In vivo and in vitro examination of the efficacy of targeted endodontic microsurgery

Ph.D. Thesis

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Publications, presentations related to the subject of the thesis

I. ***Nagy E****,* Fráter M, Antal M. Gyökércsúcs rezekciója navigált endodontiai mikrosebészeti technikával [Guided modern endodontic microsurgery by use of a trephine bur]. Orv Hetil. 2020 Jul;161(30):1260-1265. Hungarian. doi: 10.1556/650.2020.31778. PMID: 32653869. **IF: 0.540**

II. Antal M, ***Nagy E****,* Braunitzer G, Fráter M, Piffkó J. Accuracy and clinical safety of guided root end resection with a trephine: a case series. Head Face Med. 2019 Dec 21;15(1):30. doi: 10.1186/s13005-019-0214-8. PMID: 31861995; PMCID: PMC6925511. **IF:1.882**

III. Antal M, ***Nagy E****,* Sanyó L, Braunitzer G. Digitally planned root end surgery with static guide and custom trephine burs: A case report. Int J Med Robot. 2020 Aug;16(4):e2115. doi: 10.1002/rcs.2115. Epub 2020 Jun 3. PMID: 32304137. **IF: 2.547**

IV. ***Nagy E****,* Braunitzer G, Gryschka DG, Barrak I, Antal MA. Accuracy of digitally planned, guided apicoectomy with a conventional trephine and a custom-made endodontic trephine: An in vitro comparative study. J Stomatol Oral Maxillofac Surg. 2021 Sep 30:S2468-7855(21)00200-7. doi: 10.1016/j.jormas.2021.09.014. Epub ahead of print. PMID: 34601166. **IF: 1.569**

Introduction

Modern methods and instrumentation can provide a solid base to tooth preservation. The final treatment options prior to extraction and implantation have become more commonly available, for both patients and dentists. Removal of the apex and the surrounding inflammation is a well know procedure after the orthograde root canal treatment was not successful. With the help of CBCT, magnification and new materials, these interventions have become less invasive and more successful. The corner stone of this microsurgical invention is the angle of the resection line, which opens less dentinal tubules and can remove 98% of apical ramifications and lateral canals at the 3mm level from the apex. This facilitates the proper retrograde preparation and obturation, which is a must to prevent bacterial leakage after the treatment. The technique was described by Kim et al, emphasizing the importance of the 90-degree cut, magnification, piezo instruments, and the usage of bioceramics as retrograde obturation materials.

Guided surgical procedures are frequently used in implant dentistry. The aim is to make these procedures faster and more precise for every dental surgeon – even in complicated cases. 3D digital planning software can be used for the planning and with the help of stereolithographic printing, every step can be guided during the surgery.

By combining the guidance of the printed templates, the advantage of 3D imaging and the microsurgical principles, apicectomy can be modified to a safe and precise intervention. To reduce the steps, increase precision and exclude the 'operator factor' our idea was the usage of template guided bone-trephines for a one-step apicectomy. In my thesis I tried to find answers to anatomical questions and details on precision regarding this method.

Aims of the study

Our research is composed of different layers to understand and to prove the validity of this new technique.

1) To examine and evaluate the efficacy of apex removal with a trephine bur on the elimination of apical

ramifications and accessory canals. Searching for significant alterations in statistics compared to the 90° straight resection line.

Hypothesis: There is no significant difference between the 90 degrees cut and the semi-circular resection line with trephine bur, regarding the elimination of apical accessory canals.

2) Measuring the precision of trephine-bur apicectomies, utilizing 3D planned, stereolithographically fabricated, tooth supported surgical templates and assess the effect of specially designed trephine (endo-trephine) on the osteotomy depth, angulation, and size of the surgical window.

Hypothesis:

- Overpenetration would be a frequent finding with a conventional trephine, and less frequent or absent with the trephine equipped with a stop.
- There would be no difference in the accuracy of the procedures performed with the two different trephines (conventional and endo-trephine).

3) To examine the in vivo application of the template-and-trephine method, analysing the advantages and

disadvantages of the guided apical resection with trephine bur.

Hypotheses:

- There would be no difference in frequency and severity in the intra- and postoperative complications between the studied/tested method and the freehand technique
- The method would allow the resection of the root with the trephine in all cases
- By utilizing this method, the vertical error of root-end resection and the error of osteotomy depth would not be greater than ±1 mm
-The angular accuracy of the osteotomies would be close to that of template guided dental implantations.

Material and Methods

1) For measuring the precision of the trephine-bur cut, in vitro comparison with the help of a micro tomograph was performed on extracted front teeth. After microCT pre-scanning, teeth with apical ramification were fixed with Krampon pliers and were cut perpendicularly at exactly 3mm from the apex with a trephine bur. The number of

accessory canals in the remained semilunar surface was detected with the help of the postoperative CT scanning. The cutting surface of teeth with canals remained in the semi-circular area were cut according to the modern microsurgical principles.

2) For the accuracy measurements of guided apicectomy 11 patients were enrolled (mean age: 48.9 ± 12.4 years) with altogether 13 teeth. Written informed consent was obtained from each participant. Pre-operative CBCTS were acquired with standard settings for all patients, A-silicone impressions were scanned separately. The images were reconstructed as a volume (i-CAT Vision, Imaging Sciences International, Hatfield, PA, USA), and saved as DICOM files to provide input for surgical planning. For 3D surgical planning, SMARTGuide 1.25 (dicomLAB Ltd., Szeged, Hungary) was used. For the planning of the surgeries, a virtual cylinder of the same dimensions as the actual trephine was used. The surgical template was stereolithographically printed and was used for guiding the trephine during surgery. With the help of the trephine, bony window preparation and apicectomy were performed

in one step. Post-operative CBCT was performed for later statistical evaluation.

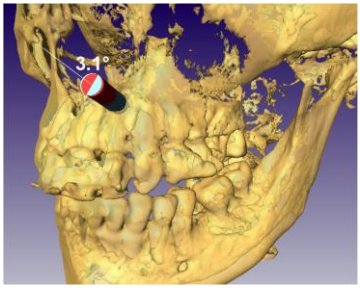
3) For the experiments on the precision of custom-made trephines with a stop, 8 porcine mandibles were used. The process of surgical planning (SMARTGuide 1.26) itself and 3D printing (ProJet MD3510, 3D Systems) followed the protocol of dicomLAB Dental Ltd. (Szeged, Hungary). In the control group, commercially available, 4.21 mm diameter bone trephines were used (Hager & Meisinger, Neuss, Germany) through a 4.25 mm guiding sleeve embedded in the surgical template. In the study group the 4.46 mm endo-trephine from our set was used through a 4.50 mm guiding sleeve. In both groups 20mm long trephines were used. The apicectomies were performed with copious water-cooling at 800RPM. Post-op CBCT scans were acquired with the same sized metal pins to aid the segmentation-based statistical analysis.

Statistical analysis

1) For efficacy of the semi-circular resection the data were analysed descriptively, in line with the aims of the study.

A SNC was defined as any CT-identifiable additional canal besides the main root canal, regardless of being a lateral canal or a ramification.

2) Frequencies and percentages were calculated for the template guided apicectomy. The angular deviation was analysed in Amira 5.4.0 (Thermo Fisher Scientific, USA) with dedicated algorithms. Pre- and postoperative CBCT



scans of the given patient were transformed into the same coordinate system. The angular deviation, ARE (apex removal error) and ODE (osteotomy depth error) were defined. The calculations were performed three times for each case, and the mean of the three measurements was used for further analyses. All statistical calculations were done in SPSS 23.0 (IBM, USA).

3) For the statistical analysis of custom-made trephines with a stopper, the end-position of the trephine inside the bone was reproduced with metal pins, which could then be digitally compared to the planned end-position. Analyses

were conducted in Amira 5.4 (ThermoFisher Scientific, USA), with dedicated algorithms (dicomLAB Dental, Szeged, Hungary). Deviation along three axes (x, y, z) and global deviation were calculated. Global deviation (GD) was defined as the square root of the summed squares of the deviations along the three axes. As for the axes, x represented the horizontal (bucco-lingual) dimension, y represented depth (mesio-distal deviation) and z represented the vertical (craniocaudal) dimension. Special attention was paid for over-/underpenetration in the bucco-lingual dimension. Then linear regression analysis was used. Having excluded the confounding effect of the templates themselves, the variables (GD, x, y, z) were compared with one-way ANOVA by group. Descriptive statistics (means and standard deviations) were also calculated by group. Accuracy was defined as the closeness between the planned and the actual spatial position of the apical endpoint.

Results

1) Regarding the efficacy of semi-circular resection, all SNCs in 94% of the study specimens were eliminated, and with the trephine 97.3% of the total number of SNCs in all study specimens were eliminated. The 33 teeth contained 72 SNCs altogether.

2) In the template-and-trephine method, the median angular deviation was 3.95° (95% CI: 2.1-5.9). The median apex removal error in the vertical plane (ARE) was 0.19 mm (95% CI: 0.03-0.07). The highest overpenetration was 0.51 mm, while the shallowest penetration fell behind the plan by 1.56 mm.

3) The following results were found when the accuracy of the endo-trephine was examined. The degree of underpenetration was quite similar in the two groups, approximately 0.7 mm, while the degree of overpenetration differed vastly. In the study group, the mean overpenetration was 0.36±0.31 mm, while the control group overpenetrated by a mean of 2.45±1.88 mm. The mean global deviation in the study group was 0.92±0.60 mm [95% CI: 0.64-1.18 mm], in contrast to

2.45±1.88 mm [95% CI: 1.66-3.05 mm] in the control group. ANOVA also indicated significant difference in deviation along the x axis (F= 12.01, df=1, P= 0.001, two-tailed).

Discussion

The previously introduced surgical technique is a great curiosity itself because it combines the guided surgery, the usage of trephine burs and the principles of modern endodontic apicoectomy. Any of these can increase to success rate of apicoectomy, but we cannot find much evidence in the literature about the combination of these aids. Only few studies agree that guided root-end resection is efficient and superior to the freehand surgery. As data on guided interventions performed with a trephine is scarcely available, we could mainly use our results to answer the initially set questions in this topic.

The efficacy of the semilunar cutting design with trephine burs correlates to the results of the actual standards of microsurigical apicectomy.

The angular deviation of the template guided apicectomy was expected to be to be slightly poorer than guided implantation with tooth-supported guides. Tahmaseb et al. reported an overall angular deviation of 3.5°. The median deviation of 3.95° we found confirms that expectation, hence endosurgical guides are partially mucosa-supported.

Regarding the custom-made trephines, significant difference between the two groups was found in global apical deviation and in deviation along the x axis (bucco-lingual depth). This suggests that the control of penetration depth is indeed the key issue of the accuracy (and safety) of trephine apicoectomy.

Conclusion

In my thesis, I investigated the accuracy of microsurgical apicectomy performed with trephine burs. To validate this novel technique, further examination was necessary on different levels.

Regarding our research on the precision of the trephine bur apicectomy, we can conclude that the semi-circular cutting line can eliminate the accessory canals and ramifications

of the critical 3 mm of the root apex with great efficacy. This is equal to the 90 degrees cutting method which is the guideline to be followed in modern endodontic surgery so far.

We can state that the guided apicectomy in endodontic microsurgical procedures with strereolithographic templates increase the precision of the surgical intervention similarly to guided implantology.

The accuracy of the procedures performed with the stop trephine is higher compared to conventional trephines regarding osteotomy depth. Results suggest that the usage of a stop-trephine can prevent overpenetration.

Intra- and postoperative complications are no more frequent and severe with the studied 3D guided method with the usage of a trephine, than what is usual in freehand cases as reported by the literature.

The periapical surgery performed with static guidance allows the resection of the root with the trephine, without the necessity of further manipulation.

The vertical error of static guided root-end resection and the error of osteotomy depth performed with a trephine is not greater than ±1 mm.

The trephine bur can be easily implemented into 3D planning software, and can transform the bony window preparation, the apicectomy and the biopsy taking into a one-step procedure. The initial prototype's imprecision regarding overpenetration with the trephine bur into the oral cortical plate was fixed by the usage of trephines with a definitive stop. With this continuous development of the above-mentioned technique, we tried to eliminate all the possible risk factors of microsurgical endodontic interventions and to lessen the severity of postoperative complications.

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