Current Oral Health Reports (2023) 10:8–13
https://doi.org/10.1007/s40496-023-00327-2

Do We Still Need Intraradicular Retainers? Current Perspectives on the Treatment of Endodontically Treated Teeth

Renan Vaz Machry[1] · Kiara Serafini Dapieve[1] · Gabriel Kalil Rocha Pereira[1] · Luiz Felipe Valandro[1]

Accepted: 5 January 2023 / Published online: 6 February 2023

Abstract

Purpose of Review Finding a balance between mechanical function of endodontically treated teeth and minimal remnant preparation is challenging. Minimally adhesive concepts are being explored as an alternative to the use of posts, cores, and classical fixed prostheses. Thereby, this review seeks to highlight and discuss the current knowledge on this issue.

Recent Findings Considering the mechanical characteristics encountered in the different regions of the dental arch, recent evidence points to the benefits of endocrown restorations for the posterior region, being a promising option for molars and premolars (predominant axial load); however, intraradicular retainers are still suggested for the anterior region due to the incidence of lateral loads triggered by the oblique positioning and the main occurrence of flexural loads.

Summary The quality of the remaining tooth, the possibility of maintaining the ferrule effect, and the region of the element to be treated are key factors that must be considered in the rehabilitation of pulpless teeth.

Keywords Endocrown · Fiber posts · Fixed dental prosthesis · Prosthodontics · Retainer

Introduction

The rehabilitation of pulpless teeth has been explored over the last decades, especially related to the use of intraradicular retainers to support restorations [1–3]. In fact, different options for direct and indirect restorations are possible. The direct technique using resin composite may be sufficient to solve the restorative need of teeth that present only the opening for endodontic treatment or small cavity [4]; however, additional procedures or specific techniques are necessary in teeth with greater amounts of structural loss.

Some research reports that teeth with large loss of remaining tissues need full prosthetic crowns supported by intraradicular posts [5]. It is suggested that the anchoring of the prosthetic core using a post inserted into the pulped canal improves retention of the restoration to the tooth and balances the distribution of stresses along the root [6]. Thus, intraradicular retainers have become the gold standard after the endodontic treatment of elements with significant losses of the coronary remnant. To do so, the canal obturation was partially removed, maintaining only an apical seal, and then prepared to receive a retainer, which could be a prefabricated post, i.e., with standardized shape and dimensions, or customized through canal modeling [1].

Still, resin composite restorations supported by an intraradicular retainers increase the fracture resistance and reduce the risk of interfacial gap progression in incisive and canines (anterior region) with loss of marginal ridges [7]. Similarly, adding posts as additional retention to the direct restorations promotes improved clinical behavior for posterior teeth cavities involving proximal faces, being the use of indirect restorations also indicated for these cases [4]. Furthermore, covering the cusps in premolar teeth reduces the risk of fracture of these elements, which is usually one of the outcomes observed in mesio-occlusal-distal (MOD) cavities [8•].

Initially, metallic posts were widely used for this function due to their high mechanical strength, and the

✉ Luiz Felipe Valandro
valandrolf@gmail.com

Renan Vaz Machry
renanmachry@gmail.com

Kiara Serafini Dapieve
kiara_s_d@hotmail.com

Gabriel Kalil Rocha Pereira
gabrielkrpereira@hotmail.com

[1] Post-Graduate Program in Oral Sciences (Prosthodontics Unit), Faculty of Odontology, Federal University of Santa Maria, Santa Maria, Rio Grande Do Sul, Brazil

possibility of being made from casting allowed metallic cores to exactly with the internal conformation of the root canal, resulting in a perfect adaptation to the internal anatomy of the tooth [3, 9]. Metallic retainers are still widely used; however, in vitro studies have been suggested that cast metal posts present some important concerns, such as interference in the esthetics of restorations due to the grayish color and the incidence of catastrophic root fractures due to stress concentration during mastication [10–12]. On this sense, a failure is considered catastrophic when repair of the restoration is not possible (irreparable fractures), being generally related to the involvement of the tooth root below the bone level [12].

As a consequence of the use of metallic posts, in vitro studies began to demonstrate that cores with a lower modulus of elasticity reduce the risk of catastrophic fractures of the dental element since they concentrate less stress on the root walls [13–16]. Thus, different materials were adopted as an alternative to metals such as fiber posts, considered an excellent option due to the similarity of elastic modulus to root dentin [13–17]. However, it should be noted that the root damages generated by metallic retainers is currently not a consensus, especially when it is supported by systematic review studies and clinical trials that show good fracture strength, survival, and outcomes for these materials [14, 18, 19, 20•]. Anyway, post customization techniques with composite resin were proposed for better adaptation of fiber post to the root canal [12, 21], and, more recently, milled fiber posts are also possible through digital planning of the retainer shape and preparation through milling machines [22, 23].

In parallel with the improvement and development of intraradicular retainers, luting agents and adhesives have also presented a recognized evolution over the years. The emergence of resin cements has generated new perspectives for dentistry as a material with improved mechanical and adhesive properties compared to traditional zinc phosphate-based cements [24]. This point also contributed positively to the popularization of fiber posts, since they had high bond strength with resin cements [25–28], which motivated a series of studies evaluating techniques and procedures to improve the protocol for luting retainers to pulped teeth [29, 30].

In the same way, another question that has been raised is the need to use intraradicular retainers nowadays, since restorations luted directly on the remaining tooth without the need for additional retention are possible after the great evolution of adhesive systems [31]. Besides that, the evolution of restorative materials such as dental ceramics and resin materials, as well as the computer-aided design/computer-aided manufacturing (CAD/CAM) systems, allows reliable and long-lasting restorations with reduced thickness and diversified geometries in contrast to the traditional full prosthetic crown [32, 33].

Based on the above, this review seeks to highlight and discuss the current knowledge on this issue answering the following question: do we still need intraradicular retainers? For this question, it is important to address the endocrown as a reliable restorative alternative to the conventional technique of crown and post, the importance of the ferrule effect to guide the clinical decision of the need for an intraradicular retainer, and how the position of the tooth in the dental arch can influence the evidence-based decision.

Endocrowns

Endocrown was one of the restorative options currently available that became popular after the evolution of adhesive luting and restorative materials used as monolithic restorations, i.e., composed of a single material [34]. It is based in the use of the pulp chamber of an endodontically treated tooth as a retentive and adhesive area for the restoration, dispensing the use of intraradicular retainers [31, 35]. The restoration is completely composed of a single material forming a monoblock luted directly onto the remaining tooth, eliminating the need to prepare the root canal to receive a post and consequently promoting the preservation of more tooth structure, maintaining its biomechanical integrity, and reducing the risk of root perforation [36–39].

Ceramics or composites are possible materials for endocrown restorations, highlighting the properties of each one of them [40, 41]. It should be taken into account that the thickness of the restorative material for endocrown restorations is greater than for conventional full crowns, and therefore, it is suggested that as consequence, the integrity of the restoration and its resistance to fracture are enhanced regardless of the chosen material [42, 43]. Ceramics present higher mechanical strength than resin composites, which in turn can distribute the masticatory stresses throughout the tooth due to the lower modulus of elasticity, reducing the occurrence of irreparable fractures [35, 38, 44]. Likewise, high-strength ceramics such as zirconia-based ceramic can lead to a higher risk of catastrophic tooth fractures due to the high modulus of elasticity, although they imply high loads to failure [32].

Endocrowns can perform better than intraradicular retainers associated with conventional full crowns, especially for restoring molars [40, 45•]. This fact can be due to the incidence of masticatory forces occurs perpendicularly to the tooth element (predominance of axial loads), and, therefore, there is no fulcrum movement that could lead to lateral displacement of the restoration [45•]; however, it is important that the amount of remnant around the pulp chamber is taken into account, so that there is sufficient support structure to receive the restoration and the loads impinging on it [35, 44].

On the other hand, the indication of endocrown in premolars should be evaluated with caution, since the

relationship between width and height of the restoration is less favorable (compared to molars) and there is greater interference from lateral movements compared to molars [45•]. In the same way, it is wise to think that the use of an intraradicular retainer is still necessary for the anterior region, since most of the incidence of loads occurs in the lateral direction, leading to flexural/bending of the restoration [46]. However, some studies suggest that the success of the prosthetic restoration in anterior teeth is mainly attributed to the presence of ferrule, while the fiber post leads to unfavorable failure modes and does not compensate for the absence of ferrule [47, 48].

Ferrule Effect

The ferrule effect is the embracing of a metal or ceramic ring of the restoration around a remaining coronal portion preserved during prosthetic core preparation [49–51]. It is known that the presence of a ferrule is essential for the longevity and resistance to fatigue of endodontically treated teeth [2, 46, 47]. Thus, the presence or absence of preservation of the coronal portion may be indicative of the restorative choice of the dental element and its success [52–54]. The coronal remnant does not always allow the ferrule preparation to be composed of the four walls surrounding the root canal. Incomplete ferrule, i.e., less than four walls in preparation design, is considered a better option than a complete lack of ferrule [51]; however, failure risk increases with the number of missing cavity walls [54].

Some studies suggest the use of metallic intraradicular retainers in the absence of a remnant, which avoids the deflection of the set due to the high modulus of elasticity and, thus, would lead to better restorative results [9, 20•]; nevertheless, clinical studies comparing metallic retainers and fiber posts in the presence or absence of a ferrule are still scarce, and, therefore, the outcomes still need to be better understood [18]. Alternatively, it is recommended that in cases of absence of remnants, the possibility of orthodontic extrusion should be considered, in order to allow the preparation with a ferrule effect of at least 1.5 mm in height [51].

Regarding the failure patterns, the presence of a retainer does not seem to influence the observed outcomes when four-wall ferrule is possible [54]; otherwise, there is references concluding that a ferrule also does not interfere with the type of failure found in teeth restored or not with fiber posts [48]; however, these data must be interpreted with caution, especially when considering the differences between restorations in the anterior and posterior region.

Tooth Region

Garcia et al. (2019) suggest through a systematic review of clinical studies that the longevity of restorations with intraradicular retainers is similar when comparing anterior and posterior teeth [55]. Likewise, Martins et al. (2021) also consider that there is no difference in the results for the anterior and posterior regions [18]; however, the behavior of prosthetic restorations in the posterior and anterior regions must be evaluated not only regarding the survival rates or load for fracture, but also considering the outcomes observed when a failure occurs. The force vectors for each of the situations are not equal and, therefore, cannot be compared equally.

Studies have shown promising results for the use of endocrown in the posterior region [45•, 56]. In this case, an excellent behavior of the restoration is expected for teeth with sufficient support to resist axial loads [43]. The adhesive ability of current restorative materials and the preservation of dental tissue remnants are clear benefits of these restorations, as aforementioned [35]; however, it is expected that the main failures occur related to the cement layer [43]. Thus, it seems necessary that finding ways to reduce stresses in the cement layer is more relevant than reducing stresses in the restoration itself [43]. Moreover, more longitudinal clinical follow-up studies are still needed to make the results and outcomes of this type of treatment more predictable.

Likewise, the use of endocrowns seems promising but still requires further exploration for premolars [5, 45•]. The incidence of axial loads occurs mostly considering molars, while some amount of lateral solicitation is expected for premolars [57]. The combination of compressive and lateral loading on these elements implies a high incidence of stress in the cervical region of the cusps, which is a smaller diameter zone when compared to molars and, therefore, more susceptible to failure [58]. In this sense, it is suggested that cuspal coverage is necessary and may even exclude the need for intraradicular retainers [8•]. Anyway, the use of posts is suggested for direct restoration (with resin composite) of premolars with MOD cavities [8•], and, in the same way, the use of posts, core build-up, and full crown restorations still seem to be the more scientifically accurate option [59].

Regarding the anterior region, the use of posts increases the fracture resistance of endodontically treated teeth [60]. The fewer clinical steps and simplified adhesive technique boosted the use of prefabricated fiber posts [7]. Metal retainers require more steps, including root canal shaping and metal casting, while fiber posts can be immediately luted reducing clinical time [2, 9]. As a result of all the favorable factors related to fiber posts (simplified

fabrication and luting technique, esthetics, and stress distribution), for years, in vitro studies have suggested better behavior in relation to metallic retainers [13–16]; however, currently, longitudinal follow-up studies have questioned whether this superiority is clinically confirmed, since the survival of metallic retainers is reported to be similar to fiber posts [18, 61].

Nevertheless, the type of failure plays a key role in guiding the choice of whether or not use a intraradicular retainer, as well as which one to use. The chance of irreparable failure is increased when a retainer is proposed, due to the fulcrum zone placed below the bony crest margin [60]. Thus, opting for posts with lower elastic modulus seems to be beneficial for better distributing the stresses and, consequently, reducing catastrophic fractures. On the other hand, debonding occurrences are often reported when fiber posts are used [61]. Anyway, it is a type of failure that can be repaired, as opposed to fractures caused by metallic posts that lead to the need to extract the dental element.

Conclusion

Clinical studies with longitudinal follow-up that precisely answer all the factors involved in the restoration of endodontically treated teeth are limited. Tooth remnant amount, presence or absence of ferrule, and region in the dental arch are some of the factors that should be punctually evaluated for each clinical situation. In general, it can be seen that for the posterior region, endocrown restorations (without intraradicular retainer) present very reliable results for molars, encouraging the restoration of pulpless teeth relying only on the formation of the monoblock through the adhesive luting of monolithic restorations in the pulp chamber. On the other hand, the results are quite promising for this technique for premolars; however, it should be studied in depth to clearly understand the behavior of this type of restoration in teeth with incidence of lateral loads.

Regarding the incidence of lateral forces, the restoration of anterior teeth still seems to be a challenge that requires additional care, and, in this case, it still seems necessary to use anchoring methods that prevent the restoration from moving during function. Even so, success seems to be mainly related to the quantity and quality of the coronary remnant (ferrule effect), leading to the idea that avoiding the loss of dental tissue during prosthetic preparation is essential during restoration planning and tooth preparation.

Declarations

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent No animal or human subjects by the authors were used in this study.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance

1. Morgano SM. Restoration of pulpless teeth: application of traditional principles in present and future contexts. J Prosthet Dent. 1996;75:375–80. https://doi.org/10.1016/S0022-3913(96)90028-1.
2. Marchionatti AME, Wandscher VF, Rippe MP, Kaizer OB, Valandro LF. Clinical performance and failure modes of pulpless teeth restored with posts: a systematic review. Braz Oral Res. 2017;31:e64. https://doi.org/10.1590/1807-3107BOR-2017.vol31.0064.
3. Bolla M, Muller-Bolla M, Borg C, Lupi-Pegurier L, Laplanche O, Leforestier E. Root canal posts for the restoration of root filled teeth. Cochrane Database Syst Rev. 2016;2016:3–6. https://doi.org/10.1002/14651858.CD004623.pub3.
4. de Kuijper MCFM, Cune MS, Özcan M, Gresnigt MMM. Clinical performance of direct composite resin versus indirect restorations on endodontically treated posterior teeth: a systematic review and meta-analysis. J Prosthet Dent 2022:1–12. https://doi.org/10.1016/j.prosdent.2021.11.009.
5. Rocca GT, Daher R, Saratti CM, Sedlacek R, Suchy T, Feilzer AJ, et al. Restoration of severely damaged endodontically treated premolars: the influence of the endo-core length on marginal integrity and fatigue resistance of lithium disilicate CAD-CAM ceramic endocrowns. J Dent. 2018;68:41–50. https://doi.org/10.1016/j.jdent.2017.10.011.
6. Sarkis-Onofre R, Jacinto RDC, Boscato N, Cenci MS, Pereira-Cenci T. Cast metal vs. glass fibre posts: a randomized controlled trial with up to 3 years of follow up. J Dent. 2014;42:582–7. https://doi.org/10.1016/j.jdent.2014.02.003.
7. Comba A, Baldi A, Saratti CM, Rocca GT, Torres CRG, Pereira GKR, et al. Could different direct restoration techniques affect interfacial gap and fracture resistance of endodontically treated anterior teeth? Clin Oral Investig. 2021;25:5967–75. https://doi.org/10.1007/s00784-021-03902-y.
8. • Iaculli F, Rengo C, Lodato V, Patini R, Spagnuolo G, Rengo S. Fracture resistance of endodontically-treated maxillary premolars restored with different type of posts and direct composite reconstructions: a systematic review and meta-analysis of in vitro studies. Dent Mater. 2021;37:e455-84. https://doi.org/10.1016/j.dental.2021.06.007. **A current systematic review evaluating the use of fiber posts suggests that endodontically treated maxillary premolars restored with fiber post and direct composite resin restoration demonstrated greater fracture resistance when compared to equivalent teeth without a retainer.**
9. Girotto LPS, Dotto L, Pereira GKR, Bacchi A, Sarkis-Onofre R. Restorative preferences and choices of dentists and students for restoring endodontically treated teeth: a systematic review of survey studies. J Prosthet Dent. 2021;126:489-489.e5. https://doi.org/10.1016/j.prosdent.2020.07.005.
10. Santos AFV, Meira JBC, Tanaka CB, Xavier TA, Ballester RY, Lima RG, et al. Can fiber posts increase root stresses and reduce

fracture? J Dent Res. 2010;89:587–91. https://doi.org/10.1177/0022034510363382.
11. Zhou L, Wang Q. Comparison of fracture resistance between cast posts and fiber posts: a meta-analysis of literature. J Endod. 2013;39:11–5. https://doi.org/10.1016/j.joen.2012.09.026.
12. Wandscher VF, Bergoli CD, Limberger IF, Ardenghi TM, Valandro LF. Preliminary results of the survival and fracture load of roots restored with intracanal posts: weakened vs nonweakened roots. Oper Dent. 2014;39:541–55. https://doi.org/10.2341/12-465.
13. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. J Dent Res. 2012;91:S72–8. https://doi.org/10.1177/0022034512447949.
14. Figueiredo FED, Martins-Filho PRS, Faria-E-Silva AL. Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. J Endod. 2015;41:309–16. https://doi.org/10.1016/j.joen.2014.10.006.
15. Scotti N, Rota R, Scansetti M, Paolino DS, Chiandussi G, Pasqualini D, et al. Influence of adhesive techniques on fracture resistance of endodontically treated premolars with various residual wall thicknesses. J Prosthet Dent. 2013;110:376–82. https://doi.org/10.1016/j.prosdent.2013.08.001.
16. de Coelho CSM, Biffi JCG, da Silva GR, Abrahão A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J. 2009;28:671–8. https://doi.org/10.4012/dmj.28.671.
17. Parisi C, Valandro LF, Ciocca L, Gatto MRA, Baldissara P. Clinical outcomes and success rates of quartz fiber post restorations: a retrospective study. J Prosthet Dent. 2015;114(3):367–72.
18. Martins MD, Junqueira RB, de Carvalho RF, Lacerda MFLS, Faé DS, Lemos CAA. Is a fiber post better than a metal post for the restoration of endodontically treated teeth? A systematic review and meta-analysis. J Dent 2021;112. https://doi.org/10.1016/j.jdent.2021.103750.
19. Sarkis-Onofre R, AmaralPinheiro H, Poletto-Neto V, Bergoli CD, Cenci MS, Pereira-Cenci T. Randomized controlled trial comparing glass fiber posts and cast metal posts. J Dent. 2020;96:103334. https://doi.org/10.1016/j.jdent.2020.103334.
20.• Sarkis-Onofre R, Fergusson D, Cenci MS, Moher D, Pereira-Cenci T. Performance of post-retained single crowns: a systematic review of related risk factors. J Endod. 2017;43:175–83. https://doi.org/10.1016/j.joen.2016.10.025. **Review article that emphasizes the importance of remaining coronary walls in the choice of root retainers.**
21. Machry RV, Fontana PE, Bohrer TC, Valandro LF, Kaizer OB. Effect of different surface treatments of resin relined fiber posts cemented with self-adhesive resin cement on push-out and microtensile bond strength tests. Oper Dent. 2020;45:E185–95. https://doi.org/10.2341/19-108-L.
22. Ruschel GH, Gomes ÉA, Silva-Sousa YT, Pinelli RGP, Sousa-Neto MD, Pereira GKR, et al. Mechanical properties and superficial characterization of a milled CAD-CAM glass fiber post. J Mech Behav Biomed Mater. 2018;82:187–92. https://doi.org/10.1016/j.jmbbm.2018.03.035.
23. Oliveira GR, Machry RV, Cadore-Rodrigues AC, Sarkis-Onofre R, Valandro LF, Bacchi A, Pereira G, Spazzin AO. Fatigue properties of weakened and non-weakened roots restored with CAD-CAM milled fiber post, prefabricated fiber post, or cast metal post. Oper Dent. 2022;47(6):658–69. https://doi.org/10.2341/21-032-L.
24. Hill EE. Dental cements for definitive luting: a review and practical clinical considerations. Dent Clin North Am. 2007;51:643–58. https://doi.org/10.1016/j.cden.2007.04.002.
25. Valandro LF, Andreatta Filho OD, Valera MC, Maximo De Araujo MA. The effect of adhesive systems on the pullout strength of a fiberglass-reinforced composite post system in bovine teeth. J Adhes Dent. 2005;7(4):331–6.
26. Amaral M, Santini MF, Wandscher V, Amaral R, Valandro LF. An in vitro comparison of different cementation strategies on the pull-out strength of a glass fiber post. Oper Dent. 2009;34(4):443–51.
27. Bottino MA, Baldissara P, Valandro LF, Galhano GA, Scotti R. Effects of mechanical cycling on the bonding of zirconia and fiber posts to human root dentin. J Adhes Dent. 2007;9(3):327–31.
28. Baldissara P, Zicari F, Valandro LF, Scotti R. Effect of root canal treatments on quartz fiber posts bonding to root dentin. J Endod. 2006;32(10):985–8.
29. Tay FR, Pashley DH. Monoblocks in root canals: a hypothetical or a tangible goal. J Endod. 2007;33:391–8. https://doi.org/10.1016/j.joen.2006.10.009.
30. Bergoli CD, Amaral M, Boaro LCC, Braga RR, Valandro LF. Fiber post cementation strategies: effect of mechanical cycling on push-out bond strength and cement polymerization stress. Fiber Post Cem Strateg Eff Mech Cycl Push-out Bond Strength Cem Polym Stress. 2012;14:471–8. https://doi.org/10.3290/j.jad.a28389.
31. Biacchi GR, Mello B, Basting RT. The endocrown: an alternative approach for restoring extensively damaged molars. J Esthet Restor Dent. 2013;25:383–90. https://doi.org/10.1111/jerd.12065.
32. Dartora NR, Maurício Moris IC, Poole SF, Bacchi A, Sousa-Neto MD, Silva-Sousa YT, et al. Mechanical behavior of endocrowns fabricated with different CAD-CAM ceramic systems. J Prosthet Dent. 2021;125:117–25. https://doi.org/10.1016/j.prosdent.2019.11.008.
33. Blatz MB, Conejo J. The current state of chairside digital dentistry and materials. Dent Clin North Am. 2019;63:175–97. https://doi.org/10.1016/j.cden.2018.11.002.
34. da Cunha LF, Gonzaga CC, Pissaia JF, Correr GM. Lithium silicate endocrown fabricated with a CAD-CAM system: a functional and esthetic protocol. J Prosthet Dent. 2017;118:131–4. https://doi.org/10.1016/j.prosdent.2016.10.006.
35. Tribst JPM, de Dal Piva AMO, Madruga CFL, Valera MC, Borges ALS, Bresciani E, et al. Endocrown restorations: influence of dental remnant and restorative material on stress distribution. Dent Mater. 2018;34:1466–73. https://doi.org/10.1016/j.dental.2018.06.012.
36. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of fibre post length and adhesive strategy on fracture resistance of endodontically treated teeth after fatigue loading. J Dent. 2012;40:312–21. https://doi.org/10.1016/j.jdent.2012.01.006.
37. Lazari PC, de Oliveira RCN, Anchieta RB, de Almeida EO, Freitas Junior AC, Kina S, et al. Stress distribution on dentin-cement-post interface varying root canal and glass fiber post diameters. A three-dimensional finite element analysis based on micro-CT data. J Appl Oral Sci. 2013;21:511–7. https://doi.org/10.1590/1679-775720130203.
38. Altier M, Erol F, Yildirim G, Dalkilic EE. Fracture resistance and failure modes of lithium disilicate or composite endocrowns. Niger J Clin Pract. 2018;21:821–6. https://doi.org/10.4103/njcp.njcp_175_17.
39. Hayes A, Duvall N, Wajdowicz M, Roberts H. Effect of endocrown pulp chamber extension depth on molar fracture resistance. Oper Dent. 2017;42:327–34. https://doi.org/10.2341/16-097-L.
40. Sedrez-Porto JA, da Rosa de WLO, da Silva AF, Münchow EA, Pereira-Cenci T. Endocrown restorations: a systematic review

and meta-analysis. J Dent. 2016;52:8–14. https://doi.org/10.1016/j.jdent.2016.07.005.
41. Dartora G, Rocha Pereira GK, Varella de Carvalho R, Zucuni CP, Valandro LF, Cesar PF, et al. Comparison of endocrowns made of lithium disilicate glass-ceramic or polymer-infiltrated ceramic networks and direct composite resin restorations: fatigue performance and stress distribution. J Mech Behav Biomed Mater. 2019;100:103401. https://doi.org/10.1016/j.jmbbm.2019.103401.
42. Motta AB, Pereira LC, Duda FP, Anusavice KJ. Influence of substructure design and occlusal reduction on the stress distribution in metal ceramic complete crowns: 3D finite element analysis. J Prosthodont. 2014;23:381–9. https://doi.org/10.1111/jopr.12119.
43. Tribst JPM, de Dal Piva AMO, de Jager N, Bottino MA, de Kok P, Kleverlaan CJ. Full-crown versus endocrown approach: a 3D-analysis of both restorations and the effect of ferrule and restoration material. J Prosthodont. 2021;30:335–44. https://doi.org/10.1111/jopr.13244.
44. Zheng Z, Sun J, Jiang L, Wu Y, He J, Ruan W, et al. Influence of margin design and restorative material on the stress distribution of endocrowns: a 3D finite element analysis. BMC Oral Health. 2022;22:1–12. https://doi.org/10.1186/s12903-022-02063-y.
45.• Govare N, Contrepois M. Endocrowns: a systematic review. J Prosthet Dent. 2020;123:411-418.e9. https://doi.org/10.1016/j.prosdent.2019.04.009. **This literature review critically analyzes the current perspectives about endocrowns. The authors concluded that endocrown is a suitable restoration to molars.**
46. Silva-Sousa AC, Moris ICM, Barbosa AFS, Silva-Sousa YTC, Sousa-Neto MD, Pires CRF, et al. Effect of restorative treatment with endocrown and ferrule on the mechanical behavior of anterior endodontically treated teeth: an in vitro analysis. J Mech Behav Biomed Mater. 2020;112:104019. https://doi.org/10.1016/j.jmbbm.2020.104019.
47. Magne P, Lazari PC, Carvalho MA, Johnson T, Del Bel Cury AA. Ferrule-effect dominates over use of a fiber post when restoring endodontically treated incisors: an in vitro study. Oper Dent. 2017;42:397–406. https://doi.org/10.2341/16-243-L.
48. de Batista VES, Bitencourt SB, Bastos NA, Pellizzer EP, Goiato MC, dos Santos DM. Influence of the ferrule effect on the failure of fiber-reinforced composite post-and-core restorations: a systematic review and meta-analysis. J Prosthet Dent. 2020;123:239–45. https://doi.org/10.1016/j.prosdent.2019.01.004.
49. Figueiredo FE, Santos RC, Silva AS, Valdívia AD, Oliveira-Neto LA, Griza S, et al. Ferrule design does not affect the biomechanical behavior of anterior teeth under mechanical fatigue: an in vitro evaluation. Oper Dent. 2019;44:273–80. https://doi.org/10.2341/17-296-L.
50. Da Silva NR, Raposo LHA, Versluis A, Fernandes-Neto AJ, Soares CJ. The effect of post, core, crown type, and ferrule presence on the biomechanical behavior of endodontically treated bovine anterior teeth. J Prosthet Dent. 2010;104:306–17. https://doi.org/10.1016/S0022-3913(10)60146-1.
51. Juloski J, Radovic I, Goracci C, Vulicevic ZR, Ferrari M. Ferrule effect: a literature review. J Endod. 2012;38:11–9. https://doi.org/10.1016/j.joen.2011.09.024.
52. Skupien JA, Luz MS, Pereira-Cenci T. Ferrule effect: a meta-analysis. JDR Clin Transl Res. 2016;1:31–9. https://doi.org/10.1177/2380084416636606.
53. Skupien JA die, Sarkis-Onofre R, Cenci MS érgi, Moraes RR att. de, Pereira-Cenci T. A systematic review of factors associated with the retention of glass fiber posts. Braz Oral Res 2015;29:1–8. https://doi.org/10.1590/1807-3107BOR-2015.vol29.0074.
54. Naumann M, Schmitter M, Frankenberger R, Krastl G. "Ferrule comes first. post is second!" Fake news and alternative facts? Systematic review. J Endod. 2018;44:212–9. https://doi.org/10.1016/j.joen.2017.09.020.
55. Garcia PP, Wambier LM, de Geus JL, da Cunha LF, Correr GM, Gonzaga CC. Do anterior and posterior teeth treated with post-and-core restorations have similar failure rates? A systematic review and meta-analysis. J Prosthet Dent. 2019;121:887-894.e4. https://doi.org/10.1016/j.prosdent.2018.08.004.
56. Rocca GT, Daher R, Saratti CM, Sedlacek R, Suchy T, Feilzer AJ, et al. Restoration of severely damaged endodontically treated premolars: the influence of the endo-core length on marginal integrity and fatigue resistance of lithium disilicate CAD-CAM ceramic endocrowns. J Dent. 2018;68:41–50. https://doi.org/10.1016/j.jdent.2017.10.011.
57. Abe Y, Nogami K, Mizumachi W, Tsuka H, Hiasa K. Occlusal-supporting ability of individual maxillary and mandibular teeth. J Oral Rehabil. 2012;39:923–30. https://doi.org/10.1111/joor.12008.
58. Fráter M, Sáry T, Jókai B, Braunitzer G, Säilynoja E, Vallittu PK, et al. Fatigue behavior of endodontically treated premolars restored with different fiber-reinforced designs. Dent Mater. 2021;37:391–402. https://doi.org/10.1016/j.dental.2020.11.026.
59. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, et al. A randomized controlled trial of endodontically treated and restored premolars. J Dent Res. 2012;91:S72–8. https://doi.org/10.1177/0022034512447949.
60. Jurema ALB, Filgueiras AT, Santos KA, Bresciani E, Caneppele TMF. Effect of intraradicular fiber post on the fracture resistance of endodontically treated and restored anterior teeth: a systematic review and meta-analysis. J Prosthet Dent. 2022;128:13–24. https://doi.org/10.1016/j.prosdent.2020.12.013.
61. Tsintsadze N, Margvelashvili-Malament M, Natto ZS, Ferrari M. Comparing survival rates of endodontically treated teeth restored either with glass-fiber-reinforced or metal posts: a systematic review and meta-analyses. J Prosthet Dent 2022:1–12. https://doi.org/10.1016/j.prosdent.2022.01.003.