Simultaneous crown-root shielding in endodontics: from root preparation to coronary restoration

José Edgar **VALDIVIA**[1,2]
Manoel Eduardo de Lima **MACHADO**[1]

DOI: http://dx.doi.org/10.14436/2358-2545.7.1.032-042.oar

ABSTRACT

Introduction: Restoration of endodontically treated teeth is a factor that can significantly influence treatment success. In this context, simultaneous restoration of both root and crown represents a restorative possibility. An excellent alternative is the use of fiberglass posts combined with direct composite resin restorations, mainly due to the mechanical and aesthetic properties of fiber posts associated with current composite resins. **Objective:** The objective of this study is to present a technique of instrumentation and simultaneous restoration of the root canal system by means of clinical cases reports. This technique encompasses endodontic-restorative diagnosis, mechanical root canal preparation, ultrasonic preparation of the post placement site aimed at intracanal fiberglass post cementation, concluding with functional restoration of the tooth, considering its clinical, mechanical and biological aspects. **Results:** Clinical and radiographic controls revealed both cases were asymptomatic, in occlusion, and presented repair of periapical lesions. **Conclusions:** It can be concluded that this technique allows adequate simultaneous restoration of endodontically treated teeth in a single treatment session, as evinced by the presented cases.

Keywords: Endodontics. Dental post. Composite resins. Root canal preparation. Intracanal post technique.

How to cite: Valdivia JE, Machado MEL. Simultaneous crown-root shielding in endodontics: from root preparation to coronary restoration. Dental Press Endod. 2017 Jan-Apr;7(1):32-42.
DOI: http://dx.doi.org/10.14436/2358-2545.7.1.032-042.oar

[1]Associação Paulista de Cirurgiões Dentistas (APCD Central), Especialização em Endodontia (São Paulo/SP, Brazil).

[2]Universidade de São Paulo, Faculdade de Odontologia, Pós-Graduação em Odontologia (São Paulo/SP, Brazil).

» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

» Patients displayed in this article previously approved the use of their facial and intraoral photographs.

Submitted: June 02/, 2016. Revised and accepted: January 17, 2017.

Contact address: José Edgar Valdivia
Rua Antônio Tavares 300 - Aclimação, São Paulo - Brasil
E-mail: jedgar30@usp.br

Introduction

Restoration of endodontically treated teeth has led to discussions between clinicians and researchers. It is characterized by lack of a standardized clinical protocol. Currently, Dentistry has been concerned with defining the best technique for restoration of edondontically treated teeth. These teeth deserve special care due to lower mechanical resistance when compared to teeth with vital pulp.[1]

The objective of any treatment should be preservation of the highest volume of dentin, the structural tissue of the tooth which provides elastic resistance to the dental element. Replacement of lost root dentin with intracanal posts and resin material allows proper rehabilitation of the endodontically treated tooth. Thus, the adequate combination of different types of material enables the professional to perform restorations with minimal wear of dental structure and high clinical success.[2]

As for the "ideal" restoration, there is no clinical or scientific consensus for all cases[3,4,5] regarding the decision to place a complete crown, indirect restorations, overlay, onlay, inlay, or direct restoration. Important aspects should be considered in the restoration of endodontically treated teeth, such as the amount of remaining cervical crown,[6] functional occlusion, and axial, lateral and shear forces, among others.[7] All those factors are essential for proper restoration of both the crown and root. Ray et al[8] correlated the success of adequate crown restoration with successful endodontic treatment.

In regards to root structure, fiberglass posts have rigidity very similar to dentin, absorbing the stress generated by masticatory forces and protecting the remaining root, due to the fact that they contribute to the construction of a mechanically homogeneous unit.[9]

A composite resin filling core will be inserted at the interface between the post and the morphological restoration of the treated tooth, with a view to reconstituting teeth that lost structural dentin. Additionally, intracanal posts will be combined with the aforementioned elements. This reconstruction is important not only in order to provide support and retention for direct or indirect restorative material, but also in the homogenous distribution of stress surrounding the remaining tooth.[10] In this context, contemporary resins, such as bulk-fill and flow resin composites as well as resin cements, facilitate cavity filling with quality, mechanical resistance and within a short period of time.[11]

At the coronal portion of the filling core, the final restoration is another important component in final morphological and aesthetic reconstruction of the tooth. Composite resins currently available are great options for meeting aesthetic requirements and mechanical resistance necessary for direct restorations or as a base for a future prosthetic crown.

There are several types of material and techniques for restoration of endodontically treated teeth; however, there is no doubt regarding the need to create a restoration that allows functions of this dental element to be restored. It is important to keep in mind that no restorative material replaces dental tissue with the same efficiency. This fact forces us to select a technique that is conservative towards the remaining dental structure, in addition to using material that is biocompatible, functional and that provides appropriate aesthetics.[12]

This paper aims to present, by reporting clinical cases, the concept of CRS (Simultaneous Coronal-Radicular Shielding), a technique consisting of simultaneous preparation and restoration of both the root canal system and crown. CRS involves planned biomechanical preparation aimed at immediate placement of an intracanal fiberglass post and conclusion with definitive restoration of the endodontically tooth with resin material, considering clinical, mechanical and biological aspects of the tooth.

Clinical case report

Description of clinical case 1

A female patient presented with discomfort in the mandibular first molar on the left side. Clinical examination revealed extensive restoration. Furthermore, extensive apical lesion in mesial and distal canals was discovered radiographically, characterizing chronic apical periodontitis (Fig 1).

After careful evaluation of the case, considering the diagnosis, remaining dental structure and the need for both endodontic and restorative treatments, endodontic treatment and simultaneous crown-root shielding were planned.

Before treatment onset, the diameter of the post was selected according to root anatomy of the tooth to be treated. In this case, the distal canal would receive the fiberglass post.

The operative field was isolated with a rubber dam and the access surgery to the root canal system was performed. After preparation of root canal opening, odontometry was performed with the aid of a Propex Pixi apex locator (Dentsply-Maillefer, Ballaigues, Switzerland).

Subsequently, chemical-surgical preparation (CSP) was carried out as follows:

- In the mesial canals, CSP was performed with Wave One primary and large files (Dentsply-Maillefer, Ballaigues, Switzerland).

- For the distal canal, CSP was performed by alternating reciprocating files with Gates-Glidden (Dentsply-Maillefer, Ballaigues, Switzerland) burs and with POST PREP ultrasonic tips (Trinks, São Paulo, SP, Brazil) considering the real working length (RWL). The working length for the post was then prepared to coincide with the real working length minus 5mm.

Apical access was performed with a Wave One primary file (Dentsply-Maillefer, Ballaigues, Switzerland) to the real working length. This was then followed with the insertion of a Wave One large file (Dentsply-Maillefer, Ballaigues, Switzerland) to the real working length (Fig 2) alternated with Gates-Glidden II burs (Dentsply-Maillefer, Ballaigues, Switzerland) (Fig 3) to the working length for the post. A POST PREP ultrasonic tip was inserted (Trinks, São Paulo, SP, Brazil) was inserted to working length for the post with the purpose of preparing the canal for a Reforpost™ I fiberglass post (Angelus, Londrina, PR, Brazil). At this moment, visual and tactile post try-in was carried out to check for its fitting into the prepared canal.

During preparation, copious irrigation was performed with 2.5% sodium hypochlorite (Fórmula e Ação, São Paulo, SP, Brazil). Gutta-percha cones try-in was then carried out, followed by the final irrigation protocol performed by alternating NaOCl with EDTA (Fórmula e Ação, São Paulo, SP, Brazil).

After final irrigation, root canal filling was performed by means of the continuous wave vertical condensation technique with System B apparatus (SybronEndo, Orange, CA, USA). The endodontic sealer of choice was Ah Plus (Dentsply-Maillefer, Ballaigues, Switzerland). Wave One Large gutta-percha cones (Dentsply-Maillefer, Ballaigues, Switzerland) were inserted into the mesial canals. A R50 (VDW-GmbH, München, Germany) (Fig 4) cone was then placed in the distal canal with filling carried out only in the apical third of the canal (real working length minus 5mm). This was radiologically verified (Fig 5).

Subsequently, the root and crown cavities were etched with 37% phosphoric acid gel (Condac 37 FGM, Joinville, SC, Brazil) for 15 seconds (Fig 6), washed extensively with water, followed by drying. Afterwards, the adhesive system (Ambar FGM, Joinville - SC, Brazil) was applied by means of extrafine application brushes (Cavibrush FGM, Joinville - SC, Brazil) throughout all etched areas. The post was then etched with silane (Prosil, FGM, Joinville - SC, Brazil) for one minute.

Allcem Core dual resin cement was used to cement the fiberglass post (FGM, Joinville - SC, Brazil) in the canal at its correct position and length (Fig 7). The post was then light-cured for 40 seconds. It should be noted that this cement can be used to bulk fill a cavity for future indirect restoration, particularly due to its mechanical properties.

Finally, final restoration was performed with composite resin (Opallis, FGM, Joinville - SC, Brazil) (Fig 8) and a periapical radiograph of the tooth was taken (Fig 9).

The 24-month radiographic control revealed the periapical lesion was repaired (Fig 10), the patient was asymptomatic and the tooth correctly restored.

Figure 1. Diagnostic radiograph revealing significant periapical lesion.

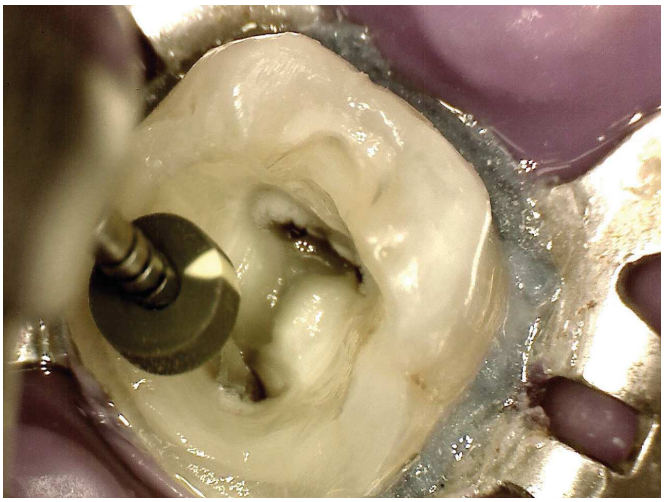

Figure 2. Wave One Large file (Dentsply-Maillefer, Ballaigues, Switzerland) performing root canal chemical-surgical preparation.

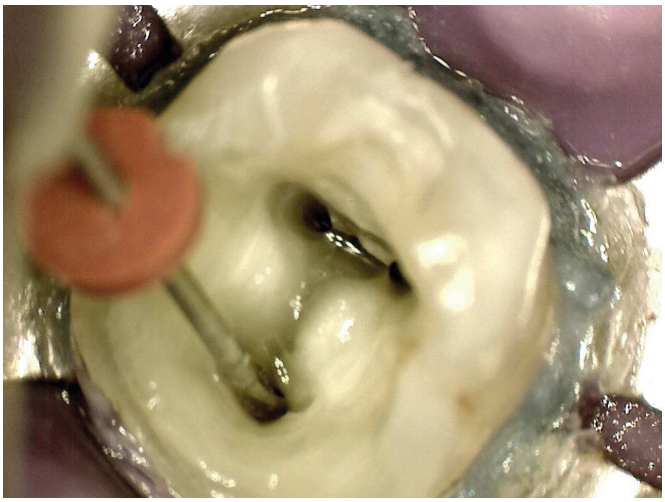

Figure 3. Gates-Glidden II bur (Dentsply-Maillefer, Ballaigues, Switzerland) performing initial root canal preparation for fiberglass post placement.

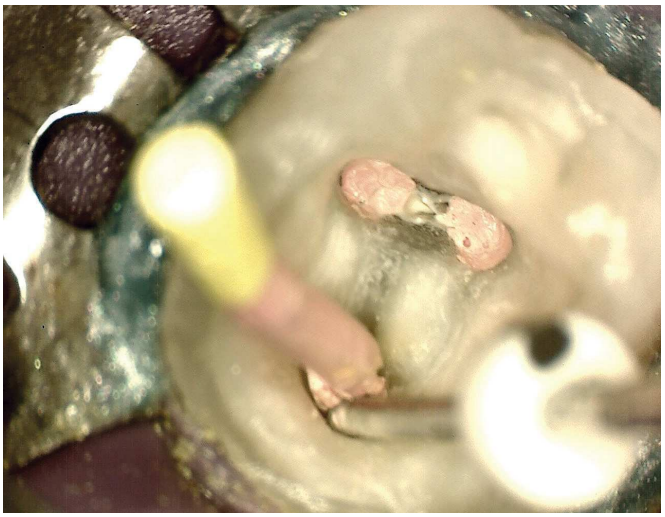

Figure 4. Schilder vertical condensation of previously heated gutta-percha.

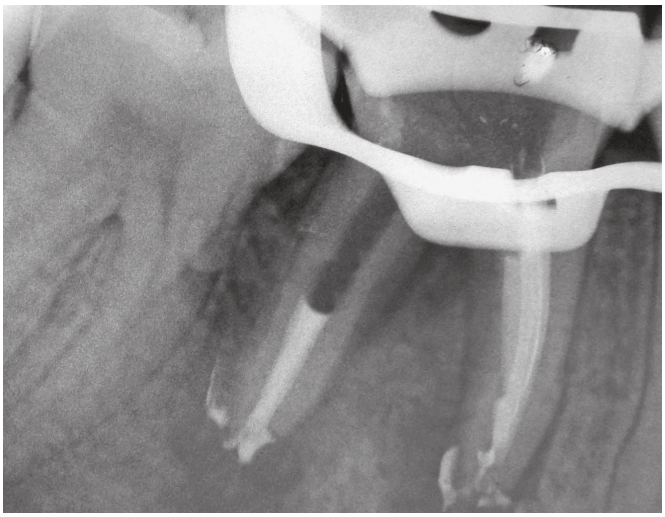

Figure 5. Radiographic examination showing root canal apical filling . Note filling only in the apical third (Real Working Length-5mm). Cervical and middle root canal thirds received intracanal fiberglass post.

Figure 6. Dentin and enamel etching with 37% phosphoric (Condac 37 FGM, Joinville – SC, Brazil).

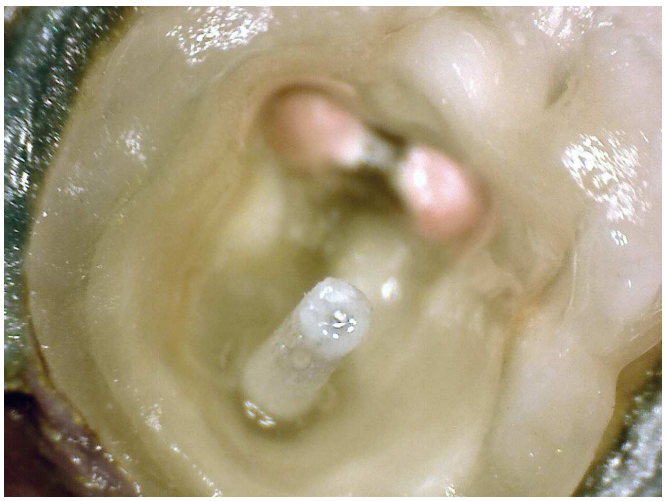

Figure 7. Note Reforpost™ I fiberglass post (Angelus, Londrina, PR, Brazil) cemented in the distal canal.

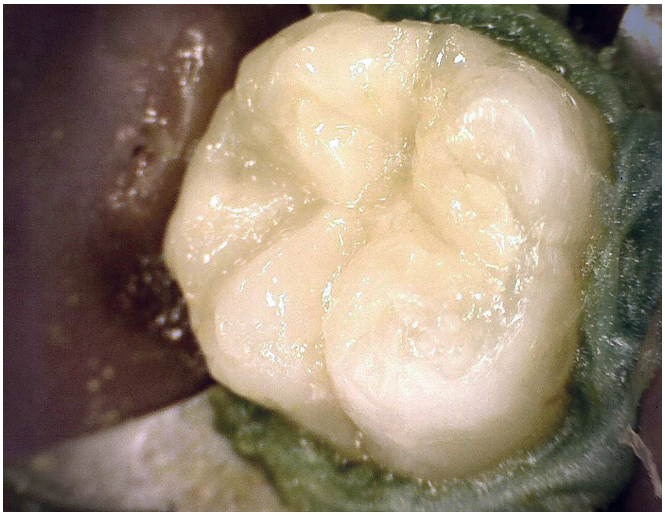

Figure 8. Final restoration in composite resin (Opallis, FGM, Joinville – SC, Brazil).

Figure 9. Final periapical radiograph. Note adequate endodontic treatment, satisfactory fiberglass post fitting and excellent sealing of final restoration material.

Figure 10. Control radiograph 24 months after treatment onset. Note periapical bone repair.

Description of clinical case 2

Male patient presented with strong throbbing pain in the maxillary first molar on the left side. Clinical examination revealed a prosthetic crown. Radiographic examination revealed a metal core , unsatisfactory endodontic treatment and apical lesion around the mesial root. The lesion characterized the diagnosis of acute apical periodontitis (Figs 1 and 2).

Considering the need for endodontic retreatment, a new intracanal post and a prosthetic crown, Simultaneous Crown-Root Shielding was planned. Before treatment onset, the fiberglass post to be placed into the palatal canal was chosen.

The prosthetic crown and the metal core were removed by wear with transmetal burs and ultrasonic tips. The operative field was then isolated with a rubber dam and gutta-percha and sealer were removed from the canals with the aid of Protaper files (Dentsply-Maillefer, Ballaigues, Switzerland).

Subsequently, chemical-surgical preparation (CSP) was carried out as follows:

- In the mesial canals, CSP was performed with Wave One large files (Dentsply-Maillefer, Ballaigues, Switzerland).

- The palatal canal was prepared with Wave One Large reciprocating files (Dentsply-Maillefer, Ballaigues, Switzerland) and R50 (VDW-GmbH, München, Germany) to the real working length, alternated with Gates-Glidden II burs (Dentsply-Maillefer , Ballaigues, Switzerland) to the working length for the post (real working length minus 5mm). POST PREP ultrasonic tips (Trinks, São Paulo, SP, Brazil) were then inserted to the real working length minus 5mm with the purpose of preparing the canal for the Reforpost™ II fiberglass post (Angelus, Londrina, PR, Brazil). At this moment, visual and tactile post try-in was carried out to check for its fitting to the prepared canal.

During preparation, copious irrigation was performed with 2.5% sodium hypochlorite (Fórmula e Ação, São Paulo, SP, Brazil). A gutta-percha cone was then carried out, followed by the final irrigation protocol performed by alternating NaOCl with EDTA (Fórmula e Ação, São Paulo, SP, Brazil).

After final irrigation, root canal filling was performed by means of the continuous wave vertical condensation technique with the System B apparatus (SybronEndo, Orange, CA, USA). The endodontic sealer of choice was Ah Plus (Dentsply-Maillefer, Ballaigues, Switzerland). Wave One Large gutta-percha cones (Dentsply-Maillefer, Ballaigues, Switzerland) were inserted into the buccal canals. A R50 (VDW-GmbH, München, Germany) cone was then placed into the palatal canal where filling was carried out only in the apical third (real working length minus 5mm) (Fig 13). Surface root dentin and excess gutta-percha were then removed with QLF-D ultrasonic tip (Trinks, São Paulo, SP, Brazil) (Fig 14).

Futurabond™ U adhesive system (Voco GmbH, Cuxhaven, Germany) was then applied by means of extra-fine Endo Tim application brushes (Voco GmbH, Cuxhaven, Germany) in all previously etched areas.

Rebilda dual resin cement was the cementing agent for the fiberglass posts (Voco GmbH, Cuxhaven, Germany). The former was agitated by EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) (Fig 15). Reforpost™ II post (Angelus, Londrina, PR, Brazil) was placed into the palatal canal, whereas accessory posts were placed into buccal canals. This complex was then light-cured for 40 seconds. It should be noted that this cement can be used to bulk fill a cavity for future indirect restoration, particularly due to its mechanical properties (Fig 16).

Afterwards, crown build-up was carried out with composite resin (GrandioSO, Voco GmbH, Cuxhaven, Germany) (Figs 17 and 18). This was followed by manufacturing of a temporary crown and patient's referral to a prosthodontist.

Radiographic control 36 months later revealed the periapical lesion was repaired (Fig 20), the patient was asymptomatic, and the tooth was rehabilitated with a prosthetic crown.

Figure 11. Clinical photograph showing the presence of a prosthetic crown on maxillary first molar.

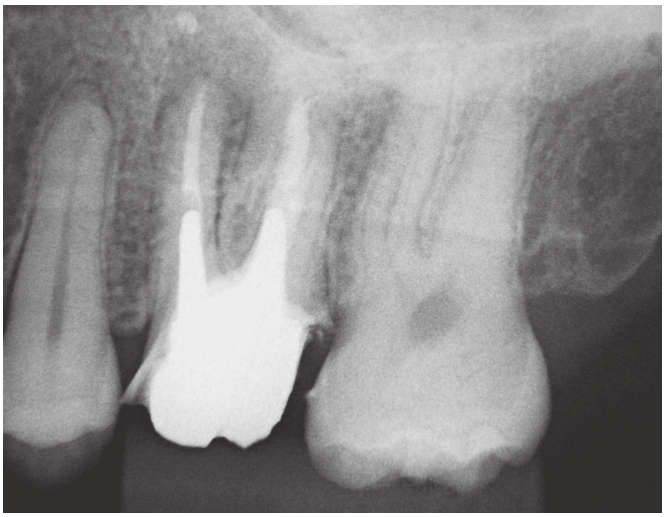

Figure 12. Diagnostic radiograph showing significant periapical lesion in the mesial root.

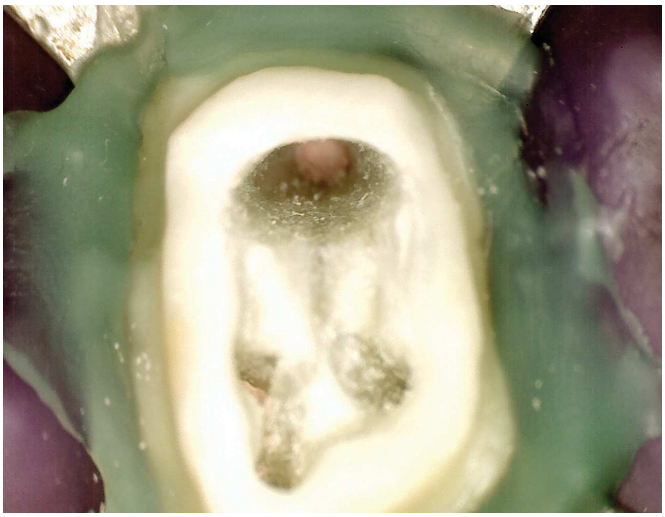

Figure 13. Clinical photograph showing apical filling of the palatal canal. Note filling only in the apical third (Real Working Length-5mm). Cervical and middle root canal thirds received intracanal fiberglass post.

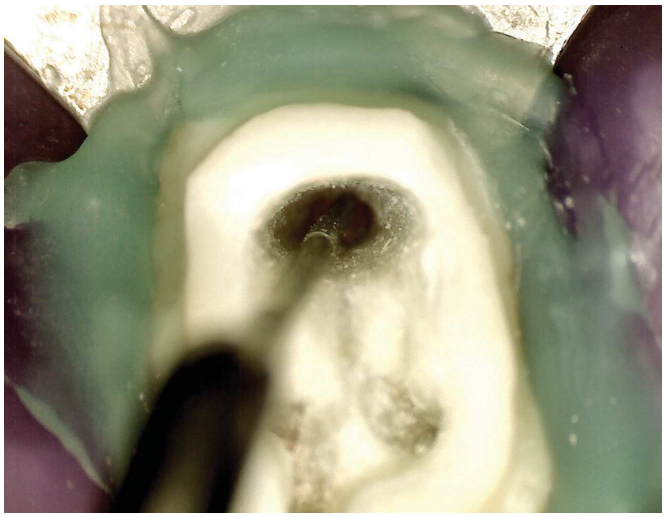

Figure 14. Dentin qualification carried out by QLF-D ultrasonic tip (Trinks, São paulo, SP, Brazil) with the objective of removing degraded dentin and excess gutta-percha from the palatal canal, thereby favoring adhesion.

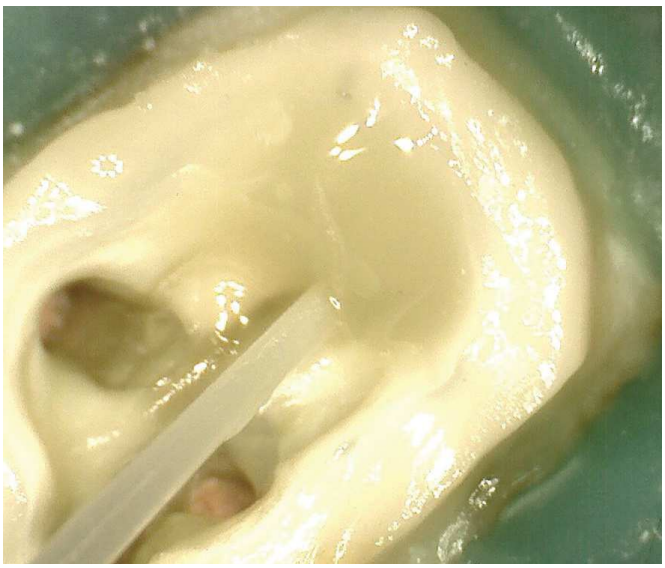

Figure 15. Sonic activation of resin cement with the aid of EndoActivator apparatus (Dentsply Tulsa Dental Specialities, Tulsa, OK, USA).

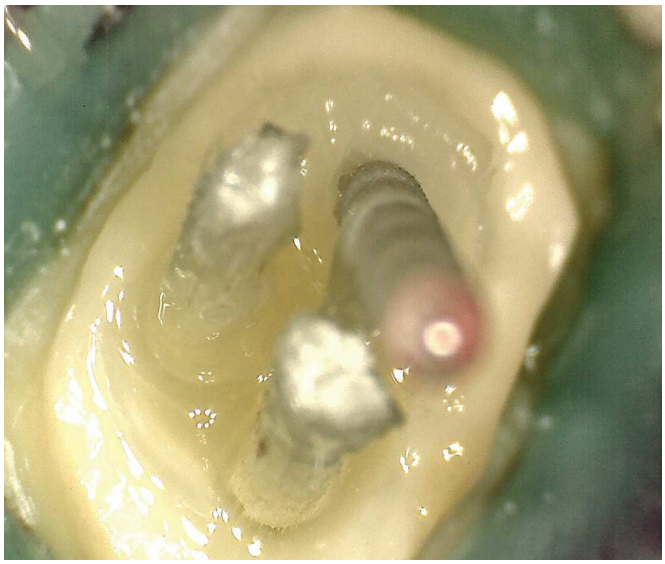

Figure 16. Cementation of Reforpost™ II fiberglass post (Angelus, Londrina, PR, Brazil) in the palatal canal and accessory posts in the buccal canals.

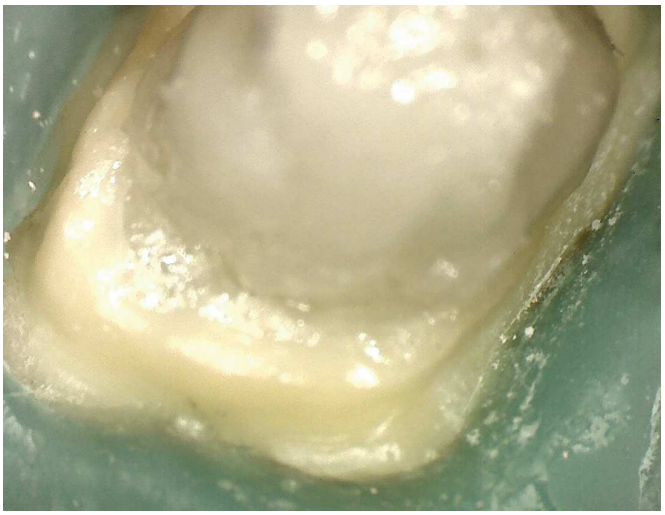

Figure 17. Manufacturing of composite resin core build-up (GrandioSO, Voco GmbH, Cuxhaven, Germany) which would function as the basis for a future prosthetic crown.

Figure 18. Removal of rubber dam isolation and referral to rehabilitation.

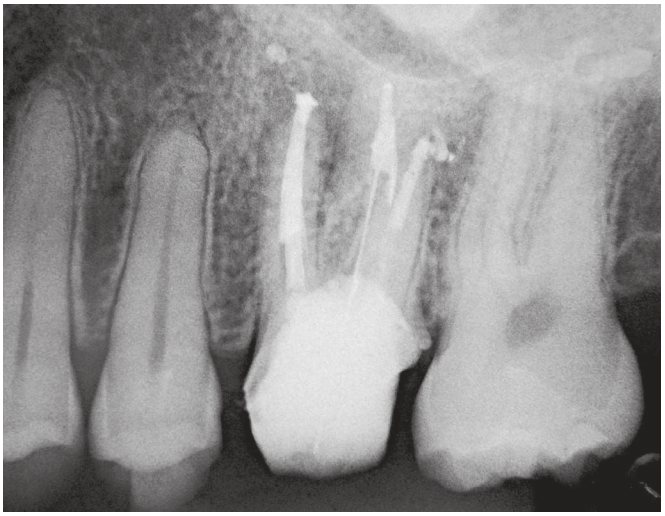

Figure 19. Final periapical radiograph. Note adequate endodontic treatment, satisfactory fiberglass post fitting and excellent crown sealing.

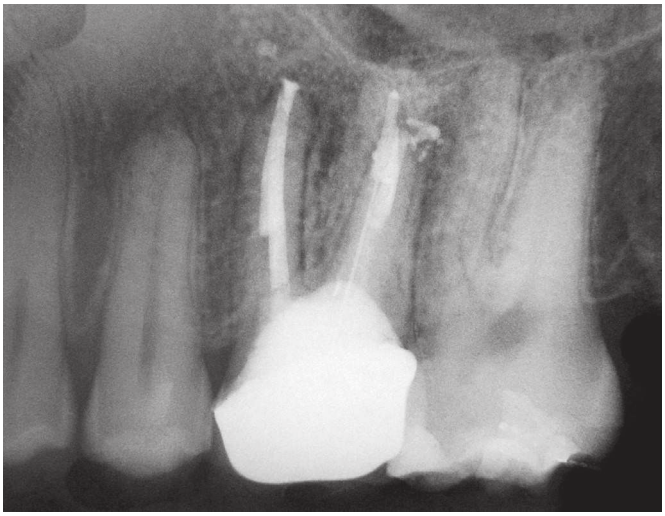

Figure 20. Control radiograph 36 months after treatment onset. Note periapical bone repair.

Discussion

The literature has described that endodontically treated teeth deserve special care during restoration. A pulpless tooth becomes weak due to biomechanical alterations. This is because the tooth underwent modification to its architecture and morphology, therefore becoming more fragile due to loss of dental structure caused by caries, fractures, cavity preparation, as well as access and excessive instrumentation of the root canal.[13] Guidelines for restoration of endodontically treated teeth are sometimes controversial. There are some criteria to consider for recommendation of certain restorative or prosthetic procedures. However, there are no studies that provide well-defined criteria for all cases, due to the wide variety of cases and situations to which teeth are subjected.[14] Based on scientific evidence, this lack of consensus on the proposed recommendations often limits clinicians to decide on one or other option.

The cast metal cores combined with prosthetic crowns are undoubtedly the most traditional solution for the process of restoring endodontically treated teeth. However, these cores have the disadvantage of being silver in color. Another factor is that the number of sessions required to manufacture them is higher when compared to the time spent with a prefabricated post. In the cases described herein, the importance of an applicable technique in the contemporary context is displayed as being a viable option in immediate rehabilitation of endodontically treated teeth. This technique is executed in a minimally invasive way, combining fiberglass posts with direct restorations in composite resin. This association represents an excellent alternative, mainly due to good mechanical and aesthetic properties of fiberglass posts and composite resins currently available.[15]

Crown microleakage can allow bacterial penetration into the root canal.[16] These bacteria can initiate and maintain an inflammatory process of periapical tissues, also known as apical periodontitis. Therefore, without adequate sealing, long-term success of endodontic treatment remains questionable.[17,18] In addition, crown fracture and consequent bacterial infiltration of root canals is another factor that may lead to failure.[19,20] Ng et al[21] conducted a meta-analysis and showed that success rates relative to teeth that presented satisfactory restorations are higher than those of teeth that had poor-quality restorations

Intracanal fiberglass posts are widely used for the restoration of endodontically treated teeth when there is insufficient tooth structure to retain a definitive restoration.[22] They have become more popular for producing satisfactory aesthetic results due to their advantageous optical properties in comparison to metallic systems.[23] Fiberglass posts exhibit elasticity similar to that of dentin, and as such protect the remaining root by absorbing stress produced by masticatory force, as they form a mechanically homogeneous unit.[24] It is worth mentioning that the direct use of those posts eliminates laboratory steps. According to Assif et al,[25] molten metal cores do not meet the needs of pulpless teeth, since they are made with metals with high elasticity and can therefore induce a high rate of root fracture. It is known that endodontic posts do not increase resistance of the remaining dental structure of endodontically treated teeth.[26] On the contrary, depending on the post design, they can weaken the root in relation to the amount of dentin removed during preparation. Tapered posts have a configuration that is compatible with tapered preparation of the root canal after instrumentation and, thus, provide optimal preservation of the tooth root structure, especially in the apical region.

Without a doubt, one of the current objectives of endodontic treatment is the preservation of root dentin and fitting of the post into the root canal, regardless of root anatomy. This article shows a planned instrumentation technique for placement of a future intracanal post. The alternating use of the POST PREP ultrasonic tip, inserted during instrumentation of the root canal, aims to prepare the canal where the post will be cemented. The use of the QLF-D tip allows dentin qualification, which consists of removal of surface root dentin, excessive gutta-percha seen in the canal, and irregularities. One should note that the use of resin cements for cementing fiberglass posts requires dentin walls to be prepared for the formation of a hybrid layer, which favors the bonding mechanism of the adhesive system to the root walls.[27,28]

It should be highlighted that, in this context, the greatest advantage of the endodontist performing intracanal restorative procedures is that this expert is familiar with the root canal system and can perform preparation for posts based on the root anatomy of each case under absolute isolation.

This avoids contamination of the root canal by saliva. On the other hand, absolute isolation eliminates humidity and fluids from the oral cavity, which can hinder adhesion.[29]

At the interface between fiberglass post and the morphological restoration of the treated tooth, a composite resin filling core would be created with a view to reconstructing dental structure that had been lost. Additionally, intracanal posts would be combined with the aforementioned elements. This reconstruction is important not only in order to provide support and retention for direct or indirect restorative material, but also in the distribution of stress, which would be more homogeneous throughout the remaining tooth. Several types of material have been found to be effective in the construction of fill cores, such as amalgam, composite resin or glass ionomer cement, which have been widely described in literature.[10] With the evolution of optical and mechanical characteristics of composite resins, there is greater predictability of outcomes relative to restorations of endodontically treated teeth. In the first clinical case, the use of composite resin combined with the intracanal posts allowed function and aesthetics to be restored, as they had been lost by the presence of caries, with minimum wear of tooth structure. In the second clinical case, it allowed the creation of a filling core for a future prosthetic crown. In addition, it should be noted that, in clinical case one, the restorative complex could eventually function as a core build-up for the creation of a unitary crown, according to the restorative needs of the patient.

In both cases overflow of endodontic sealer in the periapical region was radiographically evident. It should be considered that overflow of endodontic sealer in this region, regardless of its composition, causes irritation to periapical tissues, and may lead to larger inflammation or promote significant tissue in this area. Bearing this in mind, overflow can impair endodontic treatment and, as a consequence, the repair capacity of the periapical region could suffer significant interference.[30] During radiographic control of both cases, endodontic sealer resorption and repair of the apical region was observed. In light of this, it is evident that overflow did not affect the successful outcomes of the treatment.

A large number of scientific and clinical articles have been published discussing the benefits of fiberglass posts and adhesive material. The disclosure of clinical cases that describe techniques and that demonstrate longevity of results is of paramount importance for the credibility and safety of clinicians who will use those systems.

Conclusion

It is concluded that the preparation technique presented in conjunction with current restorative material and good endodontic and restorative planning allow adequate tooth restoration simultaneously with endodontic treatment. Endodontic standpoint regarding both root and crown preparation and restoration, whenever possible, can be considered as an approach for the rehabilitation of endodontically treated teeth.

References

1. Sedgley CM, Messer HH. Are endodontically treated teeth more brittle? J Endod. 1992 July;18(7):332-5.
2. Valdivia JE, Flores HC, Machado MEL. Conceito de blindagem corono radicular: instalação de pinos diretos como retentores de restauração extensa. FGM News. 2016;18:33-5.
3. Perel ML, Muroff FI. Clinical criteria for posts and cores. J Prosthet Dent. 1972 Oct;28(4):405-11.
4. Meyenberg K. The ideal restoration of endodontically treated teeth - structural and esthetic considerations: a review of the literature and clinical guidelines for the restorative clinician. Eur J Esthet Dent. 2013 Summer;8(2):238-68.
5. Baba NZ, Goodacre CJ, Daher T. Restoration of endodontically treated teeth: the seven keys to success. Gen Dent. 2009 Nov-Dec;57(6):596-603.
6. Assif D, Gorfil C. Biomechanical considerations in restoring endodontically treated teeth. J Prosthet Dent. 1994 June;71(6):565-7.
7. Soares CJ, Valdivia AD, Silva GR, Santana FR, Menezes MS. Longitudinal clinical evaluation of post systems: a literature review. Braz Dent J. 2012;23(2):135-140.
8. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J. 1995 Jan;28(1):12-8.
9. Santos-Filho PC, Veríssimo C, Raposo LH, Noritomi MecEng PY, Marcondes Martins LR. Influence of ferrule, post system, and length on stress distribution of weakened root-filled teeth. J Endod. 2014 Nov;40(11):1874-8.
10. Engelman MJ. Core Materials. J Calif Dent Assoc. 1988 Nov;16(11):41-5.
11. Kapoor N, Bahuguna N, Anand S. Influence of composite insertion technique on gap formation. J Conserv Dent. 2016 Jan-Feb;19(1):77-81.
12. Albuquerque RC. Estudo da resistência à fratura de dentes reconstruídos com núcleos de preenchimento. Efeito de materiais e pinos. Rev Odontol UNESP. 1996;25(2):193-205.
13. Figueiredo FE, Martins-Filho PR, 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 Mar;41(3):309-16.
14. Valdivia JE, Pires MMP, Beltran HS, Machado MEL. Importance of ultrasound use in endodontic access of teeth with pulp calcification. Dental Press Endod. 2015 May-Aug;5(2):67-73.
15. Shillingburg HT Jr, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Fundamentos de Prótese Fixa. 3a ed. São Paulo: Quintessence; 1998. p. 149-82.
16. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. J Endod. 1987 Feb;13(2):56-9.
17. Madison S, Swanson K, Chiles SA. An evaluation of coronal microleakage in endodontically treated teeth. Part II. Sealer types. J Endod. 1987 Mar;13(3):109-12.
18. Saunders WP, Saunders EM. Coronal leakage as a cause of failure in root-canal therapy: a review. Endod Dent Traumatol. 1994 June;10(3):105-8.
19. Bayram HM, Çelikten B, Bayram E, Bozkurt A. Fluid flow evaluation of coronal microleakage intraorifice barrier materials in endodontically treated teeth. Eur J Dent. 2013 July-Sept;7(3):359-62.
20. Tabassum S, Khan FR. Failure of endodontic treatment: the usual suspects. Eur J Dent. 2016 Jan-Mar;10(1):144-7.
21. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature -- Part 2. Influence of clinical factors. Int Endod J. 2008 Jan;41(1):6-31.
22. Ferrari M, Vichi A, García-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. Am J Dent. 2000 May;13(Spec No):15B-18B.
23. Morgano SM. Restoration of pulpless teeth: application of traditional principles in present and future contexts. J Prosthet Dent. 1996 Apr;75(4):375-80.
24. Asmussen E, Peutzfeldt A, Sahafi A. Finite element analysis of stresses in endodontically treated, dowel-restored teeth. J Prosthet Dent. 2005 Oct;94(4):321-9.
25. Assif D, Oren E, Marshak BL, Aviv I. Photoelastic analysis of stress transfer by endodontically treated teeth to the supporting structure using different restorative techniques. J Prosthet Dent. 1989 May;61(5):535-43.
26. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. J Endod. 2004 May;30(5):289-301.
27. Bowen RL, Eick JD, Henderson DA, Anderson DW. Smear layer: removal and bonding considerations. Oper Dent Suppl. 1984;3:30-4.
28. Martinho FC, Carvalho CA, Oliveira LD, Lacerda AJ, Xavier AC, Augusto MG, et al. Comparison of different dentin pretreatment protocols on the bond strength of glass fiber post using self-etching adhesive. J Endod. 2015 Jan;41(1):83-7.
29. Goldfein J, Speirs C, Finkelman M, Amato R. Rubber dam use during post placement influences the success of root canal-treated teeth. J Endod. 2013 Dec;39(12):1481-4.
30. Mittal M, Chandra S, Chandra S. Comparative tissue toxicity evaluation of four endodontic sealers. J Endod. 1995 Dec;21(12):622-4.