INVESTIGATION OF LATERAL INCISOR CROWN ROOT ANGULATION AND IMPACTED MAXILLARY CANINES

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ABSTRACT

Objective: The primary aim of this study was to determine if there is a difference in the mesiodistal crown-root angulation of maxillary lateral incisors between patients with impacted maxillary canines and a control population. Secondary aim 1 compared the same angle measured on panoramic radiographs to determine if a difference existed between the CBCT measurement and the panoramic radiograph measurement. Secondary aim 2 looked to determine if there was a correlation between maxillary lateral incisor tooth width and the mesiodistal crown-root angulation.

Materials and Methods: CBCT’s were reformatted so that the mesiodistal crown-root angulation of maxillary lateral incisors could be measured from the true facial viewpoint. A root measures >180° when the root is distal to the crown and <180° when the root is mesial to the long axis of the crown. 32 lateral incisors were measured in the study group with ipsilateral impacted canines. 34 lateral incisors were measured in the control group. For the first secondary aim 45 lateral incisors that had a panoramic radiograph in addition to the CBCT had the crown-root angulation measured on the panoramic radiograph. For the next secondary aim 40 maxillary lateral incisor mesiodistal widths were measured on a digital models and a correlation coefficient was determined.
Results: Primary aim: The mean angle for study group (n=32) was 173.00 and the mean angle for control group (n=34) was 183.65. This difference was statistically significant. Secondary aim 1: The difference between the means of lateral incisors measured on CBCT’s compared to panoramic radiographs was 0.036° which is not a significant difference. Secondary aim 2: The relationship between the maxillary lateral incisor crown-root angulation as measured on both CBCTs and panoramic radiographs and tooth width are positively correlated and statistically significant (rho = 0.49 p = 0.001 and rho = 0.42, p = 0.01, respectively).

Conclusions: The mesiodistal crown-root angulation of maxillary lateral incisors in patients with impacted canines is significantly smaller than in patients without impacted canines. This can be viewed on a panoramic radiograph without need for a CBCT. Clinicians can use this association as an aid in diagnosing impacted canines.
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INTRODUCTION

Orthodontists treat a variety of malocclusions and dental anomalies. Among these anomalies are impacted maxillary canines. Treating impacted maxillary canines presents unique challenges to the orthodontist. The orthodontic literature presents practitioners with various techniques for exposure, for impacted canine alignment, and different characteristics associated with impacted maxillary canines. This study aims to investigate the relationship of maxillary lateral incisor crown root angulation with impacted maxillary canines as evaluated on cone beam computed tomography. This investigation looks at the anatomy of the maxillary lateral incisor to determine if it could be used as a potential predictor of canine impaction. This is a novel association that might provide further help to the practitioner in treatment planning cases with impacted maxillary canines.

Impacted Maxillary Canine Review

A large part of orthodontics consists of fitting the right teeth in the alveolar arches at the right time. Sometimes intervention, such as braces, is required for this and sometimes no treatment or intervention is needed at all. A basic understanding of dental age and how it relates to chronological age and normalcy in dental development is required in orthodontics. Demirjian developed a way to calculate dental age that utilizes tooth development instead of tooth emergence. Using his method, a clinician can utilize radiographs to look for specific characteristics and
classify it, A through H, depending on the stage of development. These classifications have associated numerical values, and when all the values for the teeth are added up a table can be used to determine the calculated dental age.

Chronologic age is simply the years that have passed from birth up to a given point. Skeletal maturity guides have also been developed, such as the cervical vertebral maturation method which uses the anatomy of the second, third, and fourth cervical vertebrae. Proffit provides a good, concise explanation of the relationship between chronologic and dental age in Contemporary Orthodontics. Teeth are expected to erupt when roughly three fourths of their root formation is complete. In regards to the maxillary canine, eruption is generally expected at a dental age of twelve prior to eruption of the maxillary second molars. The teeth erupt with a large range of variability from the chronologic age of a patient and so other variables must be used when diagnosing and predicting an impacted canine or any other tooth for that matter.

Dachi and Howell looked at 3,874 routine full mouth radiographs of patients over the age of 20. 16.7% of these patients had one or more impactions. The most frequent impactions in this study were maxillary and mandibular 3rd molars at 22% and 18% respectively, more common in females than males. The incidence of impacted maxillary canines was found to be 0.92%. Among impacted canines, females had a higher percentage of impaction then males at 1.17% compared to 0.51%. The next most frequent impaction in that study was the mandibular premolar and then the maxillary premolar. Ericson and Kurol reported 1.7 per cent of the canines showing eruption disturbances in one study, most of these having a
palatal path of eruption. In another study an incidence of 1.5% of 3000 Children examined displayed maxillary canine eruption disturbance.\textsuperscript{6} Moyers\textsuperscript{7} listed the occurrence of impaction in Handbook of Orthodontics from most to least occurring: mandibular 3\textsuperscript{rd} molar, maxillary canine, maxillary 3\textsuperscript{rd} molar, mandibular and maxillary second premolars, and maxillary central incisors. Moyers comments on maxillary canine impactions by noting that this tooth has a more tortuous path of eruption than others. In this text, he also states that the tooth begins to upright after it hits the distal of the lateral incisor. Moyers continues by stating that there are etiological as well as environmental reasons for an impaction of the maxillary canine, especially over retained primary teeth.

Knowledge of impaction of maxillary incisors is important not only because they require mechanics specific to bringing them into the arch but also because of the destruction they can cause to the adjacent lateral incisors. Bishara\textsuperscript{8} references Shafer et al and the possible sequella of canine impaction: a) labial or lingual malpositioning of the impacted tooth, b) migration of the neighboring teeth and loss of arch length, c) internal resorption, d) dentigerous cyst formation, e) external root resorption of the impacted teeth and neighboring teeth, f) infection particularly with partial eruption, g) referred pain, and h) combinations of the above sequelae. Ericson and Kurol\textsuperscript{9} found that cases with resorption of the maxillary lateral incisor with an impacted canine tended to be more dentally advanced, have an impacted canine more medially positioned relative to the long axis of the lateral incisor, and a more mesial horizontal eruption path (10 degrees average) than controls.
Jacoby\textsuperscript{10} stated that available arch length has been known as an implication for impactions. However that study found that 85\% of palatally impacted canines had sufficient space for eruption. He explains that the bud of the maxillary canine is wedged between the nasal cavity, the orbit, and the anterior wall of the maxillary sinus with the lateral incisor and first premolar buds located behind the canine’s palatal surface. The canine bud cannot get around these adjacent tooth buds when there is an arch length discrepancy. The tooth can be palatally impacted if extra space is available in the maxillary bone via 1) excessive growth in the base of the maxillary bone, 2) space created by agenesis or peg-shaped lateral incisors, or 3) stimulated eruption of the lateral incisor or the first premolar. Jacoby also states that a dysplasia in the maxillary-premaxillary suture can cause a disturbance of canine eruption path.

\textbf{Theories of Eruption}

Genetic etiology, or a genetic theory of eruption, proposes that canines either become impacted or erupt as determined by genetic factors.\textsuperscript{11} In contrast, the guidance theory credits dental anomalies and other environmental factors, such as crowding, as the cause for canine impaction.\textsuperscript{12}

\textit{Genetic Etiology}

Peck reports a genetic etiology of canine impaction in contrast to a guidance theory.\textsuperscript{11} Peck et al point out evidence for genetic control rather than environmental as proposed by Jacoby. Some of the evidence provided by Peck
include: 1) palatally displaced canines are commonly seen with other dental anomalies such as: 1) malformed or missing teeth, 2) PDC are often seen bilaterally with studies showing ranges from 17-45%, “Beyond chance occurrence, reasonably pointing to an intrinsic etiology such as a genetic mechanism,” 3) there are sex differences in PDC with females having a higher occurrence in males in every study, 4) familial occurrence, 5) population difference, 2:1 Caucasian to Asian.

(Guidance Theory)

Becker, however, defends the guidance theory in opposition to Peck. He says genetics do influence dental anomalies such as peg laterals or lateral incisor agenesis, but the resultant canine impaction in such a case is the result of environmental influenced caused by those genetic factors. He even goes as far as to question Peck’s pure adherence to the genetic theory by pointing out Peck recommends extracting deciduous canines to help with spontaneous eruption which gives validity to the guidance theory. Becker makes an additional point of note favoring environmental control over genetic control. He says when PDC cases are observed, patients have small or peg laterals 7-8 times more than the general population. However, in cases with lateral incisor agenesis, that rate is only 3 times. According to him agenesis is recognized as a more severe phenotype of the same mutation which means the genetic theory of impactions does not make sense.

A more recent study by Al-Nimri and Bsoul supports the guidance theory as well. In their study they looked at the records of 246 patients with one or two missing maxillary lateral incisors and split the population between those with a
palatally displaced canine (PDC) and those with normally erupted canines. 12.6% of the patients had PDC. They found no correlation between sex, type of congenital absence, and occlusion classification. The association was found to be strong enough to support the guidance theory of eruption.

Etiology of Impacted Canines

Similarly to Jacoby, Nagan et al.\textsuperscript{14} state that if the etiology of palatally impacted canines is related to the availability of excessive space in the maxillary bone, the clinician should be cognizant of said spacing and peg shaped laterals because the absence of guidance could lead to a palatal eruption path. He even states that dilacerated roots in these cases is responsible for the abnormal eruption path and extracting primary maxillary canines can help to correct this path.

Jacobs\textsuperscript{15} reviewed the etiology of impacted maxillary canines and reported that palatally impacted canines appear to be genetic in origin. He concurred with other authors that labially impacted canines are evidently due to arch length discrepancy. His paper gives attention to the lateral incisor by recognizing that if the lateral incisor appears distally oriented, the canine should raise suspicion of impaction. Bishara’s review\textsuperscript{8} of impacted maxillary canines listed the most common localized causes for canine impaction: a) tooth size-arch length discrepancy, b) prolonged retention or early loss of the deciduous canine, c) abnormal position of the tooth bud, d) the presence of an alveolar cleft, f) cystic or neoplastic formation, g) dilacerations of the root, h) iatrogenic origin, and i)
idiopathic with no obvious cause. He lists endocrine deficiencies, febrile diseases, and irradiation as generalized causes of canine impaction.

More recently, Yan et al.\textsuperscript{16} investigated the etiology of palatally and labially impacted canines in Chinese patients using Cone Beam Computed Tomography (CBCT) which showed some similarities and some differences from white populations. In the Chinese population the mesio-distal dimension of the central incisors and canines did not appear to be factors for impaction, similar to white populations. However, the mesiodistal dimension of the lateral incisor was associated with palatal impactions, being smaller on the side of palatally impacted canines but not on the side of labial impactions. Another difference in the Chinese population from white populations found by Yan et al was a smaller incisor buccolingual width in impaction patients. Similar to findings in white populations, when comparing buccal impactions, palatal impactions, and controls it was found that narrow anterior dental arch and skeletal width contributed to buccal but not palatal impactions. The authors state that this could explain more frequent buccal canine impactions in Asian populations which have more commonly underdeveloped anterior maxilla. Cusp tip location was found to be a major factor as well where the tip was more often mesial to the long axis of lateral incisors in palatally impacted canines and distal to the long axis in buccally impacted canines. The authors attribute canine migration speed as a potential factor in impaction. Yan et al state their findings support the guidance theory more than the genetic theory.
Lateral Incisor Associations with Canine Impaction.

The maxillary lateral incisors are intimately related with the developing maxillary canine. In his 1941 article, Broadbent\textsuperscript{17} said that when lateral incisors are flared and distally tipped, the practitioner should take caution in correcting them because of the possibility of impacting the canines or causing resorption of the lateral incisor root.

Lateral incisors associated with impacted canines have been shown to have morphologic variance. Chaushu et al.\textsuperscript{18} investigated fifty-eight subjects with palatally displaced canines (PDC) and compared them to matched controls. Sexual dimorphism was evident in their study as had been previously reported by other investigators. For males, dental development was delayed in 50\% of the PDC patients. In the late dental age (LDA) male group smaller tooth size was noted compared to the controls. More frequent peg-laterals and anomalous lateral incisors were also found in this group. Interestingly the authors conclude that PDC populations show general heterogeneity.

Prior to Chaushu’s study, Langberg and Peck\textsuperscript{19} examined PDC groups and tooth size associations. Their study looked at dental casts of 31 patients with at least one palatally displaced canine with the primary goal of looking at mesio-distal tooth dimensions for the maxillary and mandibular lateral incisors. The mean for each of the PDC groups was smaller with three of the four being statistically significant. In their discussion, the authors elucidate that because there is more arch length available in the PDC group, evidence is provided for a more genetically controlled etiology. More importantly the authors state that because of the small
tooth sizes associated with PDC, it is understandable non-extraction treatment plans are often recommended in these patients.

Diagnosis of Impacted Canines

Diagnosis of impacted maxillary canines can be problematic as it has not been definitively described. Bishara reports that the following clinical and radiographic signs can help with the determination: 1) delayed eruption of the permanent canine or prolonged retention of the deciduous canine beyond 14 to 15 years of age, 2) absence of normal labial canine bulge, 3) presence of a palatal bulge 4) delayed eruption, distal tipping, or migration (splaying) of the lateral incisor.

Ngan et al. report that diagnosis begins with the clinical evaluation. The first sign, as one might expect, is seeing permanent canines that have not erupted when the chronological age and developmental age call for it’s presence. They go on to say that other considerations include: 1) the amount of space for the canine, 2) the adjacent teeth and there position and morphology, 3) the contours of the bone, 4) mobility of teeth such as the primary canine, and 5) radiographs to show the position of the canine’s crown, apex, and the angle of the canine in the alveolus. The authors state that the lateral incisor should be noted because a peg shaped lateral incisor is frequently seen in cases with impacted canines. They explain the often observed distal inclination of the maxillary lateral incisor in normal eruption patterns as the “result of the canine pressing on the lateral incisor root.” This is an example of Ngan giving credence to the guidance theory of eruption.
Indices have been created to diagnose the difficulty of treating impacted canines. Kau et al.\textsuperscript{21} created an classification, the KPG Index, which utilizes a CBCT to find the location of the cusp and root tips in x, y, and z axes. Each position is quantified and the sum is converted to a difficulty rating, easy to nearly impossible.

**CBCT vs. Traditional Radiographs**

Traditional radiography is used as a screening tool and has been one method of diagnosing and localizing impacted canines over the majority of the specialties existence.\textsuperscript{20} These radiographs include panoramic, periapical, occlusal, and lateral cephalometric radiographs. With traditional radiographs the clinician is trying to use information in a 2 dimensional (2D) format that represents a three dimensional (3D) object. Images should be interpreted with regards to magnification and distortion.\textsuperscript{22} Computed tomography (CT) scans have been a part of medical imaging for decades. CT scans had limited use in dentistry because of the large space requirement of the machine, the expense, and the high dose of ionizing radiation. When modified versions of the CT scan started to be made available and overcome the limitations of medical CT’s, the dental community was ready to implement them into dentistry. Nakajima et al.\textsuperscript{23} exemplify this mentality when they wrote, “We are on the verge of a great change in the way we visualize the craniofacial complex in medicine and dentistry. The impact on orthodontics will be profound”. Nakajima presents three cases (two impaction cases and one TMD case) that were treatment planned using a CBCT scan. In each case the authors felt that the CBCT improved the diagnosis and subsequent treatment plan. Without showing data, the argument in
this paper is that the CBCT slices and 3D rendering of these slice provides more information whether relating to tooth positions or joint/bone morphology. Although a magnetic resonance imaging (MRI) remains the gold standard for visualizing the articular disc of the temperomandibular joint, the authors feel the views from a CBCT are superior to MRI scans when visualizing the entire joint apparatus.

In Alqerban’s study, the traditional set of radiographs used to diagnose and treatment plan impacted canines was found to be insufficient for treatment planning in 22.5 per cent of the 64 impacted canines. Furthermore, clinicians requested additional radiographs in 63 per cent of cases. This is compared to 1.3 and 0.5 percent, when using CBCT’s. Areas of weakness for traditional radiographs when compared to CBCT’s were in determining canine position, canine development, detecting abnormality, vertical canine crown height, and presence of root resorption in the adjacent teeth. In spite of this, Alqerban concluded, “there was no statistically significant difference in treatment planning between the use of conventional and CBCT sets. CBCT images have been shown to offer useful orthodontic treatment planning information similar to that of conventional planning with a high confidence level.” It appears that even though clinicians were more comfortable diagnosing and treatment planning impacted canines when using CBCT’s, requesting less additional radiographic information, the ultimate result regarding treatment was the same regardless of traditional radiography versus CBCT’s.

Bjerklint and Ericson state that after an initial radiographic examination with a panoramic and periapical radiographs, any child with an ectopic canine
should have a CBCT taken. This establishes their position on whether or not a CBCT should be used. Their investigation of treatment plans with and without use of CBCT’s backs up their stance. In the cited paper, subjects consisted of 80 children (31 males and 49 females) with 113 retained maxillary canines. Root resorption was diagnosed to different degrees in 39 children. In 42 children extractions were planned because of the large amount of space deficiency as well as the ectopically positioned maxillary canines. The treatment plans of 43.7% of the subjects of the 80 patients were changed due to the additional information from the CT scan. 39 patients had root resorption on neighboring incisors, and 21 of these patients (53.8%) had their treatment plan altered. The authors provide a concrete example of the subsequent result of the CT scans; without them six patients would have had nine more lateral incisors extractions planned.

Another study by Alqerban in 2013 corroborated his previously found results. In this study, the authors looked at thirty two subjects with an average age of twenty five (13 males and 19 females) who were being treated with surgical intervention for 39 impacted maxillary canines. Similar to the previously mentioned study, both traditional 2D and 3D records were used to develop the treatment plans. The 3D records provided significantly different results for lateral incisors root resorption, contact between the canine and lateral incisor, and canine crown position. The conclusion in this paper was that impacted maxillary canines were not treatment planned differently in regard to using 2D or 3D records.

Botticelli et al. attempted to compare differences in diagnosis using both traditional 2D radiographs and images generated from CBCT’s. In their study,
power points with a patients records were sent to clinicians who would assess the following characterisitcs through a questionnaire:

- Inclination to the midline
- Mesio-distal position of the apex
- Vertical level of the clinical crown
- Overlap with the lateral incisor
- Labio-palatal position of the crown
- Labio-palatal position of the apex
- Root resorption of neighbouring incisor/s
- Treatment strategy
- Assessment of difficulty
- Assessment of image quality

The authors concluded that findings between 2D and 3D images showed differences. Of note, the mesio-distal position of the apex and the bucco-palatal position of the canine could be better and more assuredly assessed using 3D imaging.

Furthermore, more overlap of canine and incisor, and lateral incisor root resorption was noted with the 3D images. Ultimately the authors said that the better perception of the intra-alveolar position of the canine with a CBCT leads to better diagnosis and is of aid in treatment planning.

Wriedt et al. also looked at 2D (panoramic radiographs) versus 3D (CBCT scans) diagnostics to see how treatment planning results compared. 27 Sixty four percent (64%) of patient’s impacted canine positions were identified to the same degree using both 2D and 3D diagnostics. Canine apical regions were identifiable in
two thirds of both 2D and 3D diagnostics. One quarter of canine apical areas that were not identifiable with 2D could be identified with 3D images. Eight two percent (82%) of the treatment plans were the same for 2D versus 3D images. However, the inclination of the canine as identified on the panoramic radiograph had the most effect on the treatment plan. The authors conclude with clear recommendations which include taking a supplemental small volume CBCT when: 1) the canine inclination is more than 30° from the vertical plane, 2) adjacent root resorption is suspect, 3) dilacerations of the canine root is suspected but not confirmed with the panoramic radiograph.

Dose of radiation causes the most controversy when discussing CBCT’s versus traditional radiography such as panoramics and lateral cephalograms because of the relatively high does of CBCT. One of the basic principles of dentistry in regard to radiography is ALARA (as low as reasonably achievable). Given the fact that a panoramic radiograph dose is seven times lower than a CBCT the value of each must be considered in each patient’s specific case. In a study conducted by Silva et al., an anthropomorphic phantom was used with measurement devices, 48 TLD (Lithium fluoride thermoluminescent dosimeter) chips, in key locations. These locations represented radiosensitive organs of interest, namely the bone marrow, spine, brain, eye, thyroid gland, salivary glands, and skin. This phantom was used to measure the dose put out by NewTom 9000, the i-CAT, the Panoramic Orthopos Plus DS, and the multi-slice CT. As an example of the results, the effective dose for the machines tested on the thyroid (in micro-Sv) were 232.4, 124.3, 13.1, and 1417.7 respectively. For this specific area, we see 10-20 times the effective dose
using the CBCT’s and 100 times the effective dose with the CT. The authors make a good point in the discussion stating that most patients undergoing orthodontic care are particularly sensitive to radiation because they are still growing. In the end the conclusion from this paper recommended not using CBCT’s as part of routine records but instead when they are called for such as in cases with impacted teeth. In an official statement the American Dental Association Council on Scientific Affairs called for CBCT use to be adjunctive and when the yield would significantly improve clinical outcomes.  

Recent CBCT Investigation of Impacted Canines and Lateral Incisors

Liuk used CBCT’s to investigate maxillary lateral incisor dimension and orientation as related to patients with impacted maxillary canines. Liuk looked at CBCT’s from 40 patients with 46 palatally impacted canines. Their goal was to investigate the relationship of maxillary lateral incisor and impacted canine orientation and dimensions including: canine cusp tip, vertical position of the cusp tip, severity of lateral incisor resorption, buccolingual width of lateral incisors roots at multiple locations, mesiodistal width of lateral incisor roots at multiple locations, and lateral incisor length.

Liuk’s findings were that maxillary lateral incisors were more retroclined when viewed from the sagittal plane (AP), maxillary lateral incisors were more upright in the coronal plane by 5 degrees (when viewed from the facial they were more root mesial). He also found canines became more palatally displaced when the lateral incisors were upright and when lateral incisor roots were shorter. Finally,
canines were more vertically displaced when the lateral incisor was more upright both sagitally and coronally.

The study previously mentioned by Yan et al used CBCT’s to investigate what they called ‘etiologies’ although the factors studied could be classified as associations or factors relating to diagnosis.\textsuperscript{16} Again, the mesiodistal dimension of the lateral incisor was associated with palatal impactions, being smaller on the side of palatally impacted canines but not on the side of labial impactions\textsuperscript{16}. Yan’s findings for the lateral incisor mesiodistal width were that for buccal impaction, the mean width was 7.33mm where the control was 7.27. For palatal impaction, the lateral incisor width was 6.74mm and the control was 6.79. Interestingly no significant difference was found for these measurements.

Liuk used the same sample previously mentioned in a different study. This time he looked at maxillary lateral incisor length and mesio-distal and buccolingual width at the cementoenamel junction (CEJ) and 4 and 8mm apical to the CEJ.\textsuperscript{31} The results showed the lateral incisor root was an average of 2.1mm shorter in the PDC group. (He notes this is the same finding as Becker as quoted earlier). Furthermore, root widths of lateral incisors in the PDC group were smaller in the buccolingual dimension. That paper also concludes that measurements are accurate on a CBCT as demonstrated by intraexaminer reliability.
MATERIALS AND METHODS

This is a retrospective study investigating the mesiodistal crown-root angulation of 35 maxillary lateral incisors on the same side as an impacted maxillary canine in 20 patients. A control sample of 34 maxillary lateral incisors in patients without impacted canines was selected. For lateral incisors to be included in the study specific criteria had to be met.

Inclusion criteria included: 1) patients who presented to UAB Orthodontics who received CBCT’s as part of routine records or as part of a referral requesting a CBCT, 2) clinically diagnosed palatally or buccally impacted canines, 3) present maxillary lateral incisor on the side of the impacted cuspid, 4) mature lateral incisor root (3/4 root formation). Chronologic age was not considered in the inclusion or exclusion criteria.

Exclusion criteria included: 1) cleft lip/palate, 2) other craniofacial abnormality, 3) lateral incisor agenesis, 4) peg shaped lateral incisor, 5) root resorption that would cause less than ¾ of root to be discerned (severe or moderate), 6) any defect or radiographic artifact that would not allow for visualization of the lateral incisor root.

All patients were selected from a database of CBCT’s routinely taken for treatment with a Kodak 9500 (Carestream Health, Rochester, NY). The control group was selected from the same database, meeting the same inclusion and exclusion criteria but without impacted canines. All CBCT images were large field of
The UAB Institutional Review Board approved this study.

This aims of this study were to:

Primary aim: Compare the mesiodistal crown-root angulation of lateral incisors in patients with impacted canines to a control group.

Secondary aims:
1. Compare the mesiodistal crown-root angulations of lateral incisors when measured using CBCT and panoramic radiographs
2. Compare the mesiodistal crown width of lateral incisors in patients with impacted canines and a control group.

The primary aim of this study was to measure the mesiodistal crown-root angle of the lateral incisors under investigation and compare them to a control group. The angle of interest is that formed on the mesial aspect by the intersection of a line bisecting the long axis of the lateral incisor root and a line bisecting the lateral incisor crown as shown in Figure 1. This angle was measured and recorded for both the study population and the control group.
Figure 1. The mesiodistal crown-root angulation of a maxillary lateral incisor.

The primary aim of this study utilized CBCT volumes that were re-formatted so that in the coronal CBCT slice the lateral incisors were viewed from the facial. That is, when the viewer is looking at the computer screen he sees the facial surface of the lateral incisor. Liuk et al.\textsuperscript{31} describe this well saying the lateral incisor is viewed, “with a tangent to the labial crown surface paralleled to the computer screen”.

To achieve this, when they were viewed occlusally in the axial slice, the coronal slice was formatted so the incisal edge was perpendicular to the coronal plane as shown in Figure 2. Using the reformatting tool in the axial view, the coronal slice was adjusted by rotating it so that the line designating this plane was perpendicular to the facial surface of the lateral incisor. To ensure maximum accuracy the plane was placed bisecting the incisal edge bucco-lingually. The resultant view provides the most accurate representation of the true facial visualization of the lateral incisor. The slice thickness was adjusted for each reformatted CBCT in the coronal view with a range of 26.2mm to 30.2mm, with one
exception which only required a thickness of 7.4mm. This was picked based on the thickness the investigator considered to provide the clearest view of the entire tooth. Measurements were made on maxillary lateral incisors on the ipsilateral side of the impacted maxillary canine in the study group in the following order.

A line was drawn along the long axis of the anatomical crown.

A line was drawn along the long axis of the anatomical root.

The angle between these lines was measured. Lateral incisors that had a crown angle parallel to a root angle would be measured at 180°. If the root was angled toward the mesial the angle was recorded as less than 180° and if the root was angled distally the angle was recorded as more than 180°. Figure 3 is an example of one of the measurements recorded. The long axis of the anatomical crown was defined as the line that passed through the center of the labial or buccal surface at the most convex dimension. The line angles of the tooth, the incisal dimensions and anatomy, and perceived prominence were used as aids in drawing this line. The long axis of the root was a line of best fit utilizing the center of the cement-enamel junction and the anatomical apex as references. The anatomical position of the impacted canine, labial or palatal, for the study group was determined based on the CBCT volumes. Ten reformatted CBCT volumes were used to re-measure the lateral incisor angle in the study group more than four weeks after the initial data gathering and used to determine intraexaminer reliability.

For the first secondary aim, the lateral incisor crown root angulations were measured on panoramic radiographs for patients who had a regular routine panoramic radiographs (not extracted from a CBCT) using Dolphin Imaging
Figure 4 demonstrates this measurement. These measurements were compared to those from the CBCT’s to see if there was a difference in angle measurements.

For the second secondary aim, the maxillary lateral incisor mesiodistal width (LIW) was measured using digital OrthoCad (Cadent, Carlstadt, NJ) models when these were available. This was analyzed in relationship to impacted versus non impacted populations to see if lateral incisor width is associated with impacted maxillary canines. Forty teeth were available for measurement of the mesiodistal width.

Statistical Analysis

For the primary aim standard descriptive statistics including averages and standard deviations were used for the lateral incisor angles of both the study and control groups. The Wilcoxon test was used to determine if there was any difference between the two groups. The level of acceptable significance was set at alpha = 0.05 for all tests. SAS version 9.3 (SAS Institute Inc, Cary, North Carolina) was used for all analyses. Intra-examiner reliability was tested by re-measuring 10 reformatted CBCTs. These 10 paired observations were analyzed using intraclass correlation. This intraclass correlation utilized a Bland-Altman plot to show both significance and pattern.

For the secondary aim comparing lateral incisor angles measured on CBCT’s to those measured on panoramic radiographs a paired t-test was used to determine if there was any difference between groups. A paired (samples) t-test is used when
you have two related observations (i.e., two observations per subject) and you want to see if the means on these two normally distributed interval variables differ from one another. There was normality to the distribution curves for both CBCT’s and panoramic radiographs. For the secondary aim comparing lateral incisor widths to impactions a Spearman correlation was used. A correlation is useful when you want to see the linear relationship between two (or more) normally distributed interval variables. Moreover, a Spearman correlation is used when one or both of the variables are not assumed to be normally distributed and interval (but are assumed to be ordinal). The level of acceptable significance was set at alpha = 0.05.
Figure 2. Reformatted CBCT showing the true facial surface of the maxillary lateral incisor in the bottom left.

Figure 3. Maxillary lateral incisor crown root angle measured on a CBCT.
Figure 4. Panoramic radiograph with crown-root angulation measurement.
RESULTS

The Intra-class Correlation Coefficient was .96 with a confidence interval of .84-.98 suggesting no difference between the first and second measurements for those 10 observations (Table 1). The Bland-Altman plot in Figure 5 shows most of the measurements fall within 1° of each other, with one outlier at +3° and another at -4°.

The null hypothesis for the primary aim was that there is no difference in crown root angulation between patients with impacted maxillary canines and patients without impacted maxillary canines. Table 2 summarizes the results comparing the maxillary lateral incisor crown root angulations between those with impacted maxillary canines and those without. The mean angle for study group (n=32) was 173.00 with a standard deviation of 5.11. The mean angle for control group (n=34) was 183.65 with a standard deviation of 3.46. The results suggest that there is a statistically significant difference between the underlying distributions of the crown root angulation measures of controls and the angulation measures of study group (z = -6.7, p < 0.0001). Moreover, from the sample population patients with impacted maxillary canines had statistically significantly lower crown angulations measures than those without impacted maxillary canines.

Table 3 shows the differences between the CBCT maxillary lateral incisor angles between those with buccally versus labially impacted canines. Both groups
had an average CBCT angle of about 173°. However, there was a significant difference between controls and both patients with labially impacted canines and palatal impacted canines. More specifically, control subjects had an average CBCT angle of 183.6° while patients with both palatal and labial impacted incisors had an average that was 10 degrees less (~173°) (Table 4 and Table 5).

There was not a statistically significant difference between maxillary lateral incisor angles when comparing those with palatal and those with labial canine impactions. Figure 6 shows the distribution of maxillary lateral incisor angles for labially impacted canines and the control group whereas Figure 7 shows the distribution of lateral incisor angles in palatally impacted canines with the alpha = 0.05 (a 5% chance of a false positive).

Looking at the study group, sex (p < 0.038) showed a significant difference in maxillary lateral incisor CBCT angle (Table 6). Males had larger lateral incisor CBCT angles than females (175.1° > 171.2°). Impacted incisor sides, right and left, were very close in degree measurements. Impaction side angles were not significantly different from each other (p < 0.4) where the mean angle for the left side (n=17) was 173.9° ± 4.74 and for the right side (n=15) was 172.0° ± 5.48 (Table 7).

There were a total of 66 CBCT angle measurements of maxillary lateral incisors in this study, however only 29 of the 66 angle measurements were greater than 180°. Table 8 shows the odds ratios of the baseline characteristics for their association with an angle greater than 180°. Considering sex, age at the time of CBCT, and position of the impacted maxillary canine (labial vs palatal) none of these predictors were statistically significant when all put into a full model. When
compared to the 14-16 years old group, patients younger than 13 years of age are 65% less likely to have an angle greater than 180°. Impaction position was the most statistically significant variable when predicting whether a patient had an angle greater than 180°. When compared to the control group, those with labial impacted incisors are 98% less likely to have an angle greater than 180°.

The first secondary aim was to determine if there is a difference between maxillary crown root angulation of the maxillary lateral incisor when using a CBCT versus a panoramic radiograph. The difference between the means of lateral incisors measured on CBCT’s compared to panoramic radiographs was 0.036° (p = 0.9627) with a standard deviation of 5.087 (Table 9). This difference is not statistically significant.

The second secondary aim was to determine if there was an association between maxillary lateral incisor crown root angulation and adjacent maxillary lateral incisor tooth width. A correlation is useful to see the linear relationship between two (or more) normally distributed interval variables. The results suggest that the relationship between the angle measured by CBCT and LIW (rho = 0.49 p = 0.001) is statistically significant (Table 10). The results also suggest that the relationship between angles measured on lateral incisors with panoramic radiographs and LIW (rho = 0.42, p = 0.01) is statistically significant (Table 10). Both correlations were positive and numerically similar.
Table 1.

Intraexaminer Correlation Coefficient for 10 paired Angle Measurements for Impacted Incisors

<table>
<thead>
<tr>
<th>Intraclass correlation&lt;sup&gt;a&lt;/sup&gt;</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Measures&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.9587</td>
</tr>
<tr>
<td>Average Measures&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.9789</td>
</tr>
</tbody>
</table>

<sup>a</sup> The degree of consistency among measurements.
<sup>b</sup> Estimates the reliability of single ratings.
<sup>c</sup> Estimates the reliability of averages of two ratings.

Table 2.

Maxillary Lateral Incisor Mesiodistal Crown-Root Angle as Measured on CBCT<sup>*</sup>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>34</td>
<td>183.65</td>
<td>3.46</td>
</tr>
<tr>
<td>Impacted</td>
<td>32</td>
<td>173</td>
<td>5.11</td>
</tr>
</tbody>
</table>

$z = -6.7027$, $p < 0.0001$

* Estimated from Wilcoxon test

Table 3.

Maxillary Lateral Incisor CBCT Angle Classified by Impaction Position<sup>*</sup>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labial (1)</td>
<td>11</td>
<td>172.9</td>
<td>6.39</td>
<td>158</td>
<td>182</td>
</tr>
<tr>
<td>Palatal (2)</td>
<td>21</td>
<td>173</td>
<td>4.47</td>
<td>165</td>
<td>180</td>
</tr>
</tbody>
</table>

$z = 0.22$, $p = 0.83$

* Estimated from Wilcoxon test
Table 4.

Maxillary Lateral Incisor CBCT Angle In Palatally Impacted Canine Population*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palatal (2)</td>
<td>21</td>
<td>173</td>
<td>4.47</td>
<td>165</td>
<td>180</td>
</tr>
<tr>
<td>Control (0)</td>
<td>34</td>
<td>183.6</td>
<td>3.46</td>
<td>177</td>
<td>193</td>
</tr>
</tbody>
</table>

$z = -6.02$, $p < 0.0001$

* Estimated from Wilcoxon test

Table 5.

Maxillary Lateral Incisor CBCT Angle In Labially Impacted Canine Population*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labial (1)</td>
<td>11</td>
<td>172.9</td>
<td>6.39</td>
<td>158</td>
<td>182</td>
</tr>
<tr>
<td>Control (0)</td>
<td>34</td>
<td>183.6</td>
<td>3.46</td>
<td>177</td>
<td>193</td>
</tr>
</tbody>
</table>

$z = -4.62$, $p < 0.0001$

* Estimated from Wilcoxon test

Table 6.

Maxillary Lateral Incisor CBCT Angle in the Study Group Classified by Sex *

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15</td>
<td>175.1</td>
<td>4.38</td>
<td>165</td>
<td>182</td>
</tr>
<tr>
<td>Female</td>
<td>17</td>
<td>171.2</td>
<td>5.11</td>
<td>158</td>
<td>177</td>
</tr>
</tbody>
</table>

$z = 2.06$, $p < 0.038$

* Estimated from Wilcoxon test
Table 7.

Maxillary Lateral Incisor CBCT Angle Classified by Impacted Canine Side*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>17</td>
<td>173.9</td>
<td>4.74</td>
<td>165</td>
<td>182</td>
</tr>
<tr>
<td>Right</td>
<td>15</td>
<td>172</td>
<td>5.48</td>
<td>158</td>
<td>179</td>
</tr>
</tbody>
</table>

\[ z = -0.83, \ p < 0.4 \]

* Estimated from Wilcoxon test

Table 8.

Odds ratios* (ORs) for the Association of Baseline Characteristics with Maxillary Lateral Incisor Crown-root Angle (Greater than 180°) Based on Data from 66 Observations

<table>
<thead>
<tr>
<th>Angle &gt;180° (N=29)</th>
<th>Angle ≤180° (N=37)</th>
<th>Mean Angle (°)</th>
<th>Crude OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11 (38.0)</td>
<td>18 (48.7)</td>
<td>178.8</td>
<td>0.65</td>
<td>0.2-1.7</td>
</tr>
<tr>
<td>Female (Referent)</td>
<td>18 (62.0)</td>
<td>19 (51.3)</td>
<td>178.2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Age Group (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤11 Years</td>
<td>1 (3.5)</td>
<td>14 (37.8)</td>
<td>171.8</td>
<td>0.05</td>
<td>0.01-0.4</td>
</tr>
<tr>
<td>12-13 Years</td>
<td>6 (20.7)</td>
<td>11 (29.7)</td>
<td>177.9</td>
<td>0.34</td>
<td>0.1-1.2</td>
</tr>
<tr>
<td>14-16 Years (Referent)</td>
<td>16 (55.2)</td>
<td>10 (27.0)</td>
<td>180.9</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>17-19 Years</td>
<td>3 (10.3)</td>
<td>2 (5.4)</td>
<td>183.8</td>
<td>0.94</td>
<td>0.1-6.6</td>
</tr>
<tr>
<td>≥ 20 Years</td>
<td>3 (10.3)</td>
<td>0 (0)</td>
<td>185.3</td>
<td>∞</td>
<td>-</td>
</tr>
<tr>
<td>Race (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (Referent)</td>
<td>15 (51.7)</td>
<td>29 (78.4)</td>
<td>176.6</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>10 (34.5)</td>
<td>3 (8.1)</td>
<td>183.6</td>
<td>6.44</td>
<td>1.5-27.0</td>
</tr>
<tr>
<td>Asian</td>
<td>4 (13.8)</td>
<td>0 (0)</td>
<td>187.5</td>
<td>∞</td>
<td>-</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0 (0)</td>
<td>5 (13.5)</td>
<td>174.2</td>
<td>Undefined</td>
<td>-</td>
</tr>
<tr>
<td>Impaction Position (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (Referent)</td>
<td>28 (96.5)</td>
<td>6 (16.2)</td>
<td>183.6</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Labial</td>
<td>1 (3.5)</td>
<td>10 (27.0)</td>
<td>172.9</td>
<td>0.02</td>
<td>0.002-0.2</td>
</tr>
<tr>
<td>Palatal</td>
<td>0 (0)</td>
<td>21 (56.8)</td>
<td>173</td>
<td>Undefined</td>
<td>-</td>
</tr>
</tbody>
</table>

*Estimated from logistic regression.

∞ Represents that all the angles are >180°.
Table 9.

Comparison between CBCT and Panoramic Radiograph (PR) Measurements for Maxillary Lateral Incisor crown root angulation*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>95 % CI**</th>
<th>Std. Dev.</th>
<th>Max / Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT - PR</td>
<td>45</td>
<td>-0.036</td>
<td>-1.56</td>
<td>1.49</td>
<td>8.5</td>
</tr>
</tbody>
</table>

\[ t = -0.05, \ p = 0.9627 \]

* Estimated from paired t-test

** Confidence Interval

Table 10.

Spearman Correlations for Relationship Between crown root angulation measures (CBCT & Panoramic Radiographs) and lateral incisor width (LIW)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>LIW Corr.*</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT</td>
<td>66</td>
<td>0.49</td>
<td>0.001</td>
</tr>
<tr>
<td>PR</td>
<td>45</td>
<td>0.42</td>
<td>0.01</td>
</tr>
<tr>
<td>LIW</td>
<td>40</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

*Presented as rho values.
Figure 5. Bland-Altman Plot from 10 paired CBCT angle measurements for intra-examiner reliability.

Figure 6. Distribution of maxillary lateral incisor CBCT angles for the control group (Imp_Cat=0) and patients with labially impacted incisors (Imp_Cat=1)
Figure 7. Distribution of maxillary lateral incisor CBCT angles for patients with palatally impacted incisors (Imp_Cat=2).
DISCUSSION

This study aimed to investigate the crown root angulation of maxillary lateral incisors associated with impacted maxillary canines as evaluated by cone beam computed tomography. This novel association between an anatomical variable and impacted maxillary canines could be used by clinicians to help diagnose impacted maxillary canines.

A straight tooth with the long axis of the root parallel to the long axis of the crown would measure at 180°. An angle less than 180° was recorded when the root diverged mesial to the crown, and an angle more than 180° was recorded when the root diverged distal to the crown. The impacted canine population had a mean lateral incisor crown root angulation of 173° (p < 0.0001). The control group without an impacted canine had a mean angle of 183.65° (p < 0.0001). The difference was significant indicating an association between impacted canines and smaller maxillary lateral incisor angles ipsilateral to the impacted canine. The method in which the angles were measured should be considered accurate because of the high Intra-class Correlation of 0.96 and the Bland-Altman plot showing a tight distribution.

Co-variables examined included side of impaction, impactions position, race, age, and sex. One of the significant findings was that the female population in this study had smaller crown root angles than males in the impacted canine group. Dachi and Howell⁴ found a higher incidence of canine impactions in females, more
than double that of males. It is reasonable then that a variable associated with canine impactions would be similarly expressed. The lateral incisor crown root angles for both palatally and labially impacted canines were not found to be significantly different. This might be considered odd as the etiologies for palatally and labially impacted canines are widely regarded as different. As previously mentioned, Jacoby’s finding showed crowding was present in 15% of palatal canine impactions.10

To the author’s knowledge mesiodistal crown root angulation is a variable that has not been considered in impacted canine cases before. Because of this, many of the results cannot be corroborated with other studies. On the surface this variable seems very close to looking at lateral incisor angulation (mesiodistal) but there are distinct differences. Whereas the mesiodistal angulation of a maxillary lateral incisor is descriptive of its position, the crown root angulation of a maxillary lateral incisor is descriptive of its anatomy. Therefore this investigation was a study of a tooth anatomy and how it is associated with impacted canines. This investigation took place by comparing this specific aspect of the maxillary lateral incisor’s anatomy, mesiodistal crown root angulation, in a population that had an impacted canine and comparing it to a population that did not. Because crown root angulation, as it has been defined in this paper, had not been previously investigated, a sound method acquiring the needed measurements needed to be considered.

Cone beam computed tomography was selected as the primary means for this investigation. The literature provided a base of evidence that supports this
methodology. As early as 1987, Ericson and Kurol utilized traditional radiography and were only able to separate the maxillary canine from the maxillary lateral incisor in 37% of the patients. They stated that a panoramic radiograph was unreliable for, “the purposes of (1) determining the position of a misplaced canine in the dental arch or to the adjacent lateral incisors, and (2) showing resorption on adjacent teeth. Its value lies in giving a panoramic view of the mouth before starting orthodontic treatment.” In the previously mentioned article by Botticelli, 3D imaging allowed for better determination of the mesio-distal position of the apex in impacted maxillary canines. In that study differences were shown in treatment plans dependant on whether traditional 2D radiographs or 3D systems were used for diagnosis. Botticelli et al. are in agreement with Nakajima and Silva that 3D imaging is called for in special instances such as for diagnosing impacted maxillary canines. In spite of this evidence, panoramic radiographs have been used for decades to diagnose impacted canines and are routine radiographs taken in the orthodontic field. Because they are routine, panographs should not be disregarded and were therefore included in this study to see if there was a difference between the mesio-distal crown root angulation measured on them versus those measured on CBCT's. The average clinician knows the dosage of CBCT's is greater than on traditional panoramic radiographs, and because no statistical difference is noted between the two modalities in crown root angulation the extra radiation exposure might not be necessary.

This study required CBCT volumes to be reformatted in a way that the imaging software could make angular measurements. The method used is reported
in the materials and methods, and it should be noted that the reformatting is very similar to that used by Liuk et al.\textsuperscript{31} Liuk et al took one extra step in the reformatting so that the lateral incisor stood upright in the sagittal and coronal views. This extra step was omitted. This study elected to use an vertical orientation representing the position of the head at the time of the CBCT, likely close to a natural head position (one of the more stable positions as reported by Lundstrom\textsuperscript{32}). The reason this position was chosen is because it would be close to the position used for taking a panoramic radiograph which was one component of this study. That is, the lateral incisor crown root angulation should be drawn with the head in the same position in the CBCT as it is in the panoramic radiograph.

In regard to this point, the results show that the mesio-distal crown root angulation is not statistically different between panoramic radiographs and CBCTs. This does not discredit the use of CBCTs for diagnosing impacted canines, however it does provide evidence for using panographs to view the crown root angulation when a CBCT is not otherwise warranted. It should be noted for crown root angulation that although the means between CBCTs and panographs were not significantly different, there were cases when the angle measured on a panographs was obviously incorrect. One example of this is when a lateral incisor was rotated 90°.

Lateral incisor width was found to be positively correlated with crown root angulation. The relationship between the CBCT angle and lateral incisor width. (rho = 0.49 p = 0.001) is statistically significant. The rho for panoramic radiographs and lateral incisor width was 0.42, very similar to CBCT correlation. This means that as
the lateral incisor angle increased so did the crown width. Normal maxillary lateral incisor anatomy should show a mesio-distal crown root angulation of close to 180°. In this study those incisors associated with impacted maxillary canines had a mean angle of 173° which were considered abnormal anatomy. It is reasonable to expect the crown width of lateral incisors to decrease as the angle increases because both are aspects of abnormal anatomy and could possibly be affected by the same environmental or genetic controls. Sajnani et al.33 investigated dental anomalies associated with impacted canines finding lateral incisors to be the most commonly affected tooth, with microdontia being one of the commonly noted anomalies.

One of the weaknesses of this study was the sample size. The experimental group consisted of 32 lateral incisors next to impacted canines, and the control group was 34 lateral incisors next to normally erupted maxillary canines. Although a greater sample size would be favorable, analysis was still possible with appropriate p values. One of the reasons for the small sample size is that CBCTs are not taken on all patients in the UAB orthodontic clinic. The sample size is attributed for the fact that none of the variables investigated were found to be significant when put into a full logistic regression model. It is interesting that those less than 13 years old were 65% more likely to have a crown root angle less than 180°. Thirteen years of age was not chosen as a break point specifically; this age was found to be worth discussion because data analysis revealed it to be a naturally occurring phenomenon. A reasonable explanation follows.

A clinician requires significant evidence to diagnose a maxillary canine as impacted before a reasonable chronologic age. This evidence might include a
horizontal position in the alveolus, a cusp tip mesial to the central incisor, or a smaller than normal ( < 180° ) mesiodistal crown-root angulation of the adjacent lateral incisor as pointed out in this study. Conversely, for an adult to be diagnosed with an impacted canine (barring the chance the patient was not monitored regularly) they would need to exhibit evidence for normal eruption that would delay this diagnosis including: a good vertical position in the alveolus, a good horizontal position in the alveolus, presence of a canine bulge, and a normal ( ≥ 180° ) mesiodistal crown-root angulation of the adjacent lateral incisor. It is reasonable then that those with impacted canines, who are less than 13 years old, would have a maxillary lateral incisor angle greater than 180° and those who are older than 13 would have the same angle greater than 180°.
CONCLUSIONS

• There is an anatomical difference between lateral incisors associated with impacted maxillary canines. The mesiodistal crown-root angulation of a maxillary lateral incisor is significantly smaller than those in a control group. The mean angle for a population with impacted canines was 173° and the mean angle for a control group without impacted canines was 183.65°.

• Lateral incisor mesiodistal crown-root angulation measured on panoramic radiographs did not differ significantly from those measured on CBCTs. A CBCT is not required to measure this angle unless the lateral incisor is severely rotated or malpositioned.

• Females with impacted canines had smaller lateral incisor crown root angles than males. However, there was no difference in mean angles when comparing the side of impaction, palatal versus labial impaction, race, or age.

• The maxillary lateral incisor crown width was positively correlated with incisor crown angle (rho = .42). More appropriately, as the angle got larger so did the crown width.

• Clinical impact: When diagnosing an unerupted maxillary canine, measuring the adjacent maxillary lateral incisor mesiodistal crown-root can provide useful diagnostic information. An angle smaller than 180° as measured on a panoramic radiograph or CBCT seems to be an indicator of canine impaction.
REFERENCES


APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

DATE: May 15, 2013

MEMORANDUM

TO: Samuel Purnell
   Principal Investigator

FROM: Cari Oliver, CIP
   Assistant Director
   Office of the Institutional Review Board (OIRB)

RE: Request for Determination—Human Subjects Research
   IRB Protocol #N130215002—Investigation of Lateral Incisor Crown Root
   Angulation and Impacted Maxillary Cuspids

A member of the Office of the IRB has reviewed your application for Designation of Not Human Subjects Research for above referenced proposal.

The reviewer has determined that this proposal is not subject to FDA regulations and is not Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.