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Accessing Calcified Teeth Using Dynamic Guidance System

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Access of Calcified teeth Using a Dynamic Guidance System

by

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ARASH JAHANBAKHSH. Accessing Calcified Teeth Using Dynamic Guidance. (Under the direction of THEODORE RAVENEL)

Abstract:

Introduction: one of the most common challenging scenarios that a clinician faces on a regular basis is the treatment of a calcified tooth. Using CBCT to identify canals is becoming the standard of care and a tremendous help to clinicians. More recently, Dynamic guidance is becoming a popular among clinicians for dealing with challenging cases such as calcification.

Objective: The aim of this study was to evaluate the accuracy of endodontic access of calcified anterior mandibular and maxillary teeth using dynamic guidance.

Material and Method: 42 extracted calcified human mandibular and maxillary anterior teeth were selected. Rubber model former mold was used to mount the extracted teeth in the proper position to mimic the human jaw, and CBCT images were captured. Preoperative CBCT scans were transferred to the Dynamic Guidance system software for planning of endodontic access. To simulate a clinical scenario, the dentoforms were mounted to a manikin and placed on an operatory chair. Post-removal burs were used to gain access to the canal after calibration was completed. Once the proper depth was reached, the software prompted the operator to stop. The procedure was terminated at this point, regardless of the success of the operator to locate the canals or not. After completion, the access was evaluated by the passive placement of a #6 C file in the canal to ensure access/patency of the canal. A post-operative CBCT with and without the file in the access was taken. The teeth were then decoronated at the cementoenamel junction to remove any obstruction that would potentially deflect the file, and a file was placed in the canal and a CBCT was taken with the file. All images were assessed for access deviation and accuracy, followed by comparative statistics.

Results: Of the 32 included in this study, 28 (87.5%) canals were successfully located. The angular deviation was calculated after superimposing the pre-op CBCT over the post-op CBCT by measuring the angle between the file and the natural path of the physical canal. The average angular deviation was 4.69 degrees, the average platform buccolingual deviation was 0.38 mm, the average platform mesiodistal direction was 0.23 mm, the average of non-depth deviation (deviation in any direction other than apico-coronally) was 0.99 mm, and the average of apical non-depth deviation at the apical extent of the file trajectory was 0.70 mm

Conclusion: Calcified canals were located by an inexperienced operator in 87.5% of the time with an angular deviation of 4.69 degrees which confirms that dynamic guide system is a highly accurate and efficient way to perform a conservative access in anterior teeth.

Introduction:

Success in endodontic therapy depends on the elimination of microbes during treatment. This is achieved by proper and effective instrumentation, irrigation, and the use of intracanal medicaments (1). In his study, Kakehashi et al. proved that bacteria are the etiology. Once bacteria gain access to the root canal system, if left untreated, they will eventually cause apical periodontitis (2). The purpose of instrumentation therefore, is to remove bacteria, pulpal debris, (3) and permit irrigant penetration to the apex (4). Secondary goals include creating proper taper and flaring the canal for the final step of obturation (5). After proper cleaning and shaping of the root canal system, studies have shown that root canal therapy has a high success rate (6,7). This is only possible after the clinician has gained access to the canal, which can sometimes be challenging due to different factors. One of the most common challenging factors that a clinician faces on a regular basis is the treatment of a calcified tooth.

Calcification usually starts with increase in membrane permeability of mitochondria to calcium resulting from failure to maintain active transport system within the cell membrane. This causes cell degeneration. Calcium is then deposited in the degenerating tissue. This process can occur for a variety of reasons. Age, gender, systemic diseases, medications, deep caries, restorations, occlusal forces, and trauma all have been implicated in the process.

These calcifications serve as an impediment to performing root canal therapy. Aids in modern endodontics include the use of the dental operating microscope to help in canal location. These microscopes help the practitioner in visualizing anatomical structures, including the root canal system, in both surgical and non-surgical endodontic therapy (8). Even with the microscope, some teeth remain extremely difficult to treat. Difficulty in canal location can result in removing excess tooth structure. By doing so, the integrity of the tooth structure is weakened which compromises the long term prognosis of the tooth.

Tooth anatomy, morphology, location, and existing restoration will dictate the access cavity preparation. For esthetic reasons, anterior teeth are commonly accessed from the lingual portion of the tooth while molars and premolars are accessed from the occlusal portion. Treatment of anterior teeth tends to be less challenging compared to molars because of the ease of access and less anatomical complexities. At the same time, they can be more challenging because the clinician has less freedom on how much tooth structure can safely be removed before the fracture resistance of the tooth is severely compromised (9,10). This is especially true for lower anterior teeth due to their significantly smaller size. Hence, preserving tooth structure becomes even more crucial in these cases.

Clinicians use the cementoenamel junction, bitewings, periapical images, and CBCT to design their access cavity preparation (11-13). As mentioned above, this becomes extremely challenging when there is pulp space obliteration or calcifications, even for a seasoned endodontist. With the digital advances in the field of dentistry, clinicians have started implementing new technologies in an attempt and complete more advanced cases in a shorter time and more predictable manner

(14-17). Such techniques consist of the utilization of static 3-D printed guides or more recently, CBCT generated dynamic guidance. While both are highly accurate, dynamic guidance allows the operator can make changes, as needed in real-time. In addition, there is no need for multiple intra appointment radiographs to verify the proper path of insertion. To date, minimal studies are present evaluating the ability of dynamic guidance as an aid for endodontic access.

The aim of this study therefore is to evaluate the accuracy of endodontic access of calcified anterior mandibular and maxillary teeth using dynamic navigation guidance. During this experiment, we will evaluate the ability of the operator to gain access to the canal and measure the angular deviations of endodontic access preparations to the preplanned guide.

Methodology

Teeth Selection and Inclusion Criteria:

42 extracted calcified human mandibular and maxillary anterior teeth (central incisors, lateral incisors, and canines) with minimal caries or restorations were selected. Consensus between a second-year endodontic resident and an experienced endodontist (17+ years), was reached on the level of calcification of the teeth. Calcifications were defined as the "absence of canal presence on the periapical image (PA) in the coronal section". Preoperative faciolingual and mesiodistal PAs were taken of each tooth. Any tooth that showed a detectable pulp/canal in the coronal section of the tooth was excluded from this study. Rubber model former mold (Buyamag, Carlsbad CA) was used to mount the extracted teeth in the proper position to mimic the human jaw. The crown portion of the teeth was covered with petroleum jelly prior to placement. The roots were encased in a self-curing acrylic resin by mixing powder and liquid (Lang Dental) as instructed by the manufacturer.

Preoperative CBCT:

(X-Nav Technologies, LLC Lansdale, PA). instructions were followed for obtaining a preoperative CBCT. The X-Clip was placed in a hot water bath until the impression material turned from white to clear. The clip was then placed on the posterior region of the dentoform covering at least two teeth. The fiducials on the clip allow the dynamic guidance system to keep track of the patient, headpiece, and the computer. A full arch CBCT scan was taken of each arch with the X-Clip in place using Planmecca Promax 3D Max (Planmeca, Helsinki, Finland). Jaw setting mode at 90Kv, 10mA, and 150-micron slices were used to capture the preoperative CBCT. Each scan was reviewed and after the quality was ensured, the casts were numbered and dated. Care was taken to ensure that fiducials were completely captured in each scan.

Planning Virtual Access Design:

Preoperative CBCT scans were transferred to the dynamic guidance system software X-Guide (X-Nav Technologies, Lansdale, PA) for planning the access. Each tooth was planned separately by first defining the arch for the computer (Figure 1-A). The "planned implant" dimensions were changed to a diameter of 0.5 mm and a length of 7-10 mm to simulate a virtual file. The trajectory and path of insertion were adjusted to gain straight-line access to the canal (Figure 1-B). The length of the “planned implant” was adjusted to terminate the access slightly apical portion to the most coronal section of the canal

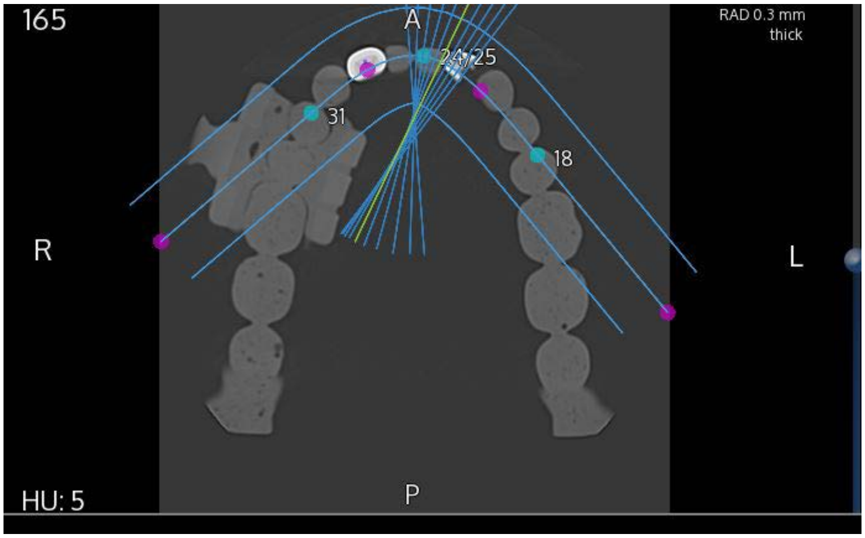

Figure 1-A: X-guide depicting defining the arch for the software by picking 3 points

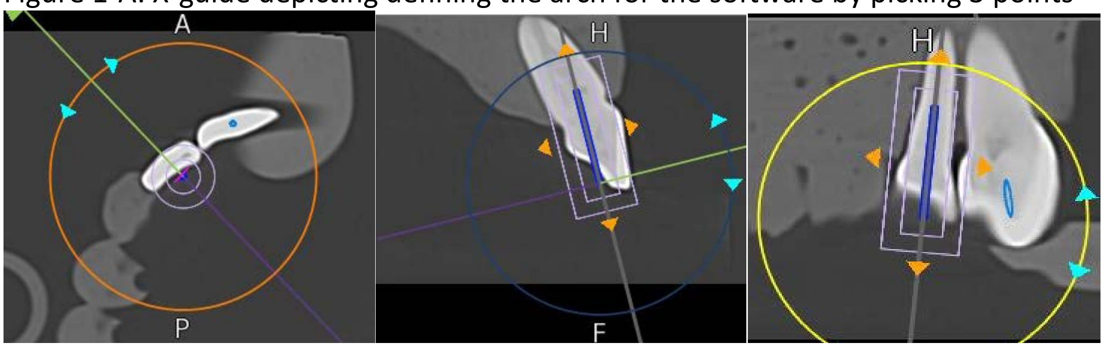

Figure 1-B: Depiction of planning the implant to gain access to the canal.

Treatment Simulation:

To simulate a clinical scenario, the dentoforms were mounted to a manikin and placed on an operatory chair. The proper arm was used to attach the X-Clip to the cast to ensure the computer/camera can track the fiducials throughout the procedure. Prior to the start of the procedure, all calibration steps required by X-Nav were completed.

After calibration was completed and the start point was determined, a #4 round bur on a high-speed hand-piece was used to drill a pilot hole in the proper orientation through the enamel. Once the dentin was reached, the hand-piece was switched with latch fit 1:1 dental surgical electric headpiece (W&H WS-56, Burmoos, Austria) and operated at 40,000 RPM while keeping the same orientation. To complete the treatment, a #1 Munce bur (CJM Engineering) or DT post-removal bur (Bisco, Schaumburg, Il) was used to gain access to the canal after calibration was completed. Once the proper depth was reached, the software prompted the operator to stop.

The procedure was terminated at this point, regardless of the success of the operator to locate the canals or not.

Post Access analysis:

After completion, the access was evaluated by the passive placement of a #6 C file in the canal to ensure access/patency of the canal. A post-operative CBCT with and without the file in the access was taken. The teeth were then decoronated at the cementoenamel junction to remove any obstruction that would potentially deflect the file, and a file was placed in the canal and a CBCT was taken with the file. All images were sent to the X-Nav company for superimposition and analysis.

Analysis:

Two factors were analyzed in this experiment. First, if the canal was successfully located or not. Second, if the canal was located, the angular deviation was measured. To measure angular deviation, the images were superimposed and the angle between the file and the natural path of the physical canal was measured based on the preoperative CBCT image (Figure 2).

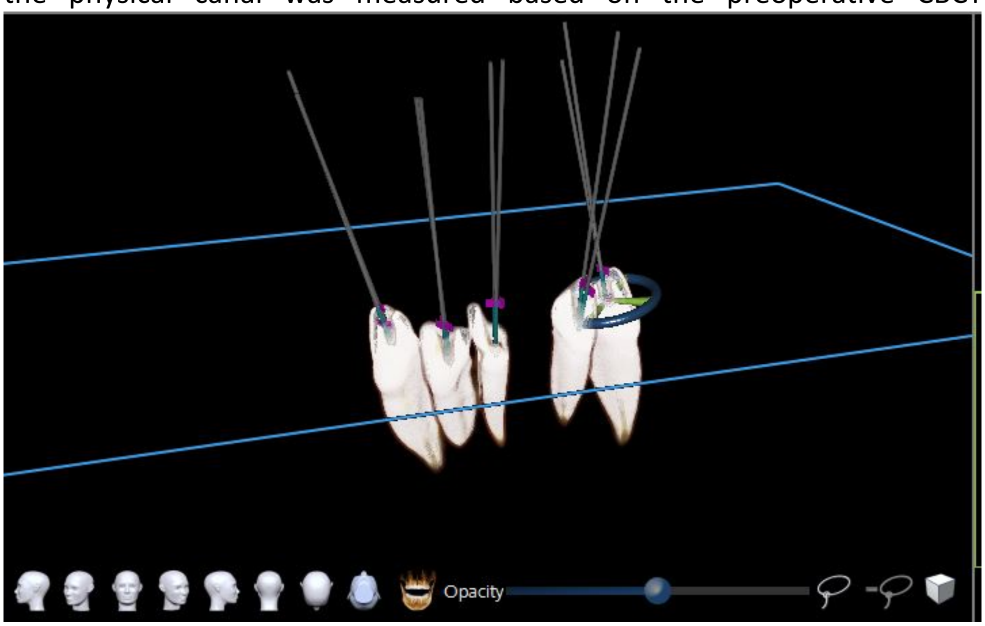

Figure 2: X-Guide image depicting planned vs. actual trajectory

Results:

Five of the mandibular central incisors were damaged during preparation and discarded. One mandibular incisor and canine were also eliminated from the study when the tip of the bur was separated. Three maxillary teeth were also eliminated from the study due to planning errors. The total number of teeth included in this study was 32.

A #6 file was placed in the access to ensure the canal could be passively located. No effort was made to establish patency. A post-operative CBCT with the file in place was taken to confirm that the file is in the canal. Of the 32 included in this study, 28 (87.5%) canals were successfully located. In three teeth, the canal was not located because the designed implant was terminated slightly short of the most coronal portion of the canal. In one case, the designed implant was lingual to the location of the canal. (Figure 3)

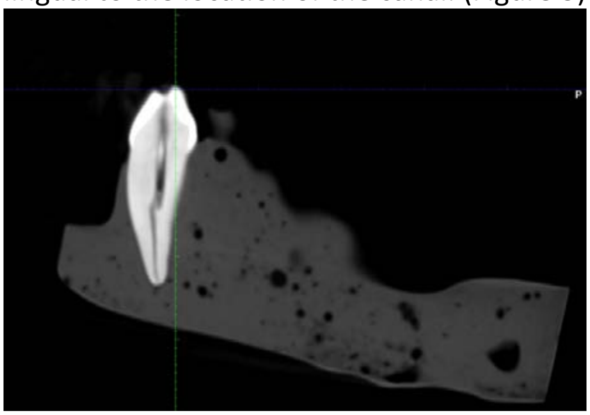

Figure 3: Coronal slice of CBCT depicting implant planned lingual in relation to the canal.

The angular deviation was calculated after superimposing the pre-op CBCT over the post-op CBCT by measuring the angle between the file and the natural path of the physical canal. The average angular deviation was 4.69 degrees, the average platform buccolingual deviation was 0.38 mm, the average platform mesiodistal direction was 0.23 mm, the average of non-depth deviation (deviation in any direction other than apico-coronally) was 0.99 mm, and the average of apical non-depth deviation at the apical extent of the file trajectory was 0.70 mm (Table 1).

STDEV			**0.00**	**0.00**	**0.00**		**0.00**		**0.00**		**0.00**
Mean		**1**	**4.69**	**1.99**	**0.38**		**0.23**		**-1.72**		**0.99**
Surgical Date	**Patient Name**	**Site Number**	**Angular Deviation (deg)**	**Global Platform (mm)**	**Platform B/L Deviation (mm)**	**B/L**	**Platform M/D deviation (mm)**	**M/D**	**Platform depth deviation (mm)**	**D/S**	**Platform non-depth deviation (mm)**
3/10/2020	1	22	4.6939	1.98749	0.37928		0.22975		-1.7235		0.9896
3/10/2020	1	23	4.0689	0.83819	0.25326		-0.52		-0.4695		0.6943
3/10/2020	1	24	3.7508	1.05976	-0.3565		-0.2692		-1.0079		0.3273
3/10/2020	1	25	4.8845	2.56348	-0.8533		0.1862		-2.498		0.5756
3/10/2020	1	26	6.9019	1.27586	-0.726		0.33031		-0.9897		0.8051
3/10/2020	2	22	3.5472	1.55722	-0.2022		-0.2798		-1.5041		0.4031
3/10/2020	2	23	2.5764	1.03729	0.4259		0.13735		1.03137		0.1105
3/10/2020	2	24	2.9363	0.92957	-0.3072		0.23335		-0.8852		0.2834
3/10/2020	2	25	2.1973	0.68684	0.34216		0.32162		-0.34		0.5967
3/10/2020	2	26	4.2244	0.83849	-0.2198		0.78288		-0.2187		0.8094
3/10/2020	3	22	2.2598	4.50106	-0.8028		-0.9435		-4.4837		0.3941
3/10/2020	3	23	10.386	6.74229	-2.0206		-2.143		-6.2994		2.4032
3/10/2020	3	24	5.2459	2.78347	-0.4894		-0.605		-2.6255		0.9241
3/10/2020	3	26	2.1964	5.37885	-1.7439		-0.1208		-5.2789		1.0317
3/10/2020	4	22	2.0449	4.21223	0.04422		-1.2685		-4.1928		0.4031
3/10/2020	4	23	3.9376	1.12357	-0.5209		0.02237		0.80864		0.78
3/10/2020	4	24	1.9672	0.5262	-0.3283		-0.2334		-0.4589		0.2573
3/10/2020	4	25	1.1473	0.1901	-0.0676		0.16962		0.04749		0.184
3/10/2020	4	27	1.0283	2.43716	-1.1264		0.10127		-2.4205		0.2842
3/10/2020	5	10	5.3437	8.46128	-2.9503		-0.9981		-8.3313		1.4769
3/10/2020	5	9	5.9769	8.02866	-3.1682		0.38209		-7.9489		1.1287
3/10/2020	5	8	3.588	6.6169	-3.326		0.23995		-6.6145		0.1766
3/10/2020	5	7	0.2825	0.258	0.18873		-0.0049		0.22548		0.1253
3/10/2020	6	6	5.7473	7.33297	-2.3936		0.08469		-7.2506		1.0956
3/10/2020	6	8	5.3418	8.25231	-4.8191		0.41546		-8.1037		1.5586
3/10/2020	6	9	1.3658	7.75714	-3.2312		-0.6758		-7.7435		0.4596
3/10/2020	6	11	6.5827	8.56062	-2.7433		-0.3239		-8.4983		1.0307
3/10/2020	7	8	0.3026	3.83511	-2.1039		0.02525		-3.8198		0.3415
3/10/2020	7	9	0.903	1.63512	-0.6392		0.79819		-1.409		0.8296
3/10/2020	7	10	3.2424	1.01446	0.11568		-0.3081		-0.8041		0.6183
3/10/2020	8	23	4.6877	3.31301	-0.1372		-1.0863		-3.1974		0.8674
3/10/2020	8	26	1.0252	3.06987	0.76953		0.31519		3.06252		0.2123

Table 1: statistical analysis done by X-Nav after superimposition of the pre-op and post-op CBCT images.

As for our control, an electronic search was done on PubMed to include available studies on endodontic access of calcified teeth. After excluding case reports, four studies were included to serve as our control. The results are summarized below.

P. Kiefner et Al. conducted a study to assess accessibility, time needed and outcome of endodontic treatment of teeth with calcified root canals in a sample of elderly participants with the use of Microscope. (18)

Author	Determination of accessibility/Time	Number of Teeth	Full working length achieved	Outcome
P. Kienfer, T. Connert, A. ElAyouti, R. Weiger	All canals accessible with 60min with the help of DOM	41	90%	80% success

In another study, T. Connert et Al. compared guided endodontics versus conventional access cavity preparation in calcified teeth by evaluating the success in detection of root canals, substance loss, and treatment duration. The results are summarized below: (19)

Authors	Number of Teeth	Substance loss Guided vs. Conventional	Time required to access Guided vs. Conventional	Detection of root canal Guided vs. Conventional
T. Connert, R. Krug, F. Eggmann, I. Emsermann, A. ElAyouti, R. Weiger, S. Kul, G. Krastl	60 identical teeth	9.8 mm^3 vs. 49.9 mm^3	11.3 min. vs. 21.8 min.	91.7% vs. 41.7%

T. Connert et Al. evaluated the accuracy of guided endodontics in accessing mandibular anterior teeth by using miniaturized instrument. They concluded that microguided endodontics provides an accurate, fast, and operator-independent technique for accessing teeth with narrow roots. The results are summarized below (20):

Authors	Number of Teeth	Mean Angular deviation	Time per tooth
T. Connert, M. Zehnder, R. Weiger, S. Kuhl, G. Krastl	60 mandibular anterior teeth	1.59%	10 minutes per tooth

The last study that we to serve as our control was done by S. Jain et Al. In their study, they evaluated the accuracy of dynamic guide to locate highly difficult canals in a simulated environment. The results of their study are summarized below (21):

Authors	Number of Teeth	2D Horizontal Deviation	3D deviation	Time
S. Jain, C. Carrico, I. Bermanis	84 mandibular and maxillary teeth (N=138)	0.9 mm from the orifice	1.3 mm from the orifice	Average of 57.8 seconds

The results of all four studies mentioned above confirmed the application of dynamic guidance in accessing challenging teeth in endodontic in an accurate, fast, and minimally invasive manner.

Discussion:

The location and negotiation of calcified canals are challenging for even an experienced clinician. In recent years, the use of microscope has helped clinicians to locate and navigate these torturous paths. Even with the help of a microscope and well-illuminated field of work, some of these cases are still extremely challenging. Additionally, this task becomes more difficult and technique sensitive when the clinician is dealing with smaller teeth, such as mandibular anteriors. Regardless of the type of tooth you are dealing with, one must aim to conserve as much tooth structure as possible. Current trends in endodontics have focused on minimally invasive dentistry. By using minimally invasive cavity preparations, it is thought to increase the fracture resistance of the tooth (22,23). The attempt to locate canals through traditional access is likely to result in higher substance loss of tooth structure compared to a conservative access by the dynamically guided technique. Thus, the biomechanical benefits of tooth substance preservation by implementing the guided access preparation might help improve the long prognosis of the endodontically treated teeth (24, 25).

This study aimed to show that calcified teeth could be conservatively accessed quickly and accurately with a dynamic guidance system. The manufacturer (X-Nav Technologies) recommends practicing on a minimum of 25 teeth to develop the hand-eye coordination required for operating this system. Depending on the skills of the operator, this acquired skill can be achieved with fewer teeth. To prepare for this study, the operator mounted, scanned, planned, and accessed 30 teeth to familiarize himself with the system. Our study showed that an inexperienced resident could locate the canals in calcified teeth in 87.5% of the time through this conservative access technique. This number could improve as the operator becomes more familiar with the planning. As mentioned, in three teeth, the canal was not located simply because the implant was terminated short of the most coronal portion of the canal (Figure 4). One tooth was considered a failure because the implant was designed and planned too lingual to the location of the canal. We believe that this is more due to lack of experience of the resident in using the X-Nav guided system than a negative reflection of the system.

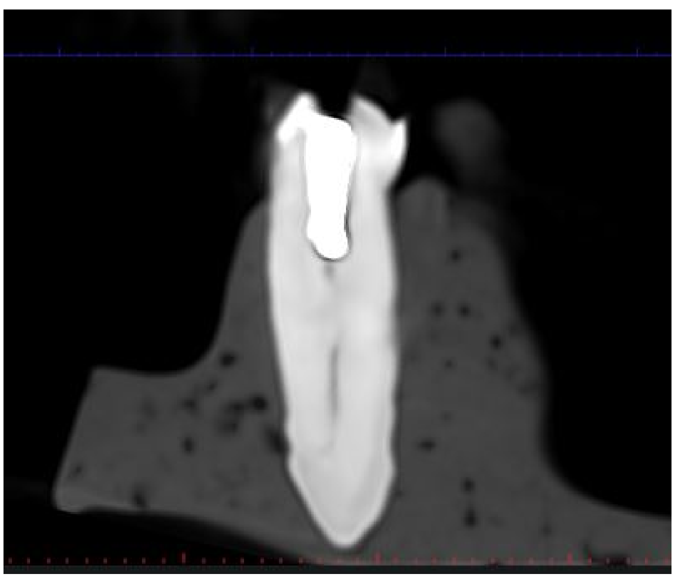

Figure 4: Coronal slice of CBCT depicting implant planned short of canal.

Additionally, as mentioned above, 5 teeth were excluded from this study after the coronal portion of the tooth was fractured through the process of drilling. This could be partially explained by the fact that some of these teeth were dehydrated and not kept in a moist medium. Finding calcified teeth that would qualify for this study was challenging and after exhausting all the options, we were able to find 42 teeth that would qualify as calcified, as defined above.

Unfortunately, some of these teeth were not stored in a proper medium which we believe caused dehydration and hence fracture of the crown of the tooth.

Another problem in this study was the technique that we implemented to perform our access cavity preparations. At the beginning of the project, Munce burs were used to initiate the access. The Munce bur is characterized by a small cutting end with a long shaft with a constant taper. This design aids in visualization of the cutting while using the microscope. The taper of the shaft is such that the diameter of the shaft exceeds the diameter of the cutting end as it approaches the shank. It is this design feature that made it unsuitable for a guided procedure. The shaft having a wider diameter than the cutting tip generated excess friction which resulted in tip separation of the Munce bur, and, in some cases tooth fracture. This technique was modified later by using the high-speed handpiece to remove the enamel using a diamond bur to reduce the stress on the Munce bur. Implementing this technique not only made it more clinically realistic but also prevented bur separation or crown fracture in 100% of the remaining cases.

The angular deviation calculation was performed by superimposing the pre-op CBCT and post-op CBCT. In some cases, the perfect superimposition of the CBCT images was not achieved, therefore some of the deviations were slightly over-estimated.

A more comprehensive study by Zehnder et al. (2016) on the accuracy of guided access using a 3D printed static model for anterior teeth revealed a mean angle deviation of 1.81 degrees with a maximum of 5.6 degree difference. In their study, only maxillary teeth models were utilized in their study. In the present study, only calcified anterior mandibular and maxillary teeth were used. In our study, angular deviation in our access for maxillary teeth resulted in 4.69 degrees, which is similar to the results found in 31 the static guide study by Zehnder et al. (2016).

Overall, the X-Guide dynamic system proved to be a very efficient and accurate way of locating calcified canals with only a slight angular deviation. As mentioned above, with more practice in planning, executing, and implementing better technique, the numbers could improve tremendously.

Conclusion:

In this study, calcified canals were located by an inexperienced operator using dynamic guidance 87.5% of the time with an angular deviation of 4.69 degrees. This confirms that the X-Guide dynamic guide system is a highly accurate and efficient way to perform a conservative access in anterior teeth. Everything considered, due to its accuracy, X-Nav system has a significant application in endodontics in which an experienced clinician can heavily rely on to complete challenging cases with a high level of confidence.

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