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Review Article

Guided endodontics: charting a new era in accuracy and efficacy

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ABSTRACT:
Guided Endodontics (GE) represents a significant advancement in endodontic therapy, particularly for cases involving pulp canal obliteration (PCO) and apical pathosis. This technique utilizes advanced three-dimensional imaging technologies, such as cone-beam computed tomography (CBCT) and digital surface scanning, to facilitate precise planning of access cavities. GE employs either static navigation via templates or dynamic navigation with camera-marker systems. Various research demonstrates that GE enhances the accuracy of access cavity preparation while reducing the risk of iatrogenic damage. Despite the promising clinical results, current evidence mainly consists of individual case reports and a few case series. This review seeks to consolidate the existing knowledge on GE, emphasizing its benefits in managing complex endodontic conditions and its role in improving treatment predictability and safety.

Keywords: Guided endodontics, Static guided system, Dynamic navigation system

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INTRODUCTION

"Guided endodontics is revolutionizing the field by making complex root canal treatments more straightforward and predictable." **- Dr. Gianluca Plotino**

Endodontic therapy (RCT) is a type of dental treatment for infected teeth. The main purpose of it is to achieve a completely disinfected teeth with three dimensional obturation of the root canal without compromising much of its anatomy using different endodontic devices. The complexity of tooth anatomy presents plethora of challenges to endodontist. One of the most common and prevalent issue faced by endodontists is calcified canal.Under such conditions, the establishment of a suitable access cavity and the identification of the canal orifice can pose significant challenges, potentially leading to considerable loss of tooth structure. This loss is correlated with an increased likelihood of fracture **(Lang et al. 2016)[1],** perforation, and a heightened failure rate **(Cvek et al. 1982)[2].** Consequently, it is highly recommended to engage in thorough preoperative planning, utilizing a microscope, while 3D imaging may serve as a valuable resource **(AAE Special Committee 2012)[3].**The three-dimensional data acquired can be integrated with the surface details of the teeth recorded by an intraoral scanner, thereby enhancing the design and 3D printing process of a treatment guide **(Dawood et al. 2015; Anderson et al. 2018)[4,5].**

This review article aims to deliver a comprehensive and detailed understanding of guided endodontics its types, techniques and applications along with its complete workflow. Furthermore, we will be discussing its impact on treatment outcomes as well as the future developments in guided endodontics, taking into account new developments and inventions that could improve the sector even further.The databases PubMed, Google Scholar, CORE, and ScienceDirect were systematically searched for literature, utilizing the keywords "guided endodontics", "dynamic navigation system" and "static guided endodontics" the relatable articles were then used for the data extraction for this review article.

"Krastl et al. (2015)[6] and **Zehnder et al. (2015)[7]** were the first to introduce the concept of "guided endodontics", which involves the utilization of computers to create guides for the preparation of access cavities **(Krastl et al. 2015; van der Meer et al. 2016)[6,8]**and endodontic surgical procedures **(Strbac et al. 2017a)[9].** Though similar notion has been used in dentistry for procedures such as implant placement. Notably, **Buchgreitz et al. (2016)[10]** was first in demonstrating the principles of guided access, later became known as "guided endodontics".

HISTORY

The initial significant investigations aimed at accurately identifying particular anatomical areas in the human dates back to the late 19th century **(Yavor Enchev 2009)[11].** Independent research conducted by **Arai et al. (1999)[12]** from Japan and **Mozzo et al. (1998)[13]**from Italy led to the introduction of Cone Beam Computed Tomography (CBCT).**Mozzo et al.** published the first description of the CBCT device in 1998. Since then, a number of CBCT machines have been introduced to the market,most likely there will be a lot more in the future. Since 2012, the integration of a CBCT scan with an optical surface scan of the same dentition has become achievable **(Buchgreitz et al. 2016)[10]**making treatment easier and reducing the likelihood of failure. Science fiction has given way to reality as X-ray application and technology have advanced greatly. From the inability to see inside the human body without invasive procedures to the creation of 3-D guided templates by combining 3-D printing with CBCT, there has been a significant leap forward in this field.

CURRENT CONCEPT

A guided approach may be either dynamic or static. The optical impression and CBCT are combined in the static guided technique to create a virtual drill route prior to the clinical treatment. Whereas drill movement records and CBCT data are incorporated in dynamic guidance **(Kinariwala & Samaranayake 2021)[14].**

In case of static guide, after the CBCT image and impression of the patient’s arch of interest is taken with an intraoral scanner the two acquired pictures are superimposed using a software, a guide covering the tooth of interest and a few adjacent teeth is created, and the bur is guided through it for the treatment. Dynamic navigation is an alternative to static navigation using templates. Initially applied in implantology **(Marquardt et al., 2007)[15],** the data from the intraoral surface scans are combined with CBCT. Previously, reference markers were attached to teeth before creating the CBCT,but recent advancements allow for digital planning and 3D printing of these markers. A real time navigation can be done by using a stereo camera linked to the dynamic navigation system coordinating the drill with the planning and markers.

In case of the static guided endodontics the endo guides are used which can be categorized based on their utilization and support. **(Niraj kinariwala Lakshman Samaranayanke’s Guided Endodontics)[14].**

1. **Based on their role in endodontic treatment procedures**

Non-surgical Guides:
They serve the purpose of locating calcified canals without the need for surgical intervention and for addressing apically extended access opening cavities, providing a non-invasive approach.

Surgical Guides:
Specifically designed for endodontic surgeries, used for procedures such as root end resection and are tailored to enhance precision during surgical interventions.

2. **Based on the type of support**

Tooth-supported Guide:
This type of guide rests over the patient's dentition without the need for an anchor pin. Primarily for non-surgical guided endodontic treatments offering stability and accuracy.

Bone-supported Guide:
Positioned on the surface of the bone after reflecting the flap. It is utilized in surgical endodontics to ensure stability during procedures that involve more extensive interventions.

The use of static guided system in endodontics offers several merits, including reduced iatrogenic damage and complications in cases of calcified canals**(Buchgreitz et al. 2019)[16],** and reduction in treatment time when compared to conventional preparation **(Ali & Arslan, 2021)[17].** It also helps in preventing perforations or canal transportation and provides a more predictable location of calcified root canals **(Connert et al. 2021)[18].**

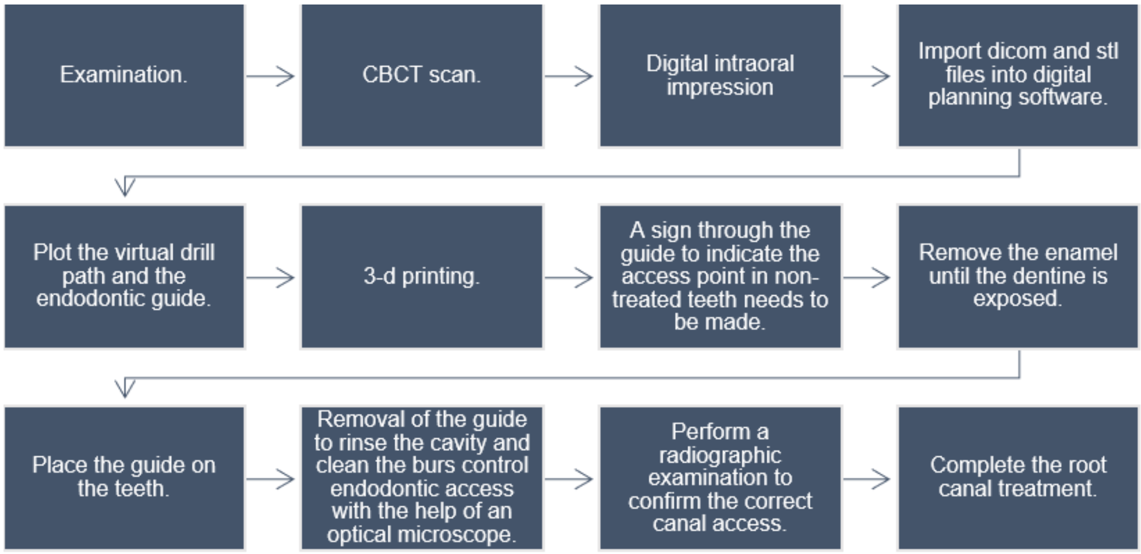
Nevertheless, it is essential to acknowledge several significant drawbacks. For example, artifacts produced by cone beam computed tomography (CBCT) due to radiopaque restorations can obstruct the alignment of scans, especially in small field-of-view CBCT applications **(Ackerman et al. 2019; Ali & Arslan, 2021)[19,17].** Furthermore, printed guides tend to be bulky and provide only a singular trajectory, which complicates the positioning of the handpiece **(Ackerman et al. 2019)[19].** Moreover, anatomical complexities such as curvature in the canals, oval roots, or isthmuses can further complicate procedures**(Connert et al. 2017; Buchgreitz et al. 2019)[20’16].** Temperature may also rise due to absence of water cooling**(Krastl et al. 2016; Zehnder et al. 2016)[21,22].** This process is not only time-consuming but also incurs significant costs **(Buchgreitz et al. 2019)[16].** Additionally, the forces applied by the bur could potentially lead to the formation of microcracks in the dentin **(Krastl et al. 2016; Connert et al. 2018)[21,23].**

Dynamic navigation systems in endodontics provide numerous benefits, including the capacity to finalize treatment within a single day, thereby minimizing both chairside duration and radiation exposure **(Dianat et al., 2020)[24].** Itis suitable for limited vertical spaces since no guide is needed **(Torres et**

al., 2021)[25] and do not require a special coupling system **(Stefanelli et al., 2019)**[26]**.** These systems simplify the procedure by eliminating the need for guide designs **(Dianat et al., 2020)**[24] and facilitate the planning and execution of multiple bur paths in multi-canal teeth **(Torres et al., 2021)**[25]**.** Additionally, they are considered safer and more accurate than freehand treatment **(Chong et al., 2019)**[27]**,** and real-time corrections to bur positioning can be made with live feedback **(Dianat et al., 2020; Jain et al., 2020)**[24,28]**.**
However, dynamic navigation systems have some drawbacks, including a high initial investment **(Dianat et al., 2020)**[24] and the need for operator training **(Torres et al., 2021)**[25]**.** Tooth mobility can cause inaccuracies **(Dianat et al., 2020)**[24]**,** and the system might encounter difficulties in identifying the drill tag when it is positioned outside the optical tracking field **(Chong et al., 2019)**[27]**.** Moreover, deviation values are currently slightly higher than the static guides **(Torres et al., 2021)**[25]**,** and the large handpiece tracker attachment can be somewhat uncomfortable**.**

PLANNING AND WORKFLOW OF GUIDED ENDODONTICS

➢ The basic outline of the workflow is as follows:



1. The initial stage involves the laboratory phase: producing the endodontic guide, during which the majority of processes are conducted without the presence of the patient, utilizing digital technologies.
2. The subsequent stage encompasses the clinical application of the guide during operative procedures.

In laboratory phase after ensuring the patient's recent, high-quality DICOM (CBCT) and STL (arch model) files **(Kuttler & Plotino, 2013)**[29]plan the guide using specialized software, avoid any vital anatomical structure and considering drill wear direction, length, and diameter **(Castellucci et al., 2014)**[30]**.** Maintaining a least of 1mm distancefrom the root surface to prevent perforation **(Zehnder et al., 2016)**[22]**.** After final review approve the guide is printed with autoclavable resins.
After all the lab procedures the printed guides are ready to use.Now comes the clinical steps in which After proper fit and stability of the guide is confirmed the access cavity is prepared and after mapping the canal with a small caliber file the conventional root canal treatment follows

FUTURE DIRECTIONS

In future MRI could be used to eliminate the ionizing radiation, making dental imaging safer, especially for younger patients **(Dula et al., 2014)**[31]**.**
Leontiev et al. (2021)[32] showed that MRI could create accurate access cavities in a lab, with a mean angle deviation of 1.82°, though clinical validation is needed. The use of augmented reality (AR) could help in enhancing the DNS by overlaying radiographic images on the operating field using a head-up display, allowing the operator to view both simultaneously, method currently used in neurosurgery but not yet in endodontics **(Song et al., 2018)**[33]**.**
The utilization of 3D printed templates facilitates precise guided osteotomy and root resection **(Strbac et al., 2017b; Ahn et al., 2018)**[34,35]**.** This approach integrates preoperative CBCT images with intraoral scans, enabling clinicians to devise accurate procedural plans, whether employing flapless techniques or traditional access methods. Additionally, surgical stents assist in guiding instruments such as piezoelectric saws, trephine burs, and implant drills.
Concurrently, CBCT-based AI applications in endodontics have surfaced, such as automated crack recognition **(Shah et al., 2018)**[36]**,** periapical lesion

detection **(Orhan et al., 2020)[37],** and mandibular nerve canal localization **(Kwak et al., 2020)[38].** AI is also being investigated as a means of distinguishing granulomas from cystic lesions **(Okada et al., 2015)[39].**At some point, this might result in the development of robotic endodontic microsurgery, initially introduced in implant dentistry **(Haidar, 2017; Wu et al., 2019)[40,41].**

CONCLUSION

Guided endodontics whether static or dynamic are more safe, accurate and offer minimally invasive methods especially for difficult cases like pulp canal obliteration or presence of an extra canal. In summary, the prognosis of endodontic treatment results has already improved, and it may continue to do so in the future. Nevertheless, additional rigorous clinical investigations concerning both static and dynamic navigation are essential.

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