Long-Term Survival of Complete Crowns, Fixed Dental Prostheses, and Cantilever Fixed Dental Prostheses with Posts and Cores on Root Canal–Treated Teeth

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Purpose: This study investigated the long-term survival of posts and cores on root canal–treated (RCT) teeth restored with complete crowns, fixed dental prostheses (FDPs), 3-unit FDPs, and cantilever FDPs (C-FDPs) made over a period of 16 to 20 years in an undergraduate clinic. ***Materials and Methods:*** Complete treatment and follow-up records of 1,037 complete crowns, 134 three-unit FDPs, 322 FDPs, and 168 C-FDPs were available for analysis. All RCT teeth studied had a post-and-core buildup. Kaplan-Meier survival curves were used to evaluate the different types of fixed restorations. ***Results:*** For complete crowns, the estimated survival rates at year 18 were 74.9% for the vital group and 79.4% for the RCT group ($P = .602$). For 3-unit FDPs, the survival rate at year 20 was 83.2% for the vital group and 60.5% for the RCT group ($P = .108$). For the FDPs, the survival rate at year 20 was 77.4% for the vital group, while for the RCT group with at least 1 RCT abutment, the survival rate was 56.7% ($P = .002$). For C-FDPs with vital abutments, the survival rate was 73.5% at year 16, while for the RCT group with at least 1 RCT abutment, the survival rate was 52.3% at year 18 ($P < .01$). ***Conclusions:*** There was no statistically significant difference in the long-term survival of complete crowns on vital abutments versus post-and-core complete crowns or in the survival of 3-unit FDPs on vital abutments versus those with at least 1 RCT abutment. For FDPs with more than 3 units and C-FDPs, the use of a post-and-core abutment led to significantly more failures. *Int J Prosthodont 2007;20:229–234.*

Over the last 2 decades, treatment options for post-and-core restorations on root canal–treated teeth have been a primary topic in the prosthetic field. Survival rates of restored endodontically treated teeth are of great importance. Clinical prosthetic procedures range from a conventional filling to complete coronal coverage by placement of a complete crown or fixed dental prosthesis (FDP). The treatment plan depends on patient-related factors. In general, socioeconomic factors play an important role in decision-making. Lack of scientific evidence calls into question some prosthetic procedures[1–3]; therefore, uniform and generalized results and randomized controlled clinical trials are necessary to assess success and survival rates, and to give the practitioner more insight into the reasons for failure. Creugers et al[1] in 1993 and Heydecke and Peters[2] in 2002 reported that there were no randomized clinical trials available on the restoration of root canal–treated teeth. Fernandes and Dessai[3] concluded that there is a need for controlled prospective clinical studies evaluating each factor affecting the fracture resistance of teeth restored with a post and core. The effectiveness and durability of post-and-core treatments have been questioned many times,[4–13] and some authors have speculated on the probable causes of failure.[6,7]

There are different treatment modalities for restoring root canal–treated teeth. The first choice is the use of silver amalgam or resin composite restorations as permanent obturation. More radical options include

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cusp-covering restorations with gold, ceramic, amalgam, or resin composite onlays or complete coverage with a crown. Controversy exists as to whether endodontic procedures are the primary cause for the loss of strength of a root canal–treated tooth.[14] Fracture resistance may be more dependent on the amount of remaining sound dentin, as suggested by several studies.[3,15,16] The best results have been achieved in root canal–treated teeth with otherwise sound tooth structure crowned without a post restoration. Nevertheless, dental caries is most often the causative factor for endodontic treatment and is linked with massive coronal destruction. In these cases, where great loss of tooth structure as a result of caries or trauma occurs, achieving sufficient anchorage in the remaining clinical crown is often impossible. Hence, this extensive loss of tooth structure necessitates complete-crown restorations with pulpal retention.

Different approaches to the placement of a post-and-core crown can be followed. There are 2 main restorative options: indirect cast post-and-core and direct restorative techniques. Various results on the outcome of these treatment modalities have been reported in both in vitro and in vivo studies.[2,3,6] Complete crown coverage, which has been advocated as a mean to strengthen root canal–treated teeth to improve their longevity, has recently been questioned.[14]

Aquilino and Caplan[17] focused on the relationship between complete crown placement and the survival of root canal–treated teeth. They concluded that root canal–treated teeth without complete crowns were lost at a 6.0 times greater rate than those with complete crowns. A second treatment choice is whether to provide a restoration with or without the use of a post. Currently, there still is not enough clear data on this treatment option.[18]

Further, the initial endodontic therapy itself seems to have divergent success rates ranging from only 60% to 75% up to 90% to 95%.[19,20] The prognosis of the initial therapy of apical periodontitis ranged from 73% to 90% in a small review group, but from 46% to 91% across all studies.[21] These success ranges are the result of variations between studies, with differences in clinical procedures, study design, case selection, evaluation criteria, and observation period.[21] The quality of the coronal restoration has frequently been related to apical periodontitis. Coronal restorations of inferior quality or posts involving the pulpal canal may be conducive to a poor prognosis, but until now there is no objective clinical study showing a correlation with apical periodontitis or a significant clinical problem.[8,9,19,21] However, Palmqvist and Swartz[10] concluded that a root canal–treated abutment does not need to be considered as a substantially increased risk. In a study of the assessment of the periapical and clinical statuses of crowned teeth over a 25-year period, Valderhaug et al[22] observed that crowned, root canal–filled teeth with high quality endodontic treatment have a similar survival rate as crowned teeth with vital pulp.

The purpose of this study was to analyze the results of 4 retrospective investigations of the behavior of posts and cores on root canal–treated teeth restored with complete crowns,[23] 3-unit FDPs,[24] FDPs,[25] and cantilever FDPs (C-FDPs)[26] all made at the same department according to the same principles.

Materials and Methods

All complete crowns, 3-unit FDPs, FDPs, and C-FDPs made over a period of 16 to 20 years in the undergraduate clinic of the former Department of Fixed Prosthodontics and Periodontology, University of Ghent, Belgium, were included in this study. A total of 1,312 complete crowns, 165 three-unit FDPs, 397 FDPs, and 213 C-FDPs were fabricated. Complete treatment and follow-up records of 1,037 complete crowns (79%), 134 three-unit FDPs (81%), 322 FDPs (81%), and 137 C-FDPs (64%) were available for analysis. Dropouts occurred for the following reasons: patients chose a private practitioner for maintenance, moved to another city, could not be located, or died during the follow-up period. None of the patients in the dropout group were contacted by telephone and no questionnaires were sent, either to the patients or to former or current clinicians of these patients, to collect supplementary information.

To avoid excessive removal of dentin substance, no special root canal preparation for the post-and-core abutment teeth was used. A standard ferrule of 2 mm was preferred, but in many cases this could not be obtained. Many of the post-and-core preparations had a limited ferrule. No direct restorative techniques or special burs with prefabricated posts were used. According to standard protocol, approximately 10 mm of root canal filling was removed (range: 7 to 15 mm), always preserving at least 3 mm of the apical part of the root filling. The impression of the prepared tooth was always made with the same polyether material (Impregum, 3M ESPE). For the root canal, an impression was made using a lentulo, but no other devices such as burnout posts were used. Using this technique, the cast post reflects the root canal in its most natural, original dimensions. All post-and-core complete crowns were cast gold posts fused with the crowns (in a single piece), but all cast gold posts and cores on the abutment teeth in FDPs and C-FDPs were made separately from their retainer. Posts and cores were made of the same gold alloy (Degudent U, Degussa) used for the retainers and pontics. Although material developments are changing rapidly, recent studies confirmed the excellent status of the cast post and core.[27,28] All reten-

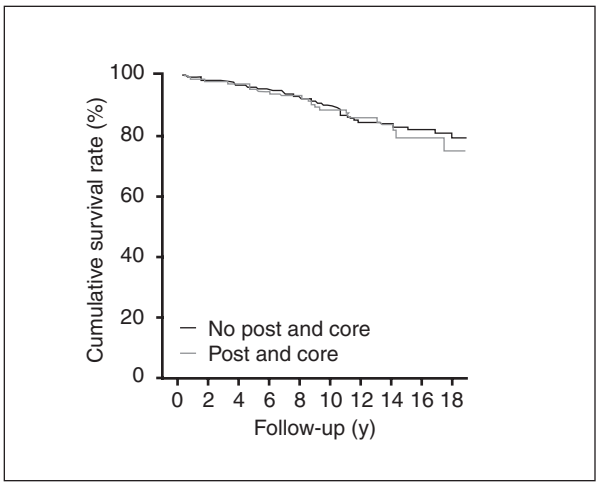

Fig 1 Kaplan-Meier survival curves for complete crowns in the vital and RCT groups ($P = .602$).

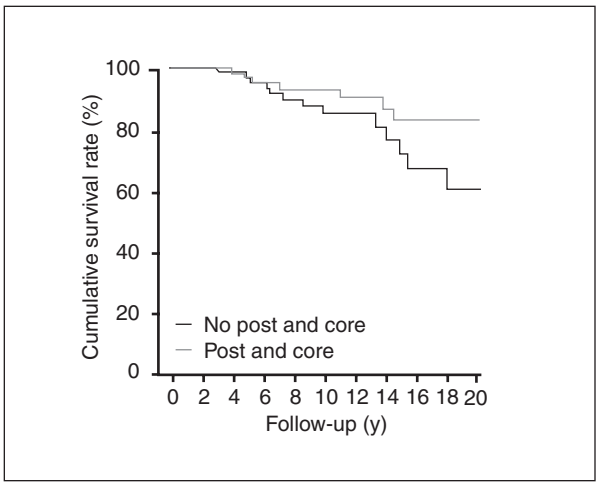

Fig 2 Kaplan-Meier survival curves for 3-unit FDPs in the vital and RCT groups ($P = .108$).

tive surfaces of the restorations were sandblasted (50 μ) prior to cementation. All complete crowns, 3-unit FDPs, FDPs, C-FDPs, and post-and-core buildups were cemented with a zinc phosphate cement (Harvard, Richmond Harvard) under the same strict conditions.

All patients were invited to participate in a regular supportive maintenance program every 6 months. During these maintenance sessions, a number of diagnostic and therapeutic steps were performed: whole-mouth plaque score after staining with a dichotomous reading, bleeding on gentle probing of the gingival sulcus, periapical radiographs, recording of new caries lesions or secondary caries, control of the retention of the restoration, and recording of mechanical failures. Probing depth at 6 or 8 sites per tooth was recorded using a Michigan Periodontal Probe. At each session, patients were re-instructed in plaque control. If the interdental morphology allowed, cleaning with interproximal brushes or superfloss was advised and instructed. At each session, plaque and supra- and subgingival calculus were removed. Patients were scheduled for scaling and root planing when periodontally indicated.[23–26]

Failures were divided into 2 groups: *irreversible complication* if the restoration or the tooth were lost and *reversible complication* if re-cementation was needed after loss of retention, endodontic treatment, or a filling on the abutment tooth, with the restoration still intact. A restoration could therefore have a reversible complication but end up in the surviving group at the final evaluation, or have a reversible complication followed by an irreversible complication, thus ending up in the failure group. This project (EC UZG 2005/100) was approved by the Ethics Committee (OG 017), University Hospital, Ghent, Belgium.

Statistical Analysis

The Kaplan-Meier[29] survival estimation method with a 95% confidence interval was used. The log-rank test was used to determine whether some survival functions differed between groups.[30] Statistical significance of difference was calculated using the chi-square test. The significance level was set at $\alpha = .05$.

Results

Complete treatment and follow-up records of 1,037 complete crowns, 134 three-unit FDPs, 322 FDPs, and 137 C-FDPs were available for analysis. In the complete crown group, the distribution of root canal–treated (RCT) teeth and vital teeth was 821 (79.2%) and 216 (20.8%), respectively. For 3-unit FDPs, the RCT group (with at least 1 RCT abutment tooth) and vital group were equally distributed (n = 67). For FDPs, there were 180 (56%) FDPs with at least 1 RCT abutment and 142 FDPs (44%) with only vital abutments. Overall, there were 458 (65%) vital abutments and 246 (35%) RCT abutments. For C-FDPs, there were 89 (65%) C-FDPs with at least 1 RCT abutment and 48 (35%) with only vital abutments.

There was no statistically significant difference (log-rank $P = .602$) for the complete crowns (Fig 1) between the survival of vital and RCT groups. The survival estimate for the vital group was 93.9% (95% CI: 91% to 97%) at year 6; 85.6% (80% to 91%) at year 12; and 74.9% (66% to 84%) at year 18. The survival estimate for the RCT group was 95.2% (94% to 97%) at year 6; 84.7% (81% to 88%) at year 12; and 79.4% (74% to 85%) at year 18.

The survival estimates for 3-unit FDPs are shown in Fig 2. No statistically significant differences were ob-

Table 1 Cross Tabulation of FDP Vital or RCT Abutments Versus Failure or Survival ($P = .001$)

Abutments	Surviving (%)	Failing (%)
RCT	172 (69.4)	76 (30.6)
Vital	370 (81.1)	86 (18.9)

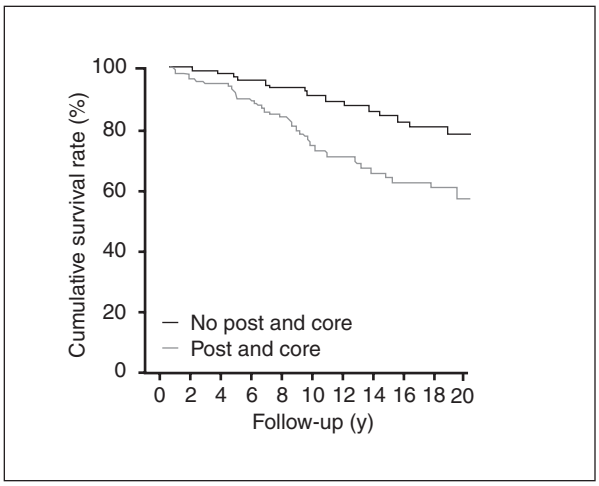

Fig 3 Kaplan-Meier survival curves for FDPs in the vital and RCT groups ($P = .002$).

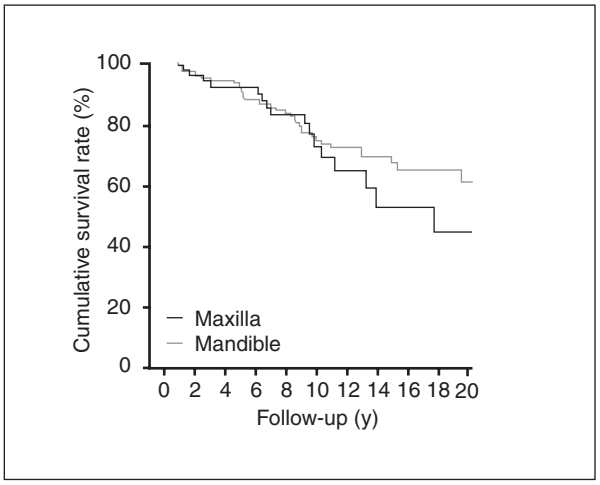

Fig 4 Kaplan-Meier survival curves for FDPs in the RCT group in the maxilla and mandible ($P = .382$).

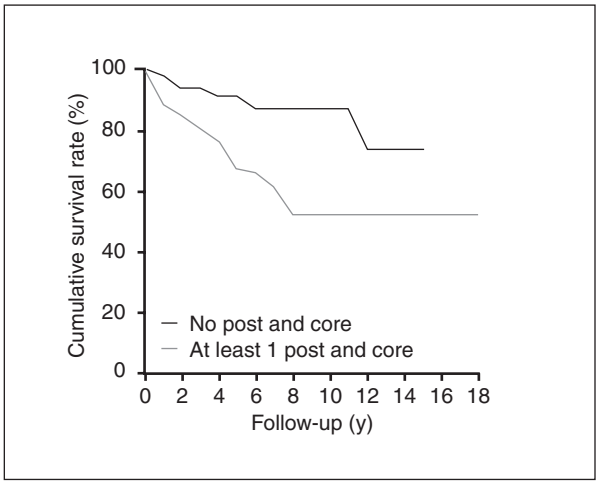

Fig 5 Kaplan-Meier survival curves for C-FDPs in the vital and RCT groups ($P < .01$).

served ($P = .108$). The group consisted 134 three-unit FDPs divided equally into a vital group and RCT group of 67 three-unit FDPs each. The survival estimation of restorations in the vital group was 94.9% (95% CI: 89% to 100%) at year 5, 90.2% (82% to 99%) at year 10, and 83.2% (71% to 95%) at years 15 and 20. For the RCT group, the survival estimate was 95.2% (90% to 100%) at year 5, 84.9% (75% to 95%) at year 10, 76.1% (62% to 91%) at year 15, and 60.5% (40% to 80%) at year 20. The divergence between the vital and RCT groups appears only late in the follow-up period (Fig 2). At that time, however, there was a lack of power because of dropping sample sizes.

The survival estimates for the FDP group are shown in Fig 3. The FDPs had 1 to 6 pontics and 2 to 4 abutments. For the vital group, the estimated survival was 95.5% (95% CI: 92% to 99%) at year 5, 90.5% (85% to 96%) at year 10, 83.5% (76% to 91%) at year 15, and 77.4% (68% to 87%) at year 20. For the RCT group, the estimated survival was 90.9% (95% CI: 87% to 95%) at year 5, 74.2% (67% to 82%) at year 10, 63.9% (55% to 73%) at year 15, and 56.7% (45% to 68%) at year 20. The difference between the 2 groups was statistically significant ($P = .002$).

At year 20, there was no significant difference ($P = .382$) between the maxilla and mandible (Fig 4) for FDPs in the RCT group. The estimated survival for the RCT group in the mandible (n = 127) was 90.3% (95% CI: 85% to 96%) at year 5, 74.7% (66% to 83%) at year 10, 67.2% (57% to 77%) at year 15, and 60.1% (48% to 73%) at year 20. In the maxilla (n = 53), the estimated survival was 92.5% (85% to 100%) at year 5, 72.6% (58% to 87%) at year 10, 53.2% (33% to 73%) at year 15, and 44.3% (21% to 67%) at year 20.

A cross tabulation of the use of an RCT or vital abutment versus failure or survival (Table 1) revealed a

highly statistically significant difference ($P = .001$). The failure rate for RCT abutments was 30.6%, while only 18.9% of vital abutments failed.

The Kaplan-Meier survival estimations for the C-FDP group are presented in Fig 5. The survival estimate for the C-FDPs in the vital group was 73.5% at year 16. For the RCT group, the survival estimate was 52.3% at year 18. This difference was statistically significant ($P < .01$). In C-FDPs with only vital abutments, 12% (n = 6) failed, whereas 37% (n = 33) of restorations in the RCT group failed.

Discussion

The purpose of this study was to examine the relationship between complete crown placement and the survival of posts and cores on RCT teeth, as well as the long-term survival of vital fixed restorations versus restorations with at least 1 RCT abutment. The fixed restorations without a post and core may be more favorable, but in this study there was no statistically significant evidence for single- or 3-unit FDPs. Despite the retrospective nature of the current study, the fact that during 16 to 20 years all studied restorations were made according to the same principles and with the same materials is quite unique.

For complete crowns, there was no statistically significant difference between both types of crowns. After 18 years of service, the survival rates for post-and-core crowns and crowns on vital teeth were 79.6% and 74.1%, respectively. This is in contrast with the results of Leempoel.[4] The effectiveness and durability of the post-and-core treatment have been questioned many times,[4–7] and probable causes of failure have been suggested.[6,7] In the present study, no special root canal preparation for the post-and-core abutment teeth was used, thus avoiding excessive removal of dentin substance. Further, no direct restorative techniques or prefabricated posts were used. Many authors have confirmed the recommendation to choose the thinnest post possible, thus avoiding excessive removal of tooth substance and preventing unnecessary weakening of the root dentin.[3,6,31,32] This is a possible explanation for the fact that there was no statistically significant difference in the long-term survival of post-and-core crowns or 3-unit FDPs with 1 or 2 RCT abutments in function, and suggests that the post-and-core system does not necessarily represent the weak spot in a fixed prosthesis.

FDPs with more units in function increase the risk of retention loss or even the loss of the restoration altogether. This type of FDP is more prone to failure because the alignment of multiple tooth preparations is complex and may result in excessive taper, which will jeopardize retention.[32] Foster[33] stressed that the more retainers used for an FDP, the shorter the lifespan will be. In the present study, the influence of RCT abutments in correlation with FDPs was studied on 2 different bases: the abutment level and the FDP level. For both analyses, the results were equivalent. The use of RCT abutments led to significantly more failures. These results are in accordance with some recent studies,[11–13] comparable but not always statistically confirmed by others,[7–10] and even statistically different from a few studies.[5,22]

Failures of the C-FDPs in this study occurred in only 12% of the vital group, while 37% of the restorations in the RCT group failed. This difference was statistically significant ($P < .01$). Hämmerle et al[34] could not confirm these results statistically; however, they did find a higher frequency of root fractures for RCT teeth (4%) compared to vital teeth (2%). Other studies combined FDPs and C-FDPs into a single group, thus making evaluations more difficult. Randow et al[35] observed more fractures of both teeth and restorations when the distal abutment was non-vital. Landolt and Lang[36] confirmed that RCT teeth showed a higher frequency of root fracture. Karlsson[37] remarked that the combination of a cantilever extension and an RCT terminal abutment was predisposed to failure. Palmqvist and Swartz[10] found no statistically significant difference between the failure of vital and RCT abutments, but did note that the highest percentage of extracted abutment teeth were RCT terminal abutments with 1 cantilever extension. Pjetursson et al[38] mentioned in their systematic review that pain tolerance was significantly higher for RCT abutments compared to vital abutments; however, they noted that even though cantilever extensions put additional occlusal loads on abutments, only 2.9% of all abutment teeth, vital and non-vital, fractured over a 10-year observation period.

Conclusions

There was no statistically significant difference between the long-term survival of complete crowns on vital abutments versus RCT abutments, or in 3-unit FDPs on vital abutments versus those with 1 or 2 RCT abutments. FDPs with more than 3 units in function increase the risk of retention loss and loss of the restoration altogether. The use of an RCT abutment leads to significantly more failures of the abutments and FDPs. Failures of the C-FDPs occurred significantly more in restorations with at least 1 RCT abutment versus those with only vital abutments.

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