Different strategies for treating intracanal fractured instruments in a single tooth: A case report

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Abstract. A fractured instrument (FI) in the root canal is a common complication during root canal therapy. Under current medical conditions, instrument separation cannot be completely avoided because of the complex morphology of root canals and the limited surgical field and operating space of the surgeon. FIs, especially those broken in the apical third of the canal, render it difficult to completely remove infection in the root canal, where the residual infection can easily develop into reinfection. The removal of FIs is therefore the preferred option for the majority of clinicians in such cases. However, root canal preparation instruments are frequently fractured during treatment because of the complex root canal morphology, such as curvature or severe calcification, which further increases the difficulty of instrument removal. In the present case, a 41-year-old female patient complained of worsening pain in the left maxillary first molar for 3 days. This patient had been treated at another hospital 2 years earlier, but the discomfort persisted after treatment. Preoperative periapical radiography revealed suspected FIs at the apical third of the mesiobuccal (MB) root and the middle third of the distal buccal (DB) root, underfilling of the palatal (P) root canal and large hypodense areas surrounding the periapical region of all roots. Next, the micro-ultrasound technique was used to remove the FI in the DB canal; a bypass through the second MB canal (MB2) was created to fill the apical stop of the MB root and the P canal was retreated. The therapeutic effect of the bypass technique was assessed by comparing bypass treatment and removal treatment for endodontic FIs. The 9-month and 27-month follow-ups revealed that the periapical inflammation surrounding the DB root treated after removal of the FI and the MB root treated by bypass was significantly controlled compared with that before the operation. In addition, the present report reviewed the research progress in bypass and removal techniques, focusing on the difficulties and key points of successful root canal therapy.

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Introduction

Delicate nickel-titanium instruments are essential in root canal therapy. However, when the operation of the surgeon is not standard or the morphology of the root canal is too complex, the force applied to the instrument exceeds the anti-fatigue strength, and the instrument is likely to fracture in the root canal (1). It has been previously reported that the worldwide probability of instrument fracturing during root canal treatment ranges from 0.7 to 7.4%, which is difficult to avoid even by experienced dentists and endodontists (2-4). Fatigue separation accounts for 50-90% of instrument separations worldwide (5). During the process of root canal preparation, tensile and compressive stresses are repeatedly applied to the instrument, resulting in microcracks on its surface. When the instrument works in the curved or narrow parts of the root canal, the cracks are easily broken, resulting in separation. The retention of fractured instruments (FIs) in the root canal makes disinfection of the root canal, a critical factor in the success of root canal therapy outcomes, difficult to achieve effectively, thus reducing the success rate of treatment (6).

From the perspective of the patient, residual FIs may trigger anxiety as they may be viewed as treatment failure or even medical malpractice. Any problems the patient encounters in the future may be attributed to this. Therefore, with the popularization and availability of dental microscopy, ultrasonic equipment and professional tools for removing FIs, the removal of FIs is becoming the first-choice strategy for clinicians (7). However, since the majority of separations occur during the treatment of root canals with poor surgical fields and small, curved and severely calcified root canals, not all files can be effectively removed. During the process of establishing a straight path in the root canal, varying degrees of tooth tissue are removed, increasing the risk of lateral perforation and root fracture (8). Therefore, bypass techniques, which consist of retaining and bypassing the FI to seal the apical stop, should be considered. However, the success rate of bypass techniques remains a topic of debate in the field of root canal therapy. This

report attempts to explore the feasibility of bypass technique for FIs by comparing the postoperative outcomes of removal and bypass techniques for the same tooth.

Case report

The present case involved a 41-year-old female patient who was conscious with no underlying disease. The patient complained of pain in the left upper posterior tooth for 6 months, which intensified in the last 3 days before presentation. The patient reported that the affected tooth had been treated in another hospital due to pain 2 years prior, but the discomfort persisted after treatment. A sudden onset of pain 6 months prior to admittance to hospital, which was not treated, had occurred intermittently since then. However, 3 days prior to admittance to hospital, the pain worsened and was only slightly relieved by anti-inflammatory drugs. In addition, 2 days prior to admittance to hospital, the patient was treated at another hospital, which suggested implant restoration after extraction of the affected tooth. In September 2021, after studying the medical history, the implantologist at Xi'an International Medical Center Hospital in Xi'an, China referred the patient to the endodontist for further evaluation of the retention value of the affected tooth.

Intraoral examination revealed a large area of defects on the distal proximal surface of tooth no. 26, with partial loss of white filling material and secondary caries at the edge of the material. The affected tooth experienced severe pain on percussion, but no discomfort from cold stimulation or probing. The extent of loosening was I°. The buccal vestibular sulcus of the affected tooth was swollen and painful to press. A fistula was observed in the mucosa of the buccal apical region. Periodontal probing revealed no significant attachment loss. Diagnostic X-ray revealed that tooth no. 26 had been endodontically treated (Fig. 1A). There were suspected FIs in the apical segment of the mesiobuccal (MB) root and the middle segment of the distal buccal (DB) root; the palatal (P) canal filling was underfilled, and there was also a large hypodense area surrounding the periapex of the three aforementioned roots (Fig. 1A). Cone-beam CT (CBCT) revealed that the MB root was suspected of having two canals, where the FI was present in the first MB canal (MB1) but there was no obvious filling in the MB2 (Fig. 1B). On the basis of these observations, a diagnosis of chronic apical periodontitis was made for tooth no. 26. Since the patient expressed a desire to retain the affected tooth, root canal retreatment of tooth no. 26 was planned after communication with the patient. Specifically, the intended protocol involved removing the FI at the middle of the DB canal, establishing a bypass through the MB2 canal for treating the MB root and then retreating the P root.

The original filling was removed via a diamond bur, after a rubber dam was used to isolate the affected tooth. Under a dental operating microscope (OMS 2380; Zumax Medical Co., Ltd.), two root canal orifices, MB1 and MB2, could be observed in the MB root (Fig. 1C). The FIs in the DB canal were removed (Fig. 1D) via the ET20 and ET25 working tips with an ultrasonic therapeutic instrument (P5 Newtron XS; Satelec; Acteon). A mechanical endodontic retreatment file (PROTAPER A1412; Dentsply Sirona, Inc.) was used to remove the filling material in the P canal. The initial working length of the root canals was measured via diagnostic X-ray and an apex locator (PROPEX II; Dentsply Sirona, Inc.). Subsequently, no. 8 and no. 10 K files (K-FILES; Mani, Inc.) were used to dredge the canals. The root canals were prepared using an X-SMART endodontic micromotor (X-SMART PLUS; Dentsply Sirona, Inc.). During preparation, the root canals were irrigated repeatedly with 20 ml of 1% sodium hypochlorite (NaClO) solution and 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) solution. The DB, MB1 and MB2 canals were prepared with a #25/0.04 taper, whereas the P canal was prepared with a #35/0.04 taper. After repeated irrigation using an ultrasonic therapeutic instrument, sterile paper tips were used to dry the root canals, and calcium hydroxide paste (ApexCal; Ivoclar Vivadent) was inserted into the root canals. Upon inserting the paste into the MB2 root canal orifice, it was observed that the paste flowed upwards from the MB1 root foramen (Fig. 1E), supporting the suspicions that the MB1 canal fused with MB2 to form a single canal at the apical segment. A sterile cotton pellet was placed in the pulp chamber before the access cavity was sealed via temporary sealing paste (Cavit-G; 3M ESPE).

At 2 weeks after the procedure, the affected tooth had no percussion pain or abnormal mobility. The apical segments of the MB2, DB and P canals were filled with large taper gutta-perchas (RECIPROC; VDW GmbH) and injectable root canal sealers (iRoot SP; Innovative BioCeramix, Inc.) via the vertical compression technique. The middle and coronal segments of the four root canals were filled with warm gutta-percha via a gutta-percha heating system (WL-B1; B&L Biotech). After filling, X-ray imaging revealed that all the root apexes were fully filled (Fig. 1F).

At 1 week later, the affected tooth demonstrated no percussion pain, no abnormal mobility and no obvious abnormalities in the buccal or lingual mucosa. The tooth was restored with an onlay.

At 9 months after surgery, CBCT revealed that the hypodense area surrounding the DB, MB and P root apex had significantly diminished (Fig. 2). At 27 months after surgery, CBCT revealed that the hypodense areas surrounding the DB, MB and P root apex almost completely disappeared (Fig. 2).

In the present case, FIs were successfully removed from the middle third of the DB canal under an oral microscope with the use of ultrasonic equipment. If attempts were made to remove the FI in the MB root, regardless of success, then a large amount of tooth tissue would have to be removed, increasing the risk of para-perforation and root fracture. In addition, preoperative CBCT revealed that the MB root had two canals, MB1 and MB2, which were suspected to have fused into one canal at the apical segment. Furthermore, the incidence of 2-into-1 canal when two canals are present in the MB root of the maxillary first molar is ~60% (9). Therefore, filling the apical foramen of the MB root by establishing a bypass through MB2 was planned before the operation, and was successfully implemented (Fig. 3).

At 9 months after surgery, the periapical hypodense areas surrounding the MB, DB and P roots markedly decreased, and the periapical tissue had almost completely recovered at 27 months after surgery.

The present report compared the postoperative outcomes of removal and bypass techniques for the same tooth. The

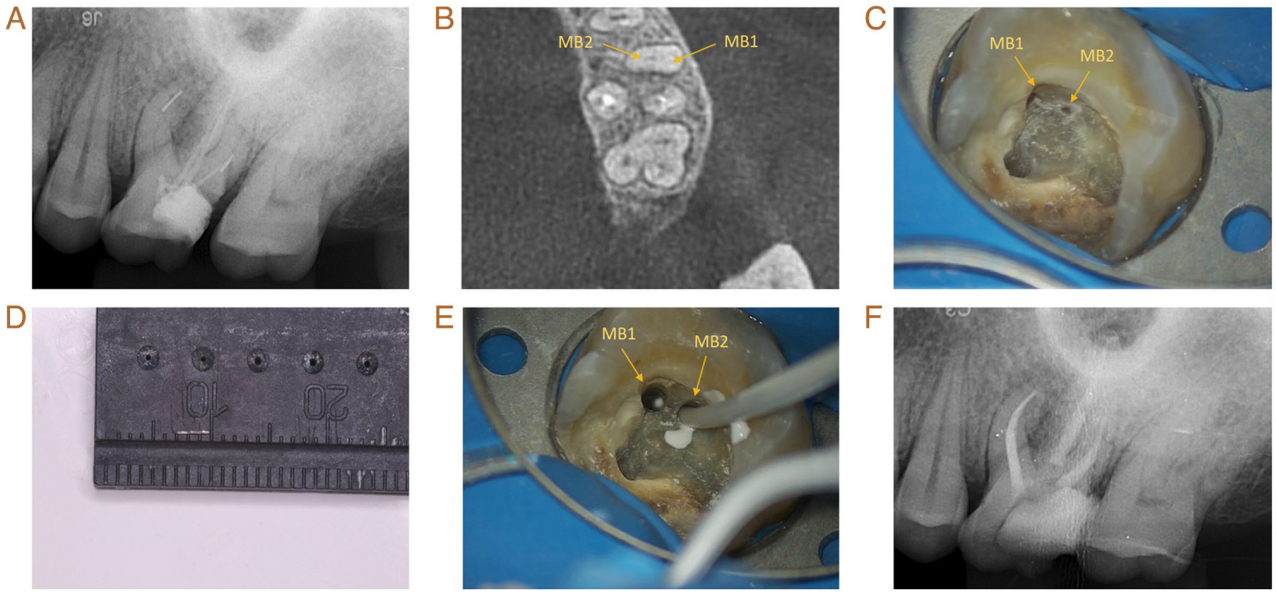

Figure 1. Root canal retreatment process for tooth no. 26. (A) Preoperative diagnostic X-ray of tooth no. 26. (B) CBCT demonstrated that the MB root was suspected of having two canals, MB1 and MB2. (C) Under a dental operating microscope, there were two root canal orifices, MB1 and MB2, in the MB root. (D) A 3-mm FI was removed from the DB root. (E) When the paste was inserted into the MB2 root canal orifice, the paste flowed upwards from the MB1 root foramen. (F) Immediately postoperative X-ray of tooth no. 26. CBCT, cone-beam CT; MB, mesiobuccal; FI, fractured instrument; DB, distal buccal.

bypass technique should therefore be considered a nonsurgical treatment if the FIs in the root canal are difficult to remove or if the post-removal risks become unacceptable.

Discussion

To the best of our knowledge, universal guidelines for the management of root canals with FIs remain elusive. A previous retrospective study suggested that the ability of a physician to make a balanced decision by combining clinical experience with the specific condition of the affected tooth is important (7). During the preoperative planning of the present case, the location of the FIs, the anatomical characteristics of the root canals and the risk of removal were considered. The final decision was made to remove the FI in the middle of the DB canal and to treat the FI in the MB canal by bypass. This allowed for the observation of differences in the therapeutic outcomes between the removal technique and the bypass technique. At 9 and 27 months of follow-up, the periapical inflammation in both roots was markedly improved and the treated tooth became asymptomatic. The results demonstrated that as long as the root canal system was disinfected as much as possible, the pathogens remaining on the FI surface of the root canal could be effectively removed and the disinfected FIs would not cause secondary infection of the root canal. When FIs are used as part of the filling process, the root canal is tightly filled to prevent the invasion of foreign pathogens and an ideal retreatment effect can be achieved. Overall, as long as the infection in the root canal is removed as much as possible and the root canal is tightly filled, successful treatment can be performed. In the present case, this was successfully achieved by using the bypass technique.

The removal of FIs has been considered the ideal treatment after instrument separation (8). Widely accepted removal techniques include the Endo Extractor system, the wire loop technique, the Masserann kit and ultrasonication (10). In previous years, several reports have proposed endodontic templates for guiding trephines (11), computer-assisted methods (12), modified hollow tube-based extractor systems (13) and innovative low-cost device techniques (14). Previous studies have shown that the success rate of removal is 85.5% when the FI is visible under an oral microscope, but only 47.7% when the FI is not visible (7,15). Among numerous file removal methods, ultrasonic techniques have been consistently reported as safe and successful (16). In the present case, the visible FI from the middle segment of the DB canal was successfully removed using an ultrasonic device under the microscope. Ultrasonic equipment has been used in endodontics since 1957 and has been constantly improved. Current handpieces operating at 1-8 kHz have been documented to improve the success rate of FI removal because of their low shear stresses and fewer changes on the canal surface (17).

In a series of cases reported by Hindlekar *et al* (18), FIs were successfully removed via the Acteon Satelec P5 Neutron, the same device used for the present case. The unit tips of the device move back and forth in a linear piston-like manner, rendering them suitable for endodontic treatment (19). However, notably, the heat generated by the friction between the ultrasonic tips and the root canal wall may lead to instrument fatigue and secondary fracture of the fragment. Therefore, ultrasonic tips at low-power levels cannot be operated for prolonged periods (20). Hashem (21) previously demonstrated that water should not be used to cool the ultrasonic tip to maintain a good surgical field of view, and the power of the device should be set to moderate and used intermittently (21).

Madarati *et al* (7) have suggested that five factors can affect the efficacy of the bypass technique: i) Severity of the tooth symptoms; ii) whether the tooth can establish a smooth bypass to reach the apical stop; iii) whether the infectious tissue surrounding the periapex of the affected tooth can be

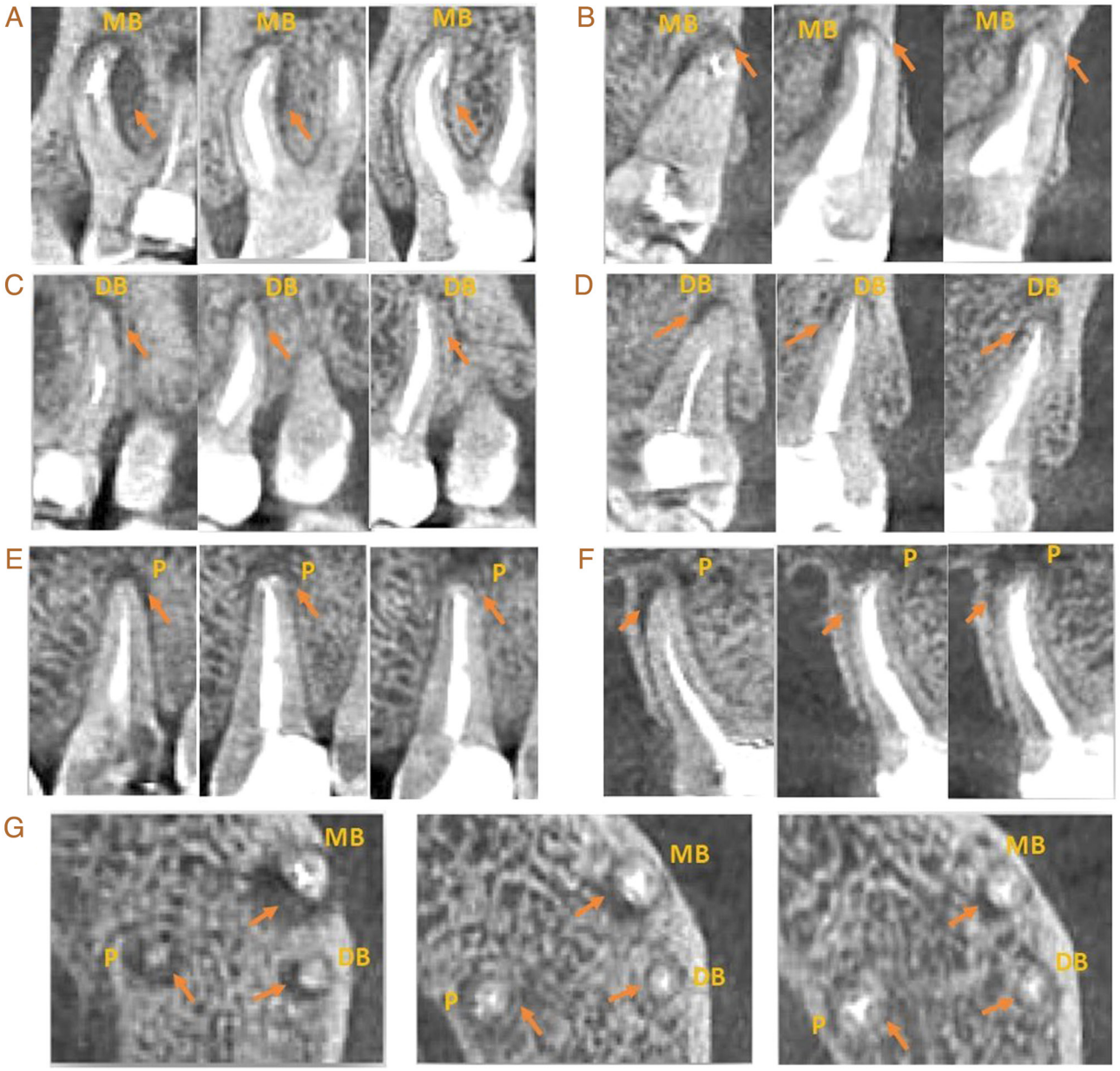

Figure 2. Follow-up observation of tooth no. 26 via X-ray. (A) Sagittal X-ray of the MB root. the first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (B) Coronal X-ray of the MB root. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (C) Sagittal X-ray of the DB root. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (D) Coronal X-ray of the DB root. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (E) Sagittal X-ray of the P root. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (F) Coronal X-ray of the P root. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. (G) Cross-sectional X-ray of the three types of roots. The first was taken before the operation, the second was taken 9 months after the operation and the third was taken 27 months after the operation. MB, mesiobuccal; FI, fractured instrument; DB, distal buccal; P, palatal.

effectively removed; iv) whether the bypass can be tightly filled; and v) whether the periodontal infection can be effectively controlled if the affected teeth have periodontal symptoms. In addition, the treatment success rate of teeth with pulpitis is considerably higher compared with that of teeth with periapical inflammation (22). Although there was severe periapical inflammation in the MB root of the affected tooth in the present case, the inflammation was effectively controlled after the establishment of a smooth bypass, removal of as much apical infectious tissue as possible and tight filling of the apical stop. The treatment effect on the affected tooth was obvious. The periapical hypodense areas surrounding the MB root apex had significantly diminished at 9 months after treatment, and almost completely disappeared at 27 months after treatment. And by now, the affected tooth has not experienced any discomfort.

Recently, with the upgrading of dental instruments and the accumulation of research data, the type of FI and the degree of canal curvature have also become important factors affecting bypass therapy outcomes (23). It has been reported that the success rate of bypassing RaCe is higher compared with that of K3 and Hero 642 rotary nickel-titanium files (23). By contrast,

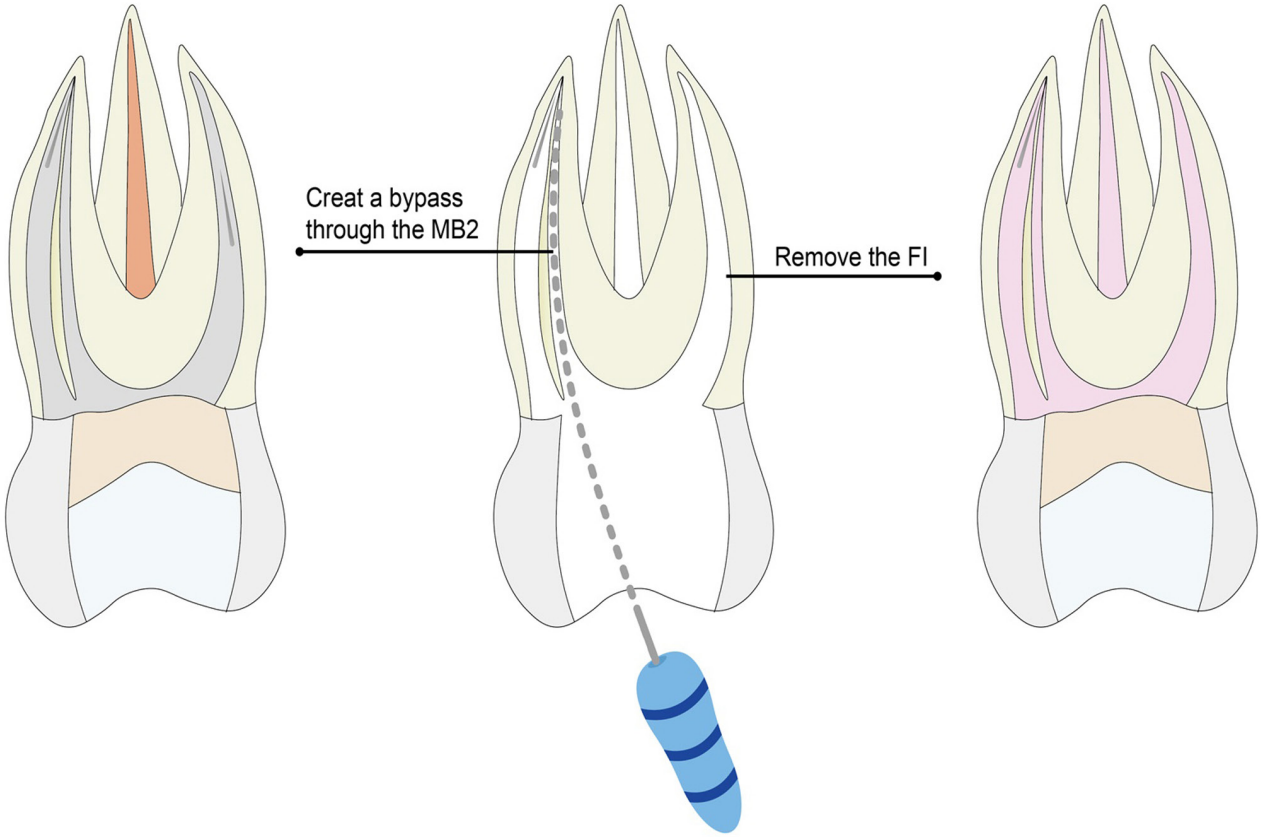

Figure 3. Different strategies for tooth no. 26. FI, fractured instrument; MB, mesiobuccal.

the success rate of the bypass technique is improved for instruments that fractured in the anterior part of the curved canal (23). In addition, compared with normal root canals, the success rate of excessively curved canals is markedly reduced (23).

Kalogeropoulos *et al* (24) suggested that preoperative CBCT examination plays an important role in decision making prior to the management of FI. In the present case, preoperative CBCT examination revealed that the MB canal where the FI was located was fused with the MB2 at the apical segment, justifying the bypass technique instead of the removal technique on the basis of clinical experience. For the effective removal of the smear layer and infectious tissues in the root canal, Sinha *et al* (25) previously demonstrated that the use of both EDTA and NaClO with the ultrasonic system appears to be the most effective combination of flushing fluid. Liu *et al* (26) reported that laser-activated irrigation (LAI) and LAI combined with the photon-induced photoacoustic streaming technique results in increased vaporized bubble kinetics and superior cleaning efficacy in the apical area, even in the presence of FIs. In addition, the filling of bypass canals is one of the key factors for the success of root canal therapy. Vadachkoria *et al* (27) demonstrated that thermoplastic GuttaMaster and GuttaFusion show superior adhesion to the walls. The heated gutta-percha has good fluidity and plasticity. The vertical condensation technique used in the filling process can fill the hot gutta-percha into all corners of the bypass canal, achieving a satisfactory filling effect for some small curved irregular gaps between the FI and the root canal wall. The cooled gutta-percha and FIs then form a dense whole in the root canal that is close to the root canal wall, achieving an ideal three-dimensional root canal filling effect, tightly sealing the root canal system and improving the success rate of root canal treatment (28).

In conclusion, the present case suggested that the bypass technique can be considered an alternative treatment if removing FIs from root canals is considered too difficult and/or risky. Clinicians should combine their clinical experience and the specific FI conditions to make further decisions. However, there are certain limitations to the present report. The results observed in only one case are not sufficiently convincing and more samples and data should be collected in follow-up research. In a follow-up study, a total of 60 teeth that were removed during orthodontic treatment will be selected and the nickel-titanium instruments in the root apical segment will be broken. One group will be treated by the removal technique, and the other group will be treated by the bypass technique. The success rates of the two groups will be recorded and the data will be statistically analysed. The results will be used to further validate the current conclusions.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

AZ and RM performed the treatment. XJ collected data, RC analyzed data and wrote the manuscript. EY and QZ made contributions to the study's conception and design. AZ conceived the study and provided financial support. AZ and RC confirm the authenticity of all the raw data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

The patient involved in the present study provided written informed consent for publication of their data and images.

Competing interests

The authors declare that they have no competing interests.

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