.062
Follow-up period	2.4	0.054
Dental methodology		
Treatment protocol	1.6	0.011
Compounds	2	0.019
Materials	1.9	0.017
Operators	2.1	0.021
Remaining tooth structure	2.4	0.027
Evaluation methodology		
Description major endpoints	3	0.078
Other evaluation criteria	1.6	0.023
Observers indicated	1.2	0.007
Statistical methodology		
Numbers	2.8	0.052
Origin of percentage success/failure	2.4	0.041
Statistical procedures	2.3	0.038
Reliability	2.4	0.041
Overall mean GSP score		0.605

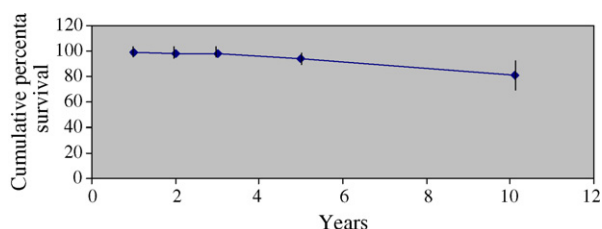


Fig. 1 – Cumulative survival curve for RCT with crowns.

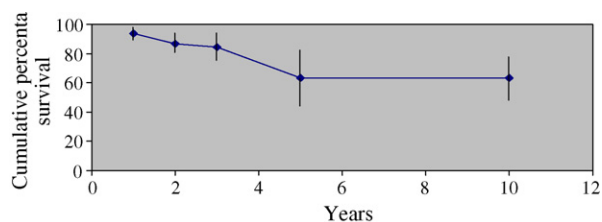


Fig. 2 – Cumulative survival curve for RCT without crowns.

combined survival curve for RCT without crowns shows a survival of 63 ± 15 after 10 years (Figs. 2 and 3) (Table 6).

4. Discussion

An interesting question that arises when performing a meta-analysis is the need of the quality assessment of the papers included in the particular analysis. For example, when comparing the results of two systematic reviews on conventional bridges³⁵ it was shown that the results are quite similar even though different sets of studies are included. Systematic reviews are not truly reproducible, but the above analogy of the results suggests that they seem to produce reproducible results. Furthermore, this constancy could indicate that the quality assessment is of minor value and is therefore not necessary to be undertaken. Nevertheless, in this study the quality assessment procedure was performed in order to serve as an instrument that indicates the reliability of the data for inference. The quality assessment of the studies involved in this analysis shows that the quality assessment of the clinical studies is far from the ideal.

Another interesting point that should be made is whether non-English papers should be excluded or not. Several reasons in favour of exclusion could be considered. It is difficult to have access to non-English journals all over the world. Furthermore, when these non-English papers are selected, as based on their abstracts, the contents must be translated. This includes the risk of unforeseen interpretation problems. Finally, it is hard to establish the features of the peer-reviewing processes of these journals.³⁵ In this study, there was only one relevant paper that was excluded and this paper was in Chinese.³⁴ Considering that it was only one paper, it was believed that it could not significantly change the results of the present study and therefore it was discounted.

Initially, it was thought to separate the results for RCT without crown coverage according to the material that was used for the core built-up (resin, amalgam, cement). It was finally chosen not to, as there were not sufficient data for each material to construct an individual survival curve. Consequently, the results were separated into two groups: one referring to RCT covered with crowns and the other referring to RCT without crown coverage, irrespective of material.

As far as the data of the included studies are concerned, there are some definitions that should be made. In the study that was undertaken by Creugers,²² it should be noted that five failures that occurred in the first month after the insertion of the post were ignored. Although true failures, they were independent of clinical aging and fatigue processes. These failures were considered “early failures” and they were excluded from further survival assessments.

Table 6 – Cumulative survival for RCT with crowns and RCT without crowns

	Years				
	1	2	3	5	10
Mean survival-crown	99 ± 1	98 ± 3	98 ± 3	94 ± 2	81 ± 12
Mean survival-no crown	94 ± 5	87 ± 7	84 ± 9	63 ± 19	63 ± 15

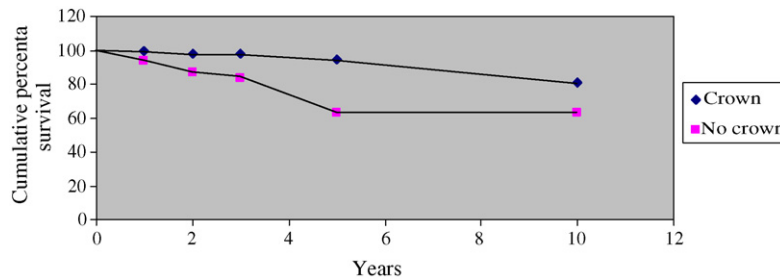


Fig. 3 – Cumulative survival curves for RCT with crowns and without crowns.

Additionally, in the study described by Grandini,²⁴ data referring to marginal leakage were not evaluated in this meta-analysis, while data on retention were assessed. Data referring to these failures cannot be evaluated as a whole, since some failures may coexist in one tooth and would lead to false results. Whether these failures consider different teeth or the same, in some cases, is not inferred in the study. Since “loss of retention” seems to be a more common “failure characteristic” than “marginal leakage”, it was chosen to include only data on retention for the present meta-analysis.

Data for evaluation are not clear in all studies. In particular, in the study described by Hansen²⁵ there is only a figure picturing the cumulative survival rate. To allow the statistical procedure, numbers were obtained by drawing horizontal and vertical lines on y- and x-axes, respectively.

This systematic review definitely shows that RCT covered with crowns have a higher long-term survival rate ($81 \pm 12\%$ after 10 years) than RCT without crown coverage ($63 \pm 15\%$ after 10 years). However, it should be highlighted that the survival rate for RCT without crown coverage is quite satisfactory for the first 3 years ($84 \pm 9\%$), while there is a significant decrease in the survival of RCT after this period.

Another fact is that the 3-year survival rate of resin-restored teeth is markedly better than that of amalgam-restored teeth.²⁵ Succinctly, amalgam is unacceptable for restoration of endodontically treated posterior teeth, whether amalgam is used as a temporary or permanent restorative material.²⁶ In contrast, enamel-bonded resin is an alternative treatment option for teeth that are in the need of a temporary restoration and have limited loss of tooth structure.¹⁹

Several authors have described the value of systematic reviews in dental research.³⁶⁻³⁸ As a result it has been recognized as a powerful research tool in evidence-based dentistry as well as for cost-benefit comparison of dental treatments.³⁹ Unfortunately, this systematic review has shown that this kind of research is difficult to undertake since most of the studies that are included are retrospective. As with all retrospective studies, there cannot be a standard clinical study methodology or reporting methodology that will contribute to effective analysis of results.

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