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Research Article

ROLE OF IMAGE GUIDED METHODS IN ENDODONTICS: - A CRITICAL REVIEW

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A B S T R A C T

Precision medicine (PM) refers to the tailoring of medical or dental treatment to the individual characteristics of each patient. Imaging has become a crucial part of PM during the last decade. PM takes into account and aims to exploit the specific profile of the patient's unique biology and problem. Imaging plays an important role by providing morphologic and functional information, focussing and guiding treatment and assessing response to therapy. Image-guided treatment (IGT), or here specifically image-guided endodontics, is not a strategy that tries to optimize 3-D cleaning, shaping and disinfection, and filling root canal systems. This is not an update on traditional endodontic access, or shape/clean/pack as the authors believe that the traditional approach to endodontic access is fundamentally flawed. Importantly, IGT is not about simply making a smaller access or smaller shape. It is about strategic dentin preservation and restoring the balance. It is about planning access, planning shape using a directed approach, and evaluating the response to treatment. So, in this meta-analysis review, we discuss about the role of image guided therapies like static CT guidance & Dynamic guidance, guided rail based on CBCT (3D printer-based template) used in conventional endodontic therapies and in endodontic surgery.

INTRODUCTION

The advancement of technology generally evokes a range of emotions in people from all walks of life. Some view technology, as a way to bring the world closer together and to help solve some of our greatest challenges. In medical field, Precision medicine is gaining most popularity in the last few decades.

Precision medicine refers to the tailoring of medical or dental treatment to the individual characteristics of each patient. Imaging has become an important part of PM during the last decades, due to advanced developments in imaging systems like CT, CBCT and 3D printing technology.

The importance of guided imaging systems plays a crucial role in endodontic treatments like root canal treatments and endodontic surgery.

Historical aspect of Guided Imaging

In 2001, Klein and Adams suggested milled CT-based drilling guides for PM[1] In 2003, Sarment, et al, reported that the accuracy of implant placement with 3D-printed drill guides was significantly better than those fixtures placed without drill guides[2].

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In 2007, Pinskey, Champleboux and Sarment proposed the use of a static CT-based stereolithographic drill guide for endodontic periapical surgery[3]
In 2016 Emery and Block introduced the X-Guide Dynamic Guidance System and proved its accuracy in clinical implant surgery[4,5].

Preparing ideal access cavity is one of the most critical and challenging aspects of root canal therapy which sets the stage for every following RCT procedure as it acts as a portal through which all instruments, materials, and solutions must pass during treatment[6].

There are increased chances of perforation, rotary file fracture, and obturation difficulties in tipped or rotated teeth due to poor alignment of access paths.

Clinicians face difficulties in certain cases like those with severe pulp chamber calcification-with serviceable crowns in which 12mm of radiographically hidden tooth structure has to be cut before getting into one of the four canals.

Cutting access into calcified root canal systems is, without a doubt, the most anxiety provoking procedure in endodontics. One must find all the canals in posterior teeth, yet preserve their structural integrity, keeping in mind that overcut access openings irreversibly decrease the long term prognosis of these teeth. Until recently, access has been done exclusively by freehand methods with a wide range of outcomes depending

totally on the clinician's innate 3D skills, training, and experience[6]

Continuous improvements in techniques, instruments, and materials have established modern endodontic microsurgery as a state-of-the-art treatment method[7].

The purpose of this meta-analysis review is to discuss the literature regarding image guided treatments in endodontics like static CT guided, Dynamic guided, CBCT guide and new surgical endodontic technique by using a three-dimensional printed template for guided osteotomy and root resection procedures.

Static CT Guidance

Accuracy of the osteotomies cut prior to placement of implant fixtures affect the outcome implant surgery to some extent and like endodontists, implant surgeons have great pride in their artful ability to direct this critical procedure freehanded. Despite that confidence, poor positioning of implant fixtures remains the most common mistake in implant surgery[6]. Several authors proposed static CT based drill guides as a solution. However, these guides pose several in vivo difficulties for use in conventional access which include[6]

1. For positioning of guide ring over the tooth, there is lack of inter-occlusal distance to accommodate the additional 10mm of drill or bur length.
2. No guide rings exist that work with high-speed handpiece burs which spin at when cutting through enamel, ceramics, and cast restorations.
3. Endodontics is a less elective procedure than implant surgery. Before scheduling the procedure, it is easy for implant surgeons and their patients to wait, for receiving printed or milled drill guides. But the same pose difficulty in case of patients with root canal disease.
4. Drill guides have 4-6mm guide rings for each drill path, making it necessary to have a drill guide for each canal and thus a matter of expense in upper molars with four canals.
5. Also static drill guides do not allow the minor but important changes in treatment plan that are often wanted during surgery.

Dynamic Guidance

Mentioned first in 1998 at a medical imaging symposium. Optical guidance was first tested in 2005 for accuracy in transferring CT-based implant treatment planning to patient's jaws[8], however, the processing speeds necessary to manipulate CT datasets in real-time could only be found in super computers, making it an impractical solution for everyday implant surgery. Five years later, this technologic inflection point was reached and dynamic optically-driven guidance systems were developed for clinical use and their accuracies are again found to be similar to static drill guidance[9], and by 2016 Emery and Block introduced the X-Guide Dynamic Guidance System (X-Nav Technologies, LLC, Lansdale, PA) (FIG 1) and proved its accuracy in clinical implant surgery[4,5].

This system was designed only for implant surgery, but Dr. Charles Maupin-an endodontist who also places implants used Dynamically-Guided Access (DGA) X-Nav system for the first time in 2016 to cut access cavities in calcified teeth. He understood that optically-driven dynamic guidance solves all the problems that static drill guides present in endodontic application[6].

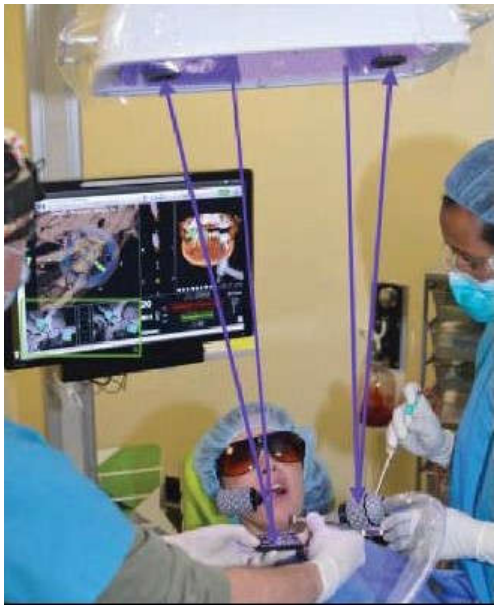

Fig 1 XNAV Dynamic guidance system

The Advantages of Dynamic Guidance for Conventional Endodontic Access[6]

1. Optically-driven guidance doesn't require long drills or burs.
2. High RPM drills and burs are easily used as they do not have to rotate within a guide ring.
3. No waiting period is required for a 3D printed or milled drill guide to be delivered from the lab. RCT can be done within 15 minutes of scanning the patient with an X-Clip fiduciary in place.
4. No guide rings are required. So, it is easy to plan and execute multiple drill paths in multi-canalled posterior teeth.
5. Any treatment changes if needed are allowed to be made at the time of surgery. So, drill paths can be updated as new information is acquired during the procedure.

Cases in Guided Endodontic Procedures

M. S. Zehnder et al[9]**.** In an in vitro study on maxillary jaw has planned 'Guided Endodontics' procedure. He calculated the deviations of planned and prepared access cavities in three dimensions and angles and has shown a low mean of angle deviation of 1.81°.

Gabriel Krastl et al[10]. presented a case of 15-year-old male patient with signs of apical periodontitis and pulp canal calcification (PCC) in his upper right central incisor in which he planned a virtual guiding template with specific drill to penetrate through the obliterated part of root canal and has obtained minimally invasive access to the apex and has successfully completed the rct. A long term followup of 15 months had shown that the patient was clinically asymptomatic. They concluded that the presented guided endodontic approach seems to be a safe, clinically feasible method to locate root canals and prevent root perforation in teeth with PCC.

Buchgreitz J et al[11]**.** In his exvivo study on teeth with pulp canal calcification has applied guided access cavity preparation and concluded that this technique is a valuable tool for negotiation of partial or complete PCC.

Connert T et al[12]. In his in vitro study on mandibular anterior teeth models has applied micro guided endodontics and concluded this technique as an accurate, fast and operator independent technique for preparation of apically extended access cavities in teeth with narrow roots.

Buchanan LS et al[6]. reported a case in which central incisor with a necrotic canal was calcified to the apical third. Using dynamic guided access (DGA), 1mm wide access preparation was cut 12mm into the root before encountering the remnant canal in its apical third.

He also reported a three-canal calcified molar with a nicely restored full crown that was accessed successfully with XNav guidance and located all the canals.

So-Yeon Ahn et al[13]. Reported a case with persistent periapical lesion even after endodontic retreatment has planned guided osteotomy to minimize the extent of osteotomy and enabled precise targeting of the apex in this case and has reported success.

Strbac G et al[7]. Has reported a case with periapical lesion and extended gutta-percha has planned guided osteotomy procedure which helped in detection and complete removal of the extruded gutta-percha material without perforation of sinus membrane. They concluded that the guided microsurgical endodontic treatment presented appears to be a viable technique that allows for predefined osteotomies and root resections.

Template Fabrication

An intra-oral scan was performed (iTero, Align Technology Inc., San Jose, CA, USA) and uploaded into a software for virtual implant planning (coDiagnostiXTM Version 9.2; Dental Wings Inc., Montreal, Canada). Both the CBCT and the surface scan were matched based on radiographically visible structures after the additional upload of the CBCT (FIG 2). For guided endodontics, drill which was used (Straumann Drill for Tempimplants, Switzerland) has a total length of 37 mm, a working length of 18.5 mm and a diameter of 1.5 mm. This was virtually designed by applying the implant designer tool of the coDiagnostiX software and virtually superimposed to the root canal. The axis of the drill was angled in such a way that the tip of the extended drill would reach the radiographically visible apex of the tooth. A virtual template was designed by applying the template designer tool of the CODIAGNOSTIX software after planning of drill positioning was completed. As for the drill, a guiding sleeve (2.8 mm external diameter, 1.5 mm internal diameter and 6 mm length) was customized using a software tool and virtually incorporated into the planning, prior to the creation of template. The virtual template was exported as an STL file and send to a 3D printer (Objet Eden 260 V, Material: MED610, Stratasys Ltd., Minneapolis, MN, USA). To fabricate the designed sleeve computerized numerical control (CNC) technology was used, which was integrated into the printed template to guide the drill during cavity preparation[9,10].

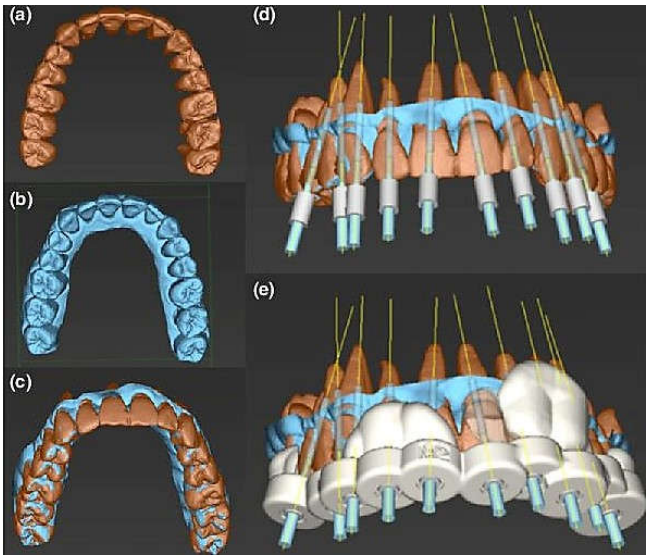

Fig 2 Matching of CBCT and surface scans

Template fabrication in guided osteotomy procedures was similar to guided endodontic procedure. The osteotomy dimensions of teeth were determined with virtually positioned surgical pins that were 1.5 mm in diameter. The lower margin of the osteotomy for each root defined the cutting plane, consistent to the recommended 3 mm apical resection level and the bevel angle degree. The upper margin of the osteotomy was planned with a vertical distance of 4 mm to the lower margin, according to the dimensions of the diamond-coated retrotips of the microsurgical instruments. These predefined margins could be implemented in the software with the aid of these individually positioned surgical pins. For achieving these specifications with a guided preparation procedure, technical stereolithography (STL) files of corresponding piezoelectric instruments were imported and virtually used within the planning software[7,13].

Preparation of virtual template in guided osteotomy procedures was given in the below mentioned picture (FIG 3 and 4)

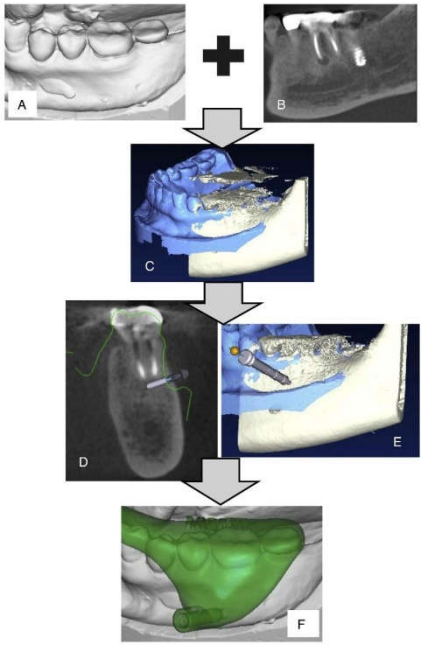

Fig 3 (A) Scanning data of the cast. (B) Tooth CBCT image uploaded into implant surgical planning software. (C) Superimposition of the scanned cast and the CBCT image. (D and E) The anchor pin was placed to target the mesial root apex of tooth (F) The final design of the surgical template.

Fig 4 Incorporation of metal sleeve in virtual template

Indications

- To perform adequate access cavity preparation and locate canals in teeth with pulp canal calcification that pose difficulty during traditional endodontic access.
- In osteotomy procedures for precise apex localization, and root-end resection and in overcoming difficulties in teeth with crucial anatomic structures.

Advantages and Limitations of Guided Procedures

- Eventhough the planning of guided Endodontics seems to be very time-consuming, the clinical chairtime during treatment is minimal.
- The additional costs for CBCT and the template may be justified by the reduction of the likelihood of iatrogenic errors such as perforation, thereby increasing the chance of tooth retention. The costs for an implant would be higher if conventional treatment with technical failure led to tooth extraction (Zitzmann *et al.* 2009)[14].
- Another potential drawback of the use of the drill for root canal location is initiation of dentinal cracks. Conversely, due to the precise planning and location of the access cavity, teeth with PCC may benefit from an increased fracture resistance if more dentine is conserved[15,16].
- Although it has a high radiation dose, it has contributed to increasing the success rate of endodontic treatment by optimizing technical treatment planning[23]. In 2015, the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology updated their guidelines on the use of CBCT imaging in endodontics. They recommend CBCT imaging for the location of calcified root canals because of the high level of difficulty associated with this procedure[24]. Also, without 3D imaging, a root canal treatment that requires multiple radiographs to determine the root canal location or even subsequent treatment for managing anterior tooth loss in adolescence can ultimately lead to a higher overall radiation dose[10].
- A considerable technical effort is also needed for guided procedures, but CBCT and intra-oral scanners are becoming increasingly popular among dentists. Due to this rapidly proceeding trend, the combination of these datasets for different reasons, may become standard in the future. Thus, it is likely, that guided endodontic procedures may also be established in clinical practices[12].
- Guided osteotomy procedures reduces postoperative complications by reducing the length of surgical procedure and enhancing the healing[17,18].
- Surgical templates are particularly helpful in difficult cases involving teeth near potentially crucial anatomic structures which includes adjacent root tips, the inferior alveolar nerve, the mental foramen, and the maxillary sinus[7].
- Scattering in CBCT images, originating from metallic restorations, may cause inaccurate superimposition with scanned stone models. Thus, the accuracy of the surgical template is limited in patients with several metallic prostheses. Clinicians may consider artificial landmarks to overcome this limitation[19,20].
- The preservation of the cortical bone and dental structures, as recommended in the guidelines for state-of-the-art endodontic surgery, could be credited as potential benefits and may justify additional planning time and costs[10,21].
- Another disadvantage as mentioned by Van Der Meer et al., is the restricted visualization of the treatment when the guide is uded despite its transparent nature. The intermittent removal of the guide may be needed to ensure that the proper path is still being followed[22].

CONCLUSION

Guided endodontics approach seems to be a safe, clinically feasible method for locating root canals and preventing root perforation in teeth with PCC that cannot be predictably accessed via traditional endodontic therapy. Aside from teeth with PCC, in the future, guided procedures in endodontics may help to easily and precisely access and treat specific areas in the root, which is hampered due to resorptions, perforations or fractured endodontic instruments[10].

The outcome of the guided surgical approach appears to be promising; it was possible to perform as planned and with adequate consideration of the recommended guidelines for modern surgical endodontic treatment. However, to confirm the reliability of this method in the future, clinical studies should be performed to prove and confirm its viability and accuracy[7]. Surgical template in endodontic surgery helps to minimize the extent of osteotomy and facilitates locating the root apex in cases with a thick and intact buccal bone plate. The surgical template would be useful in apical surgery on teeth with problematic anatomic structures. Additionally, surgical time would decrease by the diminished time consumed to search for the root apex although the preparation time for surgery might be increased because designing and fabricating surgical stents take time. Nevertheless, proper case selection and a delicate design process are necessary for producing an effective surgical template[13].

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