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Research Article

Endodontic Microsurgery Using Dynamic Navigation and Trephine Burs

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Abstract

Objectives: The use of the surgical operating microscope, CBCT imagining, biocompatible filling materials and ultrasonic instruments have improved the success and predictability of apical surgery. Despite these advances, more accurate and precise techniques for creating osteotomies and root-resections (apicoectomies) have not been widely adopted. This study highlights how dynamic navigation systems (DNS) can help avoid unnecessary dentin removal and “mitigate iatrogenic errors” such as root perforation.

Methods: A total of 56 root-end resections were planned and completed on two sets of identical TrueJaw Endosurg models (DE Labs, Santa Barbra, CA, USA). One set of maxillary and mandibular jaws were used for 28 preparations, performed with a DNS (X-Guide, X-Nav Technologies, Lansdale, PA, USA). A second set of maxillary and mandibular jaws were used for 28 preparations executed freehand (FH), with pre-op measurements taken from a CBCT scan (CS 9600; Carestream, Atlanta, GA, USA). A Mann-Whitney test was used to compare the accuracy of the two groups

Results: The average preparation depth was 10.77 mm. For the DNS group the average angular deviation was 2.35 degrees. The average deviation at the terminal end of the preparations was 0.96 mm (global apical deviation). For the freehand group average angular deviation was 13.55 degrees and the average global apical deviation was 2.62 mm. Significant differences were identified between the DNS and FH groups for angular deviation ($p<0.05$), apical non-depth deviation ($p<0.05$) and between the Global apical deviation($p<0.05$).

Conclusion: Dynamic navigation demonstrated superior accuracy and precision over freehand in the context of apical microsurgery preparations. This study provides further proof of concept for the application of DNS in Endodontics.

Clinical significance: Apical surgery can be a daunting task for an endodontist. Surgical guides can make the procedure easier, but they take time and money to make. DNS virtual planning can be completed rapidly and may be altered mid-procedure. This inherent flexibility makes same-day guided apical surgeries practical and predictable.

***Keywords:** Endodontic Microsurgery; Apical Surgery; Trephine Burs; Dynamic Navigation*

Introduction

The use of the surgical operating microscope, CBCT imagining, biocompatible filling materials and ultrasonic instruments have improved the success and predictability of apical surgery. Despite these advances, more accurate and precise techniques for creating osteotomies and root-resections (apicoectomies) have not been widely adopted. Poor estimates may lead to incomplete root resections, excessive bone removal or even iatrogenic damage to neighboring anatomical structures. Estimations can be challenging when the cortical plate is still intact or if the roots located are far away from the cortical plate. Apical microsurgery is seldom attempted on palatal roots due to the difficulty in estimating the location of the root and neighboring neurovascular bundles.

In these situations, guided surgery can be an invaluable aid. (Giacomino et al. 2018) presented several case reports of how CBCT scans were utilized to produce static surgical guides for targeted endodontic microsurgery with trephine burs. This technique is akin to the widely utilized, and accurate static guides used for placing dental implants. Some limitations of static guides are the need to acquire an intra-oral scan, the time required to fabricate the physical guide and limited intraoral space required to use the guide in certain areas of the mouth. Care also must be taken to ensure that irrigation to the bone is possible since a static guide will cover the surgical site during osteotomy preparation.

Figure 1. *Dynamic navigation system and TrueJaw Endosurge models.*

The use of dynamic navigation systems (DNS) for guided implant placement has also demonstrated exceptional accuracy and ease of use (Block et al. 2017).

"Dynamic navigation integrates surgical instrumentation and radiologic images using an optical positioning device controlled by a dedicated computerized interface. A clinical real-time interface displays and guides users to drill into the targeted position through the prefixed trace according to the output of the preoperative planning software", (Gambarini et al. 2019).

Unlike static guides, the virtual planning of DNS can be completed rapidly, and if required, may be altered mid-procedure. This inherent flexibility makes same-day guided surgeries practical and predictable. Several recent studies have explored how this technology may be applied to the practice of endodontics. (Jain et al., 2020) demonstrated the high accuracy of using dynamic navigation with a high-speed handpiece to locate "highly difficult calcified canals". This study highlighted how DNS can help avoid unnecessary dentin removal and "mitigate iatrogenic errors" such as root perforation.

(Gambarini et al., 2019) published a case report using DNS for a minimally invasive osteotomy and root-end resection during endodontic surgery and evaluated how a non-experienced operator could precisely perform the procedure.

To date there are no published studies which specifically evaluate the accuracy of preparing osteotomies using trephine burs with DNS. The aim of this study is to evaluate the accuracy of osteotomy preparation and root-end resection using trephine burs driven by an endodontic handpiece and guided by the X-Nav, X-Guide DNS.

Materials and Methods

A total of 56 root-end resections were planned and completed on two sets of identical TrueJaw Endosurg models (DE Labs, Santa Barbra, CA, USA). One set of maxillary and mandibular jaws were used for 28 preparations, performed with a DNS (X-Guide, X-Nav Technologies, Lansdale, PA, USA). A second set of maxillary and mandibular jaws were used for 28 preparations executed freehand (FH), with pre-op measurements taken from a CBCT scan (CS 9600; Carestream, Atlanta, GA, USA) All resections and osteotomies were performed by the same operator.

The DNS group utilized an X-Clip with three radiopaque fiducials. The X-Clip has a block of thermoplastic material, which when submerged in a hot water bath sets at 140 degrees F and becomes malleable. The X-Clip is then seated on the contralateral side of the jaw as the surgical site and held in place until the thermoplastic material hardens, securely locked on the surface of the teeth. With the X-Clip secure, a single arch CBCT scan was taken of each surgical model with a 0.120 mm^3 voxel size resolution. The DICOM dataset was imported on to the DNS (X-Guide) planning software. The entry point, angulation, depth of the osteotomies and root resections were planned virtually.

The order of which the FH and DNS preparations were performed and randomized using a randomizer software (Research Randomizer; www.randomizer.org). Then the surgical typodonts were mounted onto a dental chair in the supine position to mimic traditional patient positioning during apical microsurgery.

For the DNS preparations, a tracking array is mounted to the X-Clip and on the shaft of the surgical handpiece. The DNS unit has a tracking camera which is positioned above the patient, so that it can record the position of the tracking array attached to the X-Clip and the array attached to the surgical handpiece; thus triangulating the position of the bur relative to the surgical site. A Brasseler contra-angle handpiece with a 4.0 mm diameter trephine bur (Meisinger USA, Colorado, CO USA) was used on a ProMark Endodontic Motor (Dentsply Sirona, York, PA USA) programed at 1200 RPM and 1000 g -cm or torque. The operator adjusts the position and angulation of the handpiece while looking at the X-Guide computer monitor, which provides real-time imaging and positioning feedback. The operator maintains eye contact on the monitor during the entire preparation until the planned preparation is complete. Each osteotomy was planned to produce a 3 mm apical root resection.

For the FH group, detailed pre-operative measurements of each root and the depth of the ideal preparation were calculated from a CBCT scan. Just as in the guided group, a 3 mm apical root resection was planned. A 4.0 mm diameter trephine bur was used with the same settings for RPM and torque on a ProMark motor as in the DNS group.

Figure 2. *Demonstration of how the Dynamic navigation system arrays and X-guide collaborate.*

Accuracy Assessment

Once all the osteotomies/root resections were completed, the jaws were removed from the surgical manikin, then post-operative CBCT scans were taken using the same settings reported previous on the CareStream 9600 unit. The completed osteotomies were compared to the pre-operative digital preparation plans. Angular deviation, apical deviation and global deviation were calculated for both the DNS and FH groups. A Mann-Whitney test was used to compare the accuracy of the two groups.

Results

A total of 56 root resections were performed; 28 under DNS and 28 freehand. In each group, 12 of the sites were on anterior teeth and 16 on posterior teeth. The average preparation depth was 10.77 mm. For the DNS group the average angular deviation was 2.35 degrees. The average deviation at the terminal end of the preparations was 0.96 mm (global apical deviation). For the freehand group average angular deviation was 13.55 degrees and the average global apical deviation was 2.62 mm. Significant differences were identified between the DNS and FH groups for angular deviation ($p<0.05$), apical non-depth deviation ($p<0.05$) and between the Global apical deviation ($p<0.05$).

Table 1. Mean and standard deviations values of angular deviation, apical non-depth deviation, global apical deviation and apical depth deviation during root resections for DNS and FH.

Jaw	Mean/ Standard Deviation	Angular deviation (deg)	Apical non-depth deviation (mm)	Global Apical deviation (mm)	Apical depth deviation (mm)
X-Guide (DNS)	MEAN	2.3458	0.6730	0.9613	0.5729
	STDEV	1.5619	0.4089	0.6197	0.6042
Freehand (FH)	MEAN	13.5521	1.8469	2.6194	1.6654
	STDEV	7.6583	1.2928	1.8638	1.6329

Sub-analysis of the DNS group was completed to compare the accuracy of guided root resections in the anterior and the posterior. All the median values in the posterior group were higher than the anterior group, however the results were not statistically significant ($P> 0.05$).

Table 2. Median values of angular deviation, apical non-depth deviation and global apical deviation of DNS for anterior and posterior root resections.

Median	Anterior - DNS	Posterior - DNS
Angular deviation (degrees)	1.93	2.11
Apical non-depth deviation (mm)	0.37	0.74
Global apical deviation (mm)	0.71	0.88

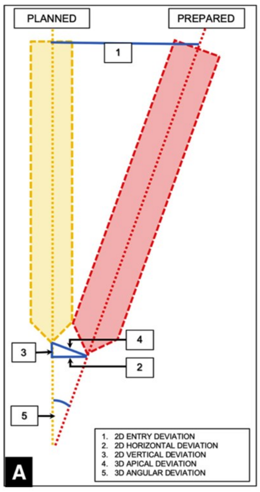
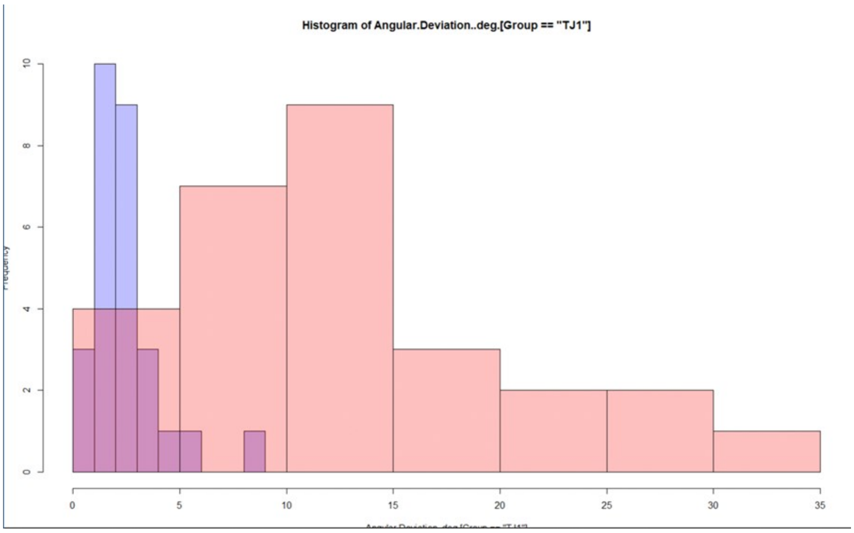
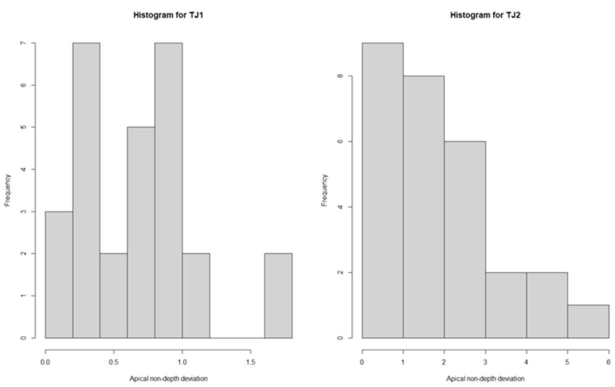


Figure 3. *The measurements and degrees of deviation from planned surgery compared to actual prepared root resections.*

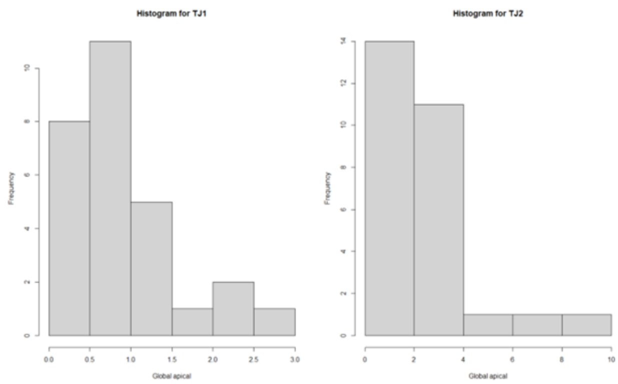
Figure 4. *Root end resection sites on TrueJaw Endosurge models.*



Graph 1. *The frequency that root resections had various degrees of angular deviation for both FH (pink) and DNS (purple).*



Graph 2. *The frequency that root resections had various measurements (mm) of apical non-depth deviations for both DNS (TJ1) FH (TJ2).*



Graph 3. *The frequency that root resections had various measurements (mm) of global apical deviations for both DNS (TJ1) FH (TJ2).*

Discussion

To date, most clinical applications of DNS have been in dental implantology and oral and maxillofacial surgery. X-Nav Technologies, announced that the X-Guide received 510(k) clearance from the U.S. Food and Drug Administration for its use to aid in minimally invasive endodontic procedures. Within Endodontics, most studies utilizing dynamic navigation have involved orthograde preparations for locating calcified canals. However, a recent study (Dianat et al. 2021) evaluated the accuracy of microsurgery osteotomies prepared with X-Guide DNS (n=20) compared to freehand (n=20). The osteotomies were performed on two human cadavers using a 3.5 mm diameter implant drill. The DNS group had an average angular deviation of 2.54 degrees and average global apical deviation of 0.65 mm. This present study found very similar result to the Dianat study, and further confirms proof of concept for the use of DNS for apical microsurgery. Beyond improved precision and accuracy, the Dianat study also demonstrated the efficiency of the DNS preparations, which on average took roughly half the amount of time as did the FH preparations.

Apical surgery is rarely utilized to address periapical infections associated with the palatal root of maxillary molars. This is due to difficultly in tissue reflection and proximity of the roots to other anatomical structures, such as the maxillary sinus and greater palatine neurovascular bundle. A flapless palatal approach root resection was performed in the present study with the DNS on both maxillary first molars. The post-operative analysis calculated an average angular deviation was 1.89 degrees and apical non-depth deviation of 0.56 mm. The palatal osteotomies were the deepest preparations of the study, with an average depth of 15.25 mm.

(Smith B.G., et al. 2020) used CBCT scans to investigate what percentage of maxillary posterior teeth that could qualify for a palatal approach apical surgery. They found that with a 2-mm safety margin 47% of first molars and 52% of second molars were good candidates.

There are some limitations specifically with trephine burs for this procedure. Creating the initial pilot preparation or scoring of the cortical bone can cause chatter/vibration and initial instability. To mitigate this issue, the manufacturer of the trephine burs recommends running the bur in reverse under copious irrigation to score the bone. Once this is achieved, the vibration is eliminated. Soon, piezoelectric instruments will be available for use on the X-guide unit which will further increase the flexibility of this technology for procedures like apicoectomies. (Villa-Machado et al. 2020) shared several case reports using piezoelectric instruments along with dynamic navigation for endodontic microsurgery. Piezoelectric has a distinct advantage of being gentle on soft tissues while also efficient at cutting hard tissue.

Conclusion

Dynamic navigation demonstrated superior accuracy and precision over freehand in the context of apical microsurgery preparations. This study provides further proof for the application of DNS in Endodontics.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this paper.

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