Literrature Review

Restoration of flared incisor roots: a case report with 16 years of follow-up and review of literature

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Abstract

The deteriorated anterior tooth is always a challenge for dentists to ideally restore to proper form and function for long-term usage. Sometimes, compromised treatment of a flared root is indicated to avoid its extraction and to prolong the use of the tooth in function until the final treatment plan can be done. This paper aims to provide an alternative proposal for restorative treatment of compromised anterior teeth with a flared root, which is presenting itself as a suitable alternative to conventional cast metal post-and-cores with 16 years of long-term follow-up. Considerations regarding the restoration of flared incisor roots were also addressed based on the review of published references.

Key words: flared root, endodontically treated tooth, root canal therapy, fiber post, dental adhesive

Introduction

Patients who have suffered from large carious lesions or trauma to a front tooth during childhood and adolescence always end up having weakened roots with large canal space and poor remaining structure to ensure an adequate ferrule for the crown restoration[1-3]. Further, the tooth with a widely flared root canal and thin residual dentin wall makes the restoration more difficult, which can imply a poor prognosis for the restored tooth regarding its' long-term functionality[4,5].

In general, these teeth with poor restorability are considered and evaluated for removal and a more predictable prognosis like a fixed or removeable prosthesis is recommended for adult patients. However, in childhood and adolescent age patients, the treatment for these flared roots becomes more complicated and challenging. When teeth with flared roots are removed, some possible treatment options are offered to the young patients by the clinicians. For example, a dental flipper or a removable partial denture can be used to replace the missing tooth to meet the minimum esthetics and functions, which is an easy and economical way. However, the removable appliance is uncomfortable and should be relined or replaced occasionally following the patient's growth.

A 3-unit bridge could be another option, which is more comfortable for patients and provides certain functions in terms of esthetics and functions. Since the pulp tissue is relatively large in young patients, a provisional bridge with under preparation of adjacent teeth is usually recommended to reduce the risk of pulp damage of the abutment teeth. Another alternative is, instead of a gross reduction for abutments, using an adhesive bridge to restore missing teeth with minimum tooth preparations. From the pro side, the minimum preparation ensures pulp vitality of abutment teeth. While on the con side, adhesive bridges are considered as semi-permanent restorations, and bridge loosening with secondary decay is not uncommon. Further, the clinical crown is relatively short in young patients, which could therefore hinder bridge retention and/or hygiene maintenance. Moreover, in recent years the patient's perceptions may change and lead to a greater demand for preservation of sound abutment tooth structure, which makes the treatment of flared roots more challenging.

Most of the time, an implant restoration is not an option for young patient, as early implant placement can stunt the growth of the surrounding teeth and jawbones, which could result in serious issues down the line. Therefore, the development of the patient should be carefully evaluated before any implant can be inserted, regardless of the general guidelines which suggest that female teenagers must be at least 15 years of age and male teenagers must be at least 17 years of age to receive dental implants[6,7]. To complement the implant replacement for the weakened tooth till the completeness of jawbone growth, how to restore the compromised flared root of anterior tooth becomes an important issue. Thus, this case report aims to propose an option for the treatment of an upper anterior weakened tooth using fiber posts with composite crown restorations, to discuss the important clinical steps involved in the success of this protocol, to report a case with 16 years of long-term follow-up, and to address the considerations in the treatment of flared anterior tooth.

Case report

The 11-year-old male student presented with a chief complaint of an ill-fitting Nance appliance in the mouth, which was inserted by his orthodontist 2 years ago in order to serve as a space maintainer to prevent upper molars from drifting forward (Fig. 1A). Clinical examination revealed that besides the presence of the appliance, upper right central incisor (tooth 11 in the FDI numbering system) was previously prepared and restored with a denture tooth. Apical radiograph showed that 11 had a previous root canal treatment, but the quality of root filling was quite poor, and a periapical radiolucency was noted (Fig. 1B). The denture tooth of 11 was utilized and assumed to protect the fractured tooth which might be caused by a traumatic injury when the patient was 9 years old.

The mission of the Nance appliance was considered accomplished as all the teeth in front of the first molars were in a good position, therefore the appliance was detached. The provisional crown of 11 was removed and the tooth was thoroughly evaluated. The tooth was sensitive to palpation and percussion but probing depths were within normal limits. The remaining clinical crown height was less than 2 mm at the labial side (Fig. 1C). While at the palatal side, marginal caries underneath the provisional crown was noted, and no coronal dentin existed (Fig. 2A). After removal of the carious dentin, the tooth ended up with a flared canal with a rather thin dentin wall surrounding it. The restorability of the tooth with conventional treatment for endodontically treated tooth was questioned since the remaining structure could not provide sufficient ferrule to protect the tooth.

The three-unit bridge or implant crown to replace 11 was also not suggested, because pulp size in the adjacent abutments was large, the patient was young, and the jawbone was still growing. Further, the patient preferred keeping the adjacent teeth intact, therefore the semi-permanent adhesive bridge was not acceptable. The treatment plan of using a removable partial denture to replace 11 was considered but not approved. Because the patient felt wearing a removable flipper was uncomfortable and inconvenient. Moreover, the edentulous ridge resorption under denture might complicate the consequent implant treatment, if the removal of the root is too early before jawbones are well developed for implant therapy. To keep the tooth in function as long as possible and to avoid early extraction of the tooth, the patient accepted the treatment plan of directly restoring the weakened tooth with fiber posts and composite crown restoration.

The tooth 11 was endodontically retreated under a modified rubber dam technique to isolate the operative field. At the follow-up appointment two weeks later, it was noted that the tooth sensitivity to palpation and percussion was remitted (Fig. 2B). During the following visit, No. 4 Gates-

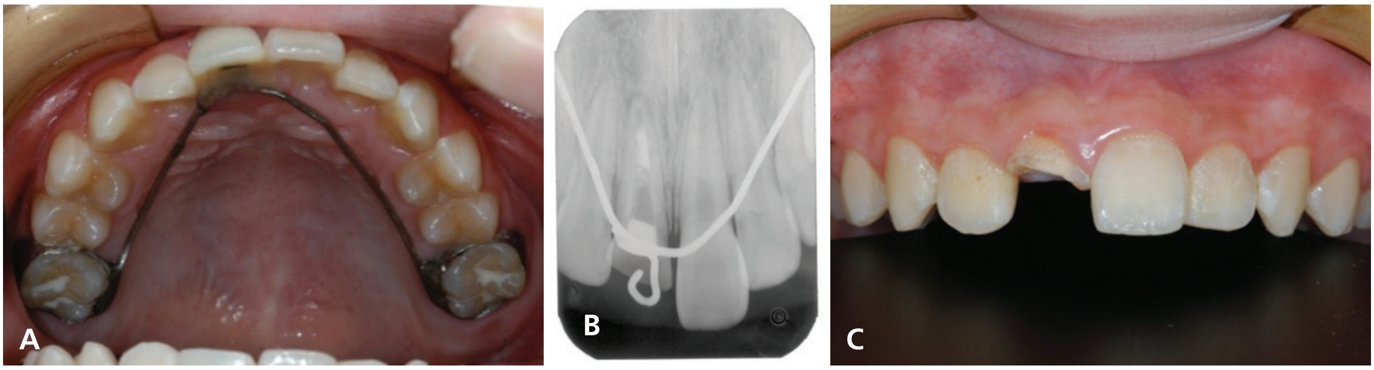

Figure 1. Initial visit.
(a) Nance appliance in the mouth.
(b) Radiograph showing apical rarefaction.
(c) short remaining tooth after crown removal.

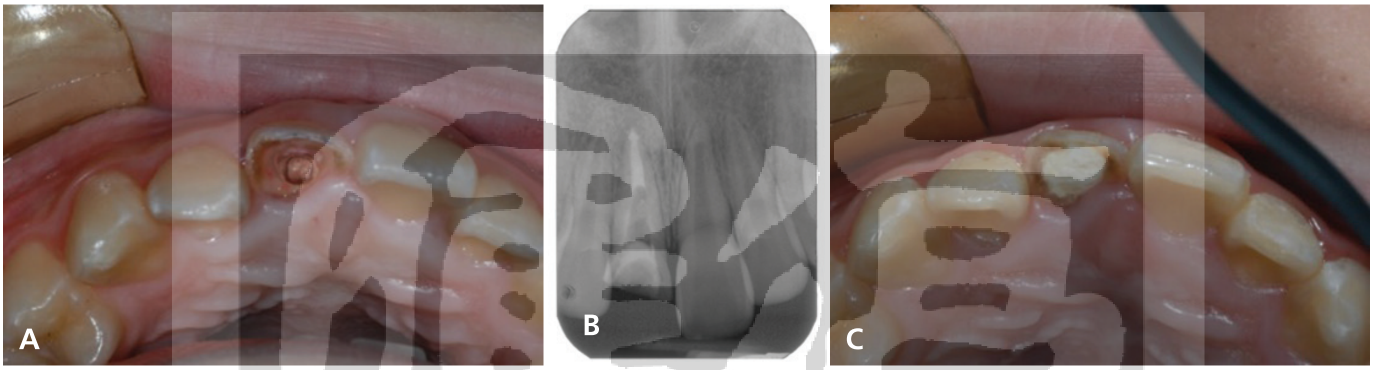

Figure 2. Endodontic retreatment.
(a) Large pulp chamber after instrumentation.
(b) Radiograph showing flared root canal.
(c) Thin dentin walls with poor ferrule.

Glidden drills (Maillefer, Ballaigues, Switzerland) were used for gutta-percha (GP) removal of the root canal until 5 mm of GP was left, then a series of fiber posts were checked for adaptation inside the root canal. Due to a mismatch between the post and the flared root canal space, modification of post fabrication was indicated. For this purpose, the number and sequence of fiber posts try-in was carefully evaluated.

Thereafter, the deep margin elevation protocol was conducted to isolate the subgingival palatal margin[8-10], followed by immediate dentin sealing and coronal elevation of the deep margin to a supragingival position using a direct bonded composite resin base. A curved Tofflemire matrix was modified by reducing matrix height to 2-3 mm at the palatal side for better matrix adaptation. Since the narrowed matrix will allow itself to slide into the subgingival sulcus easier and seal the margin more efficiently. The ideal matrix height was further adjusted to slightly higher than the desired elevation for better visibility of the subgingival margin. Prior to bonding, a Teflon strip was rolled and placed to improve deep isolation and reveal the true limits of the cavity, the margin was gently re-prepared using a fine diamond bur on a low-speed electric handpiece. The canal wall was also retouched since the freshly cut dentin is ideal for bonding. Following the manufacturer's instruction, the root canal and remaining dentin was conditioned, primed and bonded using the Optibond FL adhesive system (Kerr, Orange, CA, USA) in the presence of the matrix. Then, a flowable composite (Filtek Supreme XT, 3M ESPE, St. Paul, MN) was placed to get a better adaptation of margin, following by Z100 composite (3M ESPE) to build up a palatal wall for elevating the margin supragingivally.

Three fiber posts (RelyX size 1 tapered post, 3M ESPE) were placed into the flared root canal, to obtain better support for composite crown restoration (Figs. 3A & 3B). The lengths of fiber posts were reduced to allow at least 1 mm veneer space for the composite resin. The posts were cemented into the canal with a dual-cured resin cement (Nexus 2, Kerr) in apical third, and light-cured for 20 s. The remaining canal space was filled with flowable resin (Filtek Supreme XT),

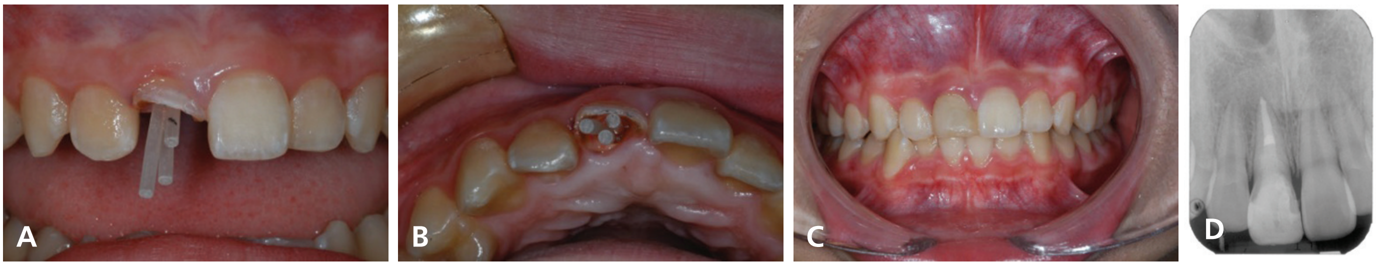

Figure 3. Post insertion and composite crown resonation.
(a) Try-in of three fiber posts.
(b) Occlusal view showing post position deep palatal wall.
(c) Crown build-up with composite resin.
(d) Radiograph showing smooth proximal walls.

Figure 4. Six years of follow-up.
(a) Generalized gingivitis with labial external stain of 11.
(b) Radiograph showing normal healthy apical tissue.
(c) One week after full mouth scaling and resin repair of 11.
(d) Close-up view of 11 after resin repair.

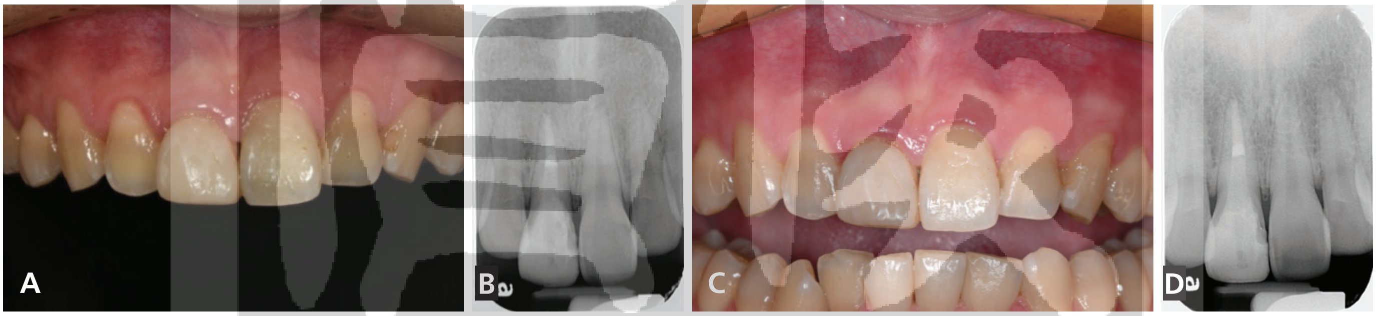

Figure 5. Twelve and sixteen years of follow-ups.
(a) Twelve years of follow-up of 11.
(b) Radiograph showing normal healthy apical tissue and alveolar bone.
(c) Sixteen years of follow-up of 11.
(d) Radiograph showing normal healthy apical tissue and alveolar bone.

and the crown portion was finished directly with regular composite (Z-100) incrementally. After completeness of crown build-up, a sharp explorer and interdental flossing were used to check for the absence of overhangs and flash (Fig. 3C). Further, an apical radiograph was taken to ensure that no excesses or gaps were present (Fig. 3D). Static and dynamic occlusions were checked to confirm that 11 was not subjected to occlusal force alone. At the end of the visit, the importance of avoiding biting on hard foods with this tooth and keeping good oral hygiene were addressed.

The tooth was functional and esthetically accepted by the patient, and had been scheduled for regular follow-up every year. At 6 years of follow-up, the young male student presented with a dark, unpleasant stain at 11 labial surface and generalized gingivitis, which could be due his neglecting dental hygiene when he was under heavy pressure from his schoolwork (Fig. 4A). Luckily, the apical film of 11 showed smooth proximal contours with normal apical tissue and periodontal bone profile (Fig. 4B). The patient received full-mouth ultrasonic scaling with intensive oral hygiene instruction, and 1 week later he had a composite resin replacement on 11 labial surface (Figs. 4C & 4D). From then to now, the 16 years of follow-up, the tooth 11 was still functional and maintainable. Radiographic evaluation did not reveal any periapical and periodontal changes. The patient was satisfied with the treatment outcome, and had plenty of time to decide when and what types of restoration he wishes to use to replace the weakened tooth.

Discussion

The longevity of the presented flared tooth was beyond common expectations. During the 16 years of follow-up, the preservation of alveolar bone around the tooth had achieved the intended goal, and the tooth was still in function. The success of the treatment could be due to delicate procedures in restoring the tooth and regular follow-up for comprehensive maintenance. The regular maintenances focused on oral hygiene, soft tissue condition, initial or secondary caries, marginal integrity and especially occlusal prematurity. Usually, a follow-up apical radiograph is a routine to evaluate periodontal and periapical conditions. In restoring a flared incisor root, several concepts and related skills should be addressed, including preserving tooth structure, deep margin elevation, post selection and modification, adhesive approaches, and guided occlusion.

Decision making for a flared root

Treatment of an endodontically involved anterior tooth is really challenging for schoolchildren and their parents. In spite of a large pulp chamber, caries and trauma usually result in substantial loss of coronal tooth structure, which needs a post and core to retain the artificial crown. However, most of the time the remaining tooth structure is too weak to provide a good ferrule in these young patients. Although orthodontic extrusion and surgical crown lengthening procedures could be considered to partially solve the problems, the treatments cost time and money, and cause discomfort to patients. Further, it may compromise the crown and root ratio and result in unfavorable esthetic outcomes. What makes the matter worse is that these teeth usually combined with a flared root having rather thin dentin walls around the canal just like the presented case. Basically, the optimal treatment for the flared incisor root is to remove the weakened root and install an implant for the adult patient. However, implant treatment for growing children is contraindicated[11]. Therefore, the best treatment for this patient was to provide a provisional crown which is functional and esthetically acceptable, and more importantly, it should not only maintain the alveolar bone height but also not impede subsequent bone growth.

Preserving tooth structure

There is a consensus that the remaining tooth structure plays an important role in the survival of endodontically treated teeth[3,12]. Therefore, caries should be removed carefully, and remaining sound tooth structure should be kept as much as possible. Most of the time, healthy dentin and enamel are carelessly removed by air-driven turbines at high speed during caries removal. However, for the flared root remaining sound tooth structure is so precious that a high-torque electric handpiece at low speed is requested for precise caries removal. Because electric handpiece at low speed can provide a better tactile sensation in caries removal, which shall maximize preservation and conservation of remaining tooth structure.

Deep margin elevation

Subgingival margins were encountered at proximal and palatal surfaces of the case, which complicated the use of direct or indirect adhesive restorations. Because such cases cause significant challenges during isolation of the operatory field for adhesive bonding, impression taking, and adhesive luting. When these procedures are not properly executed, it can and may generate marginal leakage and thus affect the longevity of the restoration and the periodontal tissues. Clinically, there are two common approaches to handle deep subgingival caries[8]. One is Crown Lengthening procedure which relocates gingival margins apically by surgically removing supporting tissue and recreating the space necessary for deep restoration without violating biologic width. The other approach was suggested by Dietschi and Spreafico[10] for deep caries by relocating the restoration margin coronally, instead of relocating gingival margin apically by crown lengthening procedure. This procedure was named as deep margin elevation (DME) by Magne and Spreafico[9], which is based on the ability to get proper isolation after carious tissue removal, immediate dentin sealing (IDS)[13-15], and the bonding of several layers of composite onto the deep margin to create a new, more coronal restoration margin. In addition, a well-adapted matrix is indicated for building-up the subgingival restoration with an adequate emergence profile[9]. Thereafter, the indirect restoration can be prepared and cemented on top of the elevated margin.

According to previous references, DME was considered a feasible noninvasive alternative to crown lengthening, which also facilitate the placement of large direct composite resin restorations. To reduce polymerization shrinkage stresses, incremental filling technique and compensatory techniques are commonly suggested. The later includes building up large restoration with various composite layering systems, incorporation of a composite resin or ceramic insert, or application of a glass-ionomer base, to minimize the stresses developed in adhesive interfaces. Frankly, the marginal seal is the prerequisite for DME[8-10]. Another concern is the long-term biocompatibility of restorative resin. Information on the gingival reaction to subgingival restoration is very controversial[16-18]. Some studies have shown a higher plaque index around composites compared to a healthy enamel surface, while others showed no significant differences in term of plaque accumulation and gingivitis. In general, resin materials seem to be tolerable subgingivally, if the restoration is carefully finished and polished, and plaque control is well taken of[18-20]. However, the presented patient did not take great care of his oral hygiene and it lead to gingivitis frequently but did not violate periodontal attachment, which might be inferred that gingival response to biofilm may vary between individuals[18,20].

Fiber post modification

Because of the improved physical properties and adhesion to root canal dentin, composite resin materials alone have been used for posts and cores if the teeth have a great amount of remaining tooth structure[3]. However, for teeth with a flared root and a weakened coronal structure, studies had shown that the post and core that were exclusively restored through the resin composite lacked sufficient strength[21-23]. For many years, cast metal posts and cores were regarded as the main option for the rehabilitation of endodontically treated teeth with flared roots. Because these customized metal posts provide a good fit to the canal wall, thus providing high retention with a thin cement layer[24]. However, because of the high elastic modulus and stiffness in comparison to tooth, metal posts potentially lead to catastrophic root fracture[25-27]. Furthermore, the wedging force from cast posts and cores would impose serious impacts on the weakened coronal portion. The risk is even higher for the flared root, since it has a stronger post and a weaker root having limited remaining dentin[28]. Considering stress distribution and incidence of catastrophic root fracture, fiber posts with a similar elastic modulus to dentin are highly recommended. Further, fiber posts could provide better optical translucency feature by the combined use of a resin core. However, the mismatch of the prefabricated fiber posts and flared root canals should be carefully justified. Merely luting fiber post with resin cement is not suggested, the strength of the cement can be questioned, moreover, the excessively thick cement favoring polymerization shrinkage and formation of bubbles which could thus weaken the restoration[4,29,30].

Up to date, several ways to fill the voids between the prefabricated fiber post and the flared root canal can be approached. Some authors suggested to reline the fiber post with composite resin to create an individual anatomic post, and/or fill in with accessory glass fiber posts to reduce the amount of cement[2,21,31-33]. However, Kubo et al[21] found that the use of a prefabricated glass fiber post in the center of the post space was ineffective in strengthening the composite resin post and core, while the use of glass fiber ribbon outside of the post space could provide stronger strength[21]. The elastic behavior of fiber posts is considered to benefit the stress distribution, however, too much flexibility could also generate higher cyclic bending during function, which could induce micro-gaps in crown/post/root interfaces. The similar finding of strengthening fiber posts was reported, where a fiber sleeve was used[34]. In this case, accessary fiber posts instead of fiber ribbon or sleeve were used for the reinforcement of the composite resin post and core.

Adhesive approaches

Fiber posts reinforced with ribbon, sleeve, or accessary posts could be done by relining with composite resin to form anatomical posts easily. Although the anatomical customization of the fiber post showed a more uniform cement layer[24], the customization procedure included the application of a water-soluble gel into the root canal to serve as a separating agent during relining, which could impede adhesive bonding if the gel was not completely removed. Further, root canal walls sometimes are over-prepared to remove undercuts to facilitate the relining procedure, which not only weakens the tooth structure but also reduces the bonding potential.

It is crucial to get good and lasting bonding between the dentin, posts, and composite. During the cementation of fiber post, the compatibility between the luting agent and the adhesive system is important. In our case, the three-step Optibond FL adhesive was applied into a freshly-prepared root canal and coronal dentin, then light-cured to create optimal bonding. Based on the IDS concept, three fiber posts were cemented by the dual-cured cement at apical third, then glued together by injecting a light-cured flowable composite resin into the root canal directly. The light-cured resin system has a higher degree of conversion, comparing to the dual-cured system if light irradiation is sufficient. It is agreed that a polymer with a higher degree of conversion shall benefit the physical property and biocompatibility. Accordingly, flowable resins with good translucency are suggested. However, in this procedure, some issues need to be justified that injecting resin should not induce voids into the canal, and the thickness of light-cured flowable resin should keep within its curing depth suggested by the manufacturer[21].

Areas that need improvement

The treatment procedures of the presented case can be more efficient if the caries removal could be operated under a microscope or with adjunctive caries staining solution to keep sound tooth structure as much as possible. Further, an indirect resin veneer or customized index could enhance the labial profile which not only dominates the esthetic appearance but also provides adequate support for marginal gingiva[35,36]. The overcontoured profile of a restoration at the subgingival zone might cause gingival recession, while an undercontoured profile does not support marginal gingiva optimally, and thus the gingiva tends to form a roll around the tooth and is slightly inflamed as seen in this case. When the patient presented at the first visit, the tooth was not fully erupted and with a mesial-in rotation, which biased the judgment of the subgingival contour of the restoration. Fortunately, the mild gingival inflammation did not cause any periodontal bone loss during the 16 years of follow-up. On the contrary, the undercontoured profile of the restoration lead to a coronal shift of the gingival line in comparison with the adjacent teeth, which could be easily corrected when the patient requests a new provisional or definitive prosthesis. Another shortcoming of treatment was that the patient did not consistently maintain and take good care of his oral hygiene, which worsened the gingival inflammation.

Conclusion

The clinical challenges associated with the treatment of flared roots are not uncommon. Facing all compromised situations, a risk-benefit analysis must be done to determine whether procedures attempting to restore the tooth, even just for temporary use, will prolong the function of the tooth without sacrificing the alveolar bone which is the indispensable foundation for future implantation. A functional and tolerable temporary restoration of the flared root is even more important for the growing patient since it will buy time until an implant can be placed. The success of this 16 years of follow-up case was only possible with the application of optimal and reliable adhesion, followed by the installation of modified fiber posts to strengthen crown restoration. It should be emphasized that there is no consensus regarding the preferred type of post systems to reinforce crown restoration[37]. However, preserving tooth structure, immediate dentine sealing, deep margin elevation, post modification, adhesive approaches, and guided occlusion seem to take their roles in contributing to the success of this case. Meanwhile, it should be noticed that the presented treatment protocol is not a panacea for all the flared root cases, especially for patients with deep bite, lost posterior support, clenching, bruxism, or poor oral hygiene.

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References

1. Hu S, Osada T, Shimizu T, Warita K, Kawawa T. Resistance to cyclic fatigue and fracture of structurally compromised root restored with different post and core restorations. Dent Mater J 2005;24:225-31.
2. Trushkowsky RD. Restoration of endodontically treated teeth: criteria and technique considerations. Quintessence Int 2014;45:557-67.
3. Carvalho MA, Lazari PC, Gresnigt M, Del Bel Cury AA, Magne P. Current options concerning the endodontically-treated teeth restoration with the adhesive approach. Braz Oral Res 2018;32:e74.
4. Zogheib LV, Pereira JR, do Valle AL, de Oliveira JA, Pegoraro LF. Fracture resistance of weakened roots restored with composite resin and glass fiber post. Braz Dent J 2008;19:329-33.
5. Mendoza DB, Eakle WS, Kahl EA, Ho R. Root reinforcement with a resin-bonded preformed post. J Prosthet Dent 1997;78:10-4.
6. Lan TH, Pan CY, Liu PH, Chou MMC. Fracture Resistance of Monolithic Zirconia Crowns in Implant Prostheses in Patients with Bruxism. Materials (Basel) 2019;12.
7. Landys Boren D, Jonasson P, Kvist T. Long-term survival of endodontically treated teeth at a public dental specialist clinic. J Endod 2015;41:176-81.
8. Sarfati A, Tirlet G. Deep margin elevation versus crown lengthening: biologic width revisited. Int J Esthet Dent 2018;13:334-56.
9. Magne P, Spreafico RC. Deep Margin Elevation: A Paradigm Shift. Am J Esthet Dent 2012;2:86-96.
10. Dietschi D, Spreafico R. Current clinical concepts for adhesive cementation of tooth-colored posterior restorations. Pract Periodontics Aesthet Dent 1998;10:47-54; quiz 6.
11. Mijiritsky E, Badran M, Kleinman S, Manor Y, Peleg O. Continuous tooth eruption adjacent to single-implant restorations in the anterior maxilla: aetiology, mechanism and outcomes - A review of the literature. Int Dent J 2020;70:155-60.
12. Faria AC, Rodrigues RC, de Almeida Antunes RP, de Mattos Mda G, Ribeiro RF. Endodontically treated teeth: characteristics and considerations to restore them. J Prosthodont Res 2011;55:69-74.
13. Gresnigt MM, Cune MS, de Roos JG, Ozcan M. Effect of immediate and delayed dentin sealing on the fracture strength, failure type and Weilbull characteristics of lithiumdisilicate laminate veneers. Dent Mater 2016;32:e73-81.
14. Magne P, Kim TH, Cascione D, Donovan TE. Immediate dentin sealing improves bond strength of indirect restorations. J Prosthet Dent 2005;94:511-9.
15. Iseri H, Solow B. Continued eruption of maxillary incisors and first molars in girls from 9 to 25 years, studied by the implant method. Eur J Orthod 1996;18:245-56.
16. van Dijken JW, Sjostrom S. The effect of glass ionomer cement and composite resin fillings on marginal gingiva. J Clin Periodontol 1991;18:200-3.
17. Martins TM, Bosco AF, Nobrega FJ, Nagata MJ, Garcia VG, Fucini SE. Periodontal tissue response to coverage of root cavities restored with resin materials: a histomorphometric study in dogs. J Periodontol 2007;78:1075-82.
18. Santos VR, Lucchesi JA, Cortelli SC, Amaral CM, Feres M, Duarte PM. Effects of glass ionomer and microfilled composite subgingival restorations on periodontal tissue and subgingival biofilm: a 6-month evaluation. J Periodontol 2007;78:1522-8.
19. Quirynen M, Bollen CM. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. A review of the literature. J Clin Periodontol 1995;22:1-14.
20. Santamaria MP, Suaid FF, Casati MZ, Nociti FH, Sallum AW, Sallum EA. Coronally positioned flap plus resin-modified glass ionomer restoration for the treatment of gingival recession associated with non-carious cervical lesions: a randomized controlled clinical trial. J Periodontol 2008;79:621-8.
21. Kubo M, Komada W, Otake S, Inagaki T, Omori S, Miura H. The effect of glass fiber posts and ribbons on the fracture strength of teeth with flared root canals restored using composite resin post and cores. J Prosthodont Res 2018;62:97-103.
22. Silva GR, Santos-Filho PC, Simamoto-Junior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. Braz Dent J 2011;22:230-7.
23. D'Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent 2007;98:193-8.
24. Rocha AT, Goncalves LM, Vasconcelos AJC, Matos Maia Filho E, Nunes Carvalho C, De Jesus Tavarez RR. Effect of Anatomical Customization of the Fiber Post on the Bond Strength of a Self-Adhesive Resin Cement. Int J Dent 2017;2017:5010712.
25. Coelho CS, Biffi JC, Silva GR, Abrahao A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J 2009;28:671-8.
26. Clavijo VG, Reis JM, Kabbach W, Silva AL, Oliveira Junior OB, Andrade MF. Fracture strength of flared bovine roots restored with different intraradicular posts. J Appl Oral Sci 2009;17:574-8.
27. Bonfante G, Kaizer OB, Pegoraro LF, do Valle AL. Fracture strength of teeth with flared root canals restored with glass fibre posts. Int Dent J 2007;57:153-60.
28. Ozturk C, Polat S, Tuncdemir M, Gonuldas F, Seker E. Evaluation of the fracture resistance of root filled thin walled teeth restored with different post systems. Biomed J 2019;42:53-8.
29. da Silveira Teixeira C, Santos Felippe MC, Silva-Sousa YT, de Sousa-Neto MD. Interfacial evaluation of experimentally weakened roots restored with adhesive materials and fibre posts: an SEM analysis. J Dent 2008;36:672-82.
30. Moosavi H, Maleknejad F, Kimyai S. Fracture resistance of endodontically-treated teeth restored using three root-reinforcement methods. J Contemp Dent Pract 2008;9:30-7.
31. Gomes GM, Monte-Alto RV, Santos GO, Fai CK, Loguercio AD, Gomes OM et al. Use of a Direct Anatomic Post in a Flared Root Canal: A Three-year Follow-up. Oper Dent 2016;41:E23-8.

32. Grandini S, Sapio S, Simonetti M. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. J Adhes Dent 2003;5:243-7.

33. Aggarwal V, Singla M, Miglani S, Kohli S. Comparative evaluation of fracture resistance of structurally compromised canals restored with different dowel methods. J Prosthodont 2012;21:312-6.

34. Xiong Y, Huang SH, Shinno Y, Furuya Y, Imazato S, Fok A et al. The use of a fiber sleeve to improve fracture strength of pulpless teeth with flared root canals. Dent Mater 2015;31:1427-34.

35. Wagman SS. The role of coronal contour in gingival health. J Prosthet Dent 1977;37:280-7.

36. Liu CL, Baumgarten H, Weisgold AS. The management of gingival and esthetic problems: a clinical case. Compend Contin Educ Dent 2001;22:510-5.

37. Ayad MF, Bahannan SA, Rosenstiel SF. Influence of irrigant, dowel type, and root-reinforcing material on fracture resistance of thin-walled endodontically treated teeth. J Prosthodont 2011;20:180-9.