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**Clinical Research**

# Post-retained Restorations: A Cost-minimization Analysis Nested in a Randomized Clinical Trial

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**Clinical Relevance**

Although the clinical performance of restorations was similar, the combination of glass fiber post and direct composite presented superior outcomes for cost versus other restorative possibilities for endodontically treated teeth.


## SUMMARY

**Objectives: The aim of this study was to assess four post-retained restorative strategies for endodontically treated teeth using cost-minimization analysis. Methods and Materials: The cost-minimization analysis was based on primary data from a randomized clinical trial and followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) guidelines. Two hundred twenty-five teeth (141 patients) restored using four strategies—teeth with ferrules+ restored with either glass fiber posts or direct composite or crowns, and teeth without ferrules- restored with either glass fiber or cast metal posts with crowns—were evaluated annually between 2009 and 2018. Initial costs and incremental costs per year were calculated. Survival curves were created using the Kaplan-Meier method and log-rank test. Kruskal-Wallis analysis was followed by Dunn's test, which was used to compare restorative treatments, with a significance level of 5%. Results: Initial costs were greater for cast metal posts without crowns (US$153.14). Glass fiber posts with composite (US$27.11) were least costly; the most failures occurred in this group, but they were primarily repairable restoration fractures. The number of extractions, and thus cost, was greater for glass fiber posts with crowns. The mean annual cost was significantly lower for teeth restored with composite ($p$<0.001). Ferrule presence did not significantly impact annual costs. Conclusions: The use of glass fiber posts and direct composite incurred significantly lower annual costs than did other alternatives involving crowns or metal posts.**


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## INTRODUCTION

To achieve efficiency in the provision of health services, economic evaluations are necessary for decision making and improved allocation of resources. Economic health assessments aid in the organization of information in an understandable and simplified way; they can be defined as the comparison intervention options with the consideration of costs and consequences. Different types of economic analysis are used to represent health problems analytically without changing their essential attributes.[1,2]

Cost-minimization analysis enables the evaluation of health intervention results and is imperative to inform and aid health policy decision making.[2-4] It involves the performance of a prospective economic evaluation nested in a clinical trial that has revealed no significant difference in the primary clinical outcome,[1] thereby enabling identification of the intervention with the lowest cost.

When considering endodontically treated teeth and treatment choices, there is still a low body of evidence suggesting that cast metal posts have higher survival rates for teeth without ferrules[5]; however, all posts perform similarly when at least one remaining wall or a ferrule effect is present.[6,7] Thus, in the presence of one or more remaining coronal walls, other parameters, especially the intervention cost, must be considered. The use of glass fiber posts (GFPs) is common and less expensive than the use of cast metal posts, which can influence clinical decision making. Glass fiber posts use less-expensive restorative materials and operative techniques, as adhesive approaches such as those for direct composite resin restoration reduce the amount of tooth structure removed and can extend the lifetimes of restored teeth, thereby avoiding more complex and expensive treatments.[8] Also, as minor repairs of restorations are often required, economic evaluation in these cases can be critical to support clinical practice.

Given the amount of evidence regarding this type of analysis in dentistry and considering primary data from a randomized clinical trial (RCT), this study was conducted to economically assess four post-retained restorative strategies for endodontically treated teeth using cost-minimization analysis. The hypothesis tested was that glass fiber-retained direct composite resin restorations would be less expensive than restorations retained with cast post and core (CPC) or glass fiber posts with metal-ceramic crowns.

## METHODS AND MATERIALS

This health economic evaluation was based on primary data from a parallel-arm RCT comparing success and survival for four restorative strategies for endodontically treated teeth with and without ferrule use (ClinicalTrials.gov NCT01461239). The RCT was approved by the local research ethics committee (protocol 122/2009). The reporting of this study followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS).[9]

### Target Population and Setting

The RCT was conducted at a dental school; 25 undergraduate students performed all clinical procedures under the researchers' supervision. One-hundred and forty-one participants were included, and 225 teeth were restored.

The inclusion criteria were good oral health (no active carious lesion or periodontal disease), the presence of one or more endodontically treated anterior or posterior teeth with or without ferrules (2 mm or 0-0.5 mm) requiring intraradicular retention, and the presence of bilateral posterior occlusal contact. Exclusion criteria were the presence of one or more endodontically treated teeth with periodontal or occlusal problem and the presence of a large prosthesis (Kennedy class I or II) in the opposing arch of the tooth or teeth to be restored.[6,10]

### Comparators and Sample Size

Randomization took the tooth type (anterior, molar, or premolar) into account to minimize bias due to anatomical variation. Briefly, when no ferrule was present, teeth were randomized according to the type of post (GFP, n=71; CPC, n=79) and all teeth received single metal-ceramic crowns. When a 2-mm ferrule was present, a GFP was luted, followed by a second randomization (metal-ceramic crown, n=36; direct composite resin restoration, n=39). Crowns were made with CoCr alloy[6,10] and luted with self-adhesive resin cement (RelyX U100/U200; 3M ESPE, St Paul, MN, USA). The posts were luted with regular or self-adhesive dual resin cement (RelyX ARC or RelyX U100/U200; 3M ESPE). The randomization sequence was generated using computerized random number tables. A third party not involved in the study performed allocation concealment with the use of sealed opaque envelopes.

Under the assumption of no difference between treatments, 64 participants were required to achieve 90% confidence that the limits of a two-sided 90% confidence interval (CI) would exclude a difference >18% between the treatment groups.[6,10] Considering the sample size for the GFP + $CR^+$ and GFP + $MC^+$ groups, an alpha level of 0.05, and success rates of 97.14% and 74.63%, respectively, this study had 90% power to detect incidence rate ratios ≥1.3.

### Follow-up

Overall, 225 teeth in 141 patients were evaluated annually between 2009 and 2018, with an average follow-up duration of 4.5 years (95% CI, 4.2-4.8).

### Cost Estimation

The perspective of the Brazilian Public Health System (PHS) was adopted, considering total treatment coverage, as cost estimates accrue from primary and secondary care provided free of charge to patients. Costs were converted to US dollars (US$1:R$3.866). Prices were obtained in November 2018. An annual discount rate of 6.5% was applied to account for time preference.[11]

The PHS procedure codes and national price lists were used to estimate direct medical costs, including initial treatment and maintenance (incremental) costs. Initial costs comprised those of all materials, consumables, dental technicians' work, and appointments required for the completion of a treatment. Incremental costs accrued from new interventions performed on teeth presenting repairable or irreparable failures. Material and consumable costs were accrued from the quantities (weights or amounts) of materials and their purchase costs, based on Brazilian PHS catalogs. Dental technician costs were in agreement with national standards for private practice. Incremental costs were calculated by summing the procedures required to repair a failure and/or replace a missing tooth. Non-medical costs (eg, structural costs, productive input) and indirect (opportunity) costs were assumed to be similar among treatments and were not considered.

### Health Outcomes and Effectiveness

The primary health outcome was tooth extraction due to caries, root fracture, or endodontic complication. Associated costs included the extraction of the tooth and the insertion of an implant followed by a metal-ceramic implant-supported crown. The choice of this treatment was based on the inclusion criteria, justifying the replacement of the extracted tooth with a single implant in all cases of failure requiring tooth extraction. Secondary outcomes included the costs of repair, re-cementation, retreatment or apical surgery, and post/crown replacement. When restorative treatment or removal/replacement of the crown/restoration was performed at another dental practice (by another dentist) for no reconstructable reason, the affected tooth was censored and data from the last clinical assessment were considered.

### Analysis

The analysis was performed using Excel 2016 MSO (Microsoft Corporation, Redmond, WA, USA) and Stata 12.0 (StataCorp, College Station, TX, USA) software. Descriptive analysis was used to characterize the patients (teeth) included in the study and the reasons for failure. Survival curves were created using the Kaplan-Meier method, followed by the log-rank test. As cost estimates were distributed asymmetrically ($p<0.05$, Shapiro-Wilk normality test), non-parametric tests (the Kruskal-Wallis test, followed by Dunn's test) were used to compare restorative treatments. A 5% $\alpha$ error level was adopted.

## RESULTS

The treatment distribution among restorative strategies and between maxillary/mandibular locations was homogeneous (Table 1); in contrast, we observed a larger number of cast metal posts with crowns used in anterior teeth due to the larger number of patients requiring anterior rehabilitation. Kaplan-Meier survival curves showed no significant difference in tooth longevity during the follow-up period according to the restorative approach (Figure 1).

The cost of dental extraction and tooth replacement with dental implants was highest (US$363.92), followed by the use of cast metal posts with crowns (US$153.14). Restoration repair (US$16.47) and re-cementation (US$6.11) were the least expensive treatments (Table 2).

Table 3 shows initial, incremental, and average annual costs by restorative strategy (itemized prices are provided in Supplementary Table 1). Initial costs were lowest for GFP + $CR^+$ (US$27.11) and highest for CMP + $MC^-$ (US$153.14). The most failures occurred in the GFP + $CR^+$ group, but they were primarily restoration fractures that were repaired. In contrast, the largest number of teeth lost, incurring high costs, was in the GFP + $MC^+$ group. Overall, the mean annual cost was significantly lower in the GFP + $CR^+$ group than in the other groups ($p<0.001$), with no significant difference among the other groups or according to ferrule presence.

## DISCUSSION

The rehabilitation of endodontically treated teeth is discussed widely in the literature, with several dental material options and indications for restorative procedures, considering ferrule, tooth location, and esthetics. Survival was similar among restorative strategies examined in this study, corroborating previous findings[6,7,10,12] and justifying a cost-minimization approach for economic evaluation. Although cost-minimization analysis can be used to identify the least costly option among treatments with equivalent outcomes, the economic factor alone should not be

Table 1: *Descriptive Analysis of Patients and Teeth Included in the Study*

| | | Glass Fiber Post with Crown⁻ n=79 (SD) | Cast Metal Post with Crown⁻ n=71 (SD) | Glass Fiber Post with Crown⁺ n=36 (SD) | Glass Fiber Post and Composite Resin⁺ n=39 (SD) | Total N=225 (SD) |
|---|---|---|---|---|---|---|
| Follow-up, y | | 4.6 ± 2.2 (4.1-5.1) | 5.0 ± 2.0 (4.5-5.5) | 4.9 ± 1.8 (4.3-5.5) | 3.3 ± 1.6 (2.8-3.8) | 4.5 ± 2.1 (4.2-4.8) |
| Age, y | | 46.1 ± 9.5 (43.9-48.2) | 43.9 ± 13.5 (40.7-47.1) | 47.1 ± 10.8 (43.4-50.8) | 42.1 ± 13.2 (37.8-46.4) | 44.8 ± 11.9 (43.2-46.4) |
| Location | Upper | 60 (75.95%) | 55 (77.46%) | 27 (75%) | 24 (61.54%) | 166 (65.10%) |
| | Lower | 19 (24.05%) | 16 (22.54%) | 9 (25%) | 15 (38.46%) | 59 (34.9%) |
| Tooth type | Incisor | 39 (49.37%) | 44 (61.97%) | 9 (25%) | 6 (15.39%) | 98 (50.2%) |
| | Premolar | 32 (40.5%) | 15 (21.12%) | 15 (41.67%) | 13 (33.33%) | 75 (29.41%) |
| | Molar | 8 (10.13%) | 12 (16.91%) | 12 (33.33%) | 20 (51.28%) | 52 (20.39%) |

Abbreviations: CI, confidence interval; SD, standard deviation; y, years.
+: with ferrule; -: without ferrule; mean ± SD are given for follow-up and age (95% confidence interval), while sample size is given for location and tooth type.

extrapolated for clinical decision making, especially as factors such as the tooth type, remaining tooth structure, quality of endodontic treatment, parafunctional habits, and caries risk could act as confounders for outcomes and in clinical practice. However, the economic factor is among the main aspects that directly influence the choice of dental restorative material. Although differences between public and private clinical practices exist, both need to satisfy the needs of policymakers and patients.

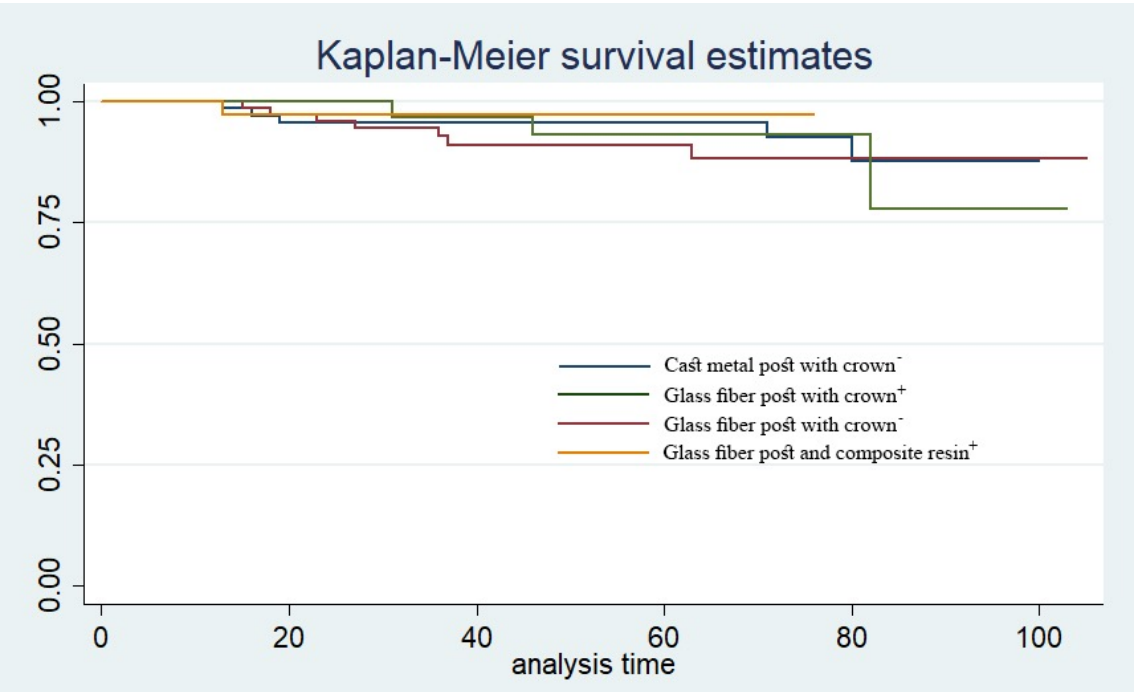


Figure 1. *Kaplan-Meier curves according to the groups investigated (p=0.864; + with ferrule; - without ferrule).*

| Table 2: *Estimated Cost of Treatments*[a] | |
|---|---|
| **Treatment** | **Costs (US$)** |
| Cast metal post with crown | 153.14 |
| Glass fiber post with crown | 121.75 |
| Glass fiber post and composite resin | 27.11 |
| Tooth removal, implant placement and crown | 363.92 |
| New crown | 114.78 |
| Endodontic retreatment | 56.97 |
| Apical surgery | 52.14 |
| Restoration repair | 16.47 |
| Recementation of a crown | 6.11 |
| [a]*More details are presented in Supplement Table 1.* | |

The most common health economic analysis in the dental literature is cost-effectiveness analysis, which, together with other analyses, is based on an assumed difference among treatments examined. Cost-minimization analysis was used in the present study due to the lack of a significant difference among treatments. This finding is corroborated by systematic reviews being unable to reliably rank the different treatment options;[13,14] which could be due to the lack of statistical power, given the limited availability of clinical data, rather than to the true absence of such a difference.

Glass fiber posts with direct composite resin restorations had the lowest annual costs over the follow-up period in this study, as direct composite resin is initially less costly and limited costs were generated during follow-up, in part because the main type of reintervention performed was repair. Thus, this approach was least costly in the long term, compensating all reinterventions. Reintervention was possible because the failures were not catastrophic, corroborating results from a cost-effectiveness analysis reported in the literature, which revealed more debonding-related failures among glass fiber post

Table 3: *Costs of the Different Restorative Strategies (US$, mean ± SD)*[a]

| | **Glass Fiber Post and Composite Resin⁺ n=39** | **Glass Fiber Post and Crown⁺ n=36** | **Glass Fiber Post and Crown⁻ n=79** | **Cast Metal Post and Crown⁻ n=71** | ***p-value*[b]** |
|---|---|---|---|---|---|
| **Initial cost** | 27.11 | 121.75 | 121.75 | 153.14 | |
| **Incremental costs** (maintenance costs) | 17.35 ± 58.78 A | 38.16 ± 104.76 B | 33.85 ± 104.38 B | 25.80 ± 93.73 B | 0.025 |
| **Mean annual costs** (initial + maintenance costs per year) | 23.83 ± 56.71 A | 39.73 ± 35.62 B | 51.46 ± 65.59 B | 53.27 ± 77.87 B | <0.001 |
| **Total costs over follow-up** | 1,734.14 | 5,756.90 | 12,292.69 | 12,704.76 | |

*Abbreviation: SD, standard deviation*
+: with ferrule; -: without ferrule
[a]*Groups with different lowercase letters represent statistically significant differences in each row (*p*<0.05).*
[b]*Kruskal-Wallis followed by Dunn's test.*

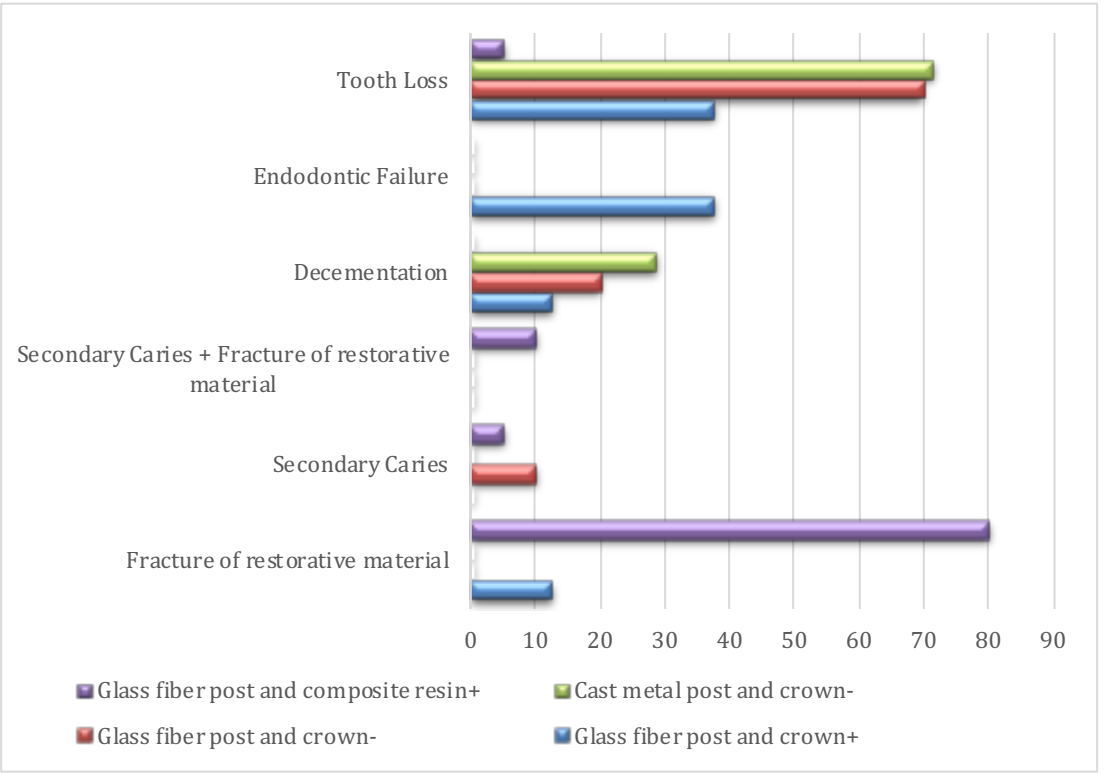


Figure 2. *Distribution and types of failure in the groups investigated (in %; + with ferrule; - without ferrule).*

restorations, making them more cost effective than cast metal posts.[8] Although survival did not differ among treatments in the present study, major complications in the GFP + MC- group necessitated reinterventions requiring laboratory work, making them more expensive. A meta-analysis revealed no significant difference in the incidence of root fractures between cast metal posts and fiber posts, but no economic analysis was performed.[15] Our findings emphasize that the maintenance of fallback options and avoidance of tooth loss, even by accepting a higher rate of reintervention, is economically advisable given the high cost of tooth removal and replacement.

Our results are in line with those of recent studies evaluating other oral health outcomes and emphasize that less-invasive treatments are often less expensive.[16-18] For example, the cost of removing all molars predicted to be at risk of extraction during supportive periodontal therapy was found to be greater than that of removing only molars with furcation involvement.[16] Similarly, less-invasive caries removal (selective excavation) was shown to be more effective and less costly than stepwise complete excavation.[19] These observations reinforce the importance of considering the economic analysis. Based on our findings, and considering differences in cost and all possible intercurrences, glass fiber post with direct composite resin can be less invasive and less expensive, while achieving clinical success similar to that achieved with other restorative strategies.

Ferrule presence has been associated with increased survival rates of endodontically treated teeth in clinical studies, as it promotes better biomechanical performance.[20] However, due to the extensive dental destruction present in patients treated in the present study, the inclusion of teeth with ferrules was challenging. For this reason, the four groups contained different numbers of teeth, especially teeth rehabilitated with direct composite resin and metal-ceramic crowns with glass fiber posts and ferrules.

The literature contains no high-quality evidence for the best treatment strategy for endodontically treated teeth.[21,22] There seems to be weak evidence suggesting that the best option for teeth with no ferrule is the use of cast metal posts;[5] however, in the presence of at least one remaining coronal wall, all posts have similar longevity.[6,7] Nevertheless, few studies of teeth treated with different rehabilitation strategies have involved long follow-up periods, and few studies have evaluated post-retained direct composite resin restorations. Even considering that teeth with and without ferrules perform differently, this comparison shows that the maintenance of a dentinal wall instead of greater tooth preparation not only preserves tissue, which is desired, but also decreases costs for patients

and clinicians. The removal of existing dentinal walls in metal-ceramic crown preparation should be discussed with patients, as it is more expensive and tooth survival could be extended by avoiding more invasive treatments.

The paucity of RCTs with long follow-up periods in dentistry has led to the absence of answers to critical clinical issues-such as the identification of the best restorative strategy for endodontically treated teeth-and even fewer trials have been designed to support health economic analyses. When the clinical outcomes of rehabilitative treatments do not differ significantly or differ only subtly, the economic evaluation of interventions is imperative for decision making.[1]

As limitations of this study, we note the smaller number of teeth included in the ferrule cluster, which had an extended run-in, leading also to shorter follow-up times for these cases. Although the mean follow-up duration for teeth without ferrules (4.5 years) was somewhat longer than in many published trials,[23-25] it may not have been sufficient to capture later complications. In addition, the calculations did not include fixed and variable expenses and costs, such as structural costs (eg, of the physical space, natural equipment wear, maintenance, cleaning, and conservation), productive inputs (eg, water and energy), chair-side time, and transportation, which would increase overall costs. Moreover, the study design did not include the present health economic evaluation. However, the detailed information extracted from the patients' files was sufficient for the analysis to be performed. The PHS codes were adopted for this study, and prices were fixed. A dentist in a private clinical practice could charge more for their services, such as the technically demanding direct build-up of a crown (especially an anterior crown) using direct composite resin; such potential differences were not taken into account in this study.

## CONCLUSION

Within the limitations of this cost-minimization analysis, rehabilitation with glass fiber posts and direct composite resin had significantly lower annual costs than did other alternatives involving crowns and metal posts. The presence of a ferrule effect did not significantly affect costs. Additional factors, such as applicability and dentists' expertise and individual wishes, should be considered in clinical decision making.

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### Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversightcommittee guidelines and policies of the Local Research Ethics Committee of the Federal Universityof Pelotas. The approval code issued for this study is Protocol 122/2009.

### Conflict of Interest

The authors have no financial interest in any of the companies or products mentioned in this article.

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