Restoration of teeth with severely compromised tooth structure using digital planning combined with orthodontic magnetic extrusion – A report of 2 cases

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Abstract

This report outlines two digitally planned cases in which the teeth underwent magnetic extrusion to preserve the supracrestal tissue attachment and regain the ferrule, followed by their restoration. Case 1: A 42-year-old male with the chief concern of a fractured right maxillary second premolar. Following the completion of root canal treatment, the remaining tooth structure was insufficient to create a ferrule for tooth restoration. For this scenario, a rapid magnetic extrusion technique was performed on tooth #4 to obtain an approximate 3 mm ferrule. The condition of both the dentition and the restorative margin was acceptable 18 months following treatment. Case 2: A 62-year-old male with the chief complaint of mobility on both sides of the maxillary arch in relation to a tooth-supported fixed partial denture (FPD). Following removal of the FPD, multiple extractions were carried out and tooth #6 was subjected to magnetic extrusion in three stages to a maximum of 4 mm to obtain a ferrule. At the 18 month and three year follow-up appointments, the tooth had no symptoms and the gingiva around the restorations had optimal architecture and margins. The three-dimensional digital planning was helpful in precisely positioning the magnets within the tooth and the provisional restorations to facilitate axial extrusion. The extruded teeth were restored with zirconia crowns in both the cases. The beneficial outcomes observed from these cases provides evidence that the integration of digital planning and magnetic extrusion holds promise as a method for reconstructing teeth whose crowns are significantly compromised.

Key words

CAD-CAM; case report; dental esthetics; ferrule; magnetic extrusion

Significance

- Magnetic extrusion is suitable for root canal treated teeth with severe destruction of coronal structure.
- Regaining a ferrule by preserving the supracrestal tissue attachment and ideal crown-root ratio is possible by this non-surgical technique.

Introduction

Restoration of root filled teeth is often challenging because of substantial loss of tooth structure often complicated with subgingival proximal margins[1]. Indeed, margins of restorations often lie deep within the gingival sulcus that will violate the supracrestal tissue attachment (STA)[2] often referred to as the biological width[3,4]. It might be difficult for a clinician to restore such teeth without impinging on the STA.

STA consists of the supracrestal connective tissue attachment and the junctional epithelium that varies in the apico-coronal dimension[5]. The consequences of STA violation are chronic progressive gingivitis or localized gingival hyperplasia with other associated periodontal complications such as periodontal pockets, bleeding, suppuration, gingival recession, etc.,[5,6].

Sufficient STA and a space of 3 mm between the alveolar crest and the crown margin are necessary for the restoration of severely damaged teeth lacking coronal structure[7,8]. In addition, a parallel dentinal wall extending coronally from the crown margin which contributes to the ferrule is essential for post-and-core crown restorations to function well over the long term[9]. Eventually, to achieve a uniform circumferential ferrule of 2 mm without compromising the STA, a tooth lacking a ferrule needs at least 5 mm of supraalveolar tooth structure[10].

There are five recommended approaches to create the supraalveolar tooth structure: (a) deep margin elevation[1], (b) surgical crown lengthening[11], (c) orthodontic extrusion[12], (d) surgical extrusion[13], and (e) extraction followed by implants[14]. Implant therapy-related esthetic concerns[15] as well as biological side-effects such as peri-implantitis[16] places extraction as the last option and favors the other options. Deep margin elevation by applying a thin layer of highly reinforced flowable composite is not feasible when optimal isolation, ideal marginal seal with root dentine and/or cementum and reestablishment of STA is questionable[17,18].

Ultimately, the choice of treatment among the remaining three options depends on numerous patient-related factors, including the tooth's position in the arch, its strategic value, its restorability, and its esthetics, clinical crown to root ratio, root proximity, root morphology, and furcation location[19,20]. Surgical crown lengthening is contraindicated when unreasonable sacrifice of surrounding alveolar bone support and esthetics with or without complications in the interproximal region (lack of space) is predicted[5]. Moreover, there is reduction in prospective crown-root ratio of the tooth following the crown lengthening procedure which compromises the load capability of post-supported root filled teeth as opposed to extrusion techniques where the ratio reduction is relatively less[21]. Surgical extrusion is an invasive technique carrying the risk of ankylosis and root resorption due to the trauma suffered by the periodontal ligament[22]. Conversely, orthodontic extrusion is a useful procedure in situations where there has already been attachment loss to the base of deep proximal caries lesions, and when surgical crown lengthening or extrusion would result in even more attachment loss. Moreover, remodeling of soft tissues and bone are rare in surgical procedures, which leads to undesired gingival disparities, especially in the anterior area that is highly visible[22].

Fixed orthodontic appliances with elastics and archwires affixed to the tooth are typically used for orthodontic extrusion of tooth with compromised crown structure[23]. However, the downside in this method is the lack of patient compliance to wear elastics and the consequent reduction in the application of continuous force[24]. These limitations may be overcome by using magnets as they are frictionless and produce predictable and consistent forces. Cases have been reported when magnets have been used to orthodontically extrude teeth with inadequate STA using a CAD-CAM milled polymethyl methacrylate (PMMA) resin based provisional fixed partial denture (FPD) and Ni/Cu/Ni neodymium-iron-boron magnets[25,26]. However, 3-dimensional positioning of magnets has never been digitally investigated and planned. Because of the recent development in the digital workflow, clinicians can control the magnetic extrusion of a tooth three dimensionally by planning the accurate position of the magnets.

This report presents two cases which were digitally planned with the teeth being magnetically extruded to respect the STA and regain the ferrule followed by their restoration.

Case Report 1

A 42-year-old male reported with the chief complaint of fractured maxillary right second premolar. The patient had no contributing medical or family history. Root canal treatment had been performed and the tooth restored with resin composite 11 years ago. Intraoral examination revealed complete crown fracture with discolored hard dentin on the mesial aspect suggestive of arrested caries and a thin layer of composite covering the gutta-percha (Fig. 1*A* and 1*B*). The tooth margins around the tooth were 3 mm coronal to the alveolar crest and level with the free gingival margin. Periodontal probing and mobility were within normal limits and there was no pain on percussion or palpation. There was insufficient tooth tissue to create a ferrule to restore the tooth with the result that there was only a minimal chance of long-term success. Preoperative intraoral periapical radiographs (IOPAR) revealed an adequately filled root canal with no periapical pathosis (Fig. 1*C*). After evaluating the possible options with the patient, rapid magnetic extrusion was proposed to achieve approximately 3 mm of ferrule while maintaining the soft tissue profile and esthetics. The patient was informed about the associated risks and benefits, and informed consent was obtained.

Carious tooth tissue was removed from the maxillary right second premolar and the perimeter was sealed with composite using Automatrix (Dentsply De Trey, York, PA, USA) (Fig. 1*D*). The space in its center was left for placing the cylindrical silane-coated Ni/Cu/Ni neodymium-iron-boron magnets (3 mm ∅ ×2 mm, $Nd_2Fe_{14}B$, Grade N48; IDEMAG, Barcelona, Spain). Small cavities/niches were made on the occlusal surface near the mesial marginal ridge of the existing composite restoration in the maxillary right first molar and the adjacent distal marginal ridge of the maxillary right first premolar to accommodate the small guide extensions of the provisional restoration (Fig. 1*D*). Both the maxillary and mandibular arches were scanned (Fig. 1*E*–*G*) intraorally using a scanner (itero element 5D; Align Technology Inc., San Jose, CA, USA) and sent to the laboratory where the scanned data was converted to standard tessellation language files using three-dimensional visualization software for Microsoft apps (exocad view; version 1.6.2, exocad GmbH, Darmstadt, Germany). Subsequently, a preliminary digital design accommodating the space for magnets (Fig. 1*H*–*K*) and ensuring their parallel alignment to generate accurate vertical force was created and approved. Two interim restorations were milled; the first one for activating the magnetic extrusion and the second one for stabilization after the vertical preparation of the maxillary right second premolar. A polymethyl methacrylate (PMMA) based polymer (TelioCAD; Ivoclar Vivadent AG, Schaan, Leichtenstein) was milled (CEREC inLAB MC X5; Dentsply Sirona, Konstanz, Germany) by a computer-aided design and computer-aided manufacturing

(CAD-CAM) controlled milling machine to fabricate the resin-bonded fixed partial denture (RBFPD). The two cylindrical silane-coated magnets were each bonded to the root (Fig. 1*L* and 1*M*) and the intaglio side of the PMMA-based RBFPD (Fig. 1*N*) with a flowable composite (SureFil SDR flow, Dentsply Sirona) and the distance between the two magnets was verified to be 2mm. Since there was no subgingival caries, only single activation was needed to achieve the required ferrule in a week (Fig. 2*A*–*D*) followed by a retention phase for one month.

After retention the post space was customised to match the diameter of fiber-reinforced composite post (RelyX Post N.2; 3M ESPE, St Paul, MN, USA) using flowable composite (SureFil SDR flow, Dentsply Sirona) and the post was luted (Fig. 2*E*-*I*) to the post space using self-adhesive resin cement (RelyX Unicem (3M ESPE). The core structure was later built-up (Ceram.x Spectra ST (HV); Dentsply Sirona) (Fig. 2*J*) for the crown preparation. Subsequently, gingivectomy was performed in relation to the maxillary right second premolar as the STA was not violated meaning there was adequate distance between the gingival margin and the alveolar crest. The tooth was prepared (Fig. 2*K*) following the biologically oriented preparation technique (BOPT)[27] and restored with the second interim RBFPD. The BOPT technique aims at intrasulcular de-epithelialization and blood coagulum to form, which later becomes stabilized to form a fully structured gingiva.

Three months later, when the soft tissues around the extruded tooth had stabilized and the emergence profile had been created (Fig. 2*L* and *M*), a new digital impression scan was made for a final zirconia restoration (Lava Plus; 3M ESPE), which was cemented with a glass ionomer cement (Ketac Cem; 3MESPE). At 18 months after treatment, both the teeth and the restorative margin were optimal (Fig. 2*N* and 2*O*). The patient reported that they were happy with their smile and could use the tooth normally.

Case Report 2

A 62-year-old man presented with the complaint of mobility of the tooth supported FPDs on both sides of the maxillary arch. There was no history of relevant systemic problems and drug allergy, and no medication was being taken. On intraoral examination and radiographic investigation, two poorly adjusted FPDs with ill-fitting margins on first and second quadrant were observed (Fig. 3*A*). Removal of both FPDs revealed substantial coronal destruction of tooth #4, 6, 12 and 15 (Fig. 3*B*). The root filled maxillary right canine was considered strategically important in the arch and had a complete crown fracture with equigingival finish lines at the time of examination (Fig. 3*C* and *D*) without exposing the gutta-percha. The tooth was asymptomatic with no significant periapical changes on the IOPAR (Fig. 3*C*). Hence, root canal retreatment was not necessary for tooth #6. After removing the crown on tooth #7, alginate impressions (Hydrogum 5, Zhermack, Badia Polesine, Rovigo, Italia) were taken to fabricate an immediate transitional partial denture (ITPD) to be placed on the day of extractions.

Multiple extractions were performed including tooth #9 (periodontally compromised) in the maxillary arch except for tooth #2, 6, 7, 8 and 16 (Fig. 3*E*) and the ITPD was placed. Weakened tooth structure on tooth #6 was removed and the perimeter was sealed with composite (Fig. 3*F*-*H*). Subsequently, new digital impressions were taken from the models (Fig. 3*I*) for scanning, digital planning and milling of two PMMMA-based interim FPDs in relation to teeth #6, 7 and 8 to perform the magnetic extrusion and stabilization. After cementing the magnet in its dedicated space within the root using flowable composite, the PMMA-based interim FPD, with the magnet already in place ensuring 1.5 mm (Fig. 3*J* and 3*K*) from the root, was cemented with Temp-bond clear (Kerr corporation, Brea, CA, USA). A baseline IOPAR was taken to confirm the alignment of magnets and the root position withing the socket.

During the following three weeks, three-step activation (1.5 mm each) was carried out to achieve a total extrusion of 4.5mm as the STA had been violated and the roots were long (Fig. 4*A* and 4*B*). At each activation step, the FPD was removed, and the root was trimmed to accommodate the next extrusion step, which was simultaneously verified with IOPARs (Fig. 4*C*). During the last activation step (Fig. 4*A* and 4*B*), gingivectomy was performed to avoid coronal migration of soft tissue as the tooth extruded. Once the extrusion was completed, the interim FPD was left *in situ* as a retention phase for 2 months to stabilize the tooth and prevent relapse. Following retention, the tooth was reconstructed with a fiber-reinforced composite post (RelyX Post N.2; 3M ESPE) and core (Ceram.x Spectra ST (HV); Dentsply Sirona) and the core prepared following BOPT to place a new provisional PMMA-based FPD (Fig. 4*D*). After 3 months (Fig. 4*E* and 4*F*), definitive digital impressions were made for a zirconium crown which was cemented in tooth #6 (Fig. 4*G*). The patient decided to have the remaining tooth replaced with a conventional removable partial dental prosthesis for economic reasons (Fig. 4*H*). During the follow-up appointment at the end of 18 months and 3 years (Fig. 4*H* and 4*I*), the tooth was asymptomatic and the gingiva near the restoration margins had optimal margins and architecture. The patient was satisfied with the esthetics and could chew food comfortably.

Discussion

These cases are the first to report the digital planning of the orthodontic magnetic extrusion for badly mutilated root canal treated teeth. To preserve the crown-root ratio at or above 1:1 without encroaching the biological width, the height of a broken down tooth must be increased by moving part of root to a more supragingival position using an orthodontic extrusion technique[12,21]. Based on a systematic review of data spanning three to twenty-five years, the survival rates after endodontic treatment and coronal restoration were 81% to 100%[28]. However, endodontically treated teeth and restorations supported by implants have similar long-term survival rates[28,29]. In both the cases, because the root canal filling was intact and there were no signs of periapical pathosis, the root was able to be preserved with a favorable prognosis. Alternate treatment options including prosthetic restoration and dental implant therapy was rejected after following the chairside decision-making process which involved the patients' choice and consent[12].

It is important to make sure that each magnet is oriented correctly in relation to the other to ensure rapid axial extrusion. A decrease in the magnetic force and flux density must be anticipated if a precise alignment cannot be guaranteed[30]. In the three-dimensional data analysis and digital planning, the position of the magnet was virtually designed to achieve the precise location of magnet inside of the provisional PMMA restoration to produce the optimum axial extrusion. For both cases, the placement of the magnets within the tooth and the provisional restoration was planned to be perpendicular to the direction of proposed extrusion and sufficiently spaced apart. Moreover, it is important to remember that when the vertical, transverse, and horizontal separation of two magnetics increase, the force of attraction decreases[31]. An extrusion force of 0.13 N is produced by the magnets at a distance of 1 mm, which increases to 0.3 N at a distance of 0.5 mm and to 0.65 N when the magnets come into contact[32].

Therefore, the separation between the magnets per activation was in the range of 1.5 to 2 mm so that the force applied was less than that recommended by WHO as biologically safe[24,33].

Strength and Limitations

The ferrule in these cases was established without any surgical procedure or compromise in crown-root ratio. The esthetics was not affected throughout the extrusion procedure as the magnets were cemented within the provisional restorations. The interaction of oral fluids with the magnet, which could cause corrosion and shorten their lifespan, is a major drawback of magnetic extrusion[34].

Conclusion

The favorable clinical and radiographic outcome in these cases demonstrate that digital planning combined with magnetic extrusion is a technique that can be used to restore teeth with severely compromised crown structure. The patient-centered approach in this case resulted in magnetic extrusion as the technique of choice. Further clinical investigations are required to evaluate the long-term success rate and cost-benefit ratio of this technique.

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Figure Legends

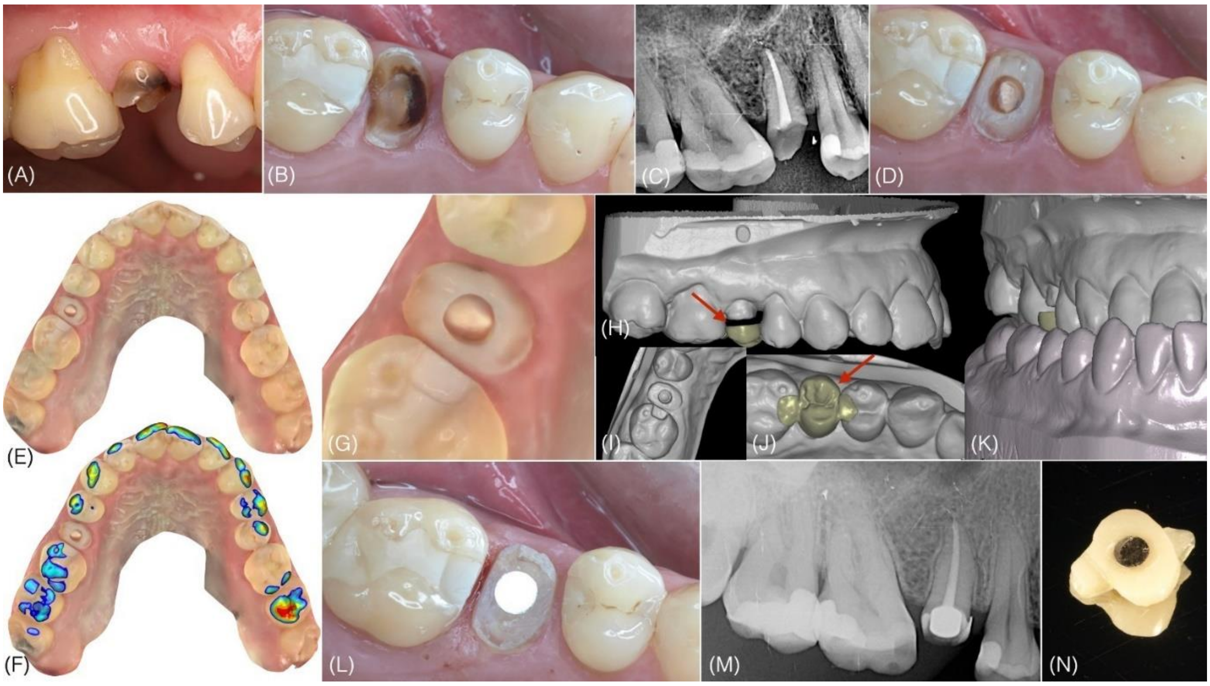

Figure 1 - Preoperative clinical situation (*A-C*) of case 1 showing tooth #4 with substantial loss of tissue. (*A*) Buccal view. (*B*) Occlusal view. (*C*) Periapical radiograph showing the degree of tooth tissue loss and the existing root filling. (*D*) Design and preparation of cavity within root canal to accommodate the first magnet. (*E-G*) Screenshots of the scans of the case in order to plan and execute the treatment in a entirely digital way. (*H-K*) Digital simulation of the cast with the provisional restoration. (*H*) Buccal view showing 2mm distance (red arrow) between the root and the provisional restoration. (*I*) Occlusal view showing the space for guide extension in teeth #3 and 5. (*J*) Occlusal design of provisional restoration (red arrow). (*K*) Profile view. (*L*) A magnet cemented on tooth (3 mm Ø × 2 mm, Grade N48). (*M*) Baseline radiograph with magnet positioned in the coronal third. (*N*) View of the provisional restoration with the second magnet attached with opposite pole facing the tooth-counterpart.

Figure 2 - Extrusion sequence(A-D) of tooth #4. Comparison of tooth before (A) and after (B) magnetic extrusion showing its coronal movement over 7 days. (C and D) Radiographic comparison showing the 2mm of extrusion achieved. (E) Tooth was isolated with rubber dam. (F) Post-space prepared. (G) Etching the post-space with etchant gel. (H) Application of adhesive withing the post space. (I) Luting the silanated fiber post. (J) Resin core build-up. (K) Vertical preparation without finishing line according to the biologically oriented preparation technique (BOPT) to create a thicker biotype thereby preventing the risk of recession and to obtain a 3mm ferrule. (L) Three months after provisionalization showing the newly created emergence profile and healthy gingiva. (M) Periapical radiograph showing the post, core, BOPT preparation, and absence of apical pathosis or resorption. (N) Buccal aspect of the crown showing integration of margins with the healthy soft tissue at 18 months follow-up. (O) Periapical radiograph showing no signs of pathosis or resorption at 18 months.

Figure 3 - Preoperative clinical situation(*A-D*) of case 2. (*A*) Labial view showing poor marginal adaptation of the FPD. (*B*) Tooth #6 with inadequate coronal structure and equigingival margins. (*C*) Periapical radiograph of tooth #6 showing root canal filling and absence of periapical pathosis. (*D*) Clinical situation after the removal of FPDs, showing the extensive coronal destruction of teeth #4, 6, 12 and 15. (*E*) Occlusal view after performing all the extractions. (*F*) Buccal view of tooth #6 after sealing the periphery with composite. (*G*) Occlusal view (*H*) Central preparation in tooth #6 to accommodate the size of magnet. (*I*) Digital design of the provisional FPD retained on teeth #7 and #8 that will be used for extrusion. (J) Proposed distance (1.5 mm) between the 2 magnets was verified on the cast. (*K*) Labial and intaglio view of provisional FPD showing the silanized Nd2Fe14B magnet in relation to tooth #6.

Figure 4 –Extrusion sequence (*A* and *B*) of tooth #6 (first activation, second activation, gingivectomy and third activation in order) in profile and labial views. The images are arranged vertically to compare before and after each step. (*C*) Radiographic sequence of the three-step activation respectively to achieve 4.5 mm extrusion. (*D*) Sequence of post-core build-up followed by provisional fixed partial denture (FPD) made using CAD-CAM. (*E*) Clinical situation of tooth #13 three months after provisionalization showing the new emergence profile created by the biologically oriented preparation technique (BOPT). (*F*) Periapical radiographic control. (*G*) Periapical radiograph after cementation of Zirconia FPD. (*H*) Postoperative clinical view showing the completed treatment. (*I*) Three-year follow-up radiograph showing no signs of periapical pathosis or root resorption.