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CASE REPORT

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Polyetheretherketone split post and core for restoration of multirooted molar with insufficient dental tissue remnants by digital techniques: a case report and 3-year follow up

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Abstract

Background Multi-rooted teeth with extensive dental defects often face challenges in stability and biomechanical failure. High-performance polymer PEEK materials, with properties closer to dentin, show promise in reducing stress concentration and preserving tooth structure. This report aimed to explore the use of a highly retentive polyetheretherketone (PEEK) for manufacturing custom-made split post and core for the restoration of grossly destroyed endodontically treated molars.

Clinical considerations A 40-year-old female patient presented with complaints of loss of tooth substance in the posterior mandibular tooth. This case involved the digital design and fabrication of PEEK split post and core to restore multirooted molar with insufficient dental tissue remnants. The restorations were evaluated over a 3-year follow-up using the World Federation criteria (FDI). The restoration was clinically evaluated through intraoral examination, radiographic assessment, and subjective patient satisfaction, and was deemed clinically good according to FDI criteria.

Conclusion The outstanding mechanical properties of PEEK, coupled with the structure of the split post, provide an effective treatment option for weakened multirooted teeth. Simultaneously, the restoration configuration effectively addressed the challenge of varying postinsertion directions, and the interlocking mechanism between the primary and auxiliary posts enhanced the stability of the post and core.

Keywords Polyetheretherketone, Post and core restoration, Split post, Dental pulp cavity, Computer-aided design and computer-aided manufacturing

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Background

Endodontically treated molars often exhibit extensive loss of tooth tissue and reduced clinical crown height [1]. This challenges the establishment of a stable foundation for restorations and increases the risk of biomechanical failure, thus affecting the long-term success of these restorations [2–4]. Furthermore, endodontically treated teeth differ from vital teeth in terms of fracture resistance owing to the absence of structural integrity and pulp tissue, lack of nutritional support provided by the pulp, degeneration of dentin collagen fibers, and loss of sensitivity, leading to increased load bearing on these teeth [5–7]. Additionally, with at least two missing surfaces, it is not possible to achieve a durable adhesive bond, even when various pretreatment methods are applied [8]. Regarding the restoration of such molars, the central concern for clinicians is enhancing fracture resistance, improving the survival rate of tooth tissue, and simultaneously achieving secure retention.

Post and cores play a vital role in prosthodontic dentistry, securing abutment teeth with extensive crown loss when traditional full-crown retention is unfeasible [9]. Additionally, they offer increased tooth stability following root canal treatment, thus reducing the risk of fracture in the remaining tooth structure [10]. However, owing to the large-angled root furcation of the molar, achieving a coherent insertion direction for a one-piece post can be challenging. Forcing placement under such circumstances may result in excessive wear of the root wall tissues, potentially leading to the perforation of the root canal wall. Accordingly, scholars have proposed the concept of multipiece posts for addressing this issue [11, 12]. During restoration using the multipiece post, the split post is inserted into the root canal in a specialized insertion direction, restoring the core to a completely crown-fixed form, thereby providing exceptional retention for full-crown restoration [13].

Advancements in dental materials and endodontic techniques now allow for the preservation of most residual crowns through root canal therapy. Post and core restorations can extend the utility of the crowns remaining after root canal treatment [14]. However, for posterior teeth with extensive loss of occlusal surfaces, especially in patients with thin pulp chamber floors and post space walls, the use of high-modulus of elasticity post-and-core materials can lead to stress concentration, potentially increasing the risk of root fractures [15]. Prefabricated posts are commonly used in clinical practice. However, their adaptability to root canals is often limited, particularly in cases involving oval or tapered root canals [16]. In such scenarios, a lack of adequate adaptability can compromise the long-term treatment effectiveness.

Recently, restoration using high-performance polymer polyetheretherketone (PEEK) materials has been gradually introduced into the field of dentistry. PEEK exhibited excellent biocompatibility, mechanical properties, and chemical stability [17]. The elastic modulus of PEEK is closer to those of human dental enamel and lower than those of traditional post and core materials, including glass fiber, metals, and ceramics. This characteristic can effectively reduce the stress concentration, minimize the occurrence of root fractures, and help preserve the remaining tooth structure [18, 19]. The use of computer-aided design and computer-aided manufacturing (CAD-CAM) technology for the precise milling of customized post and cores enhances their fit within the root canal and, therefore, improves their cement strength and enhances resistance to dental tissue fracture [20, 21]. Currently, there have been some clinical case reports on the use of PEEK post-and-core for restoring single-rooted teeth, showing promising results in short-term follow-ups. However, there are no reports on the digital design and fabrication of PEEK split posts for restoring multirooted molars with insufficient dental tissue remnants [22–24].

This case report describes the clinical sequence for fabricating customized multipiece PEEK posts and cores using a CAD-CAM system and provide a survival analysis of the corresponding restoration over a 3-year follow-up period.

Case presentation

Diagnosis and planning

A 40-year-old female patient initially visited our center in 2020, presenting with extensive posterior mandibular tooth loss and expressing a desire for restoration. Clinical and radiographic examinations revealed that the affected tooth had undergone root canal treatment 2 weeks prior to the visit. However, the tooth exhibited a significantly reduced coronal structure, with thin dentin remaining on the floor of the pulp chamber (Fig. 1). Given that the remaining coronal tooth structure was insufficient to provide stable support for the crown, various treatment options, along with their potential consequences and risks, were thoroughly explained to the patient. After a comprehensive discussion, it was decided that the most suitable course of action for the patient was a post-and-core crown restoration. To minimize the stress on the remaining tooth structure, a PEEK post and core with a low elastic modulus was used prior to crown restoration. Informed consent to write this study and release its corresponding photographs was obtained from the patient.

Tooth preparation and digital model acquisition

The post space was carefully prepared using post drills (Cytec; Hahnenkratt, Königsbach-Stein, Germany) with gradual expansion to match the root canal diameter. Residual root canal filling material was meticulously removed from the canal walls using an ultrasonic tip (Instrument Nr.; Dentsply Sirona, Charlotte, NC, USA). Abutment tooth preparation included an initial shoulder preparation for prosthetic restoration, followed by the meticulous refinement of the cervical shoulder and a final polishing process.

Fig. 1 Endodontically treated right mandibular molar before restoration. **A** Intraoral view reveals extensive loss of tooth substance. **B** Periapical radiograph demonstrates satisfactory root canal filling with no evidence of low-density shadows at the root apex, and thinning of the dentin at the base of the pulp chamber

The dental arch was dried and an intraoral scanning device (Trios 3, 3Shape A/S, Copenhagen, Denmark) (Fig. 2A) was used to capture digital impressions of the prepared tooth, opposing dental arch, and occlusal relationship. The scanning scope of the opposing dental arch corresponded precisely to the relevant area. This procedure generated digital models (Fig. 2B). Subsequently, to clean and dry the post space, a two-stage impression of the tooth under treatment, as well as the positions of the two adjacent teeth, was captured using a scannable polyvinylsiloxane silicone material (Honigum Pro Light and Heavy Scan; DMG Dental, Hamburg, Germany). The excess silicone was trimmed to expose the scanned areas. Thereafter, the impression was digitized using the intraoral scanner to obtain a three-dimensional digital representation of the post space morphology (Fig. 2C). Subsequently, we imported the digital models of the arch and impressions into a reverse engineering software (Geomagic Wrap 2021; 3D Systems, Rock Hill, SC, USA). Initially, the normal of the silicon digital model was inverted to transform it into a corresponding reverse three-dimensional structural digital model (Fig. 2D). Thereafter, the digital model of silicon was superimposed on the arch model using a three-point alignment. Specific regions for the best-fit algorithm were selected using adjacent teeth (Fig. 2E). Incomplete portions of the post space in the arch model were removed, and the remaining model was merged and fused with the post space in the impression model. This yielded a digital model that included the complete morphology of the post space and the remaining tooth structure of the treated tooth (Fig. 2F).

Design of split post and core

The digital model was imported into a dental design software (Dental System 19; 3Shape A/S, Copenhagen, Denmark) for the post-and-core crown design process. First, the core margins were outlined. The insertion directions and morphologies of the two posts were designed separately (Fig. 3). The core form was adjusted. Finally, the crown restoration design around the core was completed.

The distal post, designated as the primary post, formed an integral connection with the core. The mesial post was designated as the auxiliary post. Owing to the differing

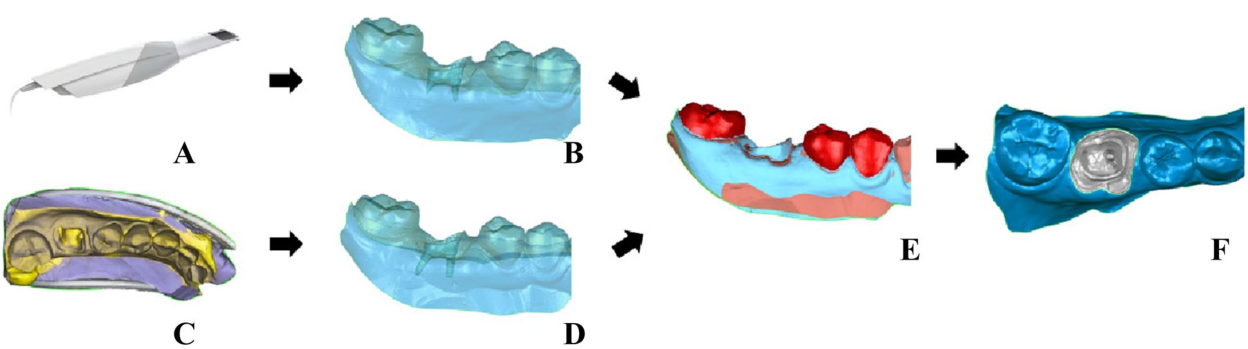

Fig. 2 Acquisition process of the complete digital impression of the post space. **A**, **B** Obtaining digital models of the dental arch with incomplete post space data using an intraoral scanner. **C**, **D** The digital model of the silicone rubber impression was obtained using an intraoral scanner and converted into the corresponding reverse three-dimensional structural digital model using Geomagic software. **E** Register the two models through the remaining dentition. **F** The two models are stitched to obtain the complete post canal and residual dentition model

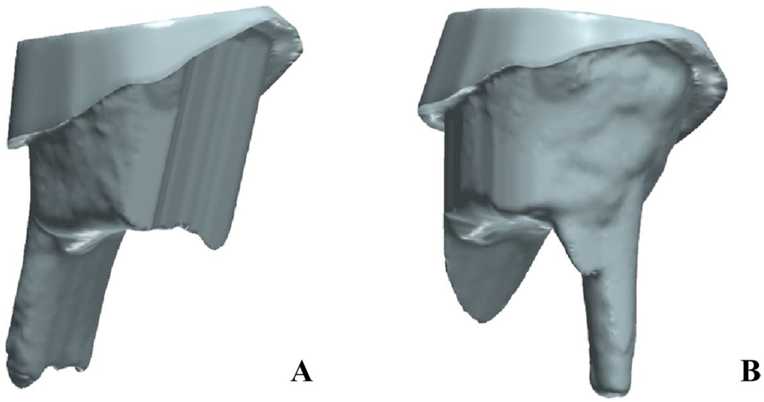

Fig. 3 The post and core, as well as the crown, were designed using CAD software. The mesial (**A**) and distal (**B**) posts and cores are designed separately

insertion directions of the primary and auxiliary posts, and to ensure smooth placement of both posts, the designed file was imported into reverse engineering software (Geomagic Wrap 2021; 3D Systems) to create a split post.

Given the significant angular deviation between the placement directions of the primary and auxiliary posts, the distal post was positioned in place with the core first, and the mesial post was positioned as a split post afterward. The mesh of the mesial post was fitted as a cone to ensure complete coverage of the core with this cone, which served as the split post (Fig. 4A). The split post was offset by 0.1 mm (as an adhesive gap), and this offset post was subtracted from the main post and core, resulting in the final main post-and-core model (Fig. 4B, C). Subsequently, a three-dimensional virtual model representing the final restoration was transformed into a standard tessellation language (STL) file, which was subsequently transmitted to the 5-axis milling machine (Ceramill Matik; Amann Girrbach) to precisely craft the PEEK (BioPAEK; Sino-Dentex Co. Ltd., Changchun, China) restoration.

Definitive restoration

The posts were initially tested for fit within the root canals (Fig. 5A, B). The surfaces of the PEEK posts and core were thoroughly cleaned using 75% ethanol and dried with compressed air. An adhesive substance (Visio.link; Bredent, Senden, Germany) was applied to the surface of restorations using brush, and then was polymerized for 90 s with the help of halogen light curing unit. The polymerization time was chosen according to the manufacturer recommendation. Simultaneously, the post space and remaining tooth structure were etched with 35% phosphoric acid for 15 s, followed by rinsing and air drying. A uniform layer of adhesive (Single Bond Universal Adhesive, 3 M Oral Care, St. Paul, Minnesota) was applied on the tooth structure. Then a resin adhesive (RelyX™ Ultimate Adhesive Resin Cement; 3 M Oral Care, St. Paul, MN, USA) was injected into both the root canal and interior of the crown using a Centrix (Shelton, CT, USA) syringe to facilitate the concurrent cementation of the post and crown (Fig. 5C). X-ray images were obtained after cementation to confirm the success of

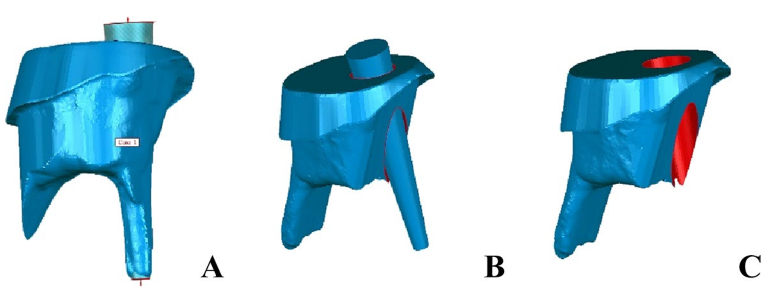

Fig. 4 Design process of split post. **A** The cone feature is fitted according to the meshes of the auxiliary post. **B** The cone offset is subtracted by 1 mm from the primary post and core. **C** Final primary and auxiliary post-and-core model

Fig. 5 Trial fit of the post and core. **A** Trial fit of the primary post and core. **B** Trial fit of the auxiliary post, followed by the removal of the portion above the core. **C** Occlusal relationship after final cementing

the procedure. Subsequently, the patient received comprehensive oral hygiene education upon completion of the restoration.

Follow-up

At a 3-year follow-up examination, the evaluation of the restorations was performed was conducted using the World Federation criteria (FDI) [25]. The restoration was clinically evaluated for aesthetics, function, and biocompatibility through intraoral examination (Fig. 6A), radiographic assessment (Fig. 6B), and subjective satisfaction of the patient. Based on FDI criteria, the restoration was deemed clinically good.

Discussion

Restoration of the remaining crowns and roots plays a crucial role in restoring a patient's chewing function and maintaining the integrity of the dental arch [26]. The preservation of residual roots not only retains the sensory system of the periodontal ligament but also slows down the rate of alveolar bone resorption, contributing to the preservation of alveolar bone height [27]. Restored residual roots and crowns can serve as abutments to replace the missing adjacent teeth. This restoration is particularly important for cases with residual roots and crowns at the end of the dental arch as it effectively prevents sinking or tilting of removable partial prostheses at the end of the dental arch, yielding favorable clinical outcomes [28].

The use of split post and core addresses the challenge of inadequate retention of restorations, such as inlays and full crowns, while also providing a solution to the challenge of achieving a common insertion direction. Primary and auxiliary posts do not require a mutual path of insertion; instead, they rely on mutual interlocking within the core, which enhances retention, improves fracture resistance, and offers antirotational properties. The core can restore the full crown preparation form, ensuring a secure fit for full crown restorations [13].

The stress distribution within the tooth roots is closely related to the elastic modulus of the post and core material. Materials with an elastic modulus similar to that of the dentin tend to exhibit higher stress levels post-restoration. This is done to minimize the distribution of stress transferred to the tooth structure and mimic the mechanical properties of natural teeth [29]. Under the same physiological occlusal conditions, stress transmitted from post-restoration with a higher elastic modulus to dental dentin with a lower elastic modulus can result in stress concentration within the root canal walls, thereby increasing the risk of irreversible vertical root fractures [12]. Additionally, greater tensile and shear

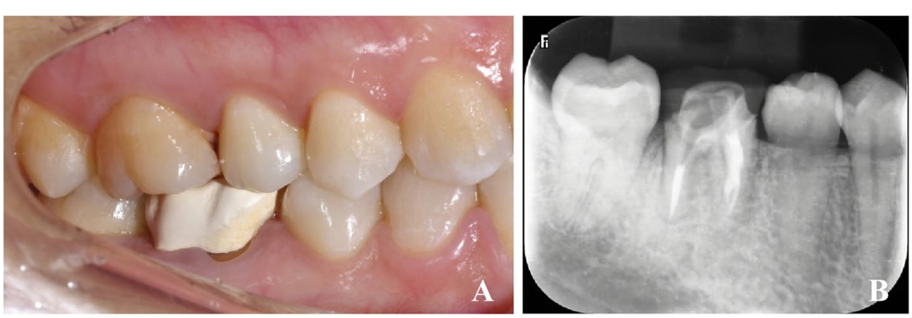

Fig. 6 Intraoral photographs and periapical radiographs taken during the 3-year follow-up. **A** Intraoral photographs show no abnormalities except for slight discoloration of the restoration. **B** Periapical radiographs also show no abnormalities

forces can occur at the cement interface, potentially leading to decementation of the post [30].

Pure PEEK material has an elastic modulus of 3–4 GPa, lower than dentin's 18.6 GPa. Therefore, the mechanical properties of PEEK can be adjusted by adding or modifying the filler content. This can change the elastic modulus of PEEK and, to some extent, enhance its mechanical strength, which helps prevent issues such as insufficient mechanical strength and poor stress resistance in PEEK restorations. Compared to glass fibers and metals, PEEK posts distribute stress more favorably in restorations and tooth structure [31]. However, although the risk of root fractures is reduced, PEEK post-and-core restorations transfer more stress to adjacent adhesives and crowns, thus increasing the possibility of decementation [19]. Additionally, due to the bioinertness of PEEK, surface modification is necessary to enhance its bonding strength [6]. In this case, PEEK restorations were treated with concentrated sulfuric acid and Visio.link adhesive to improve surface roughness, increase mechanical interlocking, and enhance bonding strength. In PEEK multipost restorations, the different angles of primary and auxiliary posts are managed by high-angle limitations, effectively mitigating the risk of decementation. A follow-up examination 3 years later did not reveal any decementation or damage to the remaining tooth structure.

Compared to the process of casting metal split post and core, this report greatly reduces technical sensitivity and time costs. Simultaneous design and manufacture of the post core and crown also reduce the number of patient appointments. Compared to the prefabricated fiber post process, this process requires additional time to process the post and core in the laboratory. However, after suitable trial placement, the post and crown can be directly bonded simultaneously, reducing chairside operation time with consistent appointments. In the future, technicians familiar with the digital design and fabrication process of the post core in this study will further save time and cost in the laboratory.

Repairing weakened roots through post core restorations is a challenging process, particularly due to the thin remaining tooth structure. In this case, the remaining tooth structure was insufficient, and opting for prefabricated posts would have required additional tooth structure preparation to match the geometrical shape. Studies have shown that, compared with CAD-CAM milled posts, prefabricated posts are associated with significantly higher rates of catastrophic fractures [32, 33]. This is attributed to the potential of poorly adapted posts to induce increased deflection and wedging motions within the post space, resulting in irreparable failures [34]. CAD-CAM enables the creation of more anatomical shapes, reduces cement thickness, adhesive interface between the post and core, and minimizes void formation [21, 35, 36]. This approach results in improved accuracy, the frictional resistance of the post and core within the canal, bonding strength and better adaptation with less canal preparation required [37, 38]. Additionally, customized post and cores are recommended when alterations to the coronal angle are necessary [39].

Accurate information on canal morphology is necessary for adequate customized post and core design and fabrication. Traditional lost wax techniques and impression materials for casting metal posts and cores can be prone to distortion and require high technical skill, potentially decreasing the accuracy of restorations [40]. The challenge in digitizing canal impressions with intraoral scanners is that the light source cannot reach the deepest part of the post space because of the obstruction of the remaining tooth structure and narrow anatomical structure of the canal, which prevents the acquisition of complete and precise canal impressions [41]. In the present case, a partial canal impression was scanned to obtain an intraoral digital impression, and two models were merged to immediately acquire a complete digital model of both the canal morphology and remaining tooth structure. Research suggests that the accuracy of this indirect digital scanning technique for canals falls within clinically acceptable ranges, and, in some cases, exceeds that of traditional methods [42, 43].

The limitation of this case was that PEEK material exhibits low radiopacity, necessitating adjustments in image brightness and contrast to clearly discern the morphology of the PEEK crown. Additionally, PEEK crown has a somewhat whitish color, which may not match the color of the adjacent teeth, making it suitable only for posterior restorations where aesthetics is less critical. Subsequent improvements in aesthetic performance can be achieved using resin-based adhesive materials [23].

Conclusion

Based on the exposed and documented follow-up examinations, CAD-CAM milled multiposts can yield acceptable outcomes for cases involving extensive loss of tooth structure and thin dentin at the root canal floor, with no abnormalities detected during a 3-year follow-up. However, it is necessary to gather additional cases and conduct long-term follow-up observations to assess the restorative effectiveness of PEEK post-and-cores in such teeth.

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None.

Authors' contributions
Xin Wang performed drafting of the manuscript, writing, patient data acquisition of the manuscript and literature search. Sheng Zhong and Dan Ma contributed substantially to the conception, design, and patient data acquisition of the manuscript. Chen Liu and Yuchen Liu searched literatures and edited the format of the manuscript. Yimin Zhao: performed the clinical diagnosis, treatment. Shizhu Bai performed the clinical diagnosis, treatment and revised the manuscript as the corresponding author.

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Availability of data and materials
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
To declare that this retrospective study conducted in Digital Center, School of Stomatology, The Fourth Military Medical University was conducted by the applicable ethical principles, including the 1964 World Medical Association Declaration of Helsinki and its later versions. It was also reviewed and approved (Approval Code: IRB-REV-2022188; Date: 01/12/2022) by the Ethics Committee of the Third Affiliated Hospital of the Fourth Military Medical University. In addition, informed consent forms were obtained from the patient before the treatments.

Consent for publication
A written informed consent for publication was obtained from the patient to publish all clinical date and any accompanying images and also a written consent to publish this information was obtained from study participant.

Competing interests
The authors declare no competing interests.

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