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Comparing the Outcomes of Closed vs. Open Surgical Exposure of Palatally Impacted Canines: A Pilot Randomized Clinical Trial

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Comparing the Outcomes of Closed vs. Open Surgical
Exposure of Palatally Impacted Canines: A Pilot
Randomized Clinical Trial

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Master of Dental Sciences Thesis
Comparing the Outcomes of Closed vs. Open Surgical
Exposure of Palatally Impacted Canines: A Pilot
Randomized Clinical Trial

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Introduction

Background

Maxillary canine impaction can be a challenging clinical problem which affects about 2% of the population [1]. Females are twice as likely to experience this clinical condition than males, and nearly 8% of those affected show bilateral impaction of the canines [2]. Impactions can be either buccal or palatal. Although older literature shows that palatal impaction occurs three times more frequently than buccal impaction [3], recent studies suggest that buccal and palatal impactions may be equally as likely to happen [4, 5]. The exact etiology of canine impactions is not fully understood; however, lateral incisor is suggested as a critical factor in guiding the eruption of the canine [6]. If the lateral incisor is absent or malformed, the eruption path of the canine will be disturbed, which can result in the development of canine impaction [4, 7]. Other factors that have been proposed in canine impaction include tooth size-arch length discrepancies, abnormal tooth bud formation, as well as prolonged retention or early loss of the deciduous canine [6, 8].

Treatment

Exposing and guiding the eruption of impacted maxillary canines requires a multidisciplinary approach; the uncovering of the tooth is usually provided by a surgeon [periodontist or oral surgeon] and an orthodontist will manage the traction and alignment of the tooth in the dental arch. The surgical approach may be different depending on where the canine is impacted or the vertical position of the tooth relative to the mucogingival junction [1]. The different approaches to exposure aim to minimize detrimental periodontal outcomes that may take place when the tooth is orthodontically extruded through the overlying tissue. Buccally impacted canines may be covered by either non-keratinized or keratinized tissue (depending on the

vertical position), but palatally impacted canines are always covered by keratinized tissue, so regardless of the method, the periodontal attachment may be compromised simply because of the initial location [9].

There are two primary surgical methods to expose an impacted canine: closed and open. The open exposure method involves removing the overlying soft and bony tissue and placing a periodontal pack over the site for 7-10 days to allow for healing to occur [9]. After the periodontal pack is removed, the canine is either given time to passively erupt into the arch [10] or is erupted actively soon after the exposure surgery. Active eruption occurs by the application of an orthodontic force from an attachment bonded to the canine during the exposure surgery [2].

On the other hand, the closed exposure method involves raising a flap to expose the impacted canine and bonding an attachment with a chain to the tooth surface [11]. The flap is then sutured back into position and the chain is threaded through the border of the flap. This allows for the immediate application of an orthodontic force to the tooth via the chain and facilitates orthodontic traction—the process of eruption of the canine through the closed periodontium [12].

There are many factors that need to be considered when deciding which surgical technique is best to be performed in clinical practice, such as convenience of a surgical method, the need for additional surgeries, overall treatment time and/or long-term periodontal health. Pearson et. al reported up to three times shorter surgical times with the open exposure method, over the closed exposure method [13]. However, in another study, Iramaneerat et. al found no difference in treatment duration between the closed the open surgical techniques [14]. Eruption of impacted canines has also been implicated as one of the major causes of increased orthodontic treatment time [15]. The current scientific literature is unclear as to which surgical method (open

or closed exposure) is the most efficient for erupting the impacted canine into the maxillary arch [13, 16].

Another important problem associated with impacted canines is the need for re-exposure if the first surgical intervention fails. In the closed surgical approach, re-exposure may become necessary due to breakage of bonded attachments. On the other hand, regrowth of overlying tissue may require re-exposure in the open exposure method. In an examination of a series of 72 patients, Ferguson *et al.* found that the open technique and autonomous eruption of the canine was successful in a majority of cases without requiring re-exposure [17]. Furthermore, Pearson and colleagues found that approximately 30% of closed exposure cases required a second surgical intervention, in comparison to 15% of cases treated with the open exposure approach [13].

An added concern with impacted canines is the long-term health of the bone and the periodontium adjacent to the canine. Kohavi *et. al* reported that extensive removal of bone surrounding the impacted tooth at the time of the exposure can negatively impact the bony support of the tooth once it is brought into the dental arch [18]. Another study showed a reduction in periodontal support and loss of alveolar bone height in orthodontically corrected canines compared to untreated canines [16, 19]. However, there are other reports indicating no significant difference in periodontal status between treated and untreated canines when outcomes such as pocket depth, level of attached gingiva, bleeding score, occlusal function and/or gingival recession are evaluated [20-22].

There have been a number of systematic reviews and meta-analyses that have investigated whether a significant difference exists between the outcome of the open versus the closed surgical exposure of palatally impacted canines. Three teams that have recently investigated the topic

have been Cassina et al., Sampaziotis et al., and Parkin et al. [23-25] The findings of systematic reviews on the outcomes of open versus closed surgical exposure of impacted canines have not always been consistent. In the study by Cassina et al., open surgical exposure was found to be superior in treatment duration and ankylosis risk over the closed technique; however, Cassina included both palatally and labially impacted canines in his investigation [23]. On the other hand, both techniques were found to be equally successful by Parkin et al. [24]. Despite contradicting findings, all the reviews agree that there is a need for further research on the topic due to the limited number of high quality randomized clinical trials.

Diagnosis of Impacted Canines

Radiographic evaluation is necessary to diagnose impacted canines and determine the need for surgical exposure. Further, radiographic assessment has to be done to localize impacted canines and decide where to make the surgical access during exposure. A number of different radiographic methods have been described in the literature that help diagnose impacted canines. They utilize a combination of panoramic, periapical, occlusal, or 3D radiographs. Traditionally, Clark's SLOB rule was applied for determining the buccal or the palatal position of impacted canines. The technique utilizes consecutive periapical radiographs with an incorporated mesial shift [26].

On panoramic radiography, Ericson and Kurol have described the position of the impacted canine relative to the midline of the lateral incisor; this position allows predicting the likelihood of canine's self-eruption following the extraction of the deciduous canine. [27-28] Angulation of the canine relative to the lateral incisor and sector localization on panoramic radiograph further allow describing the severity of the impaction. [29-30] The primary

limitation of traditional radiographs is that they are 2 dimensional in nature; this leads to the localization of impacted canines being confounded by overlapping structures and distortion. Due to the named shortcoming of 2D radiographs, nearly 80% of clinicians need to use two or more supplemental radiographs to localize the impacted tooth. [30]

3D imaging technologies allow for more accurate diagnosis and localization of impacted canines. Historically, multi-slice medical CT scans were the only form of 3D imaging available. They came with many limitations, such as high radiation dose, expense, a large footprint and limited access for dentists as they are primarily located in hospitals. Recently, the cone beam CT (CBCT) has gained popularity for imaging the craniofacial region. It delivers a significantly lower dose of radiation compared to the conventional CT and can be used in lieu of other 2D images such as panoramic radiograph or lateral cephalogram. However, studies have shown great variability in the amount of radiation exposure among different CBCT machines, and hence caution should be exercised in their use. [31-33] Use of CBCT should be advised on a case-by-case basis. The literature indicates that cases with impacted teeth are good candidates for CBCT imaging; due to the orthogonal 1:1 representation, CBCT will produce images that are free of distortion or any overlapping structures. [32, 34]

CBCT imaging can also be very useful in detecting root resorption in the cases of canine impaction. Root resorption can occur when the impacted canine is impinging on the root of the adjacent lateral incisor. Root resorption is a primary adverse effect of impacted maxillary canines and can impact the long-term prognosis of the affected teeth. This phenomenon can be difficult to detect in panoramic or intraoral radiographs. [5, 35] Scientific literature shows that CBCT can be significantly more sensitive for the detection of external root resorption of the lateral incisor in the cases of canine impaction [36]. As per Algerban et al. CBCT systems have

a high diagnosis accuracy in evaluating the severity of root resorption on lateral incisors in the cases of canine impaction. [38] On a similar note, Oberoi and Kneuppel showed that CBCT facilitates accurate localization of impacted canines and assesses root resorption on lateral incisors, which was moderate to severe in 18% of cases [37].

Although CBCT technology is very valuable in diagnosing impacted canines and evaluating adjacent structures, it still comes with radiation dose concerns. This has partly been addressed by newer small-volume CBCTs, which have a small and focused field of view and further reduce the radiation dose. A comparison of 14 CBCT devices showed significantly lower radiation exposure with small volume CBCT compared to traditional full field of view CBCTs; [39] the Kodak 9000 3D CBCT had the lowest overall dose of radiation, with an effective dose of 19 μ Sv in the anterior maxillary region. Conventional intraoral radiographs for detecting impacted canines include 2 periapical or an occlusal x-ray, which have effective doses of 10 μ Sv and 7 μ Sv respectively. [40, 41]

Study Rationale

While both the open and closed surgical exposure methods are used for the management of palatally impacted canines, the dental literature lacks evidence on whether one method is superior to the other. In fact, there are very few prospective randomized studies available which compare the closed versus open surgical exposure methods for palatally impacted maxillary canines. In addition, none of the studies on the topic utilize CBCT technology to evaluate bone outcome—such as bone height and bone width— between the two technique.

A recent meta-analysis by the Cochrane Collaboration comparing open to closed surgical exposure methods found insufficient evidence to support one method over the other and cited a need for high quality clinical trials to further understand the impact of these surgical methods on

dental health, esthetics, economics and other patient factors. [42-43] Therefore, the purpose of this RCT was to determine if there is a difference in periodontal, bone, or patient-reported outcomes of those with impacted maxillary canines treated by the closed versus open surgical exposure methods.

Outcome Assessment

- Primary Outcome:
 - Compare the amount of gingival recession, clinical attachment loss (CAL), keratinized gingiva, and attached gingiva, pre- and post-surgery, and between the open and closed surgical exposure techniques
- Secondary Outcome:
 - Compare the amount of bone thickness and height, pre- and post-surgery, and between open and closed surgical exposure groups.

Hypotheses, Aims, and Objectives

Hypothesis

1. There is no significant difference in the amount of gingival recession, the clinical attachment level, or the amount of keratinized gingiva between palatally impacted maxillary canines that are exposed by the open versus the closed surgical exposure methods.
2. There is no significant difference in the amount of bone width, and the bone height between open versus the closed surgical exposure methods.

General Objectives

To date, there are very few high quality randomized clinical studies comparing the

outcomes between closed and open surgical exposure methods for the treatment of palatally impacted maxillary canines. The primary aim of this study is to elucidate if the type of surgical Exposure method (closed versus open) impacts the periodontal outcome for palatally impacted maxillary canines after orthodontic traction has aligned them in the arch.

Specific Aims and Objectives

This study will determine if the type of surgical exposure method (closed versus open) impacts:

- Periodontal outcome specifically in regards to the amount of gingival recession, width of keratinized gingiva, clinical attachment
- Bone thickness and height, pre- and post- surgery

Materials and Methods

Study Design

This study was approved by the Institutional Review Board (IRB) of University of Connecticut (IRB # 16-169-1). The aim of this study was to perform a randomized clinical trial recruiting a total of 46 patients randomly divided in two groups: (1) 23 subjects undergoing the closed surgical exposure; (2) 23 subjects undergoing the open surgical exposure.

The sample size was computed based on identifying a 0.5 mm (effect size) difference in periodontal attachment level between the two treatment groups. The population means and variances of the primary outcome variable (periodontal attachment level) for the two different techniques of canine exposure were obtained from prior studies (mean of 0.3 mm for open technique and 0.8 mm for closed technique) examining periodontal attachment levels following canine exposure techniques. A sample of 46 subjects (23 per group) will be required to identify a

difference of 0.5 mm in attachment level, with a power of 80%, an alpha of 5%, and two-sided statistical tests. [44, 45, 46]

Screening and Recruitment

Patients who presented for initial orthodontic screening to the University of Connecticut Orthodontic Clinic were evaluated by their provider for inclusion in this study (Visit 1).

The initial clinical indicators of canine impaction are unerupted permanent maxillary canines with the absence of a "canine bulge" in the buccal vestibule or the presence of a "canine bulge" on the palate, and inclination of the unerupted canine towards the lateral incisor as visualized on the panoramic radiograph. Patients who were found to meet the above criteria were introduced to the PI or the co-investigator. They would determine final eligibility by evaluating the inclusion/exclusion criteria as well as the CBCT radiograph which was taken during the patients' records visit (Visit 2):

Inclusion Criteria

- Healthy patient, non-smoker
- Full complement of dentition (central incisor to 1st molar) in the quadrant with the impacted maxillary canine
- Unerupted permanent maxillary canine determined to be impacted by clinical exam and panoramic film at screening based on the criteria of impaction described by Bishara [2]:
 - o Retention of primary canines past 12 years of age
 - o Presence of palatal bulge indicating palatal impaction
 - o Splaying, migration or distal tipping of adjacent lateral incisor

- Mesial angulation of unerupted canine as noted on a panoramic x-ray in relation to lateral incisor

Exclusion Criteria

- Fully erupted canine
- Evidence of extremely poor oral hygiene
- Missing permanent central or lateral incisor, 1st or 2nd premolar, or 1st molar in the quadrant with the canine impaction
- Medical issues that affect tooth movement or ability to use the required mechanics
- Failure to provide oral and written consent to participation

If recruited into the study, subjects were allowed to withdraw at any point at their will. Also, subjects would be eliminated from the study by the investigator in the event of surgery failure (that is if the bracket bonded to the impacted canine falling off before the canine was actively erupted through the gingiva). In addition, if the CBCT indicated significant damage to the adjacent teeth, the patient would no longer be eligible for the study and the PI/Coinvestigator would discontinue the subject's participation. Lastly, subjects who were not compliant with appointments would also be eliminated from the study.

Study Procedure

After the three-dimensional position of the impacted canine was determined and verified to be palatally impacted by our calibrated oral and maxillofacial radiologist, the patient was then randomized to either the "open" or "closed" surgical exposure group using block randomization. Since study groups were subdivided by gender, separate randomization was performed for

males and females. The principle investigator was blinded to the patients' assigned study group. Block randomization was used, and based on gender, 23 envelopes for female subjects (12 for closed exposure, 11 for open exposures) and 23 envelopes for male subjects (11 for closed exposure, 12 for open exposure) were made for impacted canines.

We followed the subjects enrolled in this study for the duration of their orthodontic treatment, with a total of 5 visits included as trial timepoints. The timing of every study visit was planned to coincide with the subject's scheduled orthodontic appointments as determined by their primary orthodontic provider. Comprehensive treatment for orthodontic cases such as those with impacted canines typically lasts an average of 24-36 months. The PI/Co-investigator did not provide any direction of care to the subject's primary orthodontic provider in regards to the subject's orthodontic care. The treatment plan was dictated and carried out by the subject's primary orthodontic provider.

All subjects were bonded with 0.022-inch slot twin brackets with MBT prescription. Once the leveling and alignment phase of treatment was complete and the subjects were in a 0.019"X0.025" stainless steel wire, they would be referred to the UCONN Periodontics Clinic for surgical exposure of the impacted maxillary canine. One day before the surgery, a sealed envelope with the coded number indicating the surgical group was given to the doctor/provider performing the surgery and the subject was officially designated to that group. To ensure consistency among surgeons, Dr. Takanori Sobue was supervising all surgical procedures.

Visit 3 had to be scheduled within a week prior to the date of the surgery. Various periodontal measurements were obtained at Visit 3. Periodontal assessments were also conducted once the canine was aligned in the arch (Visit 5). Below are the periodontal outcomes that were

looked at in this study:

- **Gingival Index**

The gingival index developed by Loe and Silness [47] was used. Grades of the severity of gingivitis were scored by clinical inspection based on the size, color, and texture of the gingival margin adjacent to the bracket and bleeding on probing. 4 surfaces were examined per tooth (mesial, distal, buccal, and lingual) on the adjacent teeth (1st premolar and lateral incisor). The scoring criteria was as follows:

Score 0: Normal gingival

Score 1: Mild inflammation, slight change in color and edema. No bleeding on probing

Score 2: Moderate inflammation, redness, edema, and glazing. Bleeding on probing

Score 3: Severe inflammation, marked redness and edema. Ulceration and tendency toward spontaneous bleeding

- **Bleeding Index**

Bleeding Index is a dichotomous measurement. If bleeding is present (Gingival Index score of 2 or 3) at specific sites within 30 seconds of periodontal probing, it was recorded on the data collection form.

- **Plaque index**

The operator, using an explorer or the tip of a probe, examined each surface for soft plaque accumulations at the dentogingival junction. After the each tooth was examined and scored, an index was derived by dividing the number of plaque containing surfaces by the total number of available surfaces. The plaque index was recorded at 4 tooth surfaces (mesial (M), buccal (B), distal (D), and lingual (L)). This is a dichotomous measurement; therefore, plaque will be noted

only on those sites where it is present. After all teeth have been scored, the index will be calculated by dividing the number of surfaces with plaque by the total number of surfaces scored and then multiplied by 100 to determine a percentage of surfaces with plaque present. [48]

- Keratinized Gingiva

The amount of clinical attachment was measured as the distance from the free gingival margin to the mucogingival junction using a periodontal probe as done in previous studies. [12, 18, 21, 46, 49] Measurements were taken from the midline of the adjacent lateral incisors and 1st premolars. Also, a midpoint measurement was made in the space created for the unerupted canine. Once erupted, the measurements were taken on the midline of erupted canine.

- Gingival Recession

Gingival recession was measured with a periodontal probe as the distance between the CEJ and the free gingival margin at the midpoint of the crowns on the adjacent lateral incisors and 1st premolars [12]. Once the canine was erupted, gingival recession measurements were taken at the time of complete alignment into the arch.

- Clinical Attachment Level

Clinical attachment was determined from the 6-point probing depths on the mesial, midline, and distal aspects of both the buccal and palatal tooth surfaces. Clinical attachment level is the distance between the CEJ to the base of the periodontal pocket. In another words, it can be described as the amount of recession plus the probing depth.

In addition to periodontal outcomes, the following outcomes were also assessed in this study:

- Oral Hygiene Assessment

Every subject's orthodontic provider reported on his/her oral hygiene twice: after the subject's first appointment as well as two weeks after the canine exposure surgery (Visit 4). Oral hygiene was reported as "Excellent" or "Good" or "Fair" or "Poor."

- Patient Satisfaction Survey

At Visit 4 (2 weeks after the canine exposure surgery), subjects were asked verbally by the study coordinator about their comfort level immediately after surgery; recorded answers could be either "Excellent" or "Good" or "Fair" or "Poor." At the same visit, subjects were asked to report their general satisfaction with the surgical procedure; possible answers were either "Excellent" or "Good" or "Fair" or "Poor."

- CBCT Bone Measurements

Two small volume CBCT images were acquired for each subject during the study through the use of a Planmeca CBCT Imaging Machine. The localized field of view (38mmX50mm) would capture the canine region, including the adjacent lateral incisor and 1st premolar. The first image was acquired for diagnosis of impaction and canine localization purposes. It was used in lieu of the traditional 2-3 periapical (PA) radiographs to minimize radiation exposure. As mentioned above, the small volume CBCT is equivalent to 2 periapical radiographs, and typically at least 2-3 PA films using a mesial film shift technique are taken prior to this surgical procedure to assess the location of the impacted canines in the arch. The second small volume CBCT was taken on the day that the canine was aligned in the dental arch, typically at least 10-12 months after the first small-volume CBCT was obtained. The purpose of the final CBCT was to make measurements of the alveolar bone on the aligned canine. These measurements were compared to the initial CBCT taken prior to the time of surgery. The CBCT was also used to examine the

thickness of the buccal cortex overlying the canine. The measurements for the buccal ridge and the thickness of the ridge before and after bringing the tooth into place were later compared. Measurements were taken according to the technique described by Tadinada, et al. [50]

Statistical Analysis:

Patient characteristics were descriptively summarized. Self-reported patient outcomes were compared between the open and closed groups using Fisher's exact tests for categorical variables and two-sided two-sample t-tests for continuous variables. The bone and the periodontal outcome measurements were averaged across sites and the site average was summarized for pre- and post-treatment by group and by tooth. The open and closed groups were compared by tooth for changes in outcomes using two-sided two-sample t-tests. A p-value smaller than 0.05 was considered statistically significant. All the statistical analyses were performed in R version 3.6.1.

Results:

Recruitment commenced on the June of 2017. So far, twenty-four patients have been recruited into the study. However, nine patients had to be excluded for various reasons: one subject dropped out of the study due to parental preference to seek treatment at an outside practice; three subjects were excluded due to inability to provide parental consent signatures, and five subjects due to no longer meeting the inclusion criteria. Of the five patients who were discluded due to no longer meeting the inclusion criteria, one requested general anesthesia for her exposure surgery and hence could not be treated at the UConn Periodontics Clinic; one had her impacted canine erupt out of the gingiva without any intervention on the week prior to her surgery; two became non-compliant with presenting to appointments; and one developed very a poor oral hygiene. There were many more patients who were screened but found to be ineligible

for recruitment due to the position of the impacted canine, which was either labial, mid-palatal, or too high in the palate.

Of the 15 subjects who remained in the study, nine (60%) identified as females and 6 (40%) identified as males. Eight participants were randomly assigned to the closed exposure group, of which 5 were females (62%) and 3 were males (38%). On the other hand, 7 patients were randomly assigned to the open exposure group, of which 4 were females (57%) and 3 were males (43%). The average age for all the subjects in the study was 14 ± 1 years (minimum 12.1 years; maximum 16.4 years). When analyzed separately, the patients in the closed and the open exposure groups had the same average age of 14 years, while the standard deviation was 0.76 and 1.29, respectively. The average hygiene score for the patients in this study was 2.2 ± 1.15 , which indicates “good” overall hygiene, and there was no statistical difference between the baseline hygiene scores for subjects in the closed or the open surgical group.

The primary outcome of this trial was periodontal. Six-point clinical measurements were taken for gingival index, plaque index, bleeding index, keratinized gingiva, gingival recession, and gingival attachment level. Further, average bone height and bone width around the impacted canine was compared between subjects in the closed and the open exposure groups. All the study subjects have already received a surgical exposure for their impacted canines. However, the impacted tooth is fully aligned in the maxillary arch only in 7 of the subjects so far.

The mean pre-exposure measurement for keratinized gingiva for the canines in the closed group was found to be 5.29 ± 0.76 mm, while it was 5.17 ± 2.23 mm for the canines in the open group. The same measurement taken after the impacted canine was fully aligned in the maxillary arch was 4.8 ± 0.45 mm in the closed group and 8 ± 1.41 mm in the open group. No

significant difference was found in the amount of keratinized gingival between the two groups before or even after the exposure. Similarly, when before and after measurements were compared within each group, the difference was not found to be significant (P-value < 0.05). Further, keratinized gingiva analysis for the adjacent lateral incisor and first premolar did not show any significant difference within or between open and closed groups. The data for this can be found in table I.

As for gingival recession (GR), the average 6-point clinical measurement taken on impacted canines post exposure was 0.33 ± 0.66 mm in the closed group and 1.17 ± 1.65 mm in the open group. The difference between the two groups was not significantly different. For the adjacent lateral incisor, the average amount of gingival recession in the closed group increased from 0.06 ± 0.18 mm pre-exposure to 0.37 ± 0.73 mm post-exposure. On a similar note, the GR measurement for lateral incisors in the open group showed an increase from 0.64 ± 1.22 mm before exposure to 0.92 ± 1.3 mm after exposure. The increase in neither of the groups was statistically significant. Table II shows the GR data for the adjacent premolar. A similar trend is observed; although gingival recession increased for the premolars in both the open and the closed groups, the increase was not statistically significant. The results are presented in table II.

The average post-exposure gingival index (GI) was 0.93 ± 0.71 mm for canines in the closed group and 2.58 ± 0.12 for canines in the open group. The difference between the measurements in the two groups was statistically significant. However, when GI measurements for the adjacent lateral incisors or the adjacent premolar were analyzed, no statistically significant difference was found between pre-exposure and post-exposure GI measurements in the open or the closed groups. There was further no statistically significant difference when the measurements at each time point were compared between the open and the closed groups. The

results are shown in table III.

Canines were found to have a smaller bleeding index (BI) post-exposure in the closed group ($0.23 \pm 0.15 \text{mm}$) than the open group ($0.50 \pm 0.71 \text{mm}$). The differences was not statistically significant. We also found an increase in the bleedings index for premolars from pre- to post-exposure time points both in the open and the closed groups. The increase was significantly greater in the open group than the closed group (0.5 ± 0 vs. 0.2 ± 0.22). Similar to the canines and the premolars, the lateral incisors showed a higher average post-exposure bleeding index in the closed group (0.5 ± 0.31) than in the open group (0.42 ± 0.35). There was a minor increase in the pre- to post-exposure BI for subjects in the closed group while an opposite trend was observed for the one in the open group. However, the pre- to post-exposure change was not significantly different between the open and the closed surgical groups (Table IV).

As for clinical attachment level, the impacted canines and their adjacent lateral incisors and premolars all showed a higher average post-exposure 6-point clinical measurement in the open group than in the closed group. The post-exposure measurement was also higher than the pre-exposure measurement within each of the open and the closed groups. However, none of the inter-group or intra-group differences reached statistical or even clinical significance (Table V).

All study subjects completed a patient-reported outcome questionnaire after their exposure surgery. Patients in the closed group reported a slightly higher average post-surgical comfort and satisfaction level than the ones in the open group, however, the difference did not reach statistical significance. Similarly, there was no statistical significance between the closed and the open group in regards to the overall treatment comfort or satisfaction levels (Table VI).

Average pre-exposure bone height was found to be greater than the average post-

exposure bone height in both the open and the closed groups. However, the decrease in the bone height was greater in the open group. Although the average post-exposure bone width (9.85 ± 0.44 mm) was smaller than the average pre-exposure bone width in the open group (10.63 ± 1.82), an opposite trend was noticed in the closed group (8.94 ± 1.12 mm vs. 8.57 ± 1.04 mm). None of the differences may be statistically significant, although it is hard to elucidate at this point due to the small sample size (Table VII).

Discussion:

The main question that we attempted to address in this pilot randomized clinical trial was “is there a difference in the outcomes between closed and open surgical exposure techniques for the treatment of palatally impacted canines?” Our preliminary results indicate that there may be a general periodontal cost in exposing impacted canines and bringing them into the dental arch; however, the results are similar regardless of whether a closed and or an open surgical technique is utilized, as there is no statistically significant difference for most of our clinical outcomes in the open and the closed groups.

Previously, Schmidt and Kokich had suggested that the overall periodontal outcome of treating impacted canines with the open technique will be superior to the closed technique, as natural eruption of the canine with the former method will result in less trauma to the periodontal tissue and allow better cleansability. [51] This is in contrast to our findings in this study. We clinically assessed gingiva for color, size, and texture and quantified the finding by assigning a gingival index (GI) score. We found the GI score to be significantly higher for the subjects in the open group than the ones in the closed surgical groups, suggesting a poorer outcome. We further had a greater plaque index for the canines in the open group than the ones

in the closed group and the difference was statistically significant. The contrasting results can be due to our small sample size at this point, which makes the current results insufficient to draw conclusions from.

In regards to clinical attachment level, our results did not suggest any difference between the outcome of the subjects in the closed or the open surgical groups. This is in line with the findings of Wisth et al. [16]. Their study directly compared the periodontal health of open vs. closed surgical exposure techniques and did not find any statistical difference in the average clinical attachment level around impacted canines.

Gingival recession was another clinical outcome that was evaluated in this study. We found that 28% of our impacted canines experienced recession post-alignment. This is greater than the findings in the study by Zasciurinskiene et al, where only 18.8% of the canines were found to develop recession post-exposure. [19] The contrasting data can be explained by two factors: 1- the retrospective nature of Zasciurinskiene et al. study which has a high risk of selection, allocation, and treatment biases; 2- our small sample size which makes it hard to draw conclusions. Further, our results did not suggest any evidence of difference between open and closed surgical groups in terms of the amount of gingival recession. This finding is in agreement with the results of Smailiene et al. where both open and closed techniques were found comparable in terms of gingival recession [24].

Our CBCT data suggested a greater reduction in bone height for impacted canines in the open group (-0.25 ± 1.42 mm) than the ones in the closed group (-0.48 ± 1.38 mm). However, the difference in bone height reduction was small, and it could be questioned whether this is clinically significant in long term. Further, there was no significant difference in the change in bone height between the two groups. This finding is in agreement with the results of the study

by Parkin et al. which suggested no statistical difference in alveolar bone levels between open and closed surgical techniques [52].

We also utilized CBCT data to analyze bone width around the impacted canines. To the best of our knowledge, this is the first time that bone width is being investigated to compare outcomes of the open vs. closed surgical exposure of impacted canines. Bone width was analyzed using the technique developed by Tadinada et al. at three different levels. [50] The results indicate a greater average bone width at the post-exposure time points compared to the pre-exposure time point in the closed surgical group. However, an opposite trend is found when the data for the open surgical group is investigated. When the average bone width for the subjects in the open surgical group is compared to that of the participants in the closed surgical group, the difference is so small that it may be clinically insignificant. Further, due to the ongoing nature of the study and our small current sample size, statistical significance conclusions cannot be drawn.

One of the potential limitations in this study is the small sample size. There are many factors that may have contributed to the small sample size; one such factor is the low prevalence of impacted canines which is at about 2%. The prevalence may even be lower in central Connecticut where most of our potential subjects reside. Our restrictive study protocol and strict inclusion criteria may also have contributed to the small sample size. As per protocol, our potential subjects must receive their surgical procedure at UConn Health. This discludes potential patients who rather receive their surgical exposure at an outside practice. Further, we cannot accept any potential patient who does not have a full dentition; this excludes any potential subject who may need an extraction orthodontic treatment plan. Also, to be able to randomize patients into either of our study groups without compromising their treatment, we

exclude patients with impacted canines that are too high in the palate; those canines cannot be treated with an open approach. Utilizing CBCT technology for locating impacted canines in the maxilla has further contributed to our small sample size. Many canines that would traditionally be categorized as palatal can now be better visualized in a CBCT, are found to be mid-alveolar, and are hence discluded from this study.

Another potential limitation in this study is the very different orthodontic techniques and mechanics that subjects undergo as part of their orthodontic treatment. Literature shows that specific orthodontic techniques may have a negative influence on the periodontium. [53] For example, dental expansion may lead to recession or even clinical attachment loss and this can result in a worse periodontal outcome. [54] The high number of clinicians that provide treatment and their varying degree of competency can also be a confounding factor in the study outcomes, especially for the self-reported categorial outcomes, such as overall satisfaction.

Conclusion:

This randomized clinical trial is ongoing and final conclusions can be drawn when recruitment is completed and full data is available for 46 subjects. However, the following preliminary conclusions can be made based on our current data:

- The surgical technique used—in terms of open vs. closed exposure—to expose a palatally impacted maxillary canine does not influence the ensuing periodontal outcomes: keratinized gingiva (KG), gingival recession (GR), and clinical attachment level (CAL).
- Canines in the open surgical group had a greater plaque index and a greater gingival index—which indicates a poorer outcome—than the canines in the closed surgical

group. Although the difference for both outcomes reached statistical significance, the results should be interpreted with caution as the sample size was very limited.

- Self-reported patient outcomes such as comfort or satisfaction were comparable between the closed and the open surgical groups.
- There was a trend for a decrease in bone height and bone width in the open surgical group. The closed surgical group showed the same trend for bone height but an opposite trend for bone width. Statistical significance could not be derived between or within groups due to the current small sample size.

Tables and Figures

Table I:

Keratinized Gingiva									
	Pre			Post			Post-Pre		
	Open	Closed	P-Value	Open	Closed	P-Value	Open	Closed	P-Value
Canine	5.17 ± 2.23	5.29 ± 0.76	0.905	8 ± 1.41	4.8 ± 0.45	0.181	3 ± NA	-0.25 ± 0.5	NA
Premolar	5.65 ± 1.96	4.77 ± 0.66		7.83 ± 2.12	5.73 ± 1.32		2 ± 2.36	1.17 ± 1.38	0.706
Lateral Incisor	5.69 ± 2.18	5.33 ± 0.89		7.5 ± 0.24	6 ± 0.67		1 ± 1.89	1.07 ± 0.49	0.968

Table II:

Gingival Recession									
	Pre			Post			Post-Pre		
	Open	Closed	P-Value	Open	Closed	P-Value	Open	Closed	P-Value
Canine				1.17 ± 1.65	0.33 ± 0.66	0.603			
Premolar	0.67 ± 0.9	0.04 ± 0.12		1.17 ± 1.65	0.53 ± 0.76		-0.08 ± 0.12	0.53 ± 0.76	0.145
Lateral Incisor	0.64 ± 1.22	0.06 ± 0.18		0.92 ± 1.3	0.37 ± 0.73		-0.67 ± 0.94	0.37 ± 0.73	0.333

Table III:

Gingival Index									
	Pre			Post			Post-Pre		
	Open	Closed	P-Value	Open	Closed	P-Value	Open	Closed	P-Value
Canine				2.58 ± 0.12	0.93 ± 0.71	0.006			
Premolar	1.38 ± 0.79	0.9 ± 0.59		2.08 ± 0.82	1.03 ± 0.84		1.67 ± 0.47	0.33 ± 1.01	0.071
Lateral Incisor	1.38 ± 0.61	0.75 ± 0.6		1.67 ± 0.94	1.63 ± 0.56		0.42 ± 0.35	0.8 ± 0.61	0.364

Table IV:

Bleeding Index									
	Pre			Post			Post-Pre		
	Open	Closed	P-Value	Open	Closed	P-Value	Open	Closed	P-Value
Canine				0.5 ± 0.71	0.23 ± 0.15	0.688			
Premolar	0.48 ± 0.37	0.29 ± 0.25		0.75 ± 0.35	0.37 ± 0.41		0.5 ± 0	0.2 ± 0.22	0.037
Lateral Incisor	0.43 ± 0.38	0.31 ± 0.33		0.42 ± 0.35	0.5 ± 0.31		-0.08 ± 1.06	0.3 ± 0.3	0.699

Table V:

Clinical Attachment Level									
	Pre			Post			Post-Pre		
	Open	Closed	P-Value	Open	Closed	P-Value	Open	Closed	P-Value
Canine				2.92 ± 0.59	2.67 ± 0.55	0.663			
Premolar	2.39 ± 0.52	2.07 ± 0.62		2.92 ± 0.12	2.7 ± 0.57		0.96 ± 0.41	0.75 ± 0.7	0.655
Lateral Incisor	2.31 ± 0.77	2.08 ± 0.77		2.08 ± 0.35	2.5 ± 0.26		-0.08 ± 0.59	0.53 ± 0.69	0.346

Table VI:

	Open	Closed	P-Value
Post-Exposure Comfort	2 ± 1	1.38 ± 0.52	0.172
Post-Exposure Satisfaction	1.71 ± 1.11	1.38 ± 0.52	0.48
Overall Comfort	1.5 ± 0.71	1.6 ± 0.55	0.878
Overall Satisfaction	1 ± 0	1.4 ± 0.55	0.178

Table VII:

	Bone Height		Bone Width	
	Open	Closed	Open	Closed
Pre	20.68 ± 4.18	19.75 ± 2.24	10.63 ± 1.82	8.57 ± 1.04
Post	18.23 ± 1.94	18.95 ± 1.29	9.85 ± 0.44	8.94 ± 1.12
Difference	-1.61 ± NA	-0.25 ± 1.42	-1.83 ± NA	0.53 ± 0.94

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