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CASE REPORT

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Robotic navigation system for management of pulp canal obliteration: A case report

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Abstract

Aim: To describe the application and management of robotic navigation system in access cavity preparation of a maxillary central incisor with severe pulp canal obliteration.

Summary: The identification and preparation of root canal(s) in teeth with pulp canal obliteration (PCO) may be challenging, resulting in excessive removal of sound dentine and/or perforation. A static or dynamic navigation system has been demonstrated to be a useful aid to locate obliterated canals with minimal removal of sound dentine. However, navigation systems are not completely infallible, with potentially poorer outcomes when used by an inexperienced operator. This novel case adds to the emerging clinical literature on the robotic navigation system (RNS) in endodontics to increase the accuracy of access cavity preparation and to preserve tooth substance in a tooth with PCO and diagnosed with chronic periapical periodontitis. A 34-year-old male was referred for the management of an endodontic problem. His chief complaint was intermittent, mild discomfort which lingered for over 30 s localized to the upper left central incisor tooth #9 (21) to cold drinks for 1 week. Clinical examination revealed that tooth #9 (21) was tender to percussion and cold thermal testing reproduced the patient's presenting symptoms. A radiograph, including a cone beam computed tomography scan, revealed pulp canal obliteration and widening of the periodontal ligament of the apical third of tooth #9 (21). A diagnosis of symptomatic irreversible pulpitis was reached. The Digital Information and Communication in Medicine (DICOM) dataset was exported into an RNS. The RNS successfully accessed the canal without any human intervention, after which endodontic treatment was completed by an endodontist. At a 12-month review, the tooth was asymptomatic and a radiograph confirmed healthy periapical tissues. This case highlights the potential use of RNS for minimal access and time-saving access cavity preparation of teeth with PCO.

Key learning points:

- Multiple factors can lead to pulp canal obliteration, making it difficult to locate and negotiate the root canal.
- Robotic navigation system is a minimally invasive, efficient, and predictable solution for managing calcified root canals.

KEYWORDS

cone beam computed tomography, dental pulp calcification, robotics, root canal preparation

INTRODUCTION

Endodontic access may be challenging when there is pulp canal obliteration (PCO). The calcified blockage in the pulp chamber and/or root canal system may hinder locating the canal entrances (Cvek et al., 1982). This may result in inadvertent, excessive removal of sound dentine and even iatrogenic complications such as perforation, canal deviation, and instrument separation, which may ultimately have a negative impact on the outcome of treatment (McCabe & Dummer, 2012). Iatrogenic complications may occur even when treatment is carried out by experienced clinicians using a dental operating microscope (DOM; Yang et al., 2016).

In recent years, static navigation (SN) has been developed to manage PCO. This involves taking a cone beam computed tomography scan (CBCT) and an intraoral scan of the patient's dentition to virtually plan an access cavity preparation using implant planning software such as Mimics Medical Software (Materialise, Leuven, Belgium) to allow a customized template or stent that incorporates a sleeve to guide a pilot drill directly to the target point, thus minimizing intraoperative mistakes (Connert et al., 2018; Giacomino et al., 2018; Torres et al., 2019). Guided endodontic access techniques have been shown to efficiently create an accurate drill path while preserving more tooth substance compared to conventional access cavity preparation (Connert et al., 2019; Torres et al., 2021). However, SN still has limitations, including the lack of water cooling, obstruction of the operation field, and the need for additional (treatment) visits.

Dynamic navigating (DN) may overcome the limitations of SN issues; it also utilizes CBCT and intraoral scans of the patient's dentition. Strategically positioned reference markers are placed on specific teeth which can be tracked by stereo cameras on DN system, a handpiece with another marker is registered and matched with the reference marker on DN system (Bardales-Alcocer et al., 2021). As a result, the image of patient's teeth and handpiece can be visualized on one monitor, permitting real-time navigation and allowing the operator to precisely monitor the handpiece's position relative to the tooth undergoing treatment, thus increasing the accuracy and efficiency of the access cavity preparation. The orientation, progression, and position of the access cavity bur in relation to the tooth surface and access cavity can be assessed in three orthogonal planes.

In implant dentistry, DN has been used as a robotic navigation system (RNS) to enhance the digital workflow, enabling the clinician to step away from hands-on involvement and be substituted with a pre-programmed operational robotic arm. Several in vitro studies have demonstrated that RNS results in accurate implant placement (Chen et al., 2023; Jia et al., 2023; Zhou et al., 2023). RNS may also be used to locate severely sclerosed root canals.

The aim of this case report was to describe the application and management of RNS in access cavity preparation of a maxillary central incisor with severe PCO.

CASE REPORT

This case report has been written according to Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 guidelines (Nagendrababu et al., 2020; Figure 1).

A fit and healthy 34-year-old male was referred by his general dentist for endodontic management. The patient complained of an intermittent, mild discomfort which lingered for over 30 s localized to the upper left central incisor tooth #9 (21) to cold drinks for 1 week. There was no history of dental trauma, but the patient did have a course of orthodontic (fixed braces) when he was a teenager. Clinical examination revealed that soft tissues were healthy. Tooth #9 (21) was tender to percussion and cold thermal testing reproduced the patient's presenting symptoms; there were no other signs of endodontic or periodontal disease associated with the upper anterior sextant. A periapical radiograph (Minray Periapical DC X-ray Unit, Soredex, Tuusula, Finland) was taken at 70 kV, 7 mA, with the exposure time of 0.16 s, revealing pulp canal obliteration, partially blunted root apices, and widening periodontal ligament of the apical third of tooth #9 (21) (Figure 2). A diagnosis of symptomatic irreversible pulpitis was reached for tooth #9 (21). After discussing the different treatment options with the patient, non-surgical root canal treatment was planned with the aid of an RNS (Remebot, Beijing Baihui Weikang Technology Co., Ltd., Beijing, China; Figure 3). The rationale and nature of treatment with RNS were discussed with the patient. The patient provided verbal and written consent.

CLINICAL PROCEDURE

Preoperative preparation

A universal pre-fabricated positioning marker (Remebot, Beijing Baihui Weikang Technology Co., Ltd., Beijing, China; Figure 3) was attached to 2–3 contralateral teeth in upper dentition with self-cured acrylic resin (Protemp™, 3 M ESPE, St. Paul, MN, USA; Figure 5), after which a CBCT scan was taken at 90 kVp, with a FOV of 13 cm × 16 cm

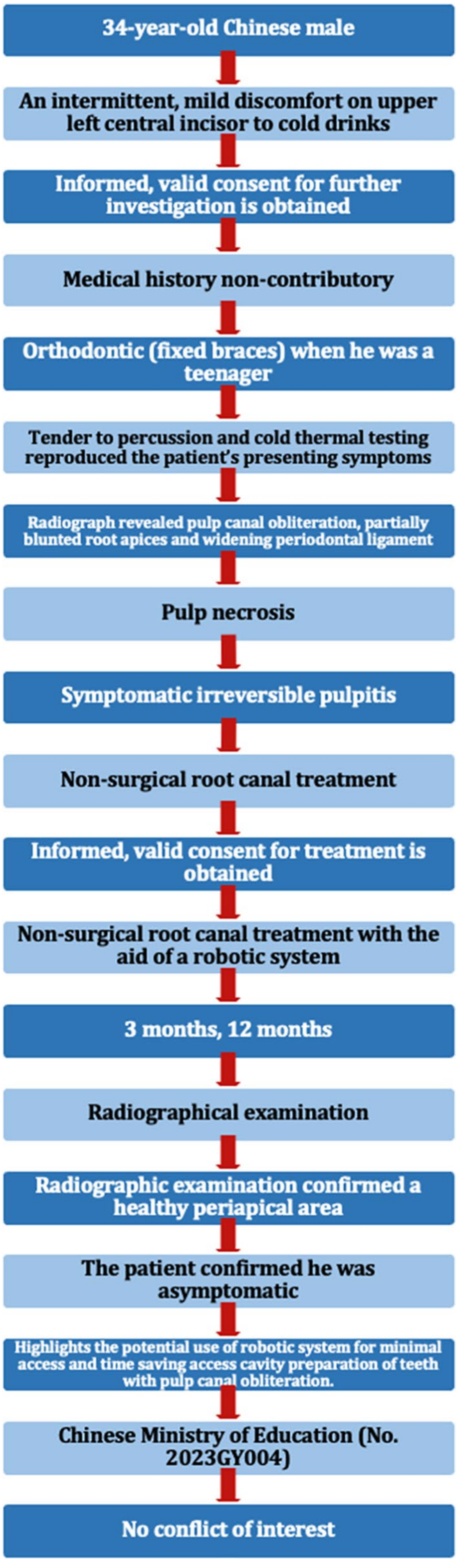

FIGURE 1 PRICE 2020 flow chart.

and voxel size 0.3 mm (Giano HR, NewTom, Imola, Italy). The Digital Information and Communication in Medicine (DICOM) dataset was imported into the RNS using companion software RemebotDent (Remebot, Beijing Baihui Weikang Technology Co., Ltd., Beijing, China; Figure 4).

Registration and calibration

Registration and calibration were performed using the optical tracker of RNS (Figures 4 and 5); seven reference points were selected and calibrated to facilitate connection between the drill fixated on the robotic arm and the CBCT scan. The path of the handpiece and bur was planned to pass through the centre of DEJ, maintaining straight-line access to a depth of 14 mm apical to the incisal edge using RembotDent software (Figure 4). Three-dimensional visualization of the access cavity was assessed in real time, allowing the clinician to monitor access cavity preparation and potentially take manual control if required.

Access cavity preparation using RNS

The robotic arm was moved towards the patient's dentition by the operator. During the whole treatment process, the operator should monitor at the right side of the patient in a normal treatment position, ready to take over the RNS in case of any kind of errors. Then registration and calibration were automatically performed by the RNS (Figure 5). A 1.2-mm diameter tungsten carbide bur (HF118A 012 FG, ökoDENT GmbH & Co. KG, Tautenhain, Germany) at 30 000 rpm was used to prepare the access cavity (Figure 4). The access cavity design was automatically executed by the RNS, and the root was prepared a further 3 mm to the estimated location of the root canal entrance. The robotic arm was then moved away, and the clinician, with the aid of a DOM, confirmed the presence of the root canal with a #8 stainless-steel K file (K-files, MANI, Tochigi, Japan).

Treatment

The working length (20.5 mm) was determined with a #8 stainless steel fine and an electronic apex locator (Root ZX, Morita, Kyoto, Japan; Figure 5). The canal was then instrumented with TruNatomy files (Dentsply Sirona, Ballaigues, Switzerland) up to a master apical size of 26#, and irrigated with 3% sodium hypochlorite (Longly Biotechnoloy, Wuhan, China); 17% EDTA (Longly Biotechnoloy, Wuhan, China) was used as a penultimate irrigate before sodium hypochlorite was used. The canal was then rinsed with saline, after which the canal was then obturated with gutta percha and bioceramic sealer (cRoot SP, C-Root Dental Medical Devices Co. Ltd, Beijing, China) using warm vertical compaction. The access cavity was restored with a self-adhesive bonding system (Clearfil SE Bond, Kuraray Noritake, Tokyo, Japan) and a composite resin restoration (Filtek Z350, 3 M ESPE, St. Paul, MN, USA; Figure 5).

FIGURE 2 Pre-operative radiograph. (a) Preoperative apical radiograph. (b–d) Cross-sectional, coronal and sagittal view of tooth #8 (11) and tooth #9 (21).

FIGURE 3 The RNS includes an operating system, a robotic arm, and an optical tracker. The accessories of the system include a positioning marker, a calibration plate, a handpiece gripper and the handpiece. Before the operation, calibration was carried out between the calibration plate, which was connected to the handpiece, and the positioning marker, which was fixated on the patient's dentition. By calibration, the position of the targeted tooth can be located by the handpiece. During the surgery, the optical tracker could capture the positioning marker, which guided the movement of the handpiece.

Follow-up

The patient's previous symptoms completely disappeared after 1 week. At a 12-month review, the patient confirmed he was asymptomatic, clinical examination was unremarkable and radiographic examination confirmed a healthy periapical area (Figure 5).

DISCUSSION

RNS harnesses the recent developments in three-dimensional radiographic imaging and optical scanning and represents a significant advancement in the management of PCO (Xue et al., 2024). Considering the challenges in the detection of root canal space of teeth with

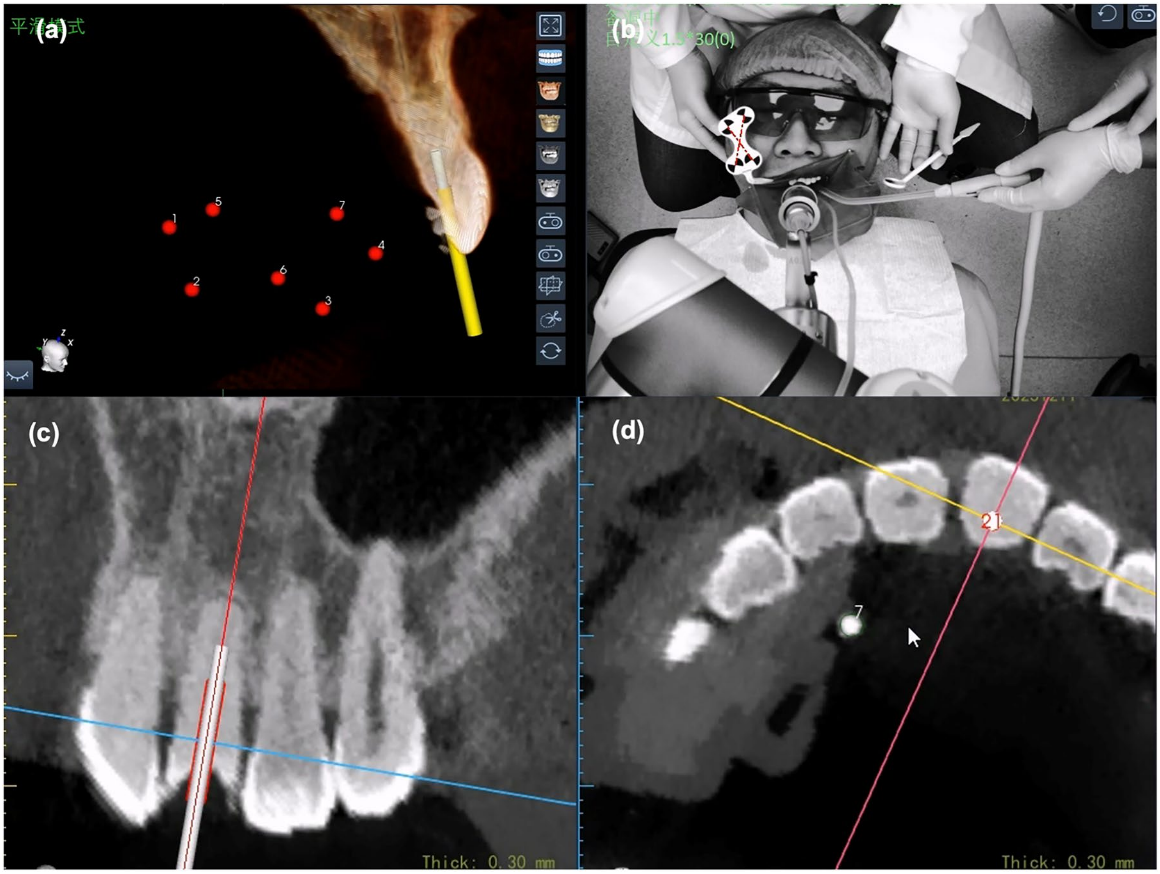

FIGURE 4 DICOM file was imported to RemebotDent software. (a) Seven references were selected and calibrated, and the drill path was designed. (b) The software could locate the marker and monitor the procedure through the optical tracker. (c, d) The drill path could be displayed on the CBCT image in real-time.

PCO, guided endodontics provides a novel approach to address this challenging clinical scenario. A systematic review concluded that the DN system reduces tooth tissue loss as well as improving the accuracy of the treatment (Mekhdieva et al., 2023).

CBCT has limitations in detecting calcified canals due to its resolution constraints (Ordinola-Zapata et al., 2017; Patel et al., 2019). The exact location of the canal cannot be distinguished on pre-operative CBCT scanning in this case; however, based on the anatomy of the pulp chamber and root canal, a drill path may be planned based on the principles of centrality, concentricity and the CEJ (Krasner & Rankow, 2004). It must be stressed that careful planning is required for DN; in addition, operator inexperience may result in deviation from the planned preparation or, in some instances, perforation (Yang et al., 2024).

The first iteration of guided surgery (Static navigation) included 3D-printed templates which were pre-fabricated by matching CBCT data with the intra-oral scan (Zehnder et al., 2016). An observational study of 50 cases with severe PCO reported clinical success in the location of the root canal for the entire group using a pre-fabricated guide (Buchgreitz et al., 2019). A more simplified approach just using CBCT data without the intra-oral scanning has also been reported to achieve similar accuracy (Chaves et al., 2023).

This case report highlights the accuracy of RNS in an extremely calcified tooth with minimal removal of sound dentine. RNS potentially reduces the likelihood of excessive dentine removal or, in extreme cases (near) perforations, thus preserving the peri-cervical region and improving the longevity of the tooth. A similar case was published in an early report; however, without further follow-up (Huang et al., 2025). A 12-month result in our report further strengthens the validity of RNS in the treatment of severe PCO.

The limitations of SN include time spent designing and printing the guide, the template obscuring the surgical site and lack of water-cooling during the drilling procedure (Liu et al., 2018). The DN system overcomes some of the aforementioned problems as a template is not required. The DN system has also been shown to be useful for inexperienced operators and improve their ability to locate root canals (Tang & Jiang, 2023).

In this case report, a heat-treated nickel-titanium (Ni-Ti) system, TruNatomy, was selected for instrumentation as

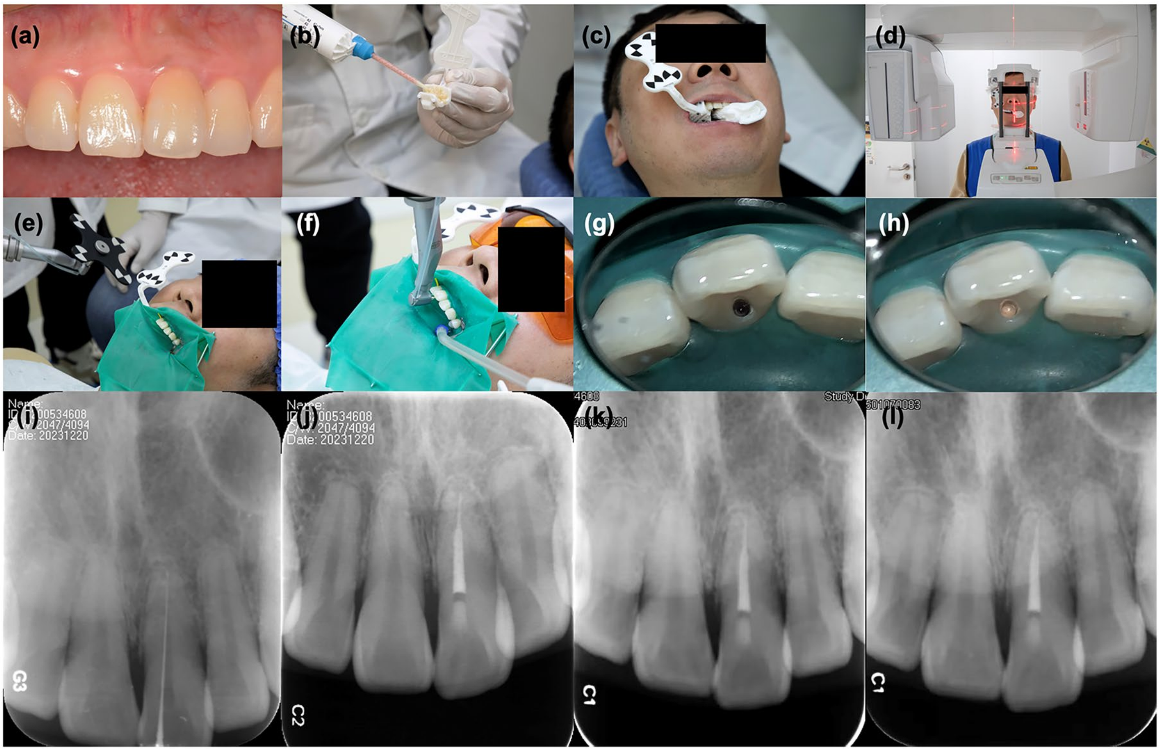

FIGURE 5 Clinical procedure. (a) Clinical view of tooth #9 (b) Self-cured acrylic resin was injected to the marker by the operator. (c) The marker was fixated on the contralateral teeth in upper dentition. (d) Patient underwent CBCT scan with the marker. (e)Registration of the handpiece with the marker. (f) Access cavity preparation was conducted automatically by the robotic arm. (g) Access cavity has been built and root canal could be located. (h) After obturation (i) Periapical radiograph with initial apical file showed that the canal had been negotiated to the full working length. (j) Postoperative periapical radiograph. (k) Radiograph of 3-month follow-up. (l) Radiograph of 12-month follow-up.

its minimal taper preserves dentine (Ribeiro et al., 2023). For a canal with severe PCO, it was advisable to use minimally invasive and flexible instruments to prevent file fractures or canal deviation.

Despite the advantages described in this report, limitations of RNS should also be taken into consideration, such as high cost, limited availability and potential technical malfunction. Dentists should also need significant technical training in designing, calibrating and operating RNS before using it on a real patient. Further research is required to validate RNS, as well as to streamline the workflow associated with its use.

CONCLUSION

This case adds to the emerging clinical literature on RNS in endodontics with a 12-month review. This innovative system does appear to be useful for access cavity preparation and locating the severely calcified root canals. The preservation of sound dentine and potentially reduced treatment time make RNS an exciting tool to assist clinicians in accessing challenging root canal systems.

AUTHOR CONTRIBUTIONS

Peng Yu: Case selection, case design and implementation and reviewing. Hao Luo: Original draft writing, and reviewing and editing. Xi-wen Zhang and Rui Zhao: Reviewing and editing. Shanon Patel: Supervision, and reviewing and editing.

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CONFLICT OF INTEREST STATEMENT

The authors thank the patient who consented for the publication of this case and deny any conflicts of interest related to this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Bardales-Alcocer, J., Ramirez-Salomon, M., Vega-Lizama, E., López-Villanueva, M., Alvarado-Cárdenas, G., Serota, K.S. et al. (2021) Endodontic retreatment using dynamic navigation: a case report. *Journal of Endodontics*, 47(6), 1007–1013.

Buchgreitz, J., Buchgreitz, M. & Bjorndal, L. (2019) Guided root canal preparation using cone beam computed tomography and optical surface scans - an observational study of pulp space obliteration and drill path depth in 50 patients. *International Endodontic Journal*, 52(5), 559–568.

Chaves, G.S., Silva, J.A., Capeletti, L.R., Silva, E., Estrela, C. & Decurcio, D.A. (2023) Guided access cavity preparation using a new simplified digital workflow. *Journal of Endodontics*, 49(1), 89–95.

Chen, J., Zhuang, M., Tao, B., Wu, Y., Ye, L. & Wang, F. (2023) Accuracy of immediate dental implant placement with task-autonomous robotic system and navigation system: an in vitro study. *Clinical Oral Implants Research*, 35(8), 973–983.

Connert, T., Krug, R., Eggmann, F., Emsermann, I., ElAyouti, A., Weiger, R. et al. (2019) Guided endodontics versus conventional access cavity preparation: a comparative study on substance loss using 3-dimensional-printed teeth. *Journal of Endodontics*, 45(3), 327–331.

Connert, T., Zehnder, M.S., Amato, M., Weiger, R., Kuhl, S. & Krastl, G. (2018) Microguided endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *International Endodontic Journal*, 51(2), 247–255.

Cvek, M., Granath, L. & Lundberg, M. (1982) Failures and healing in endodontically treated non-vital anterior teeth with posttraumatically reduced pulpal lumen. *Acta Odontologica Scandinavica*, 40(4), 223–228.

Giacomino, C.M., Ray, J.J. & Wealleans, J.A. (2018) Targeted endodontic microsurgery: a novel approach to anatomically challenging scenarios using 3-dimensional-printed guides and trephine burs-a report of 3 cases. *Journal of Endodontics*, 44(4), 671–677.

Huang, X., Mao, L. & Hou, B. (2025) Locating a calcified root canal with robotic assistance: a case report. *Journal of Endodontics*. Available from: https://doi.org/10.1016/j.joen.2025.01.019

Jia, S., Wang, G., Zhao, Y. & Wang, X. (2023) Accuracy of an autonomous dental implant robotic system versus static guide-assisted implant surgery: a retrospective clinical study. *The Journal of Prosthetic Dentistry*, 133(3), 771–779.

Krasner, P. & Rankow, H.J. (2004) Anatomy of the pulp-chamber floor. *Journal of Endodontics*, 30(1), 5–16.

Liu, Y.F., Wu, J.L., Zhang, J.X., Peng, W. & Liao, W.Q. (2018) Numerical and experimental analyses on the temperature distribution in the dental implant preparation area when using a surgical guide. *Journal of Prosthodontics*, 27(1), 42–51.

McCabe, P.S. & Dummer, P.M. (2012) Pulp canal obliteration: an endodontic diagnosis and treatment challenge. *International Endodontic Journal*, 45(2), 177–197.

Mekhdieva, E., Del Fabbro, M., Alovisi, M., Scotti, N., Comba, A., Berutti, E. et al. (2023) Dynamic navigation system vs. free-hand approach in microsurgical and non-surgical endodontics: a systematic review and meta-analysis of experimental studies. *Journal of Clinical Medicine*, 12(18), 5845.

Nagendrababu, V., Chong, B.S., McCabe, P., Shah, P.K., Priya, E., Jayaraman, J. et al. (2020) PRICE 2020 guidelines for reporting case reports in endodontics: explanation and elaboration. *International Endodontic Journal*, 53(7), 922–947.

Ordinola-Zapata, R., Bramante, C.M., Versiani, M.A., Moldauer, B.I., Topham, G., Gutmann, J.L. et al. (2017) Comparative accuracy of the clearing technique, CBCT and micro-CT methods in studying the mesial root canal configuration of mandibular first molars. *International Endodontic Journal*, 50(1), 90–96.

Patel, S., Brown, J., Pimentel, T., Kelly, R.D., Abella, F. & Durack, C. (2019) Cone beam computed tomography in endodontics - a review of the literature. *International Endodontic Journal*, 52(8), 1138–1152.

Ribeiro, G., Martin, V., Rodrigues, C. & Gomes, P. (2023) Comparative evaluation of the canal shaping ability, Pericervical dentin preservation, and smear layer removal of TruNatomy, WaveOne gold, and ProTaper ultimate-an ex vivo study in human teeth. *Journal of Endodontics*, 49(12), 1733–1738.

Tang, W. & Jiang, H. (2023) Comparison of static and dynamic navigation in root end resection performed by experienced and inexperienced operators: an in vitro study. *Journal of Endodontics*, 49(3), 294–300.

Torres, A., Lerut, K., Lambrechts, P. & Jacobs, R. (2021) Guided endodontics: use of a sleeveless guide system on an upper premolar with Pulp Canal obliteration and apical periodontitis. *Journal of Endodontics*, 47(1), 133–139.

Torres, A., Shaheen, E., Lambrechts, P., Politis, C. & Jacobs, R. (2019) Microguided endodontics: a case report of a maxillary lateral incisor with pulp canal obliteration and apical periodontitis. *International Endodontic Journal*, 52(4), 540–549.

Xue, P., Luo, Q., Huang, Y., Xu, M., Qiu, L., Wang, J. et al. (2024) Retreatment and aesthetic restoration of maxillary incisor with calcified root canal using a dynamic navigation system: a case report. *BMC Oral Health*, 24(1), 1358.

Yang, X., Zhang, Y., Chen, X., Huang, L. & Qiu, X. (2024) Limitations and Management of Dynamic Navigation System for locating calcified canals failure. *Journal of Endodontics*, 50(1), 96–105.

Yang, Y.M., Guo, B., Guo, L.Y., Yang, Y., Hong, X., Pan, H.Y. et al. (2016) CBCT-aided microscopic and ultrasonic treatment for upper or middle thirds calcified root canals. *BioMed Research International*, 2016(1), 4793146.

Zehnder, M.S., Connert, T., Weiger, R., Krastl, G. & Kuhl, S. (2016) Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. *International Endodontic Journal*, 49(10), 966–972.

Zhou, L., Teng, W., Li, X. & Su, Y. (2023) Accuracy of an optical robotic computer-aided implant system and the trueness of virtual techniques for measuring robot accuracy evaluated with a coordinate measuring machine in vitro. *The Journal of Prosthetic Dentistry*.

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