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Research Article

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Retrospective clinical and radiographic evaluation of restored endodontically treated teeth

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ABSTRACT

Objectives: The aim of this study was to perform a clinical and radiographic analysis of endodontically treated teeth (ETT) restored with cast metal posts (CMPs) or prefabricated glass fiber posts (GFPs) and crowns.
Materials and Methods: Fifty ETT were restored with 25 CMPs and 25 GFPs at a private dental clinic between 2001 and 2016. The restorations consisted of 12 all-ceramic crowns, 31 metal-ceramic crowns, and 7 composite resin crowns. Demographic data, type of teeth, type of post-and-core system, time of placement, crown restorations, the number of proximal contacts, the type of antagonist, and reports of any complications after post-and-core placement were recorded for each patient. Assessments were performed at baseline (radiographic) and follow-up (radiographic and clinical). Data were analyzed by the McNemar test, the Pearson χ^2 test, and Kaplan-Meier survival curves ($\alpha = 0.05$). The mean follow-up was 67.6 months.
Results: No significant difference was observed for any of the radiographic parameters when the baseline and final radiographs were compared. In the clinical evaluation, anatomical form ($p = 0.009$) and occlusion ($p = 0.001$) showed significant differences according to the type of crown restoration; specifically, metal-ceramic and all-ceramic crowns outperformed composite resin crowns.
Conclusions: CMPs and GFPs showed favorable results for restoring ETT after 6 years of follow-up. All-ceramic and metal-ceramic crowns showed higher survival rates and better clinical outcomes.

Keywords: Crowns; Post and core technique; Prosthodontics

INTRODUCTION

Both the clinical success and longevity of endodontically treated teeth (ETT) are influenced by the amount of remaining coronal structure after removal of the carious tissue and the end of endodontic treatment [1], the health of supporting tissues, the endodontic treatment itself, the final restoration [2], and the placement of the post-and-core system whenever necessary [1,2].

Post-and-cores are frequently indicated when ETT are restored with a full crown [3,4], and their function is to provide retention and stability for a definitive prosthetic restoration,

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which replaces the missing coronal structure [3-5]. Although several types of post-and-core systems exist, no standard clinical or scientific consensus exists on the best material to be used for the reconstruction of ETT [6,7]. The selection of materials that offer mechanical, clinical, and esthetic advantages—and, consequently, better clinical outcomes—has been discussed in the literature [8-10]. However, regardless of the type of material used for restoration, root canal filling removal, root canal preparation, cementation of the post-and-cores, and cementation of the restoration should be performed in order to avoid root canal contamination and disruption of the chain of asepsis established at the end of endodontic treatment [1]. These steps have a direct impact on the prognosis of restored ETT [11] by preventing microleakage, periapical lesions, and other events that could lead to treatment failure [1].

The selection of an adequate restoration for these teeth is guided by functional and esthetic requirements [6,12]. An ideal coronal restoration preserves the root canal, maintains the tooth structure, and restores tooth function, which is a factor determining clinical success [13]. Some retrospective studies showed correlations between a positive prognosis for post-and-core restorations and a wide variety of factors, such as number of proximal contacts, occlusal contacts, arrangement of teeth in the dental arch, and type of definitive crown [14].

The literature contains clinical and radiographic studies on ETT restored with different post-and-core systems [2,9,15-17]. However, such studies do not provide enough information when the radiographic aspects of post-and-cores are analyzed separately from the clinical features of coronal restorations. Thus, the aim of this study was to perform a radiographic and clinical evaluation of the survival rate of ETT restored with post-and-core systems and crowns. Teeth with cast metal posts (CMPs) and glass fiber posts (GFPs) restored with metal-ceramic, all-ceramic, and composite resin crowns were assessed. The null hypothesis was that the type of post-and-core and crown would not influence the survival rate of ETT.

MATERIALS AND METHODS

The study was approved by the Institutional Review Board of Universidade Positivo (CAAE: 51366215.1.0000.0093 and approval number: 1.392.567). Patients from a private dental clinic who underwent restorative treatment with post-and-core systems (CMPs and GFPs) and crowns were selected and invited to participate in the study. The inclusion criteria were: age 18 to 75 years, good systemic health status, the presence of at least 1 endodontically treated posterior tooth restored with CMP or GFP between 2001 and 2016, and a periapical radiograph available in the patient chart indicating the status of the post-and-core system and periapical tissues immediately after its placement. The following exclusion criteria were used: the presence of uncontrolled parafunctional habits (*e.g.*, bruxism or clenching), severe periodontal problems, and teeth supporting a fixed or removable partial denture.

Fifty patients who underwent restorative treatment with post-and-core systems (25 CMPs and 25 GFPs) agreed to participate in the study and signed an informed consent form. All post-and-cores were placed by prosthetic dental specialists with at least a master's degree and a minimum of 10 years of clinical experience. The decision on the type of post-and-core to be placed was made by the clinician responsible for each case. A specific clinical form was filled out for each patient. The form contained demographic data such as patient name, age, and sex, type of post-and-core system and its time of placement, luting cement for the post-and-cores, information about the coronal restoration (type of restoration, material, and

luting material), number of proximal contacts, type of antagonist, location of teeth (maxilla or mandible), the occurrence of any complications since the post-and-core restoration was placed, baseline assessment based on a periapical radiograph taken immediately after placement of the post-and-core system, the final assessment based on a periapical radiograph taken after the clinical assessment, and the date of that assessment.

The patients were invited to participate in the study and to go to the clinic where they had been treated. After receiving an explanation about the objectives of the study and signing an informed consent form, the patients underwent a clinical oral examination and a periapical radiograph was taken of the endodontically treated tooth restored with the post-and-core system.

The radiographs were taken by a single examiner using the long-cone paralleling technique and ultraspeed radiographic films with the aid of film holders for the sake of standardization. The radiographs were properly developed, fixed, and digitized for later analysis, which was carried out by an examiner previously calibrated by a specialist in dental radiology.

The radiographs were analyzed at baseline (immediately after placement of the post-and-core restoration) and at follow-up. The criteria used for the radiographic evaluation were determined by the authors and are shown in **Table 1**. The first 4 criteria were assessed at both time points. The other 7 criteria were only assessed at follow-up.

The clinical assessment was performed by a single unblinded examiner, who was trained and calibrated before the start of the evaluation, using a mouth mirror, dental explorer, and periodontal probe. The criteria used for the assessment are described in **Table 2** according to the modified United States Public Health Service criteria for the evaluation of indirect restorations [18-20].

For the post-and-cores, failure was considered to have occurred in cases of posts placed with any clinical or radiographic signs of technical failure, loss of retention, root fracture,

Table 1. Criteria for baseline (first 4 criteria) and final radiographic assessments of post-and-core systems

Radiographic characteristics	Score	Description
Periapical lesion	A	Normal periapical region, without radiolucent, radiopaque, or mixed images
	B	Radiolucent, radiopaque, or mixed images in the periapical region
Thickening of the lamina dura	A	Normal-appearing lamina dura
	B	Thickening of the lamina dura
Periapical sealing	A	Adequate periapical sealing
	B	Inadequate periapical sealing
Root attachment to the bone	A	Two-thirds of bone attachment or at least the size of the clinical crown
	B	Bone attachment smaller than the size of the clinical crown
Post-and-core centering	A	Centered post-and-core
	B	Uncentered post-and-core
Root fracture	A	No root fracture
	B	Horizontal, vertical, or cross-sectional root fracture
Trepanning	A	No trepanning
	B	Presence of trepanning
Post-and-core fracture	A	No post-and-core fracture
	B	Presence of post-and-core fracture
Caries	A	No caries between tooth and restoration
	B	Caries between tooth and restoration
Post-and-core length	A	Two-thirds or three-fourths of root length or at least the size of the clinical crown
	B	Length smaller than the size of the clinical crown
Post-and-core width	A	Maximum of one-third of root width
	B	Larger than one-third of root width

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Table 2. Criteria used for the clinical assessment of the full crowns

Clinical characteristics	Score	Description
Caries	A	No caries between tooth and restoration.
	B	Caries between tooth and restoration.
Marginal discoloration	A	No visual evidence of marginal discoloration. There is no difference between the color of the restorative material and the color of the surrounding tooth structure.
	B	Evidence of visual marginal discoloration. Small difference between the color of the restorative material and the color of the surrounding tooth structure.
	C	Evidence of visual marginal discoloration. Remarkable difference between the color of the restorative material and the color of the surrounding tooth structure.
Marginal integrity	A	The explorer does not get stuck when moved along the restoration surface and towards the tooth.
	B	The explorer gets stuck and there is visible fracture where the explorer penetrates, indicating that the margin of restoration does not fit snugly to the tooth structure. Dentin and/or base is not exposed and the restoration has no mobility.
	C	The explorer penetrates into the restoration space that extends to the cementoenamel junction.
Anatomical form	A	The restoration preserves the anatomical form.
	B	A superficial concavity is evident, but dentin or base is not exposed. The general contour of the restoration does not follow the contour of the tooth.
	C	Loss of restorative substance with evident superficial concavity and exposed dentin and/or base. The restoration has an overhang.
Color	A	Restoration color is identical or very similar to that of the adjacent teeth and remaining tooth structure.
	B	Restoration color is slightly different from that of the adjacent teeth and remaining tooth structure, but clinically acceptable, with no need for replacement.
	C	Restoration color is different from that of the adjacent teeth and remaining tooth structure, and replacement is necessary.
Occlusion	A	Equally strong points of occlusal contact in the crown and adjacent teeth; no supraocclusion or infraocclusion.
	B	Points of occlusal contact in the crown and adjacent teeth that are not equally strong; no supraocclusion or infraocclusion.
	C	No points of occlusal contact in the crown (infraocclusion).
Surrounding tissues	A	Normal surrounding tissues, without swelling, bleeding on probing/pocket, and/or fistula.
	B	Surrounding tissues with some changes (increase in volume, presence of fistula, periodontal problems—bleeding on probing/pocket, mobility, pain on palpation and/or pain on percussion).

or post-and-core fracture. For crowns, failure was considered to have taken place in cases of caries, tooth fracture, framework fracture, fracture or chipping of the veneering ceramic, marginal gap/discoloration, and loss of retention. The treatment outcome for post-and-cores and crowns (survival or failure) was a dichotomous variable. Patients who required dental care were referred to specialists for future treatment, such as endodontic retreatment and manufacture of a new prosthesis. Patients who needed no dental care were given instructions on prophylaxis and oral hygiene.

Descriptive analyses were conducted of the patients and teeth included in the study and the reasons for failure. The McNemar test was used to compare the radiographic findings at baseline (placement of post-and-core) and at follow-up for the CMP or GFP. Frequency distributions were used to describe categorical data related to the clinical evaluation of the crowns, which were compared using the Pearson χ^2 test. The longevity of the restorations was analyzed using Kaplan-Meier statistics and the log-rank test for differences between groups. All analyses were performed with a significance level of 0.05 using SPSS version 20 for Mac (IBM Corp., Armonk, NY, USA).

RESULTS

The mean age of the patients was 55.7 ± 4.3 years. Of these patients, 34 were women and 16 were men. The sample consisted of 50 post-and-core restorations (25 CMPs and 25 GFPs). All post-and-cores were placed in posterior teeth; 4 upper and 9 lower premolars, and 6 upper and 6 lower molars were restored with CMPs, whereas 8 upper and 6 lower premolars and 3 upper and 8 lower molars were restored with GFPs. The CMPs were luted with zinc phosphate

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cement and the GFPs were luted with dual-cured or self-adhesive resin cement. Twelve crowns were all-ceramic, of which 9 had natural teeth as antagonists and 3 had all-ceramic crowns as antagonists; 31 crowns were metal-ceramic, of which 19 had natural teeth as antagonists and 12 had all-ceramic crowns ($n = 4$) and metal-ceramic crowns ($n = 8$) as antagonists; and 7 crowns were composite resin, of which 3 had natural teeth as antagonists and 4 had metal-ceramic crowns as antagonists. The metal-ceramic crowns were luted with zinc phosphate cement, while the ceramic and composite resin crowns were cemented either with dual-cured or self-adhesive resin cement. The post-and-cores used in the teeth restored with all-ceramic crowns were GFPs, and none of these teeth were restored with CMPs. Among the 31 teeth restored with metal-ceramic crowns, 11 used GFP and 20 used CMP, whereas of the 7 teeth restored with composite resin, 2 used GFP and 5 used CMP. The average follow-up time was 67.6 ± 32.9 months, which corresponds to approximately 6 years (5 cases: 10 to 12 months of follow-up; 14 cases: 13 to 36 months of follow-up; 15 cases: 37 to 72 months of follow-up; and 16 cases: over 73 months of follow-up). Sixty-two percent of the cases were followed up for more than 3 years and 32% for more than 6 years.

In the radiographic assessment of teeth restored with CMPs, 9 teeth had periapical lesions at the time of post placement, and 6 still presented the lesions at follow-up ($p = 0.250$). Of the 6 periapical lesions, 3 were present without symptoms and 3 were considered endodontic failures (restored with CMP and metal-ceramic crowns). Thickening of the lamina dura ($p = 1.000$), apical sealing ($p = 0.375$), and root attachment to the bone ($p = 1.000$) showed no statistically significant differences between the baseline and final radiographic assessments. For teeth restored with GFP, periapical lesions ($p = 1.000$), thickening of the lamina dura ($p = 1.000$), apical sealing ($p = 1.000$), and root attachment to the bone ($p = 1.000$) did not reveal any statistically significant differences between the baseline and final assessments (**Table 3**). In 1 case, a periapical lesion was observed at follow-up, and was considered endodontic failure (restored with GFP and an all-ceramic crown). Forty-nine post-and-cores were centered, whereas 1 was uncentered (CMP). No root fracture, trepanning, or post fractures were observed. The length of the post-and-cores was adequate in 46 teeth and inadequate in only 4, while all complied with width standards.

In the clinical assessment, teeth restored with all-ceramic, metal-ceramic, and composite resin crowns did not reveal any statistically significant differences regarding the presence of caries ($p = 0.464$), marginal discoloration ($p = 0.151$), marginal integrity ($p = 0.615$), color ($p = 0.557$), surrounding tissues ($p = 0.120$), discomfort or pain ($p = 0.731$), pain on vertical percussion ($p = 0.731$), and pain on horizontal percussion ($p = 0.731$). Statistically significant differences were found in anatomical form ($p = 0.009$) and occlusion ($p = 0.001$) (**Table 4**). The anatomical form was inadequate (failure) in 4 teeth (1 restored with a metal-ceramic

Table 3. Radiographic characteristics at baseline and final assessments of teeth restored with glass fiber posts (GFPs) and cast metal posts (CMPs)

Radiographic characteristics	Score	GFP			CMP		
		Baseline	Final	*p*	Baseline	Final	*p*
Periapical lesion	A	21 (84)	20 (80)	1.000	16 (64)	19 (76)	0.250
	B	4 (16)	5 (20)		9 (36)	6 (24)	
Thickening of the lamina dura	A	20 (80)	20 (80)	1.000	10 (40)	10 (40)	1.000
	B	5 (20)	5 (20)		15 (60)	15 (60)	
Apical sealing	A	21 (84)	21 (84)	1.000	19 (76)	22 (88)	0.375
	B	4 (16)	4 (16)		6 (24)	3 (12)	
Root attachment to the bone	A	24 (96)	24 (96)	1.000	21 (84)	21 (84)	1.000
	B	1 (4)	1 (4)		4 (16)	4 (16)	

Values are presented as number (%).

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Table 4. Clinical characteristics related to the coronal restorations (full crowns)

Clinical characteristics	Score	All-ceramic	Metal-ceramic	Composite resin	*p*
Caries	A	12 (100)	28 (90)	6 (86)	0.464
	B	0 (0)	3 (10)	1 (14)	
Marginal discoloration	A	6 (50)	15 (48)	2 (29)	0.151
	B	6 (50)	16 (52)	4 (57)	
	C	0 (0)	0 (0)	1 (14)	
Marginal integrity	A	5 (42)	13 (42)	2 (29)	0.615
	B	7 (58)	17 (55)	4 (57)	
	C	0 (0)	1 (3)	1 (14)	
Anatomical form	A	6 (50)	15 (48)	2 (29)	0.009
	B	6 (50)	15 (48)	2 (29)	
	C	0 (0)	1 (4)	3 (43)	
Color	A	6 (50)	15 (48)	2 (29)	0.557
	B	6 (50)	15 (48)	4 (57)	
	C	0 (0)	1 (4)	1 (14)	
Occlusion	A	7 (58)	17 (55)	2 (29)	0.001
	B	5 (42)	14 (45)	2 (29)	
	C	0 (0)	0 (0)	3 (43)	
Surrounding tissues	A	8 (67)	26 (84)	7 (100)	0.120
	B	4 (33)	5 (16)	0 (0)	

Values are presented as number (%).

crown and 3 restored with composite resin crowns). GFP was used for the tooth restored with a metal-ceramic crown and CMPs were used for the 3 teeth restored with composite resin crowns. Three teeth showed inadequate occlusion (failure) and were restored with composite resin crowns and CMP.

Considering the post-and-cores, no failure (post-and-core fracture or displacement or root fracture) was observed during the follow-up period. Consequently, the survival rate of the restored teeth was 100%. The restorations with GFPs were followed up for 10 to 144 months (1 to 12 years), compared to 12 to 180 months (1 to 15 years) for the CMPs.

Regarding the restorations, the survival rate was 100% for the teeth restored with all-ceramic crowns. The metal-ceramic crowns presented a survival rate of 81% (25 of the 31 crowns). Of the 6 failed crowns, 4 were in teeth restored with GFPs and 2 in teeth restored with CMPs. Of these teeth, 2 were maxillary and 4 were mandibular; 3 were premolars and 3 were molars. The survival rate of the composite resin crowns was 29% (2 of 7 crowns). Of the 5 crowns that failed, 2 were in teeth restored with GFPs and 3 in teeth restored with CMPs; 3 were maxillary teeth and 2 were mandibular teeth. All of the failures occurred in molars. The criteria considered for crown failure were marginal integrity, caries, occlusion, anatomical form, color, and marginal discoloration.

The log-rank test showed significant differences in the survival rate among the 3 groups (p = 0.001). The Kaplan-Meier curves are shown in **Figure 1**.

DISCUSSION

Failures were assessed both radiographically and clinically in patients whose teeth were restored with CMPs and GFPs using all-ceramic, metal-ceramic, and composite resin crowns. The null hypothesis was accepted for the type of post-and-core system, but rejected for crown restoration, since the teeth restored with composite resin crowns had a higher failure rate after a mean follow-up time of 6 years.

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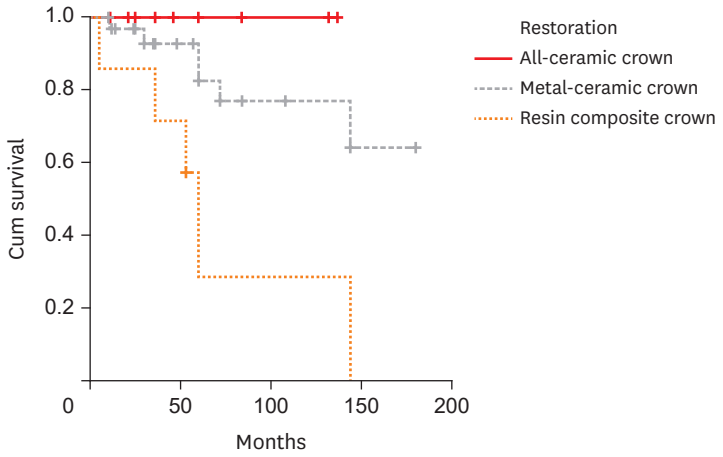

Figure 1. Kaplan-Meier curves and log-rank test for overall survival ($p=0.001$).

The restoration of ETT has been widely investigated, with inconsistent results. There have been conflicting reports about the clinical procedures and materials that should be used to restore these teeth, given that they are more prone to failures [6]. The success rate is as high as 94% to 97% [21,22] when a GFP is used, because the modulus of elasticity of the post-and-core system is similar to that of dentin [3,9,23]. In a retrospective study, Ferrari *et al.* [24] compared the mechanical properties and failure mechanisms of 3 types of GFPs and they concluded that after 7 to 10 years of follow-up, the success rate ranged from 89% to 93%. The mechanical failures were related to the lack of residual coronal structure, and the relatively large number of clinical failures can be attributed to the long follow-up period.

Clinical studies have reported that the success rate of teeth restored with GFPs ranged from 89% to 98% in prospective studies [14,25]. Ghavamnasiri *et al.* [15] concluded there was no difference in survival rates of ETT when factors such as dental arch (maxilla or mandible), occlusion (natural or amalgam restoration) and follow-up time (1 to 6 years) were controlled for. In contrast, in the present study, the survival rate was 100% for both CMPs and GFPs, and there were no significant differences between the baseline and final radiographic assessments depending on the post-and-core system. This may be explained, to some extent, by the conservative approach used for the restoration, especially regarding endodontic treatment and the placement of post-and-core restorations. The clinicians involved in the placement of the post-and-cores and the restorations used similar clinical protocols, which allowed the cases to be analyzed together in the present study. It is important to note that when GFPs were placed, the 2-mm ferrule was respected. The post-and-cores were adequate in terms of length, width, and centering in all of the assessed teeth and were functional at the time of follow-up. Since the post length was correctly observed in all cases, the high survival rate can also be explained by the mechanical retention promoted by the lateral walls of the posts along two-thirds of the root length. It has been reported that the loss of structural integrity concomitant with endodontic access preparation leads to a higher incidence of root fractures [13,26-28]. Studies assessing the biomechanics of vital and non-vital teeth have demonstrated that the amount of residual tissue is the most important factor associated with resistance to masticatory forces [13]. According to a systematic review [29], similar rates of catastrophic failure were found in teeth restored with CMPs and GFPs. The authors also reported that the incidence of non-catastrophic failures was higher in teeth restored with GFP, but the survival rate was similar for both post-and-core systems.

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In the present study, the statistical analysis revealed significant differences in anatomical form and occlusion, regarding the type of crown. Teeth restored with composite resin crowns showed unfavorable outcomes when compared to all-ceramic and metal-ceramic crowns, which had similar clinical performance. Composite resins have lower hardness than enamel and ceramic [30,31], and tend to wear out and lose their anatomical form over time as a result of masticatory forces. The wear is a determinant factor for the long-term success of restorative materials [31]. Randomized controlled trials have shown occlusal wear of composite resin crowns, with surface loss of approximately 120 μm after a 3-year follow-up. [31] It is also important to note that the rate of wear of dental enamel is around 30 to 40 μm per year [32]. Clinical studies have pointed out that occlusal wear of composite resin crowns is 4-fold higher than the wear of metal-ceramic crowns [32,33].

In the present study, the failures were not catastrophic (*e.g.*, root fractures or post-and-core fractures), but rather failures closely related to the properties of the material chosen for crown restoration. These failures can be repaired by replacing the crown, without affecting the endodontic treatment and the post-and-core restoration. Most failures occurred in teeth restored with composite resin, and a single failure was detected in a tooth restored with metal-ceramic crown. Clinical studies [34-36] have described failures in restorations with composite resins, which were mainly caused by occlusal wear and secondary caries, as also observed in the present study. Because of these failures, the indication of restorative composites for teeth with extensive loss of coronal tissue, cusp, and supporting structures remains controversial [35].

The present study corroborates the findings of other trials that also showed that metal-ceramic and all-ceramic crowns had better clinical outcomes than composite resin crowns [17,23]. Mannocci *et al.* [37] evaluated ETT restored with metal-ceramic crowns and direct composite resin restorations for 3 years and did not find catastrophic failures; all failures were related to loose restorations and radiographically detected marginal gaps.

Some studies have pointed out that all-ceramic and metal-ceramic crowns show similar clinical behavior [19,38]. Few studies have assessed and discussed biological aspects such as changes in soft tissues or radiographic findings of endodontic treatment [39]. In general, all-ceramic crowns tend to have better outcomes regarding soft tissues, and they exhibit better color-matching with the natural adjacent teeth than do metal-ceramic crowns [40].

This study had a retrospective design, which allowed data on the predicted variables to be collected after the outcomes had occurred. This type of study has the advantage of having lower costs, requiring less time, and being easier to carry out than prospective studies, in addition to allowing the collection of data related to procedures performed in private practice settings, reflecting clinical results that are representative of the daily practice of dentists. However, retrospective studies are subject to a number of biases. The main biases that must be taken into consideration when analyzing the results are the fact the procedures were performed by more than 1 operator, the use of different endodontic cements, and the use of different luting agents for post-and-core and crown cementation.

Finally, data based on long-term clinical trials are essential for decision-making in clinical practice. The selection of the best protocol and material for the restoration of ETT depends on the amount of residual coronal structure, periodontal status, crown and root morphology, occlusal contacts, oral hygiene, risk of caries, and restoration cost. Moreover, dentists should

determine which post-and-core restoration is suitable for each clinical situation and also correctly choose the type of definitive restoration to improve the longevity of treatment and to prevent future failures. This retrospective clinical study demonstrated that both types of posts could be successfully used in the restoration of ETT, regardless of the crown that will be selected for the clinical situation, provided that the recommended protocol is used and clinical procedures are correctly performed.

CONCLUSIONS

In this retrospective study, CMPs and GFPs were found to be efficient for restoring ETT after a mean follow-up period of 67.6 months. All-ceramic and metal-ceramic crowns showed higher survival rates and better clinical outcomes than composite crowns.

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