Guided Endodontics - Exploring the Correct Path: A Review

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Abstract

The purpose of this review is to shed light on the use of guided technology and digital planning in endodontics. Recently, a new strategy for handling complex situations has arisen called guided endodontics, which refers to computer-aided static and dynamic navigation technology. The new technology of guided endodontics is still developing. Technology advancements and scientific advancements have improved the predictability of therapeutic procedure outcomes. The accurate representation of interior anatomy made possible by the development of cone-beam computed tomography equipment and software linked to digital tools for 3D modeling and printing. It is used in a variety of procedures, including accessing and identifying root canals in teeth with pulp canal obliteration, performing endodontic microsurgery, and removing glass fiber posts during endodontic retreatment. Technology advancements and scientific advancements have made it possible to forecast therapeutic procedure outcomes more accurately. The use of guided endodontics has some benefits over more traditional clinical techniques, including quicker clinical visits, better treatments, and improved patient comfort. This narrative review seeks to update readers on the current state of guided endodontics and to point out pertinent research areas that may help this technology continue to advance.

Keywords: 3D printing, Cone-beam computed tomography, Dynamic navigation, Review, Static navigation.

Introduction

One of the most significant difficulties that endodontists have in clinical practice is the intricacy of the architecture of the root canal.[1,2] Modern techniques and materials are thought to offer higher standards, better root canal care, and proper management of procedural errors than those used back then. However, there is little proof to back up the advantages of modern endodontic procedures.[3] With its rapid advancements and geometric progression, the technology revolution has been an ongoing in the field of health. Modern, effective equipment has led to safer root canal procedures, quicker office visits, and increased patient comfort.[2]

The adaptability of the ultrasonic instrument in various clinical stages, the most accurate diagnosis with the aid of the apex locator,[4,5] determining the working length using some of the technological advancements that have boosted endodontics, and improved the quality perspective of results include the use of cone-beam computed tomography (CBCT),[6] safety in automated root canal instrumentation with Ni-Ti files,[7] and better operative field visualization with magnification.[8]

Better guidance can be provided by magnifying glasses, microscopes, and CBCT, although it might be challenging for the operator — especially a novice — to interpret the CBCT images, develop a guide, and carry out the therapy manually at the same time.[9] A computer-assisted therapeutic strategy was created to pinpoint calcified root canals in a minimally invasive manner, and the name "Guided Endodontics" was established in order to reduce the risk of technical errors and shorten the treatment time.[10]

Guided endodontics, either with computer-aided static (SN) or dynamic navigation (DN) techniques, has recently emerged as an alternative for access cavity preparation in the clinical management of complex cases,[11] including partial or total root canal space calcifications, anomalous teeth, glass fiber post-removal, dens invaginatus and evaginatus, dystrophic calcification, teeth presenting with rotations and/or versions, teeth with fixed prosthetic rehabilitation, selective root canal treatments, access through calcium silicate-based cements

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(e.g., MTA), non-surgical endodontic retreatment, and microsurgical endodontic procedures.[12] Static guidance implies the use of template, while DN relies on markers positioned in the patient's mouth and a camera system.[3]

CBCT datasets serve as the foundation for computer-aided SN and DN procedures. Surgical guides that are fixed in place are referred to as static guides and are created utilizing computer-aided design and computer-assisted manufacturing.[13]

The drilling procedure for DN, on the other hand, needs to be guided by an optical triangulation tracking system that makes use of real-time stereoscopic motion tracking cameras to account for the anticipated angle, pathway, and depth of endodontic access cavities. To do static-guided endodontics (SGE), a CBCT image of the patient's upper or lower arch is taken, depending on the location of the tooth that needs to be treated. The patient's arch of interest is registered at the same time. This can be done using an intraoral scanner or by taking an impression that will be scanned later. Software is used to superimpose the two obtained images, allowing for the creation of a guide that will encompass the tooth of interest (as well as some nearby teeth).

This guide can be used to create a drill hole with the proper diameter and angulation to provide direct access to the calcified canal. Then, cylinders or "sleeves" can be made to enable a drill to have steady, precise access to the inside of the root canal through the drill hole.

A smaller inner cylinder fabricated with metal. Once the designs are finished, the planning program exports the file in a stereolithography (STL) format allowing the guides to be printed using 3D technology. You can send the file to a laboratory if you do not have access to a 3D printer. Before using the guides, rubber dam isolation is carried out, and the guide is put on to make sure that it securely fits the patient's teeth. Once the calcified tissue has been entirely removed, the root canal procedure is proceeded as usual[14] using the internal metal cylinder as a guide to access and remove it.

The foundation of dynamic guided endodontics (DGE) is the use of CBCT pictures with reference markers that are positioned in the patient's mouth on the side that will not be operated on (before the CBCT). The trajectory of the drills into the pulp chamber and root canal is coordinated in real time with the aid of a stereo camera attached to a DN system. In this method, the operator may observe whatever he or she does and make any necessary corrections to the instruments' angulation.[15]

Digital Flow of the Guided Endodontics

The steps involved in the guided surgical procedure for implant installation are conducted in the same order as in the guided digital flow of implantology. Once the need for an endodontic guided procedure has been identified, the expert must confirm that the patient has both a digital copy of their arch model and a CBCT image of the region of interest.

Requesting a CBCT test will yield a DICOM file, and scanning the patient's intraoral arch will yield an STL file. Using specialized software for preparing surgical guides, digital planning centers or skilled individuals plan endodontic guides after collecting the DICOM and STL files. These planning tools were created to direct the placement of implants rather than internal tooth wear and strain.

Due to resource limitations caused by the endodontics area of operation's smaller size, the guided endodontics procedure may occasionally be contraindicated during the planning stage. The direction and area that the drill will wear must be carefully selected in addition to the wear length and diameter. It is best to steer clear of the motions that encourage the wear of vital tooth structures such as the incisal edge, enamel bridges, and cusp tips.

Estimating the thickness of dental tissue following the guided treatment is crucial once the wear length and trajectory planning have been established. To prevent perforation mishaps, plans should not project wear closer than 1 mm to the root surface that is in contact with the periodontal ligament. Guided wear to the apical third of the root is believed to have an average of deviations of up to 0.4 mm at the end of the drill, despite the fact that it is predictable.[16]

Rigid planning and printed guidelines reduce deviations. The stability of the guide and the danger of deviation while wearing the process increase with the degree of occlusal surface adaptation of the teeth. Planning for resources that restrict mobility is necessary in clinical conditions that are unfavorable to the stability of guides. For instance, a guide supported by fewer teeth or one without teeth nearby the area of the guided treatment is unfavorable for stability. In this case, we must plan the fixation pin stability of the guide. The stability of guided wear is further improved by the use of metal rings.

A detailed virtual planning report must be given to the dentist in charge of the case for review and approval when the endodontic guide project is finished. The STL file for the guide design is supplied for 3D printing only after approval. Finally, endodontic guidance is printed on resins.[2]

Indications of Guided Endodontics

Different clinical circumstances have called for the use of guided endodontics. Greater practical applicability was made possible by a deeper comprehension of its features and the investigation of digital resources in endodontics.[2]

- The initial indication of guided access is related to calcified canals.[17]

Endodontic therapy for teeth with pulp canal obliteration (PCO) or calcified canals is frequently difficult[18] and time-consuming.[19] PCO develops when hard tissue is deposited inside the root canal space, making the area smaller. It typically exhibits no symptoms, but can be found through radiographic testing and/or tooth discoloration. This change may be brought on by the evolution of chronic caries, prior crucial pulp treatment procedures, tooth restoration, or even luxation injuries.[20] Thus, employing the guided approach offers improved safety, predictability, little removal of oral tissue, and reduced clinical time with the patient.[21]

In cases of endodontic surgery, guide endodontics have also been recommended. Many endodontic procedures can benefit from using the 3D software used for pre-surgical implant planning since it helps to prevent damaging nearby teeth and precisely locate the afflicted location. Since 3D software has been utilized successfully for pre-surgical implant planning, its accuracy can be applied equally to endodontic procedures, providing noticeably improved control over drilling location and depth.[22] In addition, these guided techniques lessen the possibility of trans and post-operative problems such bleeding or harm to nearby anatomical structures. It also resulted in a quicker recovery time and a favorable prognosis.[23]

One of the indications for utilizing endodontic guides has also been access in teeth with developmental abnormalities. Dens invaginatus is one example of a dental deformity that can make endodontic treatment more difficult. In this regard, guided access has proven to be a workable and reliable substitute.[24]

In recent years, the use of fiber glass posts in dental rehabilitation has become a reality. However, removing it when necessary can be difficult for dentists and might result in fractures, cracks, or even root deviations or perforations. Thus, virtual planning and printing of guides have reduced clinical time, increased patient comfort, and decreased professional stress.[25] They have also contributed to enhanced safety in this process.

Future Directions Static/Template Guided Endodontics

Guidance using a template and sleeve is already a very developed technological method. It would be ideal if there were a greater variety of commercially accessible drills in terms of diameter and length because this would allow for a patient-focused strategy. A drill system with progressive lengths, especially in the posterior region, could make up for the space constraints. Future developments in dentistry may see a rise in the use of magnet resonance imaging (MRI).

Leontiev *et al*. (2021) demonstrated that comparably accurate access cavities based on MRI may be produced in a lab setting. Using a splint with a hydrous gel, the tooth structure was (indirectly) seen successfully superimposing the surface scan data on top of the MRI data. With a mean angle deviation of 1.82°, root canal visibility was successfully accomplished in 91 out of 100 cases. The clinical validity of these findings must still be established, since MRI equipment is not currently accessible to dentists.

Nevertheless, this is acceptable and possible for the future, depending on technological advancement. To strengthen the case for guided endodontics,[26] superior, prospective clinical studies are still required.

Future Directions of DN

To better handle the patient in the future, it would be preferable if the systems were further scaled back. In addition, every system should be able to digitally plan the necessary markers to prevent the need for a second CBCT scan when one (without markers) is already available. Of course, the system might orient itself to the existing anatomical structures if no markers were required at all.

Augmented reality (AR) navigation could be the next step toward simplification and improving the operator experience with dynamic guidance. A view of the operating field is superimposed over pictures such as radiography images and navigation paths using a wearable head-up display or specialized microscope employed in the AR approach.

As a result, the operator may see both the operative field and 3D navigation graphics at once without having to raise their head to a display.[27]

Discussion

A method that is always evolving, guided endodontics reflect the rapid transformation that is occurring in contemporary endodontics. As technology develops, endodontic tools become more accurate and suitable, leading to a more precise method that is less expensive and easier to find to clinicians.[2] It still has its limitations, which must be considered before it is planned and put into action. Given that guided endodontics are a relatively new field that is still being researched, developed, and utilized, the present work's limitations are based on the kind of studies that have been reported in the literature.

Therefore, further and better studies, such as randomized clinical trials, are required in the future to compare the outcomes of each application of SGE and DGE, as well as any additional treatments, in actual patients, together with long-term clinical and radiological follow-ups. The fact that some of the treatments were 3D-printed, in which case the tooth's features are different from those in a real tooth, rather than all of them being performed with extracted teeth, is one of the dangers of bias provided by the chosen papers, notwithstanding this. In addition, the follow-up periods in other types of papers were brief, in some cases just a few days or weeks, which is not enough time to assess the effectiveness of the technique.[5]

Static guidance has some drawbacks

1. It only works for straight parts of root canals
2. It might need a drill guide for each canal
3. Increased cost in cases involving multiple canals
4. Tooth needs to be stable during the scan and guided drilling
5. Metallic restorations may cause artifacts during imaging thereby leading to inaccurate treatment planning

6. Due to limited armamentarium, it is time consuming to prepare endo guides before the procedure.

However, dynamic guiding can get over these restrictions since it allows the doctor to see the bur in 3D on the screen and regulate how little tooth structure is actually removed.

There is no need for guide rings, high speed drills and burs can be utilized, and any changes to the treatment plan can also be addressed. However, a small mouth opening could be problematic, particularly for the back teeth.[28]

Systems that are static or dynamic both have benefits and drawbacks. Digital planning has the significant benefit of allowing for detailed navigation planning and pre-operative visualization of the root canal placement without the need to mentally translate the preparation to the clinical setting. As a result, dentists will be able to produce dependable results without needing to possess advanced endodontic expertise.[14] It's important to keep in mind that the PCO extension may have an impact on both computer-aided approaches' accuracy.[13]

The standard of the CBCT is a significant factor for accurate pre-operative planning, regardless of the procedure. When extremely radiopaque materials are present, the spatial resolution of the CBCT may not always allow for the visibility of the root canal, endangering the accuracy of digital planning.[29]

Using surgical templates, the SN method eliminates the requirement for drilling guidance during treatment.[30] In addition, it was stated that SN decreased chair-side operating times and excessive tooth structure loss. In addition, drilling accuracy was guaranteed by employing one bur or two burs.[31] Despite the benefits of this strategy, there are a number of drawbacks, one of which is that numerous teeth must be isolated during the technique because, to maintain its stability, the guide must fit precisely against the teeth.[14]

Furthermore, removal of the guide is necessary whenever the operator wants to validate the treatment path because it prevents visual access to the endodontic cavity.[32]

To give direct access to specific root canals in posterior teeth, static guiding necessitates the creation of numerous templates. It is also important to note that the design and production of the surgical template have a significant impact on the technique's accuracy.[30] Regarding clinical application restrictions, the static-guided method necessitates a straight line to the target, making it challenging to apply this technique in situations with narrow or constrained mouth openings and/or posterior teeth with constrained interocclusal space. To get around this problem, an intracoronal guide has been suggested. In addition, slower-moving drills with a wider diameter might cause the periodontal ligament to get damaged by producing too much heat and creating fissures on the tooth's surface. Finally, the lack of 3D real-time visualization prevents intraoperative changes in the predefined drill trajectory.[33]

One of the key advantages of DN is that it allows for a direct view of the operating room and enables real-time direction adjustment of the endodontic access cavity bur.[30] In addition, since a template is not required, it is especially helpful in cases of limited mouth opening or posterior region treatments. There is also no requirement for an intraoral scan, the risk of overheating resulting from the lack of a barrier between the water source and the bur is decreased, and it is not necessary to employ an intraoral scan.[34] Furthermore, DN can handle endodontic emergencies, whereas the static technique necessitates an extra stage of template preparation and printing.[35]

Despite DN's correctness, drawbacks and restrictions were also listed. The main drawbacks of the technique include its lengthy learning curve and the difficulty of keeping the system display in view during the procedure, which necessitates adequate operator training before to treatment.[13]

However, it has been proposed that AR technology can be used to communicate the virtual image shown by the DNS while keeping the visibility of the therapeutic region. Furthermore, there is a significant initial equipment investment.[35]

Conclusion

In comparison to traditional freehand approaches, computer-aided static and DN processes enable more precise and secure endodontic access to cavities.

In addition to endodontic cavity access and canal placement with PO, EG applications include retrograde fillings, removing fiberglass supports, and managing teeth with anatomic asymmetries. They can also be used in situations of osteotomy and apicoectomy.

The following are SGE's benefits:

It is more precise and safer than standard endodontics, does not depend on the operator's level of skill, and requires less patient treatment time.

The following are SGE's drawbacks:

It takes more time to create and make 3D guides, requires linear accessibility that only works with straight canals, and is less stable in the mouth for patients who are partially dentate.

The following are some advantages of DGE:

It enables for the real-time modification and reposition of the working instruments, is more ergonomic (in that it eliminates the need to glance at the screen during treatment), is more accurate because it does not build up design flaws, and is helpful in situations involving multiple-rooted teeth.

The following are DGE's drawbacks:

It needs simultaneous hand-eye synchronization and deeper learning for mastery and is heavily dependent on the operator's expertise.

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