Clinical Endodontic Applications of 3D Printing, A Review

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Abstract

Objective: Current research suggests that there is an emerging value of 3D surgical guide use in the endodontic field. Computer-aided design and computer-aided manufacturing technologies can be used to create 3D surgical guides with endodontic clinical application. The aims of this project were to asses all current applications of 3D surgical guide usage in endodontics, to determine when 3D surgical guide use is effective in clinical endodontic settings and possible incorporation in the didactic Endodontics setting.

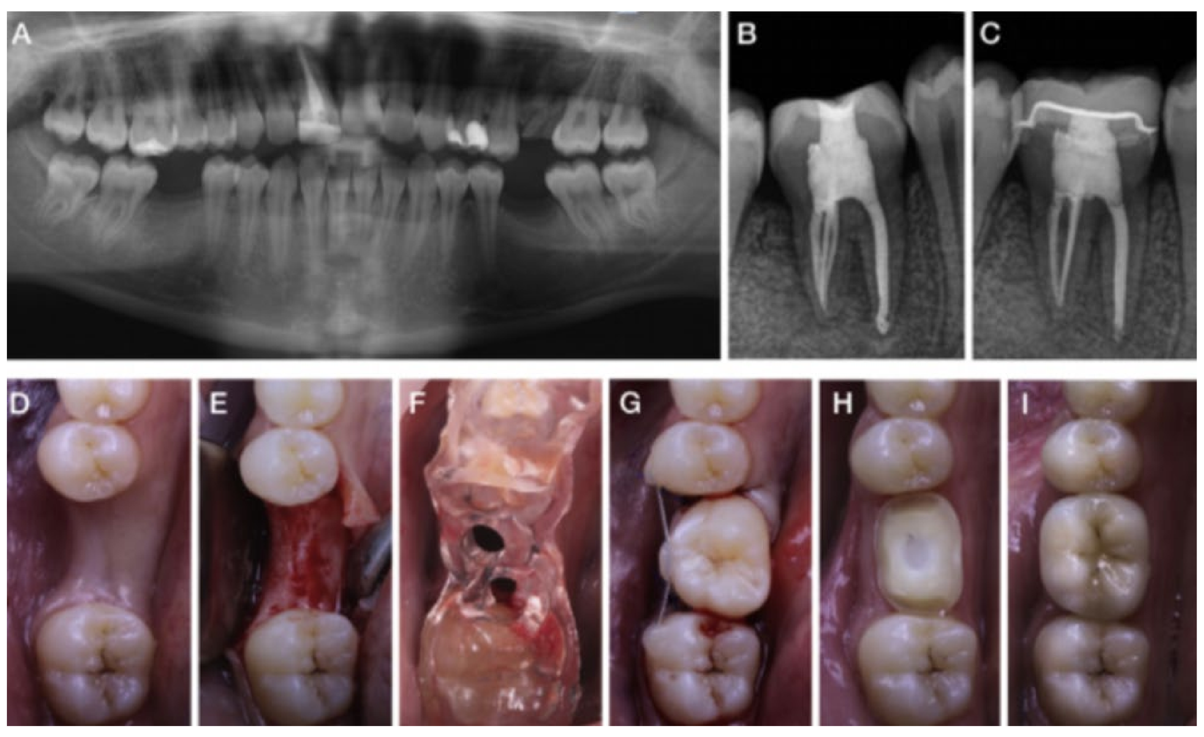
Methods: A literature search was conducted on PubMed, Ovid, Google Scholar and Scopis using the following key terms: endodontic surgical guide, guided endodontic surgery, guided endodontic access and guided autotransplantation until June 25th 2021, no year restrictions were applied. Only articles published in English were included. Studies were included that appeared after entering the search criteria (key term, English language and appropriate time period) and (i) explored the utility of 3D printed surgical guides in guided endodontic access, guided endodontic microsurgery and guided endodontic autotransplantation, (ii) studies that compared treatment accuracy of 3D printed surgical guides to conventional methodology, (iii) case reports, case series and preclinical in vitro and ex vivo studies. The exclusion criteria included: (i) articles written in a language other than English, (ii) cases where CBCT was used as navigation without the presence of a surgical guide, (iii) studies that included a 3D template used outside the realm of guided endodontic access towards a root canal, guided endodontic access towards root apex and autotransplantation of a tooth and (iv) studies outside the realm of dental medicine.

Results: A total of 51 published papers were included in this review, including two systematic reviews, twenty-nine case reports, six case series and thirteen preclinical studies.

Conclusions: The implementation of 3D printing in endodontics opens the door to promising techniques with highly predictable outcomes and low risk of iatrogenic damage. Results become less technique sensitive and more teeth can be saved. Endodontic treatment time diminishes and becomes less invasive; this results in greater patient comfort and satisfaction.

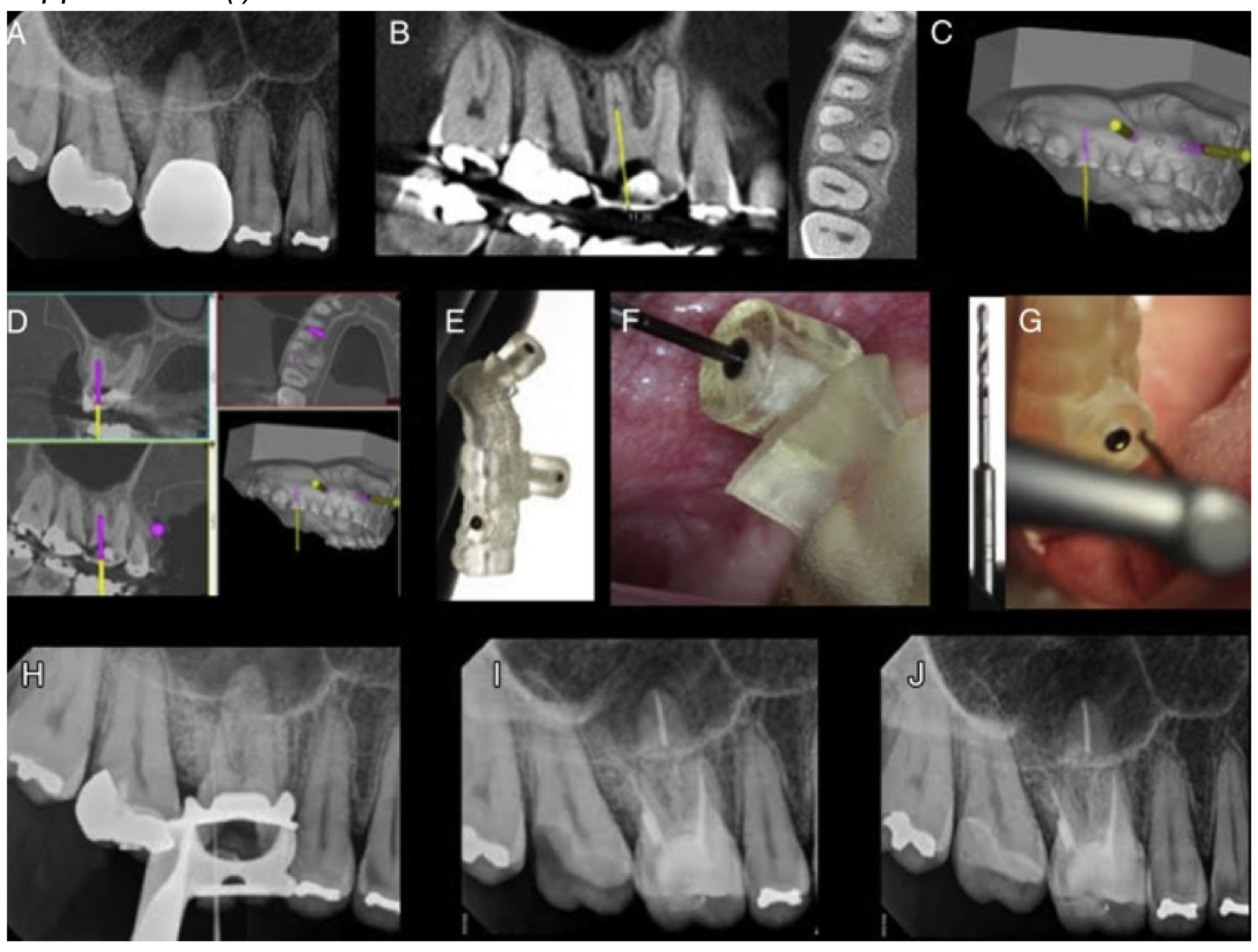
Future Directions: Larger clinical studies with more participants, longer follow up time and standardized methodology are required to increase the validity of the proposed techniques in this review. Further research examining the accuracy of 3D surgical guides printed by affordable, benchtop 3D printers applied to endodontic procedures is also warranted.

Review of Clinical Endodontic Application



Autotransplantation:

Figure 1 A clinical sequence of wisdom tooth autotransplantation into a surgically created socket. Patient is missing her lower right molar (a). Successfully transplanted wisdom tooth into the previously edentulous area after root canal therapy (b). Transplanted tooth is fitted with a crown to resemble tooth #30 and maintain proper occlusion (c). The soft mucosa of the edentulous sight (d). Exposed bone of the edentulous sight (e). 3D printed surgical guide used to prepare the artificial socket (f). Successfully transplanted wisdom tooth into the recipient sight (g). Crown preparation for the transplanted wisdom tooth (h). Completed crown 8 months after the surgical appointment (i)[1].



Guided Endodontic Access:

Figure 2 Radiographic examination of the second upper premolar (a). A CBCT image showing partial obliteration of the root canal and apical periodontitis (b). A 3D model of the oral cavity (c). 3D root canal planning (d). Perforations performed for guide fixation (e). The bur positioned in the 3D template (f). Canal patency (g). The final radiograph (h). The radiograph at the 6-month follow-up (i). The radiograph at the 1-year follow-up (j)[2].

Treatment of Dens Invaginatus:

Teeth afflicted with dens invaginatus have abnormal development of enamel including infolding. This can make endodontic treatment more difficult[5]. Guided endodontics can help endodontist negotiate canals in dens invaginatus and minimize risk of perforation[6].

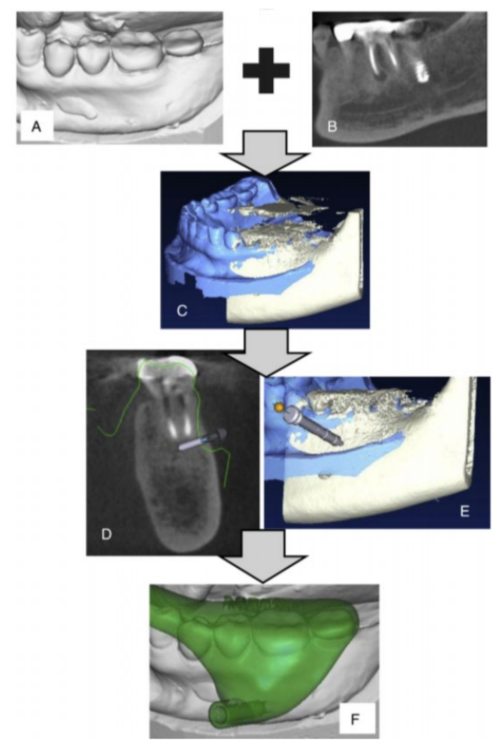
Guided Post Removal:

The conventional method for post removal is difficult and includes the risk of root perforation, axis deviation and weakening of the roots[7]. 3D printed guides introduce a guided approach to post removal. The guide enables the clinician to maintain the axis of the drill at precisely the axis that the post should be removed which minimizes the stated risks.

Guided Endodontics in Education:

Literature suggests that guided endodontic exercises should complement traditional endodontic curriculum[8].

Review of Clinical Endodontic Application



Guided Endodontic in Periapical Surgery:

Figure 3 Data acquired from intraoral scans (a). CBCT DICOM uploaded into specialized surgical guide design software (b). Superimposition of the scanned cast and CBCT image (c). The anchor pin was placed to target the mesial root apex of tooth 19 (d and e). The final design of the surgical template (f)[4].

Background

In order to perform a 3D printing, an intraoral scanner, cone beam computed tomography (CBCT) imaging, data processing and design software and a 3D printer are all required. The fabrication of a 3D printed dental appliance involves three basic steps: gathering information, appliance design (using specialized software) and the milling process. Once acquired, the intraoral scan is converted into a Standard Tessellation Language file, and the CBCT image is converted into a Digital Imaging and Communication in Medicine (DICOM) file; both of which are then uploaded and superimposed in the 3D design software. The surgical guide is adapted to fit on existing tooth structure and/or surrounding oral mucosa. Access pathways into the tooth can then be configured. Lastly, the blueprint for the dental appliance is sent to a 3D printer for fabrication.

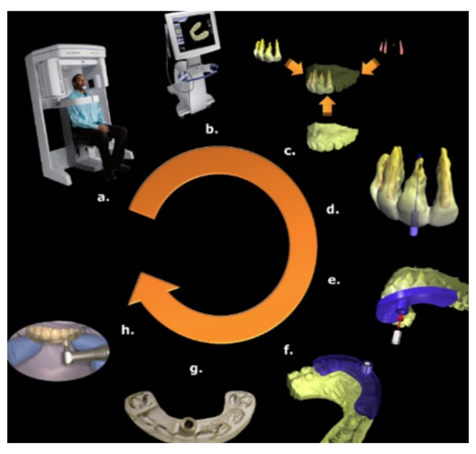
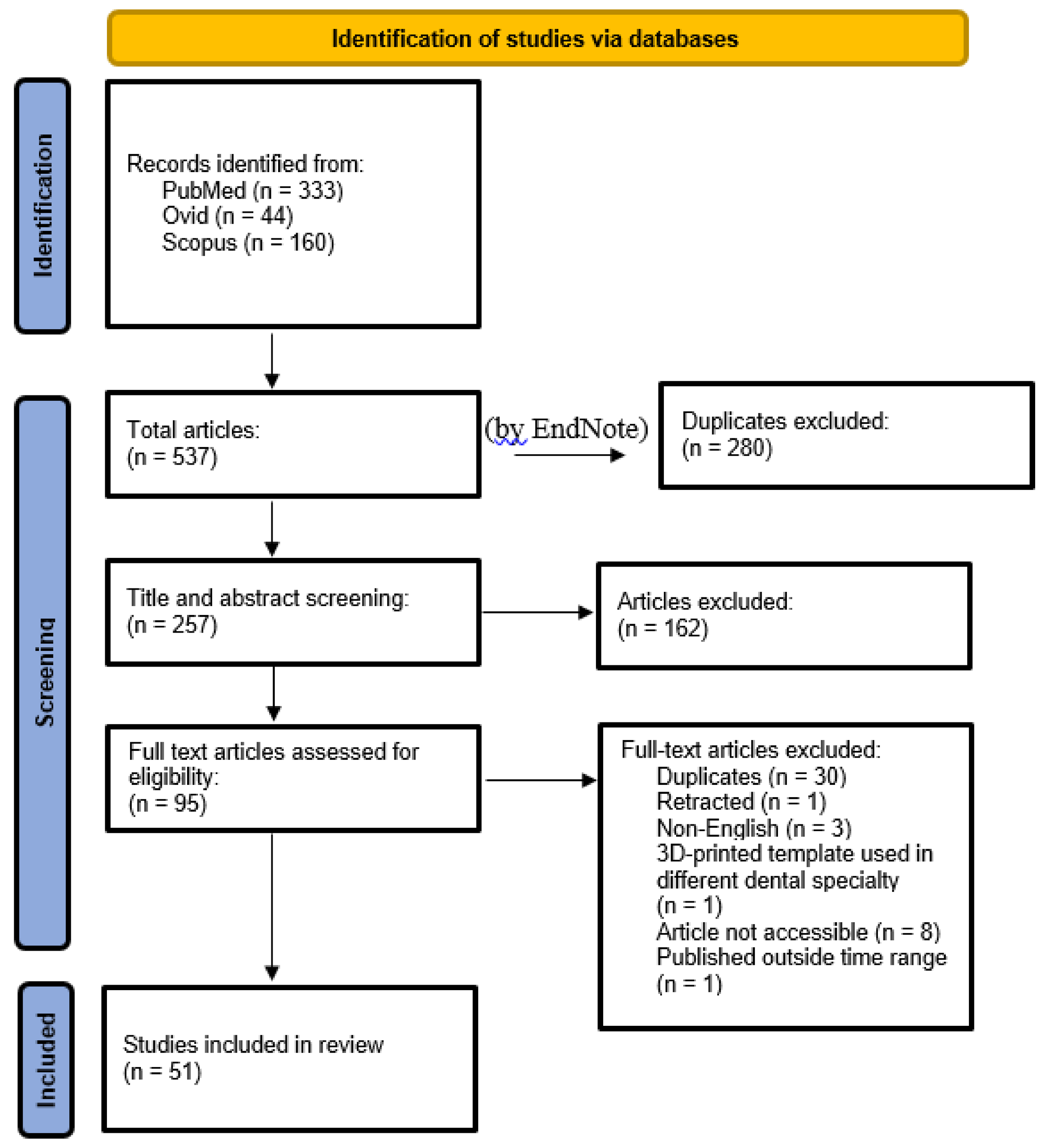


Figure 1 This figure demonstrates the work flow resulting in the production of a 3D printed surgical guide for endodontic treatment. A CBCT is taken for the teeth involved in treatment (a). An intraoral scanner then takes an impression of the dentition (b). In specialized software, the datasets of the teeth, pulp, bone and digital impressions are registered (c). In 3D software the planning of the direction of the access is made (d) and a guide is designed with space reserved for the metal guiding sleeve (e). The final design (f) is sent to a dental lab or rapid prototyping facility for printing. The printed guide (g) is used in the mouth of the patient (h)[3].

Materials and Methods



PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources[9]

Conclusions

The implementation of 3D printing in endodontics opens the door to promising techniques with highly predictable outcomes and low risk of iatrogenic damage. Results become less technique sensitive and more teeth can be saved. Endodontic treatment time diminishes and becomes less invasive; this results in greater patient comfort and satisfaction. Larger clinical studies with more participants, longer follow up time and standardized methodology are required to increase the validity of the proposed techniques in this review. Further research examining the accuracy of 3D surgical guides printed by affordable, benchtop 3D printers applied to endodontic procedures is also warranted. Lastly, the success of 3D applications in endodontics is dependent on clinicians learning how to use new design software.

Acknowledgements and References

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