“There are no atheists in a calcified tooth.”

Cutting ideal access preparations is one of the most critical and challenging aspects of root canal therapy. For all cases, the quality of the access preparation sets the stage for every following RCT procedure as it is the portal through which all instruments, materials, and solutions must pass during treatment. In cases of tipped or rotated teeth, poor alignment of access paths increase chances of perforation, rotary file fracture, and obturation difficulties. Cases with severe pulp chamber calcification--especially those with serviceable crowns--can require clinicians to cut through 12mm of radiographically-hidden tooth structure before getting into one of four canals. Cutting access into calcified root canal systems is, without a doubt, the most anxiety-provoking procedure in endodontics (Figures 1A, 1B). Beyond that, clinicians must find all the canals in posterior teeth, yet preserve their structural integrity, knowing that overcut access openings irreversibly decimate 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.

Static CT Guidance

Implant surgery outcomes are affected to the same extent by the accuracy of the osteotomies cut prior to placement of implant fixtures, and like endodontic specialists, 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, such that in 2001, Klein and Adams\(^1\) suggested milled CT-based drilling guides as a solution. A year later, Wat, et al.\(^2\) described how this new approach could be accomplished in practice, and in 2003, Sarment, et al.\(^3\), reported that the accuracy of implant placement with 3D-printed drill guides was significantly better than those fixtures placed without drill guides. This has been repeatedly confirmed.\(^4-8\)

In 2007, Pinskey, Champleboux and Sarment\(^9\) (same guy as above) proposed using a static CT-based stereolithographic drill guide for endodontic periapical surgery, inspiring the author’s development of CT-guided endodontic surgical procedures, which culminated in his live patient demonstration of endodontic surgery done through a CT-based static drill guide at the annual AAE Scientific Session in 2011. The author also worked to apply this technology to conventional access, and in a live demonstration at the 2015 Annual ADA Scientific Session, used a static drill guide to direct an Erbium/Yag laser (J. Morita Manufacturing Company, Osaka, Japan) while it cut a 0.4mm opening through the occlusal surface of a maxillary molar. The accuracy of that guidance allowed a #15 K-file to drop directly into the DB canal orifice.

In 2016 Buchgreitz, et al.\(^10\) and Zehnder, et al.\(^11\) showed ex vivo research confirming the accuracy of using a CT-based drill guide (static) for access cavity preparations, however, using static drill guides, whether they are milled or printed, pose several in vivo difficulties.

The author’s experience revealed that the first challenge of using a static drill guide for conventional access is the common lack of inter-occlusal distance to accommodate

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Figures 1A, 1B. Severely-tipped lower molar bridge abutment with necrotic pulp. The crown on this tooth was up-righted 45° to the root structure and was 12mm from cusp to margin. <S. Klein case>
the additional 10mm of drill or bur length required by the guide ring position over the tooth. The second difficulty experienced when using static drill guides is that no guide rings exist that work with the 150K RPM that high speed handpiece burs spin at when cutting through enamel, ceramics, and cast restorations. Third, endodontics is a less elective procedure than implant surgery. Implant surgeons and their patients can easily wait to receive printed or milled drill guides before scheduling the procedure. Root canal disease commonly presents in such acute form that nobody, patient or doctor, wants to wait for a printed or milled guide. Fourth, 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. Finally, 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, however, the processing speeds necessary to manipulate CT datasets in real-time could only be found in supercomputers, 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, and by 2016 Emery and Block introduce the X-Guide Dynamic Guidance System (X-Nav Technologies, LLC, Lansdale, PA) and proved it’s accuracy in clinical implant surgery.

XNav works by referencing two fiduciary scanning drums—one secured to the patient’s jaw before CT imaging, the
other secured to a latch-grip handpiece attachment with two overhead cameras, allowing the computer processor to generate an avatar of the jaw and the drill in real time allowing the clinician to look exclusively at the computer screen as implant osteotomies are drilled (Figures 2,3).

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. The following month, the author was introduced to the X-Nav system at an implant symposium, and immediately understood that optically-driven dynamic guidance solves all the problems that static drill guides present in endodontic application.

The Advantages of Dynamic Guidance for Conventional Endodontic Access
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. Dynamic guidance requires no waiting 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. Optically driven guidance requires no guide rings so multiple drill paths in multi-canalled posterior teeth can be easily planned and executed.
5. Dynamic guidance systems allow treatment changes to be made at the time of surgery so drill paths can be updated as new information is acquired during the procedure.

In August 2017, the author and co-investigators did preliminary research on the accuracy of DGA when used for access procedures in teeth with calcified pulp chambers. This study was done in 3D printed jaws (TrueJaw™ by Dental Engineering Laboratories, Santa Barbara, CA) whose teeth had been modeled to eliminate pulp chambers to simulate calcification. Each canal was entered through its own access opening, so upper molars with four canals ended up with four 1mm openings in their occlusal surfaces (Figures 4A, 4B). Accuracies are still being statistically analyzed, however, from a strictly empirical standpoint the results were remarkable as all of the canals were easily entered with a #15 K-File after each drilling plan was completed.

Dynamic Guidance Case Reports
The first case done by the author with DGA was in a central incisor with a necrotic canal that was calcified to the apical third (Figures 4-6). Using micro-burs designed
for minimally-invasive access procedures (Guided Access burs by SS White), a 1mm wide access preparation was cut ~12mm into the root before encountering the remnant canal in its apical third (Figures 5-7).

The second case shown highlights the value of the short turnaround times possible with dynamic guidance (Figures 8-10). An 87 year old patient broke her lateral incisor and the referring dentist wanted to place a temporary post and provisional crown the same day. The only problem was the tooth had no patent canal in its coronal two thirds. Within 30 minutes of meeting the patient (at lunch time), the drilling plan had been set up from the registered CT volume, the canal was located and treated, and the patient was returned to the restorative dentist with a finished RCT and post space.

The third case is a three-canal calcified molar that was accessed with XNav guidance (Figures 11-16). As it was nicely restored with a full crown, two separate opening were cut, one to the palatal canal, the other opening was a bit more ovoid to accommodate treatment of the MB and DB canals.

**Conclusion**

Despite all the implant research studies for nearly two decades showing significantly more accurate drilling results with computer-aided surgery (CAS) than freehand drilling\(^1\)\(^-\)\(^5\), only a minority of implant surgeons use static or dynamic guidance. No doubt it will take a paradigm shift by endodontists to embrace this potent new tool in managing the most difficult cases we treat. However, the advantages of using dynamic guidance to cut the Gordian Knot of treating calcified root canal systems so far outweigh the costs of this new method, the author feels confident that endodontic specialists will come to embrace its accuracy and its capability of delivering minimally-invasive in the most difficult access situations.

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**Figure 8.** Lateral incisor that broke at the gum line. Note the severe calcification.

**Figure 7.** Post-operative radiograph showing minimally-invasive RCT of a severely calcified tooth.

**Figure 9.** Radiograph showing the drilling path as it met the canal __mm into the root.

**Figure 10.** Post-op of completed RCT with post space left for reconstruction. This case was executed within 1.5 hours of referral.
Figure 11. Upper second molar with three canals and no observable pulp chamber.

Figure 12. Radiograph confirming drill path to the MB canal.

Figure 13. Radiograph of the first file to gain passage to the MB canal.

Figure 14. Photograph of minimally-invasive access openings.

Figure 15. Post-operative radiograph of finished case. Note the three separate access pathways.

Figure 16. Photograph of restored access cavities.
References


