ADA CE Program ARTICLE 2

Titanium posts and bonded amalgam core longevity

A 22-year clinical survival retrospective study

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ABSTRACT

Background. The authors conducted a retrospective study to evaluate the long-term (18-22 years) clinic results of titanium post and bonded amalgam core restorations with metal-ceramic crowns placed in patients.

Methods. From 1992 through 1996, the authors placed 88 restorations in 66 patients. They measured the ferrule effect in the minor dentin collar area. In 2014, the authors analyzed the following variables: ferrule length, length and thickness of the post, and tooth position.

Results. The overall survival of the restorations decreased over time with survival rates of 89.6% after 5 years of follow-up appointments and 64.2% after 18 years of follow-up appointments. There were 42 failures, and the maxillary premolars had the most failures. The teeth with 2 or more millimeters ferrule length had a higher survival rate than those with a 0 to less than 2 mm ferrule length; these results were not statistically significant.

Conclusions. Statistically significant differences were detected according to the location of the tooth. The cores in the anterior teeth were 3.26 times more likely to fail than those in the molars, which presented higher survival rates; maxillary premolars had the most failures (28.5%). Both the metallic post length and its diameter did not influence restoration survival. The ferrule length was not statistically significant.

Practical Implications. The clinical technique to restore endodontically treated teeth that includes a titanium post and bonded amalgam restorations results in greater coronal destruction but shows good long-term results, ease of fabrication, and modest cost in comparison with other techniques.

Key Words. Amalgam core; ferrule; hard copper band; composite resin; survival curve; titanium post.

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Endodontically treated teeth have a shorter survival time than vital teeth,[1,2] and it has been speculated that remaining tooth structure is the most important factor for maintaining viability.[3-7] Another factor is the type of crown used. There are studies that confirm that when an endodontically treated tooth is restored with a single full-coverage crown with proximal contacts, and without being part of a tooth removal or fixed prosthesis, the tooth has a greater probability of survival.[8-10] In addition, the tooth's prognosis is influenced by other factors such as occlusal contacts, its location in the dental arch,[11,12] and ferrules. Ferrules have been defined as the necessary dentin circumferential area with a minimum height of 1.5 to 2 millimeters to obtain an adequate fracture resistance.[13-17] A ferrule reduces the stress between core restorations and dentin.[18] However, authors have proposed that lost fracture protection that the absence of ferrules may pose can be resolved using adhesive agents.[19,20]

The function of a post is to support the core restorative material,[21] but authors have speculated that its placement shortens the life of the tooth because of the removal of root dentin.[22] Therefore, a finer post increases the resistance to fracture, as it removes less dentin,[23] and a gutta-percha apical seal of 3 to 6 mm should be maintained.[24,25] In vitro studies confirm that metal posts are useful to restore endodontically treated teeth,[26] although their failure can cause tooth loss due to root fracture.[27] The most suitable material for the metal post

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TABLE 1

Distribution of the teeth.*

TOOTH TYPE	INCISORS	CANINES	PREMOLARS	MOLARS
Maxillary	6	12	24	16
Mandibular	–†	6	4	20

* Taken from 66 total participants.
† Dash indicates not applicable.

TABLE 2

Length and thicknesses of posts used.

VARIABLES	UNIMETRIC 1.0 (1-MM* DIAMETER APEX)			UNIMETRIC 0.8 (0.8-MM DIAMETER APEX)			
Length (mm)	9.5	11.5	13.5	8.25	9.5	11.5	13.5
Incisors	1	1	1	–	–	2	1
Canines	–†	4	5	–	–	3	6
Premolars	3	4	1	2	6	7	5
Molars	9	8	2	2	2	9	4

* mm: Millimeters.
† Dashes indicate not applicable.

is titanium, which causes less corrosion and is more biocompatible than magnesium or zinc.[28]

The objective of this study was the long-term evaluation (18-22 years) of titanium post restorations with a bonded amalgam core and metal-ceramic crown clinic results. The hypothesis was to determine which factors influence the restoration's long-term survival.

METHODS

Our retrospective study included restorations placed from 1992 to 1996 in a private clinic in Santiago de Compostela, Spain, which were re-evaluated in 2014. We included 88 restorations in 66 patients (42 women and 24 men; mean [standard deviation] age 44.47 [18.33] years at the time of treatment).

The clinician (V.A.P.) cemented titanium prefabricated posts and bonded amalgam cores before placing metal-ceramic crowns. The same clinician performed all treatments. The Ethics Committee of the University of Santiago de Compostela on Investigations Involving Human Subjects approved the protocol of this study, in full accordance with the World Medical Association Declaration of Helsinki.[29] Patients provided written informed consent for inclusion in the study at the time of the evaluation.

Our study participants fulfilled the following inclusion criteria: older than 18 years, full dentition without periodontal disease, no bruxism, teeth without subgingival tooth loss (ferrule $\geq$ 0 mm), temporary restorations made without eugenol, and diagnosed using periodontal probe and radiographs.

We established classification criteria for 2 groups according to the ferrule length in dentin collar height: Group 1, ferrule length 0 to less than 2 mm; and Group 2, ferrule length 2 mm or greater. The clinician measured the ferrule length with a periodontal probe (973 72W Williams, Carl Martin) at the time the restorations were made. Thirty-eight teeth had less than 2 mm of ferrule, and 50 teeth had 2 mm of ferrule or greater. The dental arch, number, and location of the teeth included in the study are shown in Table 1. The clinician took radiographs and pre-, intra-, and postoperative photographs with a camera (Nikon F-801, Nikon) and Medical-Nikkor 120 mm lens (Nikon).

In 2014, we scanned and digitized the original slides with a scanner (Nikon Super Coolscan 5000 ED scanner, Nikon) to analyze the status of the teeth at baseline, the restorations, and the clinical techniques.

Clinical techniques. For all endodontic treatments, the clinician used the lateral condensation technique and endodontic cement (Sealapex, Kerr). The core preparations were not delayed more than 7 days. The clinician isolated the operative field with a rubber dam whenever there were posterior and anterior teeth in the same hemiarch. The clinician used hard copper bands cut to the height of the future core as the matrix (E. Hahnenkratt Dentale). This matrix allowed for isolation in the preparation areas where the ferrule was less.

The posts used were titanium (Unimetric, Dentsply Sirona). The clinician performed the endodontic preparations with penetration and calibration drills, leaving apical seals between 3 and 6 mm. The clinician chose a post width depending on the root canal diameter, as measured by a periapical radiograph (Table 2). The clinician chose the distal canal of mandibular molars and the palatal canals of maxillary molars for the post placement. The clinician used adhesive resin cement in white (Panavia Ex, Kurarai) for cementation following the manufacturer's instructions. Only 1 post was used in all cases. To supply additional retention in molars and premolars with 2 roots, the clinician made amalgam extensions into the root canals. The clinician removed almost 4 mm of gutta-percha from the canal with the conformation drill of the thinner post of the Unimetric system.

Once the posts were cemented, the clinician made the cores with amalgam (Tytin, Kerr) bonded with Panavia Ex. When the clinician made the amalgam core, he condensed it into the canals with a root canal plugger. Within 2 to 5 days, the clinician completed the preparation of the tooth using diamond burs making a chamfer (1-1.5 mm) on the tooth structure. The clinician made the impression for the metal-ceramic crown with addition-cured silicone (3M ESPE) (Figure 1). The clinician placed a crown on all teeth in the study. For all treated teeth, there was at least 1 adjacent tooth that did not retain a fixed or removable prosthesis and with occlusal contacts in the natural teeth.

In 2014, the treated teeth were re-evaluated. The posts and cores with crowns had been placed 18 to 22 years

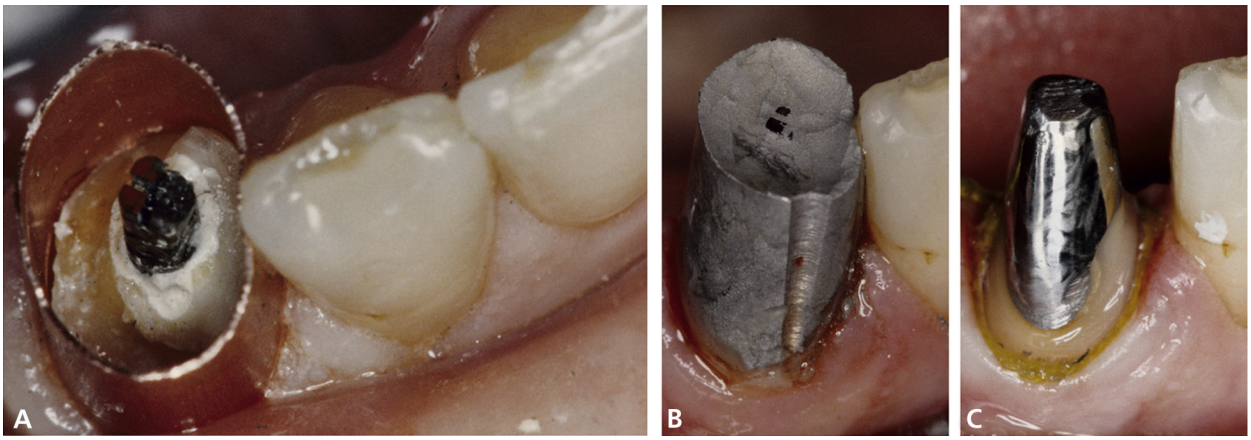

Figure 1. Photographs taken in 2014. **A**. Mandibular right canine with a titanium post (Unimetric, Dentsply Sirona) and a copper band (E. Hahnenkratt Dentale) positioned. This tooth was restored in 1993. **B**. Once the amalgam core was made, the copper band was removed by making a vertical cut with a bur. **C**. The core was prepared for taking impressions. The ferrule was 2 millimeters or greater. *Image of the copper band reproduced with permission of E. Hahnenkratt and image of the Unimetric titanium post reproduced with permission of Dentsply Sirona.*

before. The teeth and oral health of the patients were assessed by 2 postgraduate dentists who were trained before the start of the evaluation. Their examination consisted of clinical exploration and radiographs. When the results did not coincide, the examiners came to a consensus.

To perform the statistical analysis, we took the following variables into account: the location of the tooth (whether it was anterior or posterior, maxillary or mandibular), length and diameter of the titanium post, length of the ferrule in the area of lowest height, core length in proportion to the length of the root, dates of the recall visits, state of the restorations in the review, and the type of failure, if any. We considered the following as failures: subgingival caries, marginal filtration (determined by periapical radiograph and exploration with a probe), loss of retention, radicular fracture, and endoperiodontal pathology (determined by a periodontal probe and periapical radiographs).

To individually evaluate potential prognostic factors, we used the survival function of Kaplan-Meier estimates. To evaluate the whole effect of each potential risk factor, we did a multivariate analysis using the Cox proportional hazards model, considering the survival time of each restoration as the dependent variable. We assessed the magnitude of the association between the studied factors, or covariates, and survival through the hazard ratios (HR) with a corresponding 95% confidence interval (CI). We considered an association statistically significant when the *P* value was less than .05.

RESULTS

The mean (standard deviation) lifetime of the restorations was 9.6 (3.5) years. Of the 88 teeth, there were 42 failures, 26 of which were irreparable and had to be extracted (Table 3). There were 30 failures (2 incisors,

TABLE 3

Causes and treatment of the failures.*

CAUSES	TREATMENT
Subgingival Caries (n = 10)	Extraction
Radicular Fracture (n = 9)	
Endoperiodontal Pathology (n = 7)	
Marginal Filtration (n = 6)	Remake the core
Loss of Retention (n = 10)	Cast post and core (n = 4)
	Fiber post and resin core (n = 4)
	Recementation (n = 2)

* Total of 42 failures in 88 teeth.

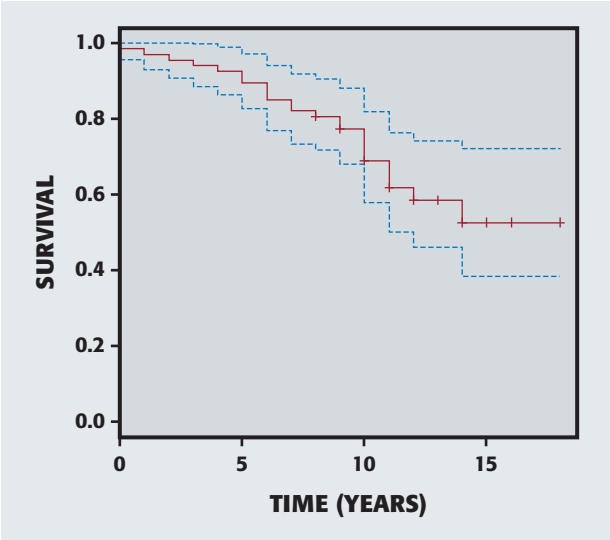

Figure 2. Kaplan-Meier survival curve showing the overall survival of the restorations decreased over time.

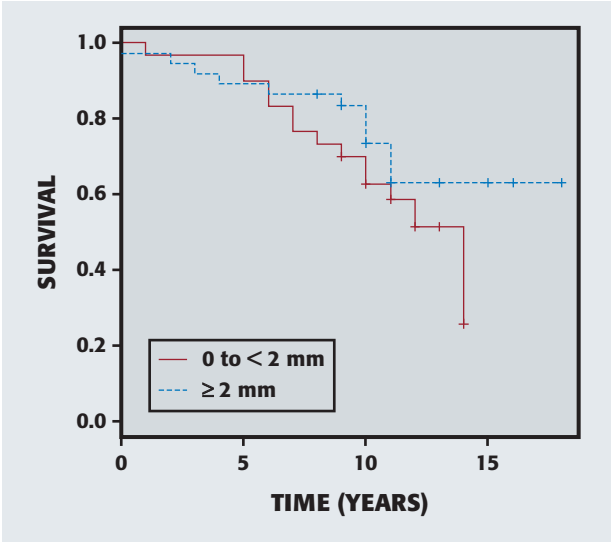

Figure 3. Kaplan-Meier survival curve according to the ferrule. Teeth with 2 millimeters or more of ferrule had a higher survival rate than the teeth with 0 to less than 2 mm of ferrule, although these differences were not statistically significant.

TABLE 4

Statistical analysis of the variables.

VARIABLES	KAPLAN-MEIER SURVIVAL CURVE	UNIVARIATE COX REGRESSION
Post Diameter	$P = .276$	$P = .276$
Ferrule	$P = .220$	$P = .226$
Proportion Root-Core	$P = .158$	$P = .165$
Post Length	$P = .776$	$P = .796$
Location of the Tooth	$P = .040$*	$P < .05$*

* $P < .05$ statistically significant differences.

8 canines, 14 premolars, and 6 molars) in the maxilla and 12 (4 canine, 3 premolars, and 5 molars) in the mandible.

The overall survival of the restorations decreased over time, with survival rates of 89.6% after 5 years of follow-up appointments, and 64.2% after 18 years of follow-up appointments. Only 8 failures occurred within 5 years of the completion of the restoration (Figure 2). At 10 years, 15 failures occurred, and at 15 years, 19 failures occurred.

Statistically significant differences were detected according to the location of the tooth (Kaplan-Meier survival curves; $P < .05$), with higher survival rates observed in molars and maxillary premolars that had the most failures (28.5%). The survival of the restorations with posts with smaller diameters was worse, though the difference was not statistically significant. The post length did not influence the survival of the restorations. Teeth with more ferrule (≥ 2 mm) had a higher survival rate than the teeth with less ferrule (< 2 mm), although the differences were not statistically significant (Figure 3).

Our univariate Cox regression analysis demonstrated a statistically significant effect of the location of the tooth on the restoration failure risk ($P < .05$). Posts in the anterior teeth had a 3.26 times higher failure risk than posts in the posterior teeth (HR, 3.26; 95% CI, 1.05-10.13; $P < .05$) (Table 4).

DISCUSSION

In this study, we did not perform temporary restorations with eugenol cements as this has been shown to alter the adhesion properties of resin-based cements.[30,31]

The increased survival of endodontically treated teeth is caused by strong apical sealing, the presence of cuspal coverage in posterior teeth, the preservation of tooth structure, and the presence of ferrule (≥ 2 mm),[3,6,17,22,32] rather than the placement of a root canal post.[4,33] One systematic review concluded that prefabricated metal posts cemented in teeth without the ferrule had a poorer survival rate than those with it.[34] In an in vivo study involving premolars, Ferrari and colleagues[35] claimed that 1 dental wall (vestibular, lingual, or palatal wall) preservation is as important as the ferrule presence versus absence.

A follow-up study by Fokkinga and colleagues[5] 17 years after placement found no differences between teeth with crowns of cast post and core, resin core with metal post, or resin core without post, and they concluded that the most important factor to survival was the existence of coronal tooth structure.

Kahn and colleagues,[36] in an in vitro research study on the fatigue of crowns with amalgam cores and 3 types of metal posts, concluded that the design of the post did not reduce the risk of experiencing root fracture, the existence of the ferrule being more important. Conversely, other authors maintain that the use of adhesive agents for preparing the core can supplement the absence of the ferrule[19,20] because they increase retention of the restoration.[37]

In an in vitro cyclic fatigue study in which 5 metal posts and 4 cores were evaluated, it was confirmed that amalgam cores are more resistant than glass ionomers, and that the amalgam cores do not contain differences between different posts.[38]

Post placement in molars may not be necessary because their wide pulp chambers retain the restorative material.[39] In an 18-year follow-up retrospective study comparing the survival of teeth restored with crowns with endodontically treated teeth restored with cast post and core, De Backer and colleagues[40] found no differences in the survival rate according to the location of the tooth. This differs from the results we found in our study, for which the titanium posts and amalgam cores in the anterior teeth had 3.26 times more risk of experiencing failure than those in molars. De Backer and colleagues[40] concluded, as does our study's research, that caries and periodontal diseases are the main causes of

failure of crown restorations. In addition to this study's results, there are other studies in which molars have high survival rates.[11,12]

In a retrospective study after 10 years, Gómez-Polo and colleagues[41] found no difference in the survival of crown restorations with metal posts and resin cores or cast posts and cores. In their study, the survival of cores with titanium posts was 84.6%, which is higher than our study's results (68%). They also observed higher failure rates in maxillary premolars, as we did in our study.

Hansen and colleagues[42] claim that bonded amalgam cores are more resistant than conventional amalgam.

Another in vitro study confirmed that bonded amalgam produces less microleakage than conventional amalgam, regardless of the adhesive agent used.[43] Simizu and colleagues[44] studied the use of Panavia Ex, concluding that it reduces microleakage in amalgam restorations. In addition, Bonsor and Chadwick[45] found no differences in the longevity between bonded and conventional amalgam restorations.

According to Peutzfeldt and colleagues,[46] tooth fracture (49.1%) and the loss of post retention (31.7%) are the most common failures in endodontically treated teeth restored with crowns. In our study, these causes accounted for 21.4% and 23.8% of failures, respectively. In another in vitro study, root fractures accounted for 21% of core failures with metal posts.[47]

According to some authors, the post length should be equal to the height of the artificial crown.[48] Nevertheless, in an in vitro study of titanium posts with different lengths (5 mm, 8 mm, and 10 mm), Nissan and colleagues[49] concluded that the length of the post had no influence on resistance to fracture if a crown with 2 mm of ferrule was placed. These results are similar to our study's results in which posts of 4 different lengths produced the same results. Regarding the thickness of the post, some researchers say that a fine post increases resistance to fracture because it removes less dentin.[23] For our study, we determined no statistically significant differences between the post diameter and the survival rate.

When fiber post and composite core are used, according to reports, some have greater long-term survival that metal posts.[50-52] In 2 clinical studies of a quartz fiber post for up to 6 years,[53] and another for up to 30 months,[54] survival rates of 85% and 98.3%, respectively, were found; at 5 years, the survival rate of our restorations was 89.6%.

A report of a 10-year survival rate with glass-fiber post concluded that 1 or fewer remaining cavity walls and anterior teeth were associated with the failure rate, an observation noticed in our findings.[55]

CONCLUSIONS

Despite the limitations of our study, it can be concluded that bonding amalgam cores in endodontically treated molars results in greater survival rates than in anterior teeth, as premolars failed the most after 18 to 22 years.

Neither the length of the metallic post nor its diameter influenced restoration survival.

We used an adhesive resin cement (Panavia Ex) for the adhesion of both the post and the amalgam core, and no statistically significant results were found correlating with the ferrule length, although teeth with more ferrule ($\geq$ 2 mm) had higher survival rates. ■

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