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LITERATURE REVIEW
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Fiberglass versus cast metal posts: a practical review based on mechanical properties

Pinos de fibra de vidro versus metal fundido: uma revisão prática baseada em propriedades mecânicas

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ABSTRACT

The current review aimed to compare the mechanical properties and clinical behavior of fiberglass and cast metal posts. It included *in-vitro* studies, finite element analysis, clinical studies, and systematic reviews that evaluated fiberglass and metal posts with reliable methodologies. The reports in the literature diverge on tooth failure modes and stress distributions in the root according to different posts. Investigations suggest that fiberglass posts are preferable because their elastic modulus is similar to dentin. Other studies mention that the flexibility of fiber posts may damage the interface. The fracture load values of different studies could not be compared. The presence of a ferrule seems beneficial. Cast metal posts provide higher characteristic strength to the set but with more unfavorable failures. Intraradicular posts with a lower elastic modulus produce more stress between the cement layer and dentin. In conclusion, fiberglass and cast metal posts can be used with a ferrule. Cast metal posts seem more appropriate for weakened teeth. The presence of a ferrule benefits the system. Weakened teeth tolerate higher loads when restored with cast metal posts, but when these posts fail, the only solution is tooth extraction. Clinical follow-ups cannot yet detect differences between the survival rates of intraradicular fiberglass and cast metal posts.

KEYWORDS

Fiberglass; Post and core technique; Dental prosthesis; Mechanical tests; Finite element analysis.

RESUMO

O objetivo da presente revisão foi comparar as propriedades mecânicas e o comportamento clínico de pinos de fibra de vidro e núcleos metálicos fundidos. Estudos laboratoriais, analise por elementos finitos, estudos clínicos e revisões sistemáticas que avaliaram pinos de fibra de vidro e metálicos, com metodologia confiável foram selecionados. A literatura mostra-se bastante controversa sobre os modos de falha do dente e a distribuição de tensões na raiz de acordo com diferentes tipos de pinos. Algumas investigações sugerem que pinos de fibra de vidro são preferíveis porque seu módulo de elasticidade é semelhante ao da dentina, enquanto outras mencionam que a flexibilidade do pino de fibra pode ser prejudicial à interface adesiva. Os valores de carga de fratura em diferentes estudos não podem ser comparados. A presença de férula é benéfica. O núcleo metálico fundido resulta em maior resistência característica do conjunto, mas falhas mais desfavoráveis. Também, pinos com menor módulo geram mais tensão entre a camada de cimento e a dentina. Em conclusão, verificou-se que tanto pino de fibra de vidro como núcleo metálico fundido podem ser utilizados quando a férula está presente. Os núcleos metálicos fundidos parecem ser mais indicados para dentes fragilizados. É evidente que a presença de férula é benéfica para o sistema. Dentes fragilizados toleram cargas maiores quando restaurados com núcleos metálicos fundidos; porém, quando falham, a única solução é a extração do dente. Os acompanhamentos clínicos ainda não são capazes de detectar diferença entre as taxas de sobrevivência dos pinos de fibra de vidro e núcleos metálicos.

PALAVRAS-CHAVE

Fibra de vidro; Técnica de pino e núcleo; Prótese dentária; Ensaios mecânicos; Análise por elementos finitos.

INTRODUCTION

Endodontically treated teeth often show major tissue loss [1-3], potentially from carious processes, fractures, extensive pre-existing restorations, or even endodontic access [4-6]. Extensive dental structure losses impair restoration retention [6], requiring the use of a dental post [1,7,8]. The most frequent dental posts used in dental treatments are cast metal posts and prefabricated fiberglass posts (Figure 1). Studies have discussed the use of dental posts, the type of retainer, and the mechanical behavior of restored teeth [3,7,9-15]. However, few studies have investigated the success rates and failure modes of post-retained restorations in clinical conditions [2,14,16].

Human dentin is different from the restorative materials available in the market [17]. The rigidity or elastic modulus of the materials used in post-retained restorations strongly influences the biomechanical behavior of endodontically treated teeth [18]. Cast metal posts have been used for many years, but they have a high elastic modulus compared to dentin, which varies according to the alloy used (Gold IV: E = 99 GPa; Ni-Cr: E = 210 GPa) [17,19]. Considering that the metal elastic modulus is higher than the values reported for human dentin (E ~ 18.6 GPa) [20,21], catastrophic root fractures may occur [22].

Fiberglass posts are extensively used in the rehabilitation of endodontically treated teeth. These posts have an elastic modulus similar to the dentin substrate (E = 9.5 - 37 GPa), are translucent, esthetic, and compatible with the Bis-GMA monomer present in most adhesive systems and resin cements [23]. However, are these characteristics sufficient to support the indication of fiberglass posts for all clinical cases? Does the low elastic modulus benefit the whole structure? Thus, this literature review aims to present and compare the mechanical properties and clinical behavior of fiberglass and cast metal posts to help dentists select the most appropriate treatment for different clinical situations.

It is worth mentioning that correctly choosing the cement is essential for post retention. There are five main cementation agents: zinc phosphate cements, polycarboxylate cements, glass ionomer cements, resin-modified glass ionomer cements, and resin cements. There is a vast literature on the bond strength of posts, which this review will not address.

Mechanical properties of cast metal posts, fiberglass posts, and dentin

Table I lists the mechanical properties of dentin, including elastic modulus (E), Poisson ratio (υ), flexural strength, and flexural modulus, and the different intracanal retainers.

Mechanical behavior

The literature is controversial about tooth failure modes and stress distributions in the root using different dental posts. Investigations [33-35] suggest that fiberglass posts are preferable because their elastic modulus is similar to dentin, but another study reported that cast metal posts provide a superior mechanical behavior [36]. Studies have measured the fracture strength of materials or treatments using monotonic tests, which produce the maximum fracture load [37,38]. These fractures are "repairable"

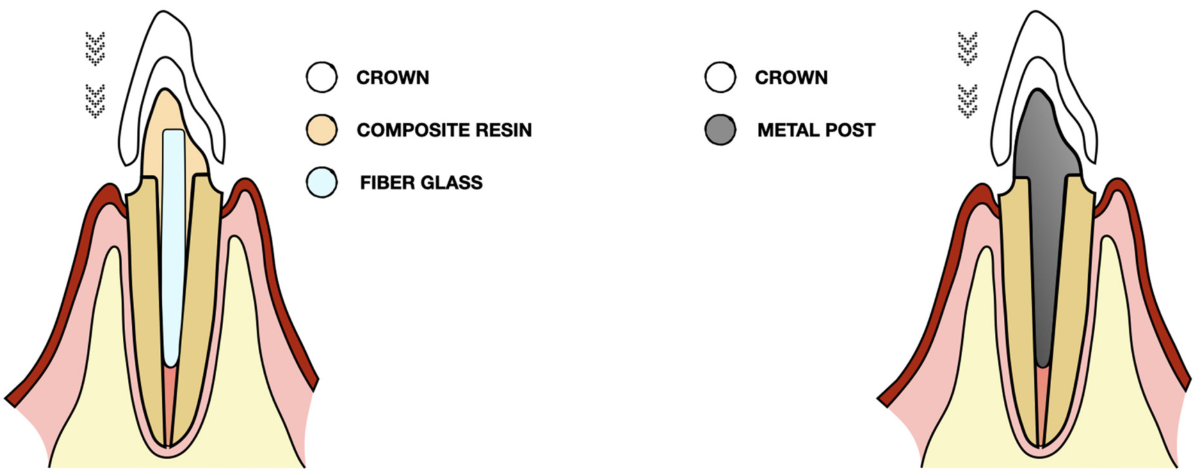

Figure 1 - Schematic comparison of an anterior tooth restored with a fiberglass post and a cast metal post.

Table I - Elastic and flexural properties of dentin and cast metal and fiberglass posts. The values in parentheses correspond to the standard deviation when mentioned in the article

Material/ Composition	Elastic modulus (GPa)	Poisson ratio	Reference	Flexural strength (MPa)	Flexural modulus (GPa)	Reference
Dentin Collagen + hydroxyapatite	14.7	0.31	Sano et al. [24]	212.9 (41.9)	17.5 (3.8)	Plotino et al. [25]
	18.6	0.32	Kinney et al. [21]	514.3 (102.7)	17.4 (6.4)	Cullen et al. [26]
Cast metal Gold – IV	99.3	0.35	Craig [27]	1545.3 (135.9)	53.4 (4.5)	Plotino et al. [25]
	95	0.33	Teshigawara et al. [28]			
Cast metal Ni-Cr	188	0.27	Morris et al. [29]	1436.1 (83.1)	108.6 (10.7)	Plotino et al. [25]
	210	0.33	Williams et al. [19]			
Fiberglass Epoxy resin + fiberglass	37	0.28	Lanza et al. [11]	562.3(24.9)	10.59 (0.97)	Soares et al. [30]
	45	0.25	Memon et al. [31]	680.5 (34.8)	15.87 (2.4)	Soares et al. [30]
				894.91(40.36)	19.85(1.83)	Elnaghy & Elsaka [32]

when the failure line is above the bone level and "non-repairable" when the failure line is below the bone level [39].

Giovani et al. [37] evaluated the load to the fracture of canine roots restored with fiberglass and cast metal posts of different lengths. The length of cast metal posts did not show any effect, while longer fiberglass posts (10 mm) caused significantly higher fracture load values than shorter ones. Cast metal posts resulted in higher fracture loads than fiberglass posts in a 6-mm length. There was no difference between post materials for an 8-mm length. For the 10-mm length, fiberglass posts showed the highest values. Cecchin et al. [40] also concluded that longer fiberglass posts (12 or 8 mm) were associated with higher fracture strength. Makade et al. [38] evaluated the fracture strength of teeth restored with different post/core combinations (10 mm in length). The control group, which did not receive post/core treatment, showed lower fracture strength. The groups restored with prefabricated stainless steel posts and fiberglass posts registered higher mean fracture strength values than cast metal cores, agreeing with Giovani et al. [37].

Santos-Filho et al. [35] evaluated fiberglass posts, prefabricated steel posts, and cast metal posts of different lengths (5.0 mm, 7.5 mm, and 10.0 mm) and reported findings differing from the previous studies. All teeth were restored with metal crowns, and the load was applied at a 45° angle, similar to the experiments by Giovani et al. [37] and Makade et al. [38]. The length of the post only affected the fracture strength of metal posts (cast metal and prefabricated steel posts), which showed lower strength for shorter lengths. Teeth restored with 10-mm cast metal posts resulted in higher fracture strength than the other groups. In the length of 5 mm, the most effective material was the fiberglass post. The failure analysis showed that all metal groups had root fractures (non-repairable). For fiberglass posts, fractures occurred in the resin filling core (repairable).

Silva et al. [41] evaluated the effect of post, core, type of crown, and ferrule on fracture strength and fracture mode of endodontically treated bovine incisors. Ferrule, restoration material, and their interaction were significant for fracture strength. The ferrule improved the mechanical performance of teeth restored with metal crowns. The type of dental post did not affect the mechanical strength of specimens, regardless of the presence of a ferrule or the type of crown. The study measured stress at the buccal root region with a strain gauge and showed higher strain values in teeth with fiberglass posts without ferrules.

Maalhagh-Fard et al. [42] evaluated the effects of different diameters of parallel cast posts (1.0 mm or 1.5 mm) and ferrule on the fracture strength of the system. There were statistically significant differences between different diameters and samples with and without ferrules. The presence of a ferrule increased fracture strength by 36% to 49% for wide and narrow posts, respectively. The wider diameter increased fracture strength by 41% for samples without ferrules and 29% with ferrules. Samples with ferrules and wider post size (490 N) showed the highest mean values, while the samples without ferrules and narrower post size (254 N) showed the lowest mean values.

Materials are subject to cyclic loads in the presence of humidity in the mouth, which causes aging and decreases material strength [43]. Cyclic loading tests can determine material variables, classify characteristics of different materials, compare clinically proven values, and estimate the risk of failure [43]. Tests with monotonic compressive loads provide an idea of material behavior, but they should be carefully extrapolated to the clinic. Therefore, laboratory tests should use an adequate substrate and apply cyclic loading (fatigue with low loads) in a wet environment to simulate oral conditions better [43].

Barcellos et al. [39] evaluated the fracture strength of upper canines restored with fiberglass posts, fiberglass posts relined with resin composite, and cast Ni-Cr alloy posts and cores (9 mm in length). Before the load to fracture test, the specimens were exposed to 250,000 cycles in a chewing simulator. The roots restored with fiberglass posts relined with resin composite showed the highest fracture strength among the experimental groups and were statistically similar to intact teeth. Fiberglass and cast metal posts had similar and lower fracture strength values.

Nam et al. [12] also evaluated the effect of the remaining structure on the mechanical behavior of endodontically treated teeth. The number of remaining walls and the presence of fiber posts affected the fracture load, meaning that teeth restored without a fiberglass post had a significant fracture strength reduction when two or fewer walls remained intact. As the remaining walls reduced, the stress was concentrated in the coronal portion. Another study [44] evaluated bovine incisors without a ferrule and with a 0.5-mm or 1-mm thick ferrule. The groups were restored with fiberglass posts and cast metal posts and cores. All groups prepared full metal crowns and subjected the specimens to mechanical cycling for aging. For the specimens restored with cast metal posts and cores, the group with a 1-mm ferrule showed higher fracture strength than without a ferrule. The presence of a ferrule had no effect when using a fiberglass post. Overall, 96.7% of the specimens survived mechanical cycling. For teeth with a 0.5-mm thick tip, cast metal posts and cores and the fiberglass posts have been associated with a high rate of unfavorable failures.

Bacchi et al. [45] evaluated the influence of ferrule and type of post (cast metal posts or fiberglass posts relined with composite) on fracture strength and stress distributions in premolars. The groups of cast metal posts and fiberglass posts relined with composite were similar to each other ($p>0.05$) in teeth with remaining coronal structure and presented higher fracture strength than samples without ferrules ($p<0.001$). There were no significant differences between cast metal posts and fiberglass posts relined with composite in teeth without remaining coronal structure ($p>0.05$). The ferrule effect was more important than the type of post in the analysis.

Wandscher et al. [36] evaluated the fracture load and survival rate of weakened and non-weakened roots restored with different dental posts. All samples were subjected to mechanical cycles for survival analysis, and the specimens that survived were loaded to failure. For groups with non-weakened roots, the restoration strategy did not affect fracture strength. For groups with weakened roots, fiberglass posts provided lower fracture strength values than metal posts. After the fracture load test, the non-weakened samples showed 39% of unfavorable fractures, while the weakened samples showed 95% of unfavorable fractures. Roots with adequate remaining dental structure can be restored with any post system evaluated.

Pereira et al. [46] evaluated the characteristic fracture load and survival probability of endodontically treated teeth restored with cast metal posts and cores, prefabricated stainless steel posts, carbon fiber posts, and fiberglass posts, under mechanical fatigue. Failure was the point at which the load applied reached the highest value by bending or debonding the post or fracturing the root or core. The data on load to failure (N) determined the Weibull distribution for the groups. Survival probability was calculated according to the load at failure for different groups, at a 95% confidence. All specimens survived fatigue loading and were subjected to single load-to-failure testing. There was a significantly higher characteristic fracture load for groups with cast metal posts (750.6 N) and carbon fiber posts (755.8 N) than groups with fiberglass posts (461.3 N) and prefabricated stainless steel posts (524.8 N). The survival probability confirmed the trend of groups with carbon, fiberglass, and stainless-steel prefabricated posts to show significantly lower values with load increase than groups with carbon fiber posts and cast posts and cores. All roots of the cast metal post group had catastrophic fractures.

Andrade et al. [47] evaluated the influence of different posts on the fatigue survival and biomechanical behavior of crown-restored central incisors. Resin composite buildup, fiberglass post-retained resin, and cast metal posts and cores were evaluated. There was no statistical difference between the treatments for the load or the number of cycles. Crown cracks were the predominant failure mode, and oblique root fractures were only observed with fiberglass and cast metal posts. The post had no significant effect on fatigue survival in endodontically treated incisors with a 2-mm ferrule. Non-restorable fractures only occurred in teeth restored with posts. This study suggests that composite buildups without posts may be an option for restoring endodontically treated incisors with a 2-mm ferrule.

Topic summary

The fracture load values from different studies could not be compared because they varied from 6.9 N to 770 N [35,37]. Despite the different methodologies found in the literature, most studies agree that:

(1) The presence of a ferrule benefits the system [12,36,44];

(2) The type of post is not significant in the presence of a remaining healthy tooth [36,41];

(3) The cast metal post seems to cause higher characteristic strength after the mechanical fatigue of the set [46];

(4) Fiberglass posts show a higher frequency of favorable failures [38,46];

(5) The 10-mm length seems safe for both posts [35,37].

Finite element analysis

Several studies investigated the stress distribution in teeth by different post-core systems with finite element analysis [10,11,18,19,48]. This tool is important to understand the failure mechanisms of teeth under compressive loads with or without posts. Nonetheless, interfaces are often considered perfect in the simulations, neglecting the effect of the bond quality among the different materials on stress distribution [13]. Stress analysis offers an extensive range of methods, and the most common is finite element analysis [10].

Lanza et al. [11] compared the stress distribution in the dentin and cement layer of an endodontically treated incisor using different post materials. They tested stainless steel, carbon, and fiberglass posts and used cements with different elastic moduli (7.0 and 18.7 GPa). The maximum Von Mises stress values ranged from 7.5 (steel post) to 2.2 MPa (fiberglass post). The highest stress concentration occurred in the cervical region of the tooth, on the buccal side. Fiberglass posts provided lower stress values at the post/cement interface than stainless steel posts. As the post stiffness decreases, the cement stiffness becomes irrelevant, being more determinant for the stress distribution of more rigid posts.

Al-Omiri et al. [49] designed a three-dimensional finite element model of a second mandibular premolar restored with an all-ceramic crown supported by a titanium post and a composite resin core. The variables investigated were the presence of posts, coronal and apical extensions of posts, diameter and shape of posts, and material of posts and cores. Horizontal loading produces higher stress levels than vertical loading. Stress levels were concentrated in the cervical region of the post-dentin interface in all models. For both loads, a higher elastic modulus and larger post diameter were associated with increased stress values at the post/dentin interface. Dental posts also provided higher dentin stress values than crowns without posts. Dental posts with elastic modulus similar to dentin and smaller diameters were associated with better stress distributions.

Dejak et al. [50] used the finite element analysis to investigate stress distribution in upper central incisors under the following conditions: intact teeth, teeth with ceramic crowns, teeth restored with composite resin posts reinforced with fiberglass, teeth restored with gold alloy posts, and teeth restored with cast Ni-Cr (nickel-chromium) posts. They calculated compressive, tensile, and shear stresses in the cement/dentin interface (around the post) and under the crown, and used the modified Von Mises failure criterion (mvM). The presence of a ferrule in teeth restored with posts reduced the stresses in dentin, post, and luting cement around the post. The maximum modified Von Mises failure criterion in the dentin decreased by 21% for the teeth restored with resin posts and 25% for the teeth restored with cast Ni-Cr posts, and intact teeth were the reference. The highest Von Mises stress in the resin cement around the fiberglass post was 55% higher than the stress around the metal post, under an oblique load. Inside the ceramic crown, the highest Von Mises stress value was 30.7 MPa for the resin substrate and 23 MPa for the cast metal substrate. Thus, the metal core resulted in lower stresses in the ceramic crown, luting cement, and cement/dentin bonding interface under the crown. Regardless of the material, the equivalent stress values for the posts did not exceed their tensile strength.

Ona et al. [51] investigated the influence of elastic modulus differences between the dentin and two types of posts (cast metal (Ni-Cr) and fiberglass) on the root fracture of endodontically treated teeth. They evaluated the conditions of bonded or not bonded to dentin, using the finite element analysis with a three-dimensional model of a maxillary premolar. The results showed that the risk of root fracture with a cast metal post is lower than with a fiberglass post, although the cast metal post showed eight times more stress than the fiberglass post. Fiberglass posts show higher tensile stress in dental structures. The estimated risk of post fracture was lower for the alloy than the composite. The highest maximum principal stress value in tooth structures occurred in the mesiobuccal cervical region for all models. The bonded composite post and core produced approximately two times the maximum principal stress value of the root at the cervical region compared to the bonded cast post and core. The highest maximum shear stress on the interfacial surface of the bonded cast post and core was at the mesial cervical region and close to the post tip. The shear stress of the bonded composite post and core was also concentrated in the cervical region but not at the post tip. The stress value was duplicated when the restoration was not bonded to dental structures.

Verri et al. [52] evaluated different materials (fiberglass or cast metal, the latter with various alloys: gold, silver-palladium, copper-aluminum, and nickel-chromium) for restoring teeth without ferrules, using a three-dimensional finite element analysis. Von Mises stress values were used for analyzing ductile materials such as posts, and maximum principal stress values to evaluate non-ductile materials such as the tooth structure. The fiberglass post presented the most favorable stress distribution, followed by Au, Ag-Pd, Cu-Al, and Ni-Cr, respectively. There was no statistically significant difference in the stress caused to teeth under axial loading, regardless of the post. Under oblique loading, fiberglass posts produced the highest stress values among the models, followed by the cast metal posts with Ni-Cr alloy. The authors recommended Au, Ag-Pd, and Cu-Al alloys to prevent higher stress on the teeth.

Kumar & Rao [10] aimed to compare stress distribution in a tooth restored with cast metal and fiberglass posts of two diameters (1.2 and 1.4 mm), using a three-dimensional finite element analysis. The maximum stress (15.37 MPa for the 1.2-mm post and 15.33 MPa for the 1.4-mm post) in the remaining radicular tooth structure for fiber post models occurred in the inner side of the proximal wall, at the cervical level, regardless of post diameter. For the cast metal models, the maximum stress (15.02 MPa for the 1.2-mm post and 14.92 MPa for the 1.4-mm post) occurred in the inner side around the post apex, regardless of post diameter. The stress of fiber post models was concentrated in the union between the fiber post and the filling core. Due to their elastic properties, the stress concentration of fiberglass and metal posts was at the cervical region and around the post apex, respectively.

Bacchi et al. [45] evaluated the influence of ferrule and type of post (cast posts and cores or fiberglass posts) on fracture strength and stress distributions. The authors obtained maximum principal stress (tensile) and minimum principal stress (compressive) values in dentin. In the evaluation with a mean load of 300 N, the group with cast posts and cores and no ferrule showed the highest maximum principal stress (101 Mpa) and minimum principal stress in dentin (14 Mpa). The other groups did not present significant differences. The site of maximum principal stress concentration for cast posts and cores and no ferrule was the root canal entry (cervical third), while for other groups, it was the root third medium. After loading each group with the respective fracture strength obtained in the laboratory analysis, the group with fiberglass posts and no ferrule (load 622 N) caused relevant higher maximum principal stress concentration in dentin (349 Mpa). The stress in groups with ferrules was concentrated in the ferrule region, but the highest stress value was transferred to the root third medium.

Pinto et al. [53] evaluated the influence of different post systems (cast metal post, prefabricated metal post, parallel fiberglass post, conical fiberglass post, and composite core without posts) on the biomechanical behavior of teeth with a severe coronal structure loss. The von Mises analysis did not show significant differences in maximum stress values among the groups. The maximum stress in metal posts was into the root canal. The maximum stress of fiber posts and composite cores were in the load contact point. The maximum mvM values observed in the study (20.9-23.5 MPa) did not reach the maximum tensile strength of dentin presented in the literature (44.4-97.7 MPa), which was used to predict the dentin risk of failure. Cast posts and cores showed the highest contact pressure values, followed by composite cores. The type of dental post had a relevant influence on the biomechanical behavior of teeth with little remaining coronal structure.

Topic summary

The studies using finite element analysis aforementioned indicate the trend for posts with a higher elastic modulus to concentrate (inside the post) higher stress values than posts with a lower elastic modulus. There is a high divergence among studies. The results and discussion of the experiments may vary according to the site evaluated by the author: post, cement, interface, and dentin (and which dentin region). Most studies focused on the cervical region of the root. The stress between the cement line and dentin and inside the cervical dentin seems higher in rehabilitations with posts with a lower elastic modulus (fiberglass post). Table II summarizes the study findings comparing both types of rehabilitation.

Clinical trials

The advancement in materials science has increased the use of prefabricated post systems. However, clinical trials still do not show a difference between fiberglass and cast metal posts in the survival rate of endodontically treated teeth [14].

Sarkis-Onofre et al. [14] conducted a randomized controlled trial comparing the survival rate of fiberglass and cast metal posts used as retainers in endodontically treated teeth without remaining coronal structure (between 0 and 0.5 mm). The authors evaluated 72 teeth restored with single metal-ceramic crowns. The participants were followed up for three years (July 2009 to May 2012), with recall visits after six, 12, 24, and 36 months after the treatment conclusion. The 3-year survival rate was similar for both retainers on teeth without coronal remnant: 92.3% for fiberglass posts and 97.1% for cast metal posts and cores. Four failures were observed: two fiberglass posts cemented with a regular resin cement debonded after eight and 26 months, one root fractured with a fiberglass post luted with self-adhesive resin cement after 15 months, and one root fractured with a cast metal post after 20 months. Thus, the type of retainer does not influence the survival rate of restorations, and the main outcome was debonding. However, a longer follow-up is required to detect potential differences among systems over time.

Cloet et al. [54] compared the 5-year outcome of fiberglass composite with cast posts and cores in 143 patients. The teeth were randomly divided into four groups: prefabricated fiberglass posts, customized fiberglass posts, composite cores without posts, gold alloy-based posts, and cast cores (control group). The patients were followed up after one, three, and five years from the start of the study. All restorations were examined clinically and radiographically. Root fractures or irreparable post/core restoration fractures leading to tooth extraction were considered absolute failures. Post retention loss with the possibility of recementation and reparable core fractures were considered relative failures. Success was defined as the absence of absolute and relative failures. Survival was defined as the absence of absolute failures. At the 5-year recall visit, there were 25 absolute failures: 14 belonged to the control group and 11 to the test groups (six failures for the group with prefabricated fiberglass posts, two for the custom-made fiberglass posts, and three for the composite cores without posts). Absolute failures occurred due to root fracture, post fracture into the root canal, caries, endodontic failure, and periodontal failure. There were 21 relative failures: 10 belonged to the control group and 11 to the test groups (seven failures for the group with prefabricated fiberglass posts, three for the

Table II - Comparison of cast metal and fiberglass posts in different studies

Study	Type of study	Cast metal post alloy	Preference	Additional explanation
Santos-Filho et al. [35]	Load to fracture with a compressive load	Nickel-chromium	Depends on the length	10 mm favors the cast metal post; 5 mm favors the fiber post.
Giovani et al. [37]	Load to fracture with a compressive load	Copper-aluminum	Depends on the length	6 mm favors the cast metal post; 10 mm favors the fiber post.
Kumar & Rao [10]	Finite element analysis	Gold	Depends on the region evaluated	The fracture occurs in the cervical region of the tooth restored with a fiberglass post and the post apex with the cast metal post.
Lanza et al. [11]	Finite element analysis	Gold	Fiberglass post	Fiberglass post resulted in lower stress values at the post/cement interface.
Makade et al. [38]	Load to fracture with a compressive load	Gold	Fiberglass post	Stainless steel and fiberglass posts registered higher load values than cast metal posts.
Barcellos et al. [39]	Fatigue + load to fracture test	Nickel-chromium	Fiberglass post relined with composite resin	Fiberglass and cast metal posts did not differ statistically and were weaker than fiberglass posts relined with composite resin.
Al-Omiri et al. [49]	Finite element analysis	Nickel-chromium	Fiberglass post	Retainers with dentin-like elastic modulus and smaller diameters were associated with better stress distribution.
Silva et al. [41]	Strain gauge	Nickel-chromium	Cast metal	Higher stress in the buccal region of the roots restored with fiberglass posts without ferrules.
Dejak et al. [50]	Finite element analysis	Gold and nickel-chromium	Cast metal	Lower stress in dentin and cement in cast metal posts.
Ona et al. [51]	Finite element analysis	Nickel-chromium	Cast metal	Higher tensile stress on dental structures restored with the fiberglass post.
Pereira et al. [46]	Fatigue + load to fracture test	Nickel-chromium	Cast metal	Significantly higher characteristic strength for groups with cast metal and carbon fiber posts.
Wandscher et al. [36]	Fatigue + load to fracture test	Gold and nickel-chromium	Cast metal in weakened roots	Roots with an adequate amount of remaining dental structure can be restored with any post system.
Verri et al. [52]	Finite element analysis	Gold, silver-palladium, copper-aluminum, and nickel-chromium	Cast metal	The use of fiberglass posts resulted in lower stress concentration in the post but increased the stress in teeth without ferrules.
Bacchi et al. [45]	Fatigue + load to fracture test + Finite element analysis	Copper-aluminum	The ferrule effect was more important than the type of post	There was a lower rate of catastrophic failures in groups without ferrules, regardless of the type of post.
Andrade et al. [47]	Fatigue + load to fracture test	Cast Ag-Sn alloy	No difference	There was no difference between resin composite buildup, fiberglass post, and cast metal post regarding the load or the number of cycles.
Pinto et al. [53]	Fatigue + load to fracture test + Finite element analysis	Copper-aluminum	Fiberglass post	Cast post and core was the only group with a prevalence of irreparable fractures.

custom-made fiberglass posts, and one for the composite cores without posts). Relative failures occurred due to post retention loss, endodontic failure (not leading to tooth extraction), and post fracture requiring replacement. The 5-year success and survival probabilities were, respectively, 87.8% and 92.1% for the custom-made fiberglass posts, 86.9% and 91.2% for the gold alloy-based posts and cast cores, 81.6% and 91.4% for the prefabricated fiberglass posts, 83.3% and 91.7% for the composite cores without posts. There were no significant differences in success or survival among the four groups. After five years of follow-up, cast gold and composite post and core systems in teeth with full ceramic restorations with ferrules performed equally well.

Salvi et al. [6] evaluated the survival rate and complications in teeth with roots restored with or without a retainer over four years. The study evaluated 325 teeth treated in a private practice. Teeth with endodontic treatment and without posts were the control. A rate of 54% of teeth was restored with a prefabricated titanium post + composite resin filling core + metal-ceramic crown or composite resin; 26.5% with a cast metal post + metal-ceramic crown; 19.5% without a dental post + metal-ceramic crown or direct composite resin. A rate of 89% of restored teeth remained free of any biological or technical complication over the observation period, 4.8% were affected by a technical or biological complication, and 6.2% were lost. The 5-year survival rate of the treatments was 92.5% for teeth restored with titanium posts, 97.1% for teeth restored with cast posts and cores, and 94.3% for teeth without post retention. The most frequent complications were root fracture (6.2%), recurrent caries (1.9%), post-treatment periradicular disease (1.6%), and retention loss (1.3%). There was no difference in the survival rate of the teeth restored with and without dental posts. Implementing high-quality endodontic and restorative protocols and periodic monitoring resulted in high survival and low complication rates over four years.

Naumann et al. [2] studied tapered and parallel fiber posts. Eighty-three patients received 105 fiberglass posts, according to the tapered (Luscent Anchorse) and parallel-sided serrated post (FibreKorw) groups. The restorations were followed up for at least 24 months. There were no failures over the first six months, and 3.8% of restorations failed after 12 months. The failures were retention loss, tooth fracture, and post fracture. The only tooth fracture occurred in the mesial root of a mandibular first molar, in which the post was placed at the distal root. After 24 months, 11.4% of restorations failed: two posts lost retention and seven fractured. Only one failure resulted in tooth extraction. Thus, the main type of failure was post fracture. Two years later, the reconstruction of endodontically treated teeth with parallel and tapered fiberglass posts had a similar failure rate.

The prospective study of Luz-Silva et al. [55] assessed the effect of the type of post to restore endodontically treated teeth on the onset, progression, and remission of periapical lesions. One hundred and forty teeth (92 patients) were endodontically treated and received fiberglass or cast metal post and the final restoration. All patients were followed up for a mean of 5.1 ± 2.2 years. The Periapical Index was used for the endodontic assessment. A rate of 67.1% of the teeth received fiberglass posts, while 32.9% received cast metal posts. There were four endodontic failures: three fiberglass post failures and one cast metal post failure. After 9.4 years, the overall success rate of the endodontic treatment was 97.1% ($p = 0.7$). The tested posts presented similar endodontic healing. The precautions taken during endodontic therapy, post cementation, and final restoration are more likely to determine endodontic treatment success than a specific post.

Ahmed et al. [9] studied why dentists choose different endodontic post systems. The research included dentists from the United States, Canada, Scotland, Ireland, and Greece. A rate of 92% of participants were general dentists with an average of 25 years of experience. Most agreed that endodontic posts are used when the coronal tooth structure is insufficient for retention and to aid stress distribution. Fiberglass posts were the most used (72.2%), followed by prefabricated metal posts (38.6%), cast metal posts and cores (33.9%), prefabricated titanium posts (30.1%), and stainless steel posts (21.7%). The resin-modified glass ionomer (40%) was the most used for cementation, followed by self-adhesive resin cements (29.6%). Screw posts were used by 11.6% of dentists, and 76.5% reported the passive use of such posts. Tapered posts were used by 42.5% of dentists, and 50.2% prefer parallel-sided posts. Most dentists (88%) understood that the main function of a post is to provide retention to the restoration.

Topic summary

The comparison of posts in clinical studies is presented in the Table III. The survival rates of fiberglass and cast metal post restorations are similar [14,54]. Further randomized clinical trials with larger sample sizes and longer follow-up times are required.

SYSTEMATIC REVIEWS

Systematic reviews are at the top of the scientific pyramid. This chapter only included reviews comparing metal and fiberglass posts.

A systematic review by Sarkis-Onofre et al. [56] investigated the influence of remaining coronal walls and the presence and type of posts on the clinical performance of restorations. The type of post was classified as a high or low elastic modulus. The study included randomized controlled trials and controlled clinical trials evaluating the combination or not of post/crown. Restoration success is defined as the ability of restorations to perform as expected, whereas restoration survival is defined by the rate of restorations remaining *in loco*, either repaired or not. There was no consensus on using the terms "success" and "survival" in the studies included. The post hoc considered success and survival together in the analysis. The data on the success or survival of restorations were collected according to the reports of the authors of the articles included in the review Teeth without ferrules highly varied for success/survival rates (0-97%), whereas the values for teeth with remaining coronal walls presented a lower variation (66.7-100%). When using posts with a high elastic modulus, the success/survival rates varied between 71.8% and 100%, whereas for posts with a low elastic modulus, success/survival rates ranged between 28.5% and 100%. Using crowns without posts resulted in success/survival rates between 0% and 100%. The systematic review suggests that the number of remaining coronal walls and the use of posts are key factors for restoration success. When providing a suitable ferrule, the post and restoration types and luting agents have a lower impact on teeth performance. Only two studies compared posts with low and high elastic moduli in teeth with insufficient dentin remnant. Although there were

Table III - Comparison of posts in clinical studies

Study	Type of study	Type of post evaluated	Preference	Additional explanation
Sarkis-Onofre et al. [14]	Randomized controlled trial	Fiberglass and cast metal posts	No difference	The 3-year survival rate was similar for both retainers on teeth without coronal remnant: 92.3% for fiberglass posts and 97.1% for cast metal posts and cores.
Cloet et al. [54]	Randomized controlled trial	Fiberglass and cast metal posts	No difference	The 5-year success and survival probabilities were, respectively, 87.8% and 92.1% for custom-made fiberglass posts, 86.9% and 91.2% for gold alloy-based posts and cast cores, 81.6% and 91.4% for prefabricated fiberglass posts, 83.3% and 91.7% for composite cores without posts.
Salvi et al. [6]	Controlled clinical trial	Prefabricated titanium post, cast metal post, and no post	No difference	The 5-year survival rate of the treatments was 92.5% for teeth restored with titanium posts, 97.1% for teeth restored with cast posts and cores, and 94.3% for teeth without post retention.
Naumann et al. [2]	Observational clinical study	Tapered and parallel fiber posts	No difference	After 24 months, 11.4% of restorations failed: two posts lost retention and seven fractured. Only one failure resulted in tooth extraction.
Luz-Silva et al. [55]	Prospective study	Fiberglass and cast metal posts	No difference	There were 4 endodontic failures: 3 fiberglass posts and one cast metal post. After 9.4 years, the overall success rate of the endodontic treatment was 97.1%.

high survival rates, both restorations required a longer follow-up to reach a reliable conclusion. Therefore, posts with a high elastic modulus should be indicated in the absence of a ferrule.

Al-Omiri et al. [4], in a systematic review with laboratory studies, finite element analysis, and photoelastic analysis, reported that teeth restored with fiber posts and composite cores were more resistant to fracture than teeth restored with cast metal posts. After functional loading, critical stress concentration areas occur at the post/dentin interface, which can initiate microcracks within the root. These microcracks grow and spread with fatigue stress. The cervical third of the root has been reported as the main stress concentration area for fiberglass posts, and the apical third shows the highest stress concentration for cast metal posts and cores. The internal root dentin is usually less mineralized and has a higher water content than the external dentin, which shows higher potential for plastic deformation and crack formation. Many factors influence the fracture strength of teeth restored with posts. Some are directly related to the post/core system, including post length, diameter, design, material, adjustment, core material, and cement. Other factors relate to the restored tooth and include cusp coverage, coronal remnant, loading conditions, the presence of a ferrule, and alveolar bone support. Increased fracture strength was associated with increased post length in all posts. Among the posts commonly used, the cast metal with a tapered thread has been reported as the riskiest for root fracture strength. Posts with a higher elastic modulus, such as cast metal, are associated with higher failure loads and catastrophic failures. Unlike rigid posts, those with the elastic modulus similar to dentin (fiber post) can distribute the stress along the post/dentin interface and prevent root fracture. Studies report that materials with a low elastic modulus bend under the cyclic load and tend to fail before the root fracture, working as a protection mechanism for the dental structure.

Corrêa et al. [57] evaluated fracture strength values and failure modes of weakened roots restored with cast posts and cores, fiber posts, and anatomical posts. They obtained fracture strength values and made the following comparisons: cast post and core vs. fiber post, cast post and core vs. anatomical post, and fiber post vs. anatomical post. There was no significant difference between fracture strength values, but there were more catastrophic failures on cast posts and cores. It was concluded that weakened roots restored with the strategies searched seem to have similar fracture strength, but fiber and anatomic posts reduce the possibility of catastrophic failures.

FINAL CONSIDERATIONS

The clinical follow-ups reported in the literature cannot yet detect a difference between the survival rates of fiberglass posts and cast metal posts and cores. This is because teeth failures are rare compared to their survival. Thus, longer follow-up times or a case-control study is suggested to determine the rehabilitation with the highest survival rate and the pattern of clinical failure in each condition.

The results of laboratory tests should be carefully extrapolated to the clinic because there is a high divergence in the literature. Studies suggest that fiberglass posts are preferable because their elastic modulus is similar to dentin and they are translucent, esthetic, and compatible with the Bis-GMA monomer (present in most adhesive systems and resin cements). However, other studies report that cast metal posts have superior mechanical behavior. This divergence is even higher in the finite element analysis. There is a trend of literature discussions to benefit fiberglass post restorations, which are more modern and esthetic, even though the numerical values of cast metal posts and cores are often superior (especially at the cement/dentin interface). Cast metal posts and cores seem to survive longer and with higher loads, but when these posts fail, the only solution is tooth extraction. Fracture load values could not be compared among studies because they ranged from 6.9 N [37] to 769.85 N [35] in compressive loads.

The presence of a ferrule benefits the system. Rehabilitations can be performed with any post with a ferrule, and in its absence, the literature shows divergent results. However, studies mentioning that cast metal is more indicated for weakened teeth are more consistent. Several studies with finite element analysis show superior stress values in the cervical dentin and the cementation line between dentin and cement using fiberglass posts.

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Author's Contributions

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Conflict of Interest

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Regulatory Statement

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