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BASIC RESEARCH:

Tooth Tissue Loss in Locating Mesiobuccal Canal during Selective Retreatment using Dynamic Navigation System: An *In vitro* Study

Pérdida de tejido dental en la localización del canal mesiovestibular durante el retratamiento endodóntico utilizando un sistema de navegación dinámica: un estudio *in vitro*

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ABSTRACT: Selective root canal retreatment has demonstrated positive success, but the process is challenging because imprecision compromises the tooth's structural durability. As there is a lack of literature on selective retreatment using DNS, this *in-vitro* study was designed for comparative evaluation of tooth tissue loss and time taken in locating mesiobuccal (MB)canal using the dynamic navigation system (DNS; Navident, ClaroNav, Toronto, ON, Canada) to the freehand (FH) method. The null hypothesis was that both methods would have similar tooth tissue loss and time required for the procedure. Twenty root canal-treated human mandibular molar teeth were mounted on Navident manikin. Using the Navident programme, the drilling path and depth were virtually designed using cone-beam computed tomographic (CBCT) scans. A minimal access cavity for locating the MB root was prepared with dynamic navigation in the DNS group and with freehand in the FH group. Volumetric tooth tissue loss was evaluated with the help of postoperative CBCT and On-demand software. Statistical analysis was done with an independent-sample T Test ($p<0.05$). The time taken for the procedure was recorded with a stopwatch. The tooth tissue loss was significantly less with the DNS group (35.83 mm^3) compared to the FH group (52.84 mm^3) with a P value of 0.001. The time taken for the DNS group was less with the DNS group (29.00 seconds) compared to the FH group (53.60 seconds) with statistical significance with a P value of 0.001. The DNS resulted in minimal tooth tissue loss with a shorter time compared to the FH group. This technique can be practised for predictable selective retreatment in endodontics.

KEYWORDS: Cone-beam computed tomography; Nonsurgical retreatment; Selective root canal retreatment; Dynamic navigation; Guided endodontics.

RESUMEN: El retratamiento selectivo del conducto radicular ha demostrado ser exitoso, pero el proceso es un desafío porque la imprecisión compromete la estructura del diente. Así, este estudio in vitro fue diseñado para evaluar de forma comparativa la pérdida de tejido dental y el tiempo necesario para localizar el canal mesiobucal (MB) usando el sistema de navegación dinámica (DNS; Navident, ClaroNav, Toronto , ON, Canadá) con el método a mano alzada (FH). La hipótesis nula fue que ambos métodos tendrían una pérdida de tejido dental y un tiempo similares. Se utilizaron veinte molares mandibulares humanos tratados con conducto radicular en un maniquí Navident. Utilizando el programa Navident, la ruta de perforación y la profundidad se diseñó virtualmente mediante exploraciones por tomografía computarizada de haz cónico (CBCT). Se preparó una cavidad de mínimo acceso para localizar la raíz del MB con navegación dinámica en el grupo DNS y con mano alzada en el grupo FH. La pérdida volumétrica de tejido dental se evaluó con la ayuda de CBCT postoperatoria y software. El análisis estadístico se realizó con una prueba T para muestras independientes ($p<0,05$). El tiempo empleado en el procedimiento se registró con un cronómetro. La pérdida de tejido dental fue significativamente menor con el grupo DNS (35,83 mm^3) en comparación con el grupo FH (52,84 mm^3) con un valor de P de 0,001. El tiempo necesario para el grupo DNS fue menor con el grupo DNS (29,00 segundos) en comparación con el grupo FH (53,60 segundos) con significación estadística con un valor de P de 0,001. La DNS resultó en una pérdida mínima de tejido dental con un tiempo más corto en comparación con el grupo FH. Esta técnica se puede practicar para un retratamiento selectivo predecible en endodoncia.

PALABRAS CLAVE: Tomografía computarizada de haz cónico; Retratamiento no quirúrgico; Retratamiento selectivo del conducto radicular; Navegación dinámica; Endodoncia guiada.

INTRODUCTION

Despite endodontic treatment having a high rate of success (1), 42% of teeth in cross-sectional studies showed signs of reinfection (2,3). Multirooted teeth with complex anatomy are more vulnerable to secondary apical periodontitis (4). Only roots with persisting peri radicular biofilm or inadequate disinfection, as seen by apical radiolucency, can be treated with selective retreatment. If the previous restoration is well-fitting and functioning, selective retreatment can be tooth-saving since the minimal path for access can retain tooth integrity while being cost-effective (5). Traditional FH method poses iatrogenic errors like, perforation, and excessive removal of tooth substance, as the clinician must navigate through a filled tooth using just mental acuity.

In endodontics, DNS technology accurately locates the complex non-negotiable, obliterated canal with the conservation of tooth substance (6). Precise post removal was reported using DNS during retreatment, recommending such a method to reduce the iatrogenic errors (7). Hence it was hypothesized that, similar to the location of canals in calcified pulp chamber (8), 3-dimensional guided endodontics could be more conservative during the selective retreatment procedure. There are no published pragmatically designed studies to verify the efficacy of DNS in selective retreatment endodontics. Hence this *in vitro* study was planned with the null hypothesis that both DNS and FH methods will have similar tooth tissue loss and time required in locating mesiobuccal canal during selective retreatment.

METHODOLOGY

Twenty freshly extracted human mandibular molars were collected from the Department of Oral and Maxillofacial Surgery, with consent from the Institutional Ethical Committee. Ref: Project No. IECVDC/2021/PG01/CE/IVT/100. The sample size was assessed based on previous research (9) with G*Power software (version 3.1.9.4., Heinrich-Heine University, Germany) with effect size d=1.98 and CI of 95%. The total sample size estimated was 12. Twenty teeth were used for the study.

PRILE 2021 guidelines for reporting laboratory studies in Endodontology were followed for the research protocol.

Inclusion criteria:
1.Teeth with normal morphology.
2. Molars with/without caries.
3. Multi rooted molars.

Exclusion Criteria:
1. Restored teeth.
2. Fractured teeth.
3. Root caries.

Twenty mandibular molars were treated with root canal treatment and access cavities were restored with composite resin restoration. A radiographic evaluation of the quality of treatment was done. Teeth were allocated into two groups of ten, by random selection by computer-generated software from a research randomizer (www.randomizer.org). Ten obturated molars were mounted in light cure denture base acrylic resin (Poly Tray Light Curing Tray Material Delta) and placed in the metal jaw base of Navident orienting all the mesial surfaces towards the midline (Figure 1.A). Each layer of resin was cured in a Delta Blu Lux unit for 5 minutes.

The jaw with samples was scanned with a high-resolution optical scanner (Medit® Seoul, Korea) Figure 1.B) and preoperative CBCT (A Cranex 3D Soredex, Tuusula, Finland) scan with Field of View 6X8 was carried out under exposure parameters 3.2mA, 90kVp, and 2.3s (Figure 1.C). The jaws were mounted on a dental manikin (Navident) and stabilized on a dental chair for oral simulation.

GROUP-I

Conservative access cavity was prepared using a manual approach aiming to reach the MB canal through composite restoration from the occlusal surface. Long shank access cavity preparation bur (Bur EA L 10 Mani Endo Access Diamond Burs) was used in a highspeed contra-angled handpiece at a speed of 100,000rpm to reach the MB orifice. Upon reaching the gutta pearcha, the orifice was evaluated with a #10K hand file and confirmed with an IOPA radiograph (Figure 2. A-G).

GROUP-II

The DICOM file and STL file generated by the extraoral scanner were imported into the Navident programme EvaluNav (ClaroNav). DNS with dedicated software for implant placing was used for planning to reach the orifice of the obturated MB canal. For all samples, a minimal access cavity to reach the MB canal was planned on the sagittal view of the CBCT image by drawing a straight-line entry to the orifice. The entry point, angle, path, and depth of the access bur was programmed. The linear and angular direction of the bur was envisioned and adjusted in all 3 planes on the display monitor for flawless entry (Figure 1.D).

The trace registration process was done in the second stage to align the CBCT scans with samples arranged on simulation jaws (Figure 1.E). The explicit superimposition provided the precise position of the root canal during the entire procedure. To enhance the accuracy, the optical tracer was secured on the simulation jaw and 3 marks on the samples were selected. The tracer tool tracked by an optical positioning sensor was used to trace the teeth surfaces and root canals in real time.

The third step was the calibration of the handpiece and burs. Calibration of the tracked handpiece and bur tip was done (Figure 1.F). This led to the real-time tracking and display of the bur's position and angulation on the monitor during the procedure.

After these steps, the designed access to the obturated canal was performed (Figure 1.G) by real-time viewing of the planned bur's direction and angulation on the computer screen. The progress of the bur when near 1mm from the planned depth was indicated by the green bar changing to yellow on the depth indicator of the target view (Figure 1.H). As soon as the desired depth was reached, the bar turned red. The orifice of the canal was evaluated by using a #10 stainless steel hand K file. Figure1.I and Figure 1.J depict minimal access cavities on a single tooth and in all samples. The time duration for locating the MB canal from the beginning of drilling through the restoration was recorded using a stopwatch. After the location of canals, a second CBCT scan of both the groups was performed for comparison of access cavities volume (Figure 1.K).

Using OnDemand viewer software,6X8 field-of-view CBCT scans were made. Using software tools segmentation and sculpt (10), the volume (cubic millimetres) of the access cavity of the obturated MB canal in the mandibular molar was assessed (Figure 1.L). This indicated the tooth tissue loss during the procedure.

STATISTICAL ANALYSIS

The data of tooth tissue loss and time taken were entered in Excel sheets. A descriptive analysis was performed for each method. Statistically significant differences were expressed by non-overlapping 95% Confidence Intervals. Statistical analysis was conducted with an Independent-Samples T Test using IBM SPSS Statistics for Windows, Version 20 (IBM Corp, Armonk, N.Y, USA).

RESULTS

The highest volume of tooth tissue loss in the FH group was 66.64 mm³ and the lowest value was 39.14 mm³ (Table 1). The mean tooth tissue loss using the FH group was 52.84 mm³ (95% C.I, 39.14-66.64 mm³). The highest volume of tooth tissue loss in the DNS group was 44.29 mm³ and the lowest value was 26.31 mm³. The mean tooth tissue loss in the DNS group was 35.83 mm³ (95% C.I, 39.14-66.64 mm³). The tooth tissue loss was significantly less in the DNS group compared to the FH group with a P value of 0.001 (Table 2).

The longest time taken by the FH group was 65 seconds and the shortest was 45 seconds (Table 1). The mean time taken with the FH group was 53.60s (95% C.I, 45-65s). The longest time taken by the DNS group was 45 seconds and the shortest was 20 seconds. The mean time taken with the DNS group was 29.00s (95% C.I, 20-45s). The time taken was significantly less with the DNS group compared to the FH group with a P value of 0.001 (Table 1).

Table 1. The Data on tooth loss and the time taken in the Free Hand Group and The DNS Group.

S No	Tooth tissue loss (mm³)		Time taken (seconds)	
	Free Hand Group	DNS Group	Free Hand Group	DNS Group
1	57.2117	34.0323	50	30
2	48.3912	31.6781	60	45
3	44.2136	28.5432	58	35
4	53.3782	39.6623	55	25
5	39.1463	26.3124	60	30
6	54.5861	40.1832	48	40
7	62.6311	44.2981	50	20
8	43.8673	33.6117	45	25
9	66.6412	43.1362	45	20
10	58.3183	36.8133	65	20

Table 2. Comparison of tooth tissue loss in mm3 between DNS and FH groups.

Group	N	Mean (mm³)	Std. Deviation	Independent sample t-test Statistic	P value
Free Hand	10	52.84	8.82	t=5.029	0.001*
Dynamic guided	10	35.83	6.05		

p<0.05.

Table 3. Comparison of Time taken for procedure between DNS and FH groups.

Group	N	Mean	Std. Deviation	Independent sample t-test Statistic	P value
Free Hand	10	53.60	6.98	t=6.947	0.001*
Dynamic guided	10	29.00	8.76		

p<0.05.

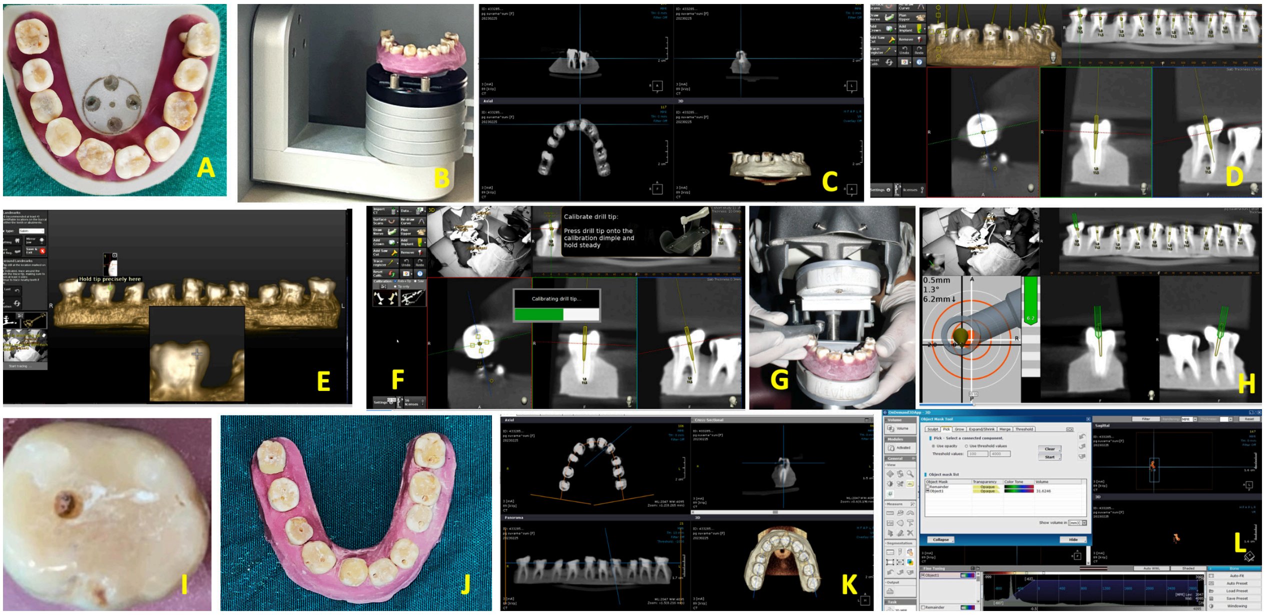

Figure 1. A. Samples in Navident Jaw. B. Samples for optical scanner. C. Pre-op CBCT. D. Virtual Planning targeting MB canals. E. Tracing of landmarks. F. Calibration of bur. G. Simulation on Navident manikin. H. Bur orientation and drilling guided by target view. I. Access in individual tooth. J. Access cavities in all samples. K. Post-op CBCT. L. Tooth tissue loss assessment using OnDemand viewer softwar.

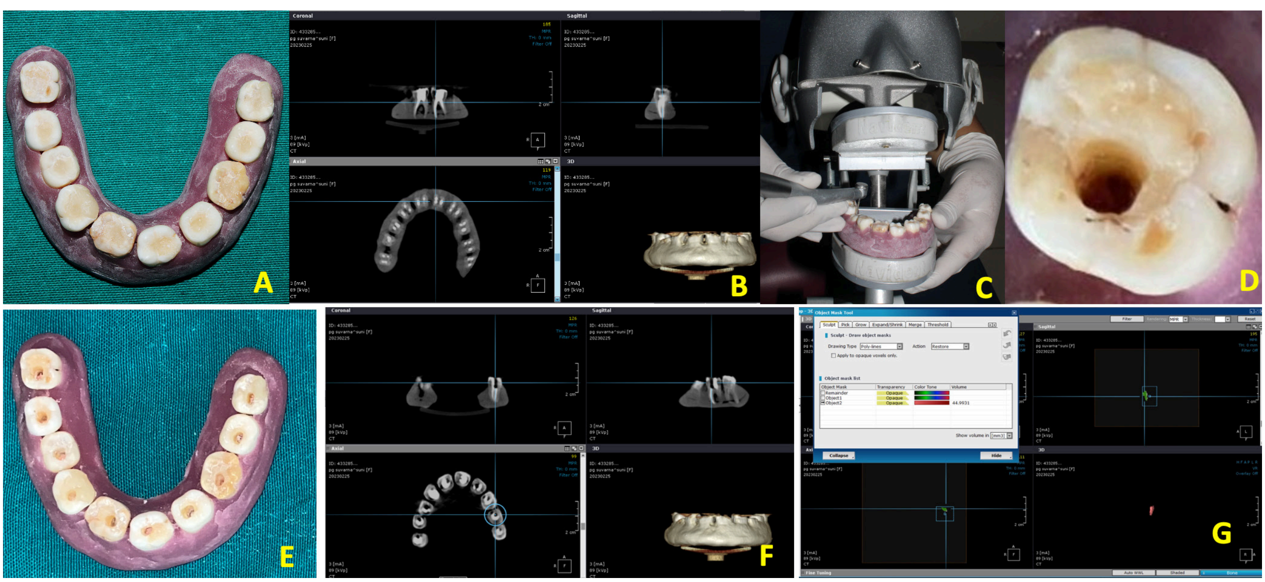

Figure 2. A. Samples in Navident Jaw. B. Pre-op CBCT. C. Simulation on Navident manikin. D.Minimal access in an individual tooth. E. Access cavities in all samples. F. Post-op CBCT. G.Tooth tissue loss assessment using OnDemand viewer software.

DISCUSSION

The present research evaluated the efficacy of DNS in the precise location of the MB canal in the retreatment of mandibular molars compared to the traditional FH method. The tooth tissue loss and the time required for the procedure were significantly less in the DNS group compared to the FH group. Both parameters are conducive to good clinical practice in saving failed root canal treatment cases.

The secondary infection of the root canal system can be associated with biological and clinical limitations. Persistent intra or extra-canal bacteria, specific bacteria or conglomeration of bacteria are biological factors. Complex pulp space anastomosis and compromised clinician skill are clinical limitations (11). Many times, in multirooted teeth, only one root may develop infection. The diagnosis of recurrent apical periodontitis associated with a single root can be precisely diagnosed with 3-D imaging (12). The traditional “all on none” approach for non-surgical retreatment is obsolete in contemporary endodontics. Selective retreatment has reported success and is the preferred modality (1).

Longevity is the primary objective in endodontic retreatment as it is the second attempt to preserve the tooth's function. FH protocol involves gaining access by drilling through existing crowns, posts, or restorations. As there wouldn’t be a guiding dentin map available in such conditions, the clinician must rely on mental imagination to reach the canals. Unwanted substance removal is a possibility. One of the reasons for extraction in nonsurgical retreatment is vertical fracture (13) resulted from excessive tooth tissue loss.

Literature on tooth tissue loss during retreatment with DNS is scarce. A case report of the successful removal of fiber posts using DNS in retreatment (7) was reported. This is the first research project comparing the DNS and FH protocol in tooth tissue loss and the time required for accessing the MB canal in selective retreatment.

The attempt to reach the obturated canal in retreatment would result in higher tooth tissue loss like in calcified canals (9), due to the unavailability of a guiding dentin map as in primary endodontics. In selective retreatment, a high level of precision is required. The tooth tissue loss with DNS was significantly less compared to the FH group (Table 2). These conservative cavities mimicked the minimally invasive access cavities such as contracted access cavities. Minimal invasive access cavities have demonstrated good structural durability in the literature (14, 15). The dentin removed during access cavity is the most important factor influencing the biomechanics of endodontically treated teeth. The weakened tooth might compromise the ability of the tooth to withstand the stress and derange the distribution of forces (16). Hence tooth tissue loss must be given primary importance. In DNS protocol, as the drilling instrument was aligned to the designed path and its movement was observed live during the procedure, the chance of unnecessary tooth tissue removal was negligible (9, 17). The results of the present study are in accordance with these studies (9, 17). But in FH protocol, the direction of the drilling instrument was not guided, relied on the experience of the clinician, and resulted in a wider access cavity.

The time required for the procedure was significantly longer in the FH group (Table 3), as the clinician must monitor the progress of the bur with reference to the long axis of the tooth all the time. Most of the time radiographic confirmation of bur direction is necessary to avoid mishaps. Whereas in DNS, the continued real-time visualization minimized the time required. A systematic review on DNS has reported efficient management of challenging cases with great efficiency in less time (18) using DNS.

The null hypothesis was rejected as tooth tissue loss and time taken for DNS protocol were different and significantly lesser compared to the FH protocol in locating the mesiobuccal canal during selective retreatment.

Advantages of Dynamic Navigation in Selective Retreatment Endodontics can be highly appreciated, which include:

- Saving of tooth substance for subsequent restoration.
- Improved load resistance.
- Facilitation of endodontic instruments.
- Reduced risk of iatrogenic errors.
- Lower time for procedure.

Some limitations of the DNS according to the author's perception are the initial steep learning curve as the drill was not stabilized as in the static guide and the high cost of the equipment. As this is an in vitro study, it can't be extrapolated to the clinical situation. Hence randomized clinical trials need to be done to confirm the efficacy of DNS.

CONCLUSION

The tooth tissue loss with the DNS protocol was significantly less compared to the FH protocol in locating the obturated mesiobuccal canal.

The time required for the procedure with DNS was significantly less compared to the FH protocol in reaching the obturated mesiobuccal canal.

The application of DNS in saving failed root canal treatment cases is conducive to good clinical practice.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

Authors declare no use of AI and AI-assisted technologies in the writing process.

Authors state: 'Declarations of interest: none'.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
Literature review: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
Methodology and validation: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
Formal analysis: G.S.S. and M.S.S.
Investigation and data collection: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
Resources: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
Data analysis and interpretation: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
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Supervision: G.S.S., M.S.S., S.R.M., N.K., N.K and R.K.S.
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