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Case Report

Laser-Sintered Precision: A Contemporary Prosthodontic Solution for Root Canal-Treated Teeth

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Abstract

Failures in endodontic therapy are frequently associated with inadequate coronal sealing or improperly executed crown restorations, both of which can compromise the long-term prognosis of the treated tooth. Direct Metal Laser Sintering (DMLS) metal-ceramic restorations have increasingly gained acceptance owing to their enhanced mechanical strength, precision, and clinical reliability.

DMLS is an advanced additive manufacturing technique that employs a high-powered laser to selectively fuse successive layers of metal powder, fabricating the structure layer by layer within an inert gas environment to minimize oxidation. The use of a DMLS-fabricated metal-ceramic crown for an endodontically treated second premolar provides both functional stability and favorable esthetics, leading to promising clinical outcomes.

The present case report describes a 40-year-old female patient who presented with a noticeable swelling in the maxillary right posterior region. A prior restorative attempt in the affected area had repeatedly dislodged, highlighting the need for a more durable and long-term restorative solution. Multiple-visits endodontic therapy was successfully performed, and a DMLS metal-ceramic crown was chosen as the definitive prosthetic restoration. This case report aims to outline the clinical protocol and evaluate the outcomes associated with the use of a DMLS-based porcelain-fused-to-metal (PFM) crown for the restoration of a second premolar following endodontic treatment.

Keywords: *Additive Manufacturing; CAD/CAM Technology; Coronal Seal; Direct Metal Laser Sintering (DMLS); Endodontically Treated Tooth; Fixed Dental Prosthesis; Indirect Restoration; Intraoral Scanner; Metal-Ceramic Crown; Post-Endodontic Rehabilitation*

Introduction

The optimal approach for restoring teeth after endodontic therapy continues to be a subject of active research and clinical debate. The long-term success of root canal treatment depends not only on the quality of the endodontic procedure but also significantly on the integrity and effectiveness of the definitive coronal restoration. Evidence suggests that inadequate coronal sealing may lead to microleakage, thereby substantially compromising the long-term success of endodontic therapy-reducing success rates by up to 40% in certain cases [1].

The choice of restorative material and the design of the definitive prosthesis for endodontically treated teeth (ETT) are influenced by multiple factors, including the amount and condition of the remaining tooth structure, its anatomical relationship with adjacent teeth, and the functional interaction with the opposing dentition.

Biomechanical considerations in endodontically treated teeth

Historically, it has been proposed that dentin in endodontically treated teeth differs structurally from that in vital teeth [1-3]. Early theories suggested that endodontic procedures might increase dentin brittleness due to dehydration and reduced collagen cross-linking, thereby heightening fracture susceptibility [1,3]. However, more recent investigations have challenged these assumptions.

In a landmark study conducted in 1991, Huang., *et al*. evaluated the physical and mechanical properties of dentin from both vital teeth and those that had undergone endodontic treatment under varying hydration conditions. Their findings indicated that neither endodontic therapy nor dehydration significantly altered dentin's physical or mechanical characteristics [4]. These conclusions were further supported by Sedgley and Messer, who compared the biomechanical properties of dentin from endodontically treated teeth with their contralateral vital counterparts and determined that ETT are not inherently more brittle [5].

Therefore, the increased incidence of fractures observed in ETT is more appropriately attributed to structural weakening resulting from access cavity preparation and pre-existing damage, rather than intrinsic changes in dentin composition [6]. Access cavity preparation contributes to greater cuspal deflection under occlusal loading, increasing the likelihood of cusp fractures and marginal microleakage [7,8]. Moreover, many ETT are already compromised due to extensive caries, trauma, or large pre-existing restorations.

Randow and Glantz further emphasized that the loss or reduction of protective neurosensory feedback mechanisms in non-vital and root canal-treated teeth impairs the modulation of occlusal forces, thereby increasing susceptibility to structural failure [9].

Accordingly, restorative strategies must not only provide an effective coronal seal but also reinforce the remaining tooth structure to withstand functional forces and maintain long-term integrity.

Impact of tooth structure loss on biomechanics

The principal biomechanical compromise in ETT arises from the loss of structural tissue, whether due to caries, fractures, or operative procedures such as cavity preparation. Conservative access cavity designs exert minimal influence on overall tooth stiffness, typically causing only about a 5% reduction in rigidity [10]. However, as additional structural components-particularly marginal ridges-are removed, the weakening effect becomes more pronounced.

Research indicates that occlusal cavity preparations can reduce tooth stiffness by 14 - 44%, whereas mesio-occluso-distal (MOD) cavity preparations may decrease stiffness by as much as 20 - 63% [11]. Such significant reductions highlight the necessity of selecting restorative approaches that aim to restore lost strength and structural support effectively.

Emergence of DMLS in dental restorations

Conventionally, cobalt-chromium (Co-Cr) alloys used for fixed prostheses have been fabricated using traditional casting techniques. Despite their widespread adoption, casting methods are associated with several limitations, including higher costs, labor-intensive procedures, material wastage, and increased potential for human error [12]. Over the past decade, digital advancements have transformed prosthodontic practice, particularly through the integration of computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies.

These digital systems facilitate the fabrication of a broad spectrum of dental prostheses, ranging from single crowns and multi-unit fixed partial dentures to removable prostheses and implant-supported restorations [13]. Among contemporary CAD/CAM modalities, Direct Metal Laser Sintering (DMLS) has emerged as a promising technique for producing high-precision metal frameworks.

DMLS is an additive manufacturing process that utilizes a high-powered ytterbium (Yb) fiber-optic laser to selectively melt and fuse metal powder in successive layers, constructing the restoration layer by layer within a controlled inert gas environment to prevent oxidation [14,15]. Each fabricated layer measures approximately 10-30 microns in thickness, allowing for exceptional detail, accuracy, and marginal adaptation. This technique enables the production of metal-ceramic restorations characterized by enhanced mechanical strength, superior marginal integrity, and reduced technique sensitivity due to minimized human error [13,16].

Purpose of the Study

The purpose of the present case report is to describe the clinical protocol and outcomes associated with restoring a maxillary second premolar using a DMLS-fabricated metal-ceramic crown following successful endodontic therapy. The report underscores the rationale behind material selection, outlines the procedural workflow, and discusses the functional and aesthetic outcomes achieved with this advanced digital approach.

Case Report

A 40-year-old female patient presented to the Department of Prosthodontics, Crown and Bridge, and Oral Implantology with a chief complaint of pain in the maxillary right posterior region. She was subsequently referred to the Department of Conservative Dentistry and Endodontics, where endodontic treatment of tooth 15 was initiated and completed over multiple appointments. Approximately one month later, the patient returned to the Prosthodontics department for definitive prosthetic rehabilitation.

The patient's medical history was non-contributory, with no history of systemic hypertension, diabetes mellitus, cardiovascular disorders, or known drug allergies. Her dental history was also unremarkable. Radiographic evaluation confirmed satisfactory completion of endodontic therapy in relation to tooth 15.

Clinical procedure

At the initial prosthodontic appointment, the patient was provided with detailed oral hygiene instructions and a comprehensive explanation of the planned restorative procedure. Written informed consent was obtained prior to treatment. Endodontic therapy had been completed in multiple sessions before initiating prosthodontic rehabilitation.

Tooth preparation was performed using a deep chamfer finish line design. Approximately 1 mm of axial reduction and 2 mm of occlusal reduction were achieved to ensure adequate clearance for the definitive restoration. Final subgingival finishing was carried out using a round-end tapered fissure diamond bur.

Gingival management was achieved using a gingival retraction cord (Roeko Stay-Put Retraction Cord, Coltene Whaledent Pvt. Ltd., Navi Mumbai, India) in conjunction with a retraction medicament (Dux GingiGEL, Kerr, California, United States) prior to impression making.

Digital impressions of both the maxillary and mandibular arches were obtained using an intraoral scanner (Medit i600, Medit Corp., Seoul, South Korea), ensuring high-resolution capture of the prepared tooth and surrounding structures (Figure 1 and 2). A digital interocclusal record (bite scan) was subsequently recorded (Figure 3).

Figure 1: Maxillary digital impression.

Figure 2: Mandibular digital impression.

Figure 3: Bite scan.

The digital data acquired from the intraoral scanner were utilized to fabricate 3D-printed master casts of both arches, thereby eliminating the need for conventional stone model pouring (Figure 4 and 5).

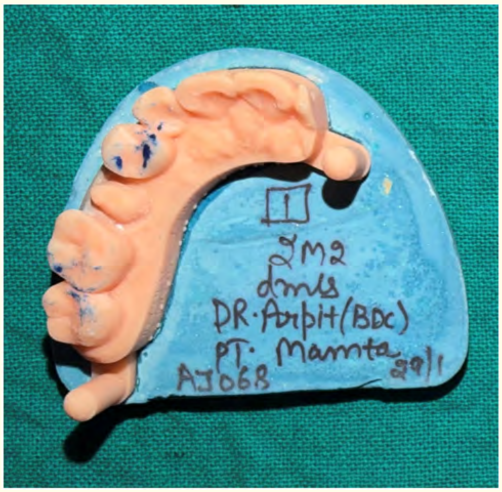

Figure 4: Maxillary digital cast.

Figure 5: Mandibular digital cast.

A provisional crown was fabricated indirectly using Protemp™ 4 Temporisation Material (3M ESPE, Karnataka, India). At the subsequent appointment, a metal try-in was performed to assess marginal fit and internal adaptation. Shade selection was carried out using a VITA shade guide (shades 2M2 and 2M3), following which the restoration was returned to the laboratory for ceramic layering and completion of the definitive crown (Figure 6 and 7).

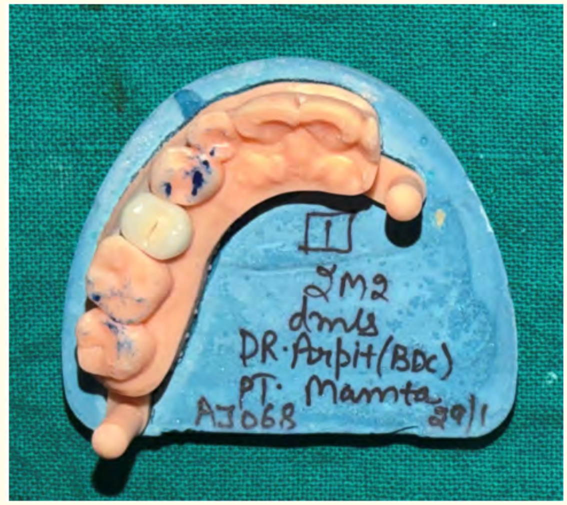

Figure 6: Final DMLS metal-ceramic (PFM) crown (Occlusal view).

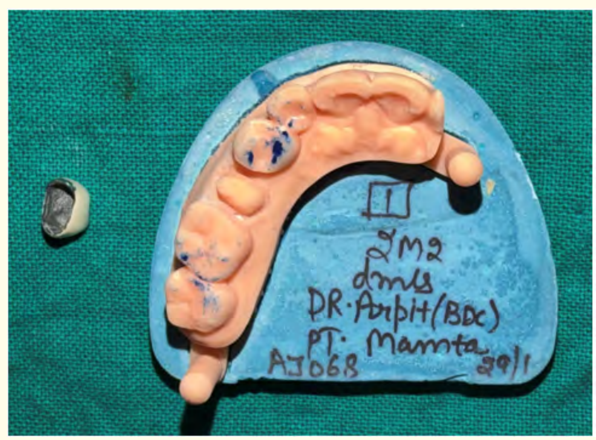

Figure 7: Final DMLS metal-ceramic (PFM) crown - an overview.

A bisque trial was conducted to evaluate marginal adaptation, occlusion, articulation, proximal contacts, and harmony with adjacent soft tissues. After necessary occlusal adjustments, the crown was sent back to the laboratory for final glazing.

Definitive cementation was performed using a glass-ionomer luting agent (GC Fuji Gold Label Type 1 Luting Cement, GC Corporation, Tokyo, Japan).

A post-cementation evaluation was carried out to assess both subjective and objective treatment outcomes. The patient reported no discomfort or functional impairment. Clinical examination revealed no tenderness on percussion, absence of marginal discrepancies, no food impaction, and no signs of periodontal inflammation. The gingival tissues appeared healthy and well adapted to the final restoration (Figure 8 and 9).

Figure 8: Final DMLS PFM crown in situ (Lateral view).

Figure 9: Final DMLS PFM crown in situ (Occlusal view).

Discussion

The concept of "success" in endodontic therapy is multidimensional and can be interpreted from various clinical perspectives. From a dental standpoint, treatment success is typically defined as the completion of root canal therapy resulting in an asymptomatic tooth that has fully regained functional capacity. Achieving this outcome requires accurate diagnosis, meticulous biomechanical preparation, effective disinfection, and a well-executed restorative phase. Both apical and coronal seals are critical to ensure comprehensive rehabilitation and long-term stability.

According to Nurulaqmar-Iwani [17], inadequate or defective restorations represent a major cause of endodontic failure. Compromised sealing at either the coronal or apical aspect permits microbial ingress and diffusion of toxins from the oral environment, leading to reinfection of the root canal system and subsequent periapical involvement. Therefore, the integrity of the definitive coronal restoration is fundamental to the overall success of endodontic therapy.

When determining an appropriate post-endodontic restorative strategy, several factors must be considered, including the amount of residual tooth structure, occlusal forces, and functional and esthetic requirements. The selected restoration should reinforce the remaining tooth, particularly in cases involving loss of cuspal support or occlusal surfaces. In the present case report, the patient's dental history indicated repeated debonding and failure of previous restorations, necessitating a more robust and long-lasting restorative solution.

The durability of a restoration is influenced by multiple interdependent variables, such as the materials employed, the restorative technique, operator proficiency, patient-specific oral conditions, and local biomechanical considerations. Literature evidence supports the use of indirect crown restorations, which demonstrate a 75 - 80% survival rate over a 10-year period. Notably, Direct Metal Laser Sintering (DMLS) metal-ceramic restorations have shown a success rate of approximately 88% beyond five years of clinical service [18-20].

In this case, a metal-ceramic crown was selected for the posterior tooth owing to its documented stability, durability, and cost-effectiveness. A cobalt-chromium (Co-Cr) framework was fabricated using the rapid manufacturing technique of DMLS. Laser sintering, a fundamental component of DMLS, belongs to the broader category of additive manufacturing or rapid prototyping technologies [21]. This approach is extensively utilized in industries such as engineering, aerospace, and defense, and has increasingly gained prominence in healthcare. Its application in restorative dentistry has expanded considerably due to its precision, efficiency, and reduced material wastage.

Compared to conventional casting procedures, DMLS offers several advantages. It allows the fabrication of highly accurate and mechanically robust fixed prostheses with superior marginal adaptation [16,22]. Additionally, the elimination of multiple laboratory steps-such as wax pattern fabrication and traditional casting-reduces human error and enhances overall consistency.

Although both titanium and cobalt-chromium alloys, in the form of fine metal powders, can be processed using DMLS technology, Co-Cr remains the material of choice due to its favorable mechanical properties and ease of fabrication. In comparison to all-ceramic systems, Co-Cr-based metal-ceramic restorations provide a cost-effective alternative without compromising structural strength, particularly in posterior regions subjected to high occlusal loads. Consequently, in the present clinical case, a Co-Cr-based DMLS-fabricated metal-ceramic fixed prosthesis was selected as the definitive restorative option for the posterior dentition.

For luting, Glass Ionomer Cement (GIC) was utilized. GIC was selected because of its clinical advantages, including simplified cementation, reduced chairside procedural errors, decreased risk of contamination, and shortened operative time. Its inherent properties-such as chemical adhesion to tooth structure and fluoride release-further enhance its suitability, particularly in endodontically treated teeth where durable sealing and secondary caries prevention are of paramount importance.

Conclusion

In conclusion, the application of a DMLS-fabricated metal-ceramic crown for restoring a second premolar after endodontic therapy provides both dependable functional performance and satisfactory esthetic outcomes. Such restorations offer effective coronal sealing and accurate marginal adaptation, thereby playing a crucial role in the overall success of treatment.

During follow-up evaluations, the patient exhibited no discomfort, absence of tenderness on percussion or palpation, no evidence of food impaction, and no detectable marginal discrepancies. Additionally, the surrounding gingival tissues remained healthy and well-maintained. In the present case, the integration of laser sintering technology with CNC machining facilitated the achievement of optimal functional integrity and esthetic results. Periodic recall visits were conducted to assess and ensure the long-term stability and success of the restoration.

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