3D Analysis of Maxillary Incisor Root Inclinations in Cases of Unilateral Maxillary Canine Impaction

By

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

Medical Sciences – Orthodontics
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Abstract

Objective: To analyze the relationship between the impacted maxillary canine and the root inclination of the adjacent maxillary incisors. While earlier literature relied on 2-dimensional radiographs, which display an overlapped representation of the maxillary incisors, this project had the advantage of using 3-dimensional imaging to measure each maxillary incisor root inclination independently.

Methods: CBCTs of 27 patients with palatally impacted maxillary canines (group P), 15 patients with buccally impacted canines (group B), and 30 patients with normally erupting maxillary canines (group C) were used in our analysis. Incisor root inclination with respect to the palatal plane was measured for each individual maxillary incisor, and an ANOVA was used to assess significant differences for each incisor between the 3 groups. Paired T-tests were conducted in groups P and B to evaluate whether or not lateral or central incisors on the side of the impacted canine showed significant differences in inclination from their contralateral counterparts. Factors such as distance away from the adjacent lateral incisor, vertical position of the canine crown, and impaction sector were recorded for each patient in groups P and B. These factors were included in Pearson correlation analyses also considering the adjacent lateral incisor's root inclination. All three statistical analyses were repeated after patients with peg-shaped/small maxillary lateral incisors were removed from the groups (3 in group P, 2 in group B, 1 in group C).

Results: Compared to group C, lateral incisors on the side of the palatally impacted canine showed an average of approximately 10 degrees more buccal root inclination, and central incisors on the affected side averaged about 5 degrees more buccal root inclination. Group B showed significant differences in the ipsilateral lateral incisor alone, which averaged 12 more degrees of palatal root inclination when compared to group C. Within group P, the ipsilateral

lateral incisor averaged 7.5 more degrees of buccal root inclination than its contralateral counterpart. In comparison, the central incisor on the affected side averaged 3 degrees more buccal root inclination than that of the contralateral side. In group B, the lateral incisor immediately adjacent to the buccally impacted canine displayed an average of approximately 10.5 degrees more palatal root inclination than the contralateral side.

In group P, moderate correlations revealed that the closer and more coronally positioned the impacted canine is with respect to the lateral incisor, the more buccally inclined the lateral incisor's root will be. A moderate correlation also showed that the more medially displaced the palatally impacted canine is situated (i.e., the higher the impaction sector), the more buccally inclined the adjacent lateral incisor's root would be. In group B, a considerable correlation showed that the more medial the impacted canine was, the more palatally inclined the root of the lateral incisor would be, however this finding should be interpreted with caution since only two cases in group B had their canines situated in impaction sector 4-5.

After peg-shaped/small laterals were removed, group P no longer showed significant differences in ipsilateral central incisor inclination compared to group C. Furthermore, the variable of impaction sector no longer shared a significant correlation with incisor root inclination in group P. Additionally, average root inclinations of all maxillary incisors demonstrated less buccal root inclination in group P and less palatal root inclination in group B.

Conclusion: Patients with impacted maxillary canines do not show significant differences in the root position of all four maxillary incisors, but only in the incisors on the side of the impacted canine. While palatal impactions are associated with buccally positioned roots of both the ipsilateral lateral and central incisors (with different degrees of inclination), buccal impactions are only associated with palatally placed roots of the ipsilateral lateral incisors.

Preface

This thesis is an original work by Nathan Light. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "*Maxillary canine displacement and its association to incisor inclination*", Study ID: MS1_Pro00087314, February 2019 – February 2021.

Acknowledgements

I would like to express my utmost gratitude to my supervisor Dr. Carlos Flores-Mir for his patience, insight, and profound wisdom that he displayed while mentoring me throughout this thesis. I would also like to thank Dr. Paul Major and Dr. Stella Chaushu for serving on my thesis supervising committee and carefully guiding me along the path towards the completion of this project.

I would also like to recognize Hollis Lai for tirelessly helping me with the statistical analysis.

Most importantly, I would like to thank my wife Sara for being Sara, for her unconditional love and tireless effort in taking care of my and my family's needs to allow me to carry out this project, and for continually inspiring within me optimism and the drive to strive further. You are my anchor that keeps me grounded when the storms of life try to knock me off course.

To my children Sammy, Annie, and Talya: you are the sweetest and goofiest bunch of kids that any father could ever have; whatever success I may merit in life, I wish you double.

Lastly, to God. Thank You for giving me a chance to do good in this world despite my inherent flaws. Let's hope I only meet You in another 70 years or so, but I am grateful for the life You have given me until now, and I look forward to the years to come.

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Chapter 1 - Introduction

Statement of the Problem

Tooth impaction frequency is large enough that it has warranted extensive research. One definition of impaction states that a tooth has become embedded in the bone without movement for more than 2 years following the expected average physiological time of eruption [1]. Others have suggested broadening the definition of an impaction as those teeth that are predicted to undergo abnormal eruption, even before their average eruption period, due to the position of the tooth germ, tooth shape, direction of eruption, and available space. [2, 3] Mandibular third molars are the most common tooth to undergo impaction, while maxillary canines fall in 2nd place occurring in up to 2.4% of the general population [4]. While the mandibular third molar does play a functional role in mastication, if fully erupted and inside the dental arch, the maxillary canine performs the additional task of guiding excursive movements in addition to its dominant position in the esthetic zone of one’s smile. In this regard, the impacted maxillary canine can arguably be considered the most significant tooth impaction, thereby adding a relatively greater interest in studying its etiology.

The most straightforward and relatively least invasive interceptive treatment during a maxillary canine’s early phase of ectopic eruption is the extraction of the ipsilateral primary canine [5], after which the canine has a far greater chance of erupting normally within the dental arch [6]. Alternative non-invasive approaches to primary canine extraction, such as maxillary expansion

[7] or anteroposterior space gaining via headgear [8], have also yielded results that significantly reduce the risk of canine impaction. At the same time, other studies demonstrate how different combinations of these approaches have offered even better success [9, 10]. However, in cases where early detection and subsequent intervention is not carried out, numerous complications, beyond shortening of the dental arch, can arise such as canine ankylosis, cystic degeneration, or resorption of the adjacent teeth (a pathological or physiological process that results in the loss of cementum, dentin or bone) [11]. It should be noted that the frequency of these complications is relatively small. Nevertheless, the process of bringing the impacted canine back into the dental arch at a later stage involves a surgical procedure to expose the tooth followed by extensive orthodontic treatment, or alternatively to extract the impacted canine followed by a combination of orthodontic and prosthodontic treatment to account for the asymmetrical absence of the maxillary canine [12].

While maxillary canine impaction occurs in under 3% of the general population [4], a specific subset of malocclusion, namely Class II division 2 (CIID2), has been suggested to experience maxillary canine impaction on a more frequent basis. Previous research has indicated that people diagnosed with a Class II Division 2 malocclusion show a prevalence of maxillary canine impaction up to approximately 33.5% [13]. The reasons behind this suggestion lie in the fact that individuals with a CIID2 have buccally tilted roots (associated with retroclined crowns) and this may impact the canine eruption guidance or because the CIID2 malocclusion and the canine impaction are genetically linked [14]. However, further details behind the nature of these canine impactions, specifically concerning the buccolingual position of the incisors near them, is less apparent from the existing literature. Seeing that the vast majority of impacted maxillary canines are situated palatal to the maxillary dental arch [15], one of our research goals was to conduct a systematic review of the literature concerning the association between the CIID2 malocclusion and palatal maxillary canine impaction. A particular area of interest within the systematic review concerned whether or not the included studies reported the element of incisor inclination in relation to the impacted maxillary canine.

Another finding that previous literature has noted is that maxillary canine impaction is often found together with the unwanted movement of the adjacent maxillary incisors [11]. However, to the best of our knowledge, the extent of this unwanted movement has not been quantified in detail in the existing literature. Previous research has explored the association between maxillary incisor buccolingual root inclination and maxillary canine impaction [14,16]; however, the data in these studies have relied upon conventional 2-dimensional radiography. Since its introduction in 1931 [17], the lateral cephalogram has always been the chosen medium in quantifying the inclination of maxillary incisors, but this method of measurement necessarily carries with it certain disadvantages. Firstly, because maxillary incisors overlap one another in the sagittal view, it is not possible to offer a measurement of inclination for each incisor. Secondly, because of this overlap, the accuracy in identifying an incisor root with its crown is greatly hindered.

The recent advent of cone-beam computed tomography (CBCT) has offered significant advantages in specific clinical scenarios in dentistry [18,19]. More specifically to orthodontics, it has dramatically impacted craniofacial imaging in particular [20,21]. With the advent of craniofacial 3D imaging, the drawbacks of examining 2-dimensional overlapping maxillary incisors can be overcome as we can now measure the root inclination of each individual incisor.

Therefore, the focus of this thesis will be centered around the association between the impacted canine and the adjacent maxillary incisor's root inclination, using 3D imaging to achieve this goal. We hope that an increased level of understanding in this regard will, in turn, aid general practitioners, orthodontists, and pediatric dentists in recognizing signs of maxillary canine impaction at an early stage, and potentially offer their patients possible preventive treatment measures before the aforementioned complications can occur.

Research Questions and Hypotheses

Question #1

Is the prevalence of palatal maxillary canine impaction in those diagnosed with Class II division 2 malocclusion different than that of other malocclusion types?

Hypothesis

Patients with the Class II division 2 malocclusion have a higher likelihood of demonstrating palatal maxillary canine impaction

- **Null hypothesis**:

  The prevalence of palatal maxillary canine impaction in those diagnosed with Class II division 2 malocclusion is the same as those with other malocclusion types.

- **Alternative hypothesis**:

  The prevalence of palatal maxillary canine impaction in those diagnosed with Class II division 2 malocclusion is different than that of those with other malocclusion types

Question #2

Do patients with palatally impacted maxillary canines exhibit differences in maxillary incisor root inclination compared to patients with buccally impacted or normally erupted canines?

Hypothesis

Patients with palatally impacted maxillary canines demonstrate buccally inclined roots of their maxillary incisors

- **Null hypothesis**:

  Patients with palatally impacted maxillary canines do not exhibit a statistically significant difference in maxillary lateral and central incisor root inclination when compared to patients with buccally impacted or non-impacted canines.

- **Alternative hypothesis**:

  Patients with palatally impacted maxillary canines do exhibit a statistically significant difference in maxillary lateral or central incisor root inclination when compared to patients with buccally impacted or non-impacted canines.

Question #3

Do patients with palatally or buccally impacted maxillary canines consistently exhibit differences in maxillary central or lateral incisor root inclination both ipsilaterally and contralaterally?

Hypothesis

A patient with an impacted maxillary canine will have a different inclination of the roots of the maxillary incisors on the side of the impaction compared to the unaffected side.

- **Null hypothesis**:

  Patients with palatally or buccally impacted maxillary canines do not exhibit a statistically significant difference in ipsilateral central or lateral incisor root inclination when compared to contralateral central or lateral incisor root inclination.

- **Alternative hypothesis**:

  Patients with palatally impacted maxillary canines do exhibit a statistically significant difference in ipsilateral central or lateral incisor root inclination when compared to contralateral central and lateral incisor root inclination.

Question #4

Does distance, vertical position, or impaction sector of the palatally or buccally impacted maxillary canine with respect to the adjacent lateral incisor have an association with the adjacent lateral incisor's root inclination?

Hypothesis

Factors pertaining to the impacted maxillary canine, such as its distance away from the adjacent lateral incisor, its vertical position with respect to the adjacent lateral incisor, and its impaction sector share an association with the root inclination of the adjacent lateral incisor

- **Null hypothesis**:

  Distance, vertical height, and impaction sector of the palatally or buccally impacted maxillary canine with respect to the adjacent lateral incisor have no association with the degree of the lateral incisor's root inclination.

- **Alternative hypothesis**:

  Distance, vertical height, or impaction sector of the palatally or buccally impacted canine crown is directly associated with the lateral incisor's root inclination.

References

1. Bass TB. Observations on the misplaced upper canine tooth. *Dent Pract Dent Rec.* 1967; 18:25–33.
2. Andreasen J O, Petersen J K, Laskin D M 1997. *Textbook and color atlas of tooth impactions, 1st edn*. Munksguard, Copenhagen
3. Becker A 2007 *The orthodontic treatment of impacted teeth, 2nd edn*. Informa Healthcare, London
4. Warford JH, Grandi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. *Am J Orthod Dentofac Orthop* 2003; 124:651-655.
5. Power SM, Short MB. An investigation into the response of palatally displaced canines to the removal of deciduous canines and an assessment of factors contributing to favourable eruption. Br J Orthod 1993;20:215–23
6. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. *Eur J Orthod* 1988; 10:283-295.
7. Baccetti T, Mucedero M, Leonardi M, Cozza P. Interceptive treatment of palatal impaction of maxillary canines with rapid maxillary expansion: a randomized clinical trial. *American Journal of Orthodontics & Dentofacial Orthopedics* 2009;136(5):657-61
8. Silvola AS, Arvonen P, Julku J, Lahdesmaki R, Kantomaa T, Pirttiniemi P. Early headgear effects on the eruption pattern of the maxillary canines. *Angle Orthodontist O* 2009;79(3):540-5
9. Leonardi M, Armi P, Franchi L, et al: Two interceptive approaches to palatally displaced canines: a prospective longitudinal study. *The Angle Orthodontist* 74(5): 581-6, October 2004
10. Sigler, Lauren M. et al. Effect of rapid maxillary expansion and transpalatal arch treatment associated with deciduous canine extraction on the eruption of palatally displaced canines: A 2-center prospective study. *American Journal of Orthodontics and Dentofacial Orthopedics*, Volume 139, Issue 3, e235 - e244
11. Alqerban A, Jacobs R, Lambrechts P, Loozen G, Willems G. Root resorption of the maxillary lateral incisor caused by impacted canine: a literature review. *Clin Oral Investig* 2009; 13: 247–255

12. Iramaneerat S, Cunningham SJ, Horrocks EN. The effect of two alternative methods of canine exposure upon subsequent duration of orthodontic treatment. *International Journal of Paediatric Dentistry* 1998;8(2):123-9.
13. Basdra EK, Kiokpasoglou M, Stellzig A. The Class II division 2 craniofacial type is associated with numerous congenital tooth anomalies. *Eur J Orthod* 2000; 22:529-535
14. Pereira PM, Ferreira AP, Tavares P, Braga AC. Different manifestations of class II division 2 incisor retroclination and their association with dental anomalies. *Journal of Orthodontics*, 2013; 40:4, 299-306
15. Nordenram A, Stromberg C 1966 Positional variation of impacted upper canine. *Oral Surgery, Oral Medicine, Oral Pathology* 22: 711–714
16. Lüdicke G, Harzer W, Tausche E. Incisor Inclination – Risk Factor for Palatally-impacted Canines. *J Orofac Orthop* 2008;69: 357–64
17. Broadbent BH. A new x-ray technique and its application to orthodontics. Angle Orthod 1931;1:45-66.
18. Oliveira CAP, Meurer MI, Pascoalato C, Silva SRC. Cone-beam computed tomography analysis of the apical third of curved roots after mechanical preparation with different automated systems. Braz Dent J 2009;20:376-381.
19. Alves MJ, Baratieri C, Nojima LI. Assessment of mini-implant displacement using cone beam computed tomography. Clin Oral Impl Res 2011 [DOI: 10.1111/J1600-0501.2010.02092.x. - Epub ahead of print].
20. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsh E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133.
21. Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, Farman AG. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone- beam computed tomography. Am J Orthod Dentofacial Orthop 2007;132:550-560.

Chapter 2 - The Class II Division 2 Malocclusion and Palatally Displaced Maxillary Canines: A Systematic Review

Introduction

Maxillary canines, which experience impaction in up to 2.4% of the general population [1], have three possible paths of impaction: Buccal, palatal, or in line with the dental arch. In the absence of local obstruction or pathology, when maxillary canines show buccal or in-line impaction, the cause is primarily due to dental crowding [2]. The reason for palatal impaction, however, is less apparent, which is why a wide array of theories regarding its etiology have been proposed in the literature [3-7]. Palatal impaction represents 70-85% of impacted canines [8] which may be the reason for being the focus of most previous studies, compared to buccal or in-line impactions.

While the etiology appears to be multifactorial, the prevalence of maxillary canine impaction within a specific orthodontic malocclusion classification has been long argued upon. Specifically, patients displaying a Class II Division 2 (CIID2) malocclusion, a specific form of malocclusion associated with mandibular retrognathism and other particular occlusal traits [9, 10], have approximately a 1-in-3 chance of having their maxillary canine impacted [11].

Based on the vast majority of maxillary canine impactions being palatal, and the heightened frequency of canine impaction within CIID2 subjects, this study aims to merge the analysis of these two factors into one review. Therefore, the purpose of this study is to systematically review the available literature that explores the link between the CIID2 malocclusion and more specifically the palatal route of maxillary canine impaction.

The question to be explored is:

> Among individuals with full permanent dentition, is the prevalence of palatally impacted maxillary canines in those diagnosed with Class II division 2 malocclusion different to that of other malocclusion types?

Methods

Our reporting methodology was conducted according to the template of The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA).

Protocol and registration

To date, there are no registered protocols on this topic, as verified by the international prospective register of systematic reviews (PROSPERO). This current protocol has been registered under ID: 193547.

Eligibility Criteria

The PICOS format was used to generate our question. Because our study was geared towards etiology, rather than intervention, the framework was altered accordingly:

Population: Patients in permanent dentition

Targeted group: CIID2 malocclusion

Comparison/Control: Other malocclusions

Outcome: Prevalence of palatally impacted maxillary canines

Study Design: Cross-sectional or Case-Control studies

Studies that demonstrated the following framework were also accepted:

Population: Patients in permanent dentition

Targeted group: Palatally impacted maxillary canines

Comparison/Control: Non-palatally (buccal or in-line) impacted, or regularly erupted maxillary canines

Outcome: Prevalence of the CIID2 malocclusion

Study Design: Cross-sectional or Case-Control studies

Both conceptual frameworks were considered as there is controversy on the timing of the assessed phenomena: Do the CIID2 malocclusion occlusal traits facilitate maxillary canine impaction or do cases developing maxillary canine impactions facilitate the development of CIID2 malocclusion?

Exclusion criteria consisted of interventional/treatment-centered studies, patients in mixed or primary dentition, syndromic patients, and cleft lip/palate patients.

Information Sources

A systematic search of six electronic databases was completed to identify relevant studies using PubMed, Medline, Cochrane, Embase, Web of Science, and Lilacs from the date of establishment of the databases to June 2020.

Search Strategy

Irrespective of language, the search was conducted using keywords, combinations of keywords with truncations, and Medical Subject Headings (MeSH). The search strategy was designed for PubMed and was adapted to facilitate our searches in the other databases [see Appendices 2.1 – 2.6]. A health sciences librarian was consulted to develop appropriate electronic searches.

Study Selection

Search results were initially reviewed by two individuals (NL and JK), where titles and abstracts were screened to remove unrelated articles. Any discrepancies were solved through the involvement of a third reviewer (CFM). Articles with relevant titles but that did not contain sufficient information in their abstracts were also selected for the next stage of review. The reference lists of selected studies were also analyzed, and pertinent articles were identified followed the same standards of selection as the original articles obtained from the database searches.

Data collection process and Data Items

Two independent reviewers (NL and JK) obtained data from each of the selected articles and compared their results for accuracy. Data that was obtained from the final selected studies included sample size, patient pool (i.e. samples grouped according to malocclusion, or samples grouped according to canine impaction), type of study, the prevalence of palatally impacted maxillary canines in CIID2 patients or vice versa.

Risk of bias in individual studies

The JBI critical appraisal tool [12] was used by the two reviewers (NL and JK) for assessing the risk of bias within each study independently, after which results were discussed until an agreement was reached.

Summary measures

In studies that used orthodontic malocclusion as their target group, summary measures were recorded as percentages representing the prevalence of patients demonstrating palatal maxillary canine impaction (either unilateral or bilateral) in the CIID2 group. Where applicable, these percentages were compared with the rate of palatal maxillary canine impaction in other malocclusion groups.

In studies that used maxillary canine impaction as their target group, percentages were recorded that represented the prevalence of the CIID2 malocclusion in the palatal impaction group. When applicable, these percentages were compared with the proportion of the CIID2 in the buccal impaction or control groups.

Synthesis of results

A statistical combination of data was not performed in our systematic review. The identified methodological, clinical and statistical heterogeneity did not support any meta-analysis.

Risk of bias across studies

An assessment of the risk of bias across studies was made for the primary outcome of this study, namely the prevalence of palatally impacted maxillary canines in different malocclusion types.

Results

Study Selection

The article selection process at each stage of the review is represented in Figure 2.1. Of the 1,246 citations initially identified through electronic searching, only 15 were considered eligible, and full texts were retrieved after reading of abstracts. Subsequently, 11 articles were excluded for specific reasons (Table 2.1), leaving 4 studies being included in this systematic review.

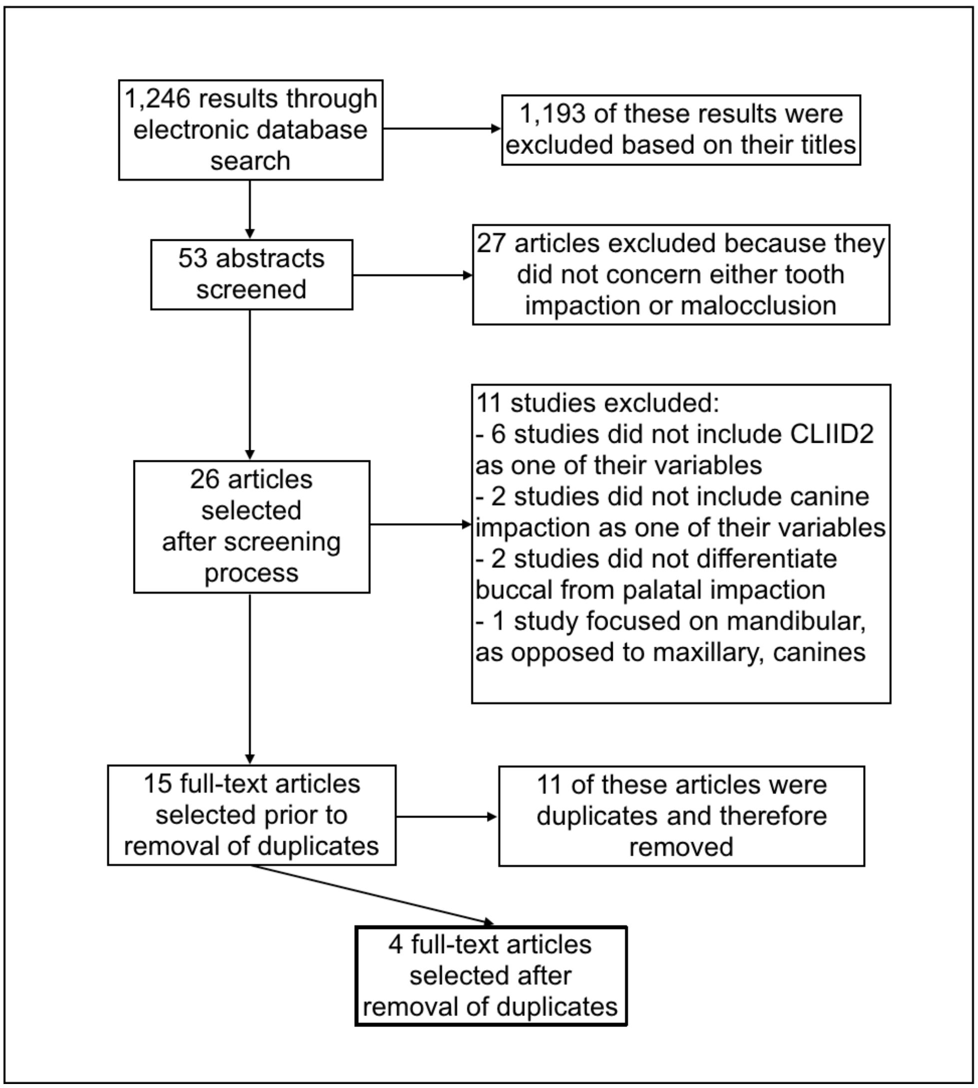


Figure 2.1. Flow chart of the study selection process

Author / Year / Country	Title	Reason for exclusion
Harzer et. al *1994* *Germany*	*The orthodontic classification of impacted canines with special reference to the age at treatment, the angulation and dynamic occlusion*	No differentiation was made between buccal vs. palatal impaction
Basdra et. al *2000* *Germany*	*The Class II division 2 craniofacial type is associated with numerous congenital tooth anomalies*	No differentiation was made between buccal vs. palatal impaction
Basdra et. al *2001* *Germany*	*Congenital tooth anomalies and malocclusions: A genetic link?*	The article did not specify the CIID2 malocclusion
Mossey et. al *1994* *Belgium*	*The palatal canine and the adjacent lateral incisor: a study of a west of Scotland population*	The article did not specify the CIID2 malocclusion
Al-Jabaa and Aldrees *2013* *Saudi Arabia*	*Prevalence of Dental Anomalies in Saudi Orthodontic Patients*	The article did not specify the CIID2 malocclusion
Mercuri et. al *2013* *Italy*	*Skeletal features in patients affected by maxillary canine impaction*	The article did not specify the CIID2 malocclusion
Amini et. al *2017* *Iran*	*Associations between occlusion, jaw relationships, craniofacial dimensions and the occurrence of palatally displaced canines*	The article did not specify the CIID2 malocclusion
Al-Amiri et. al *2013* *Buffalo*	*The Prevalence of Dental Anomalies in Orthodontic Patients at the State University of New York at Buffalo*	The article did not specify the CIID2 malocclusion
Walkow *2002* *California*	*Dental arch width in Class II Division 2 deep- bite malocclusion*	Despite the title potentially suggesting it may discuss tooth impaction, after reading the article it was clear that it did not
Jain et. al *2014* *Australia*	*Permanent mandibular canine(s) impaction: expansion of our understanding*	This article studied impacted mandibular, as opposed to maxillary, canines
Willems et. al *2001* *Belgium*	*Prevalence of dentofacial characteristics in a Belgian orthodontic population*	This paper studied general “tooth impactions”, as opposed to canine impaction

Table 2.1. A summary of the 11 excluded articles from the final process of the study selection

Study Characteristics

The selected articles all consisted of cross-sectional analyses of retrospective data and were published between the years of 2005 and 2013. One of the original 15 chosen articles was written in German [13], which was translated with the help of a graduate student at the University of Alberta who was fluent in written German. The final 4 articles were written all in English. There were two articles whose targeted group was canine impaction, with sample sizes ranging from 34-148 palatal maxillary canine impactions. The remaining two articles had CIID2 as their targeted group, with sample sizes ranging from 51-115 CIID2 patients. See Table 2.2 for a summary of the study characteristics of the four articles included in the review.

Risk of Bias in the included Studies

All included studies contained a selection bias in that the patient pool consisted strictly of individuals seeking orthodontic treatment, which is not likely representative of the general population. Another critical issue in these papers is the lack of detail in how CIID2 malocclusions were diagnosed. Two papers (*16, 17*) only addressed the reliability of measurements between two evaluations from the same examiner, and one study [14] lacked any sign of exclusion criteria. All papers addressed cofounding variables to some degree, albeit different variables within each article. (Table 2.3)

Results of the Individual Studies

All the included studies were considered cross-sectional studies.

Of the four articles, three [14, 16, 17] (*Al-Nimri et al. 2005, Pereira et al. 2013, Ludicke et al. 2008*) included specific information regarding palatal vs. buccal maxillary canine impaction. All three of these articles discovered an increased prevalence of maxillary palatal canine impaction in CIID2 subjects, with percentages ranging from 20-45%. Although one article from our final selection did not differentiate between buccal or palatal impaction [15] (*Uslu et al. 2009*), it was nevertheless selected. The reason for this is because it found a complete absence of tooth impaction (which by definition would include maxillary canine palatal impaction) in the CIID2 malocclusion. Unlike the 33.5% prevalence of generalized maxillary canine impaction found by Basdra et al. [11], where it is impossible the exact prevalence of specifically palatal impactions, it can be inferred from Uslu et al. that palatally impacted maxillary canines showed a prevalence of 0% in the CIID2 malocclusion. A summary of the selected articles is represented in Table 2.2, with the pertinent prevalence highlighted in bold.

Synthesis of results

As mentioned in the methods section, a synthesis of results across studies was not performed in our review.

Risk of bias across studies

Because all the included studies were analytical cross-sectional studies with significant methodological deficiencies the available quality of evidence to answer the stated review question was considered very low.

Author/Year/ Country	Title	Study	Sample	Results
Al-Nimri et. al. *2005* *Jordan*	*Space conditions and dental and occlusal features in patients with palatally impacted maxillary canines: an etiological study*	Cross Sectional	Palatal impactions (34) Control (34)	• **Palatal canine impaction occurred most frequently in subjects with a CIID2 malocclusion (44%)**, compared to CLI (35%), CIID1 (9%), and CLIII (12%) malocclusions • Palatal canine impaction was associated with anomalous lateral incisors ($P = 0.01$) and a wider transverse arch dimension ($P < 0.01$)
Ludicke et al. *2008* *Germany*	*Incisor Inclination – Risk Factor for Palatally-impacted Canines*	Cross Sectional	Patients with impacted canines: Palatal (148) Buccal (51)	• 74.4% of canine impactions were palatal (PI), thus concurring with the incidence reported in the general population • **Symptoms of CIID2 exist in 45% of those patients with palatally impacted (PI) canines**, as opposed to the general population (10%) • Mean incisor inclination was significantly more retroclined in patients with palatal (18.1°) than buccal (19.2°) impaction • The angle between the long axis of the canine and occlusal plane was statistically significantly smaller in the PI group (67.3°) than the BI group (77°)
Pereira et. al. *2013* *Portugal*	*Different manifestations of class II division 2 incisor retroclination and their association with dental anomalies*	Cross Sectional	Group 1: Retroclined Centrals Only (48) Group 2: Retroclined Four Incisors (67)	• In the total sample, the **prevalence rate of maxillary canine impaction was 20.0%, all of which were palatal** • **100% of these impactions were in group 2 only (34.3%)** • There exists a strong association of palatal canine impaction, tooth agenesis and maxillary lateral incisor microdontia with Group 2 but not with Group I
Uslu et. al. *2009* *Turkey*	*Prevalence of dental anomalies in various malocclusions*	Cross Sectional	CL1 (358) CIID1(325) CIID2 (51) CIII (166)	• Except for tooth impaction and short/blunt roots, no statistically significant correlations were found between dental anomaly and type of malocclusion • 2.9% of patients showed tooth impaction (26/900), with the maxillary canine being the most frequent at 30.8% (8/26) • **Impaction was lower in the CIID1 (1.2%) and CIID2 (0%) groups** than in both CI (4.2%) and CIII groups (4.2%)

Table 2.2. Summary of study characteristics of the included articles

Risk of bias Criterion	Study			
	Al-Nimri	Ludicke	Pereira	Uslu
Were the criteria for inclusion in the sample clearly defined?	**No** Exclusion criteria were not defined	**Yes**	**Yes**	**Yes**
Were the study subjects and the setting described in detail?	**Yes** Demographics, location and time period were specified	**No** While demographics were specified, there was no mention of location or time period of treatment	**Yes** Demographics, location and time period were specfied	**No** While demographics and location were specified, there was no mention of time period of treatment
Was the exposure measured in a valid and reliable way?	**No**	**No**	**No**	**No**
Were objective, standard criteria used for measurement of the condition?	**No** The study fails to provide key criteria for clinical diagnosis of CLIID2 mal-occlusion, such as radiographs and clinical examination, and was based on dental casts alone. No mention of molar relationship was made, and diagnosis relied strictly on incisor inclination	**No** The study only uses SNA in its radiographic sagittal assessment, and its results for direction of growth (MP-PP) suggested a vertical growth pattern, as opposed to the pathognomonic horizontal growth pattern of CIID2	**No** The CLIID2 malocclusion was diagnosed based on "class 2 molar relationship", "overbite equal or greater than 50%", and "angle between the maxillary incisor long axis and the palatal plane". However, radiographic measurements along with growth direction were not included	**No** While the study describes details used in diagnosing CIID2 (cephalometric measurement ANB, molar relationship, and deep bite), there is no mention of growth direction nor incisor inclination.
Were confounding factors identified?	**Yes**	**No** While "congenitally missing lateral incisors" were excluded from the study, there was no mention of anomalous or peg-shaped maxillary lateral incisors	**Yes**	**Yes**
Were strategies to deal with confounding factors stated?	**Yes** "The differences between the impaction and comparison groups were determined using a chi-square test for anomalous lateral incisors"	**N/A**	**Yes** "Chi-square tests were performed in order to evaluate whether there is an association of DDAs with the groups studied"	**Yes** "Chi-square, Fisher exact, and z tests were conducted to determine the statistical significance of dental anomalies by malocclusion type"
Were the outcomes measured in a valid and reliable way?	**Yes**	**No** There was no mention of intra-examiner reliability analysis, and only that "*all measurements were taken by a single investigator*" without any further information	**No** The only quantifiable variables were "angle between maxillary incisors and palatal plane" and "amount of deep bite", of which no mention of intra-examiner reliability analysis was mentioned	**Yes**
Was appropriate statistical analysis used?	**Yes**	**Yes**	**Yes**	**Yes**

Table 2.3. JBI critical appraisal tool assessing risk of bias

Discussion

Our systematic review revealed very few published studies that evaluated the association between CIID2 malocclusion and palatally impacted maxillary canines. While several articles [18-19] reported that there was no statistically significant association between palatally impacted maxillary canines and the CII malocclusion, they did not include the Division 2 subtype in their research. Other studies [20-21] that did incorporate the CIID2 malocclusion did not specify type of canine impaction. Two of the pre-selected articles [11, 13] observed rates of generalized (buccal or palatal) maxillary canine impaction in CIID2 patients at rates of 33.5-41%; however, since these articles did not offer information specific to the palatal route of impaction, they were excluded.

While two of our finally selected articles noted a 44-45% prevalence of the CIID2 malocclusion in palatal impactions and one noted a 20% prevalence of palatal canine impactions in the CIID2 malocclusion, these studies did not provide adequate detail regarding criteria used to diagnosis of CIID2 malocclusion.

Al-Nimri et al. [14] relied on dental casts alone and diagnosed strictly on incisor inclination without any recording of molar relationship. And while Pereira et al. [16] included molar relationship, overbite, and incisor inclination in their diagnosis, they failed to include cephalometric criteria or growth direction.

Ludicke et al. [17] did include cephalometric criteria, which included SNA and Mandibular Plane to Palatal Plane Angle. However, SNA does not provide information regarding the position of the mandible in relation to the maxilla, and therefore cannot contribute to the diagnosis of the CIID2 malocclusion. Furthermore, the study reported all patients had a mandibular-to-palatal-plane angle ranging from 23.3° to 25.8°, all of which were above the cited reference value of 21° in that study. An increased angle such as this would indicate more of a vertical growth pattern, which is atypical of the CIID2 malocclusion that usually displays a horizontal growth pattern [9-10]. Another critical issue with this study is that it refers to a "Table 1" when it mentions the prevalence of CIID2 in cases of palatal impactions, however this table is nowhere to be found, nor does the article include any information regarding the prevalence of the other malocclusions in palatal impactions.

The article [15] that identified a 0% prevalence of palatal (and even buccal) canine impaction in CIID2 malocclusion patients (Uslu et al.) also lacked substantial detail in diagnosing CIID2 malocclusion. The diagnosis of ClID2, which has the smallest sample size compared to the other malocclusion (n=51 compared to n>165), included sagittal cephalometric parameters (ANB), molar relationship, and "deep bite". Details relating to the direction of skeletal growth pattern and incisor inclination, however, were not provided.

Further insight may be obtained by considering articles based on their respective targeted groups: (1) canine impaction, or (2) malocclusion type. The two studies (Al-Nimri et al., Ludicke et al.) that used palatally impacted canines as their targeted group reported very similar prevalence results, where 44-45% of the samples displayed a CIID2 malocclusion. Conversely, the two studies (Uslu et al., Pereira et al.) that reported a prevalence ranging from 0-20% had CIID2 malocclusion patients as their targeted group. It can therefore be interpreted that the prevalence of the CIID2 malocclusion in patients with palatal maxillary canine impaction stood at approximately 45%, in contrast to the prevalence of palatal impactions in patients displaying the CIID2 malocclusion, which ranged from 0-20%.

The differing prevalence of palatal canine impaction reported by the two studies that targeted CIID2 malocclusion, with one study showing 20% and the other 0%, can potentially be explained in light of the fact that the CIID2 malocclusion can further be subdivided into two groups: (A) Retroclined central and lateral maxillary incisors, and (B) retroclined central incisors, with lateral incisors showing normal inclination or proclination. Pereira et al., who reported the 20% prevalence, made this differentiation in CIID2 malocclusion patients and further pointed out that every single case of palatal impaction in their study was found in group A (all four incisors retroclined). In contrast, none were found to be in group B (retroclined centrals, normal laterals). Since Uslu et al. did not report the sub-classifications of the CIID2 malocclusion, it is possible that their sample consisted of CIID2 malocclusion patients belong primarily to group B. Indeed, earlier "classic" articles and textbooks that aimed to define the CIID2 malocclusion only mention patients matching the group B classification [22-24], an approach that Uslu et al. may have also been using.

Concerning this potential association between palatal maxillary canine impaction and lateral incisor retroclination, two of the included articles actually quantified incisor inclination to some extent [16, 17]. However, these measurements were made off of 2-Dimensional radiographs that likely assessed the overlap of several incisors. A high degree of uncertainty exists if what was actually measured was a specific incisor type or if it was the right or left incisor. Nevertheless, not all CIID2 malocclusion types depict the same incisor root inclination trends.

<u>Limitations</u>

Beyond the number of biases within the individual studies, the grey literature was not explored, which represents a potential for incomplete retrieval of identified research on the topic in question.

The methodological, clinical and statistical heterogeneity between the included studies made it impossible to conduct a meta-analysis for our systematic review, but this is a reflection of the limited available identified evidence, rather than a limitation of the systematic review.

Future Research

Our discussion suggests that palatal maxillary canine impaction may at least in part be affiliated with the inclination degree of the adjacent lateral incisors more so than other aspects of the CIID2 malocclusion. While two of the included studies suggested that palatally impacted maxillary canines may be associated with a decreased inclination of upper incisors [16,17], a significant drawback in these studies is that incisor inclination assessment was carried out using 2-dimensional radiographic measurements. One reason why these measurements are unfavorable is because they only give a singular value of inclination for all 4 maxillary incisors, often correlating to the central incisors only. Furthermore, the unavoidable overlap of teeth in a 2-dimensional image potentially yields inaccurate measurements. Future research with 3D imaging may provide insight regarding the relative association of lateral incisor inclination with palatal maxillary canine impaction.

Conclusions

The available literature suggests an increased prevalence of maxillary canine palatal impaction in the Class II division 2 malocclusion. However methodological and clinical differences in the published studies, including lack of clarity on diagnostic criteria of the malocclusion, precludes definitive conclusions.

References

1. Warford JH, Grandi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. *Am J Orthod Dentofac Orthop* 2003; 124:651-655.

2. Jacoby H 1983 The etiology of maxillary canine impactions. *American Journal of Orthodontics* 84: 125–132

3. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. *Angle Orthod* 1994; 64:249-256.

4. Becker A, Chaushu S. Dental age in maxillary canine ectopia. *Am J Orthod Dentofac Orthop* 2000; 117:657-662.

5. Becker A, Smith P, Behar R 1981 The incidence of anomalous lateral incisors in relation to palatally displaced cuspid. *Angle Orthodontist* 51: 24–29

6. Stellzig A, Basdra E K, Komposch G 1994 The etiology of canine impaction–space analysis. *Fortschritte der Kieferorthopädie* 55: 97–103

7. McConnell T L, Hoffman D L, Forbes D P, Jensen E K, Wientraub N H. 1996. Maxillary canine impaction in patients with transverse maxillary deficiency. *Journal of Dentistry for Children* 63: 190–195

8. Nordenram A, Stromberg C 1966 Positional variation of impacted upper canine. *Oral Surgery, Oral Medicine, Oral Pathology* 22: 711–714

9. Dodda KK, Prasad SERV, Kanuru RK, Nalluri S, Mittapalli R, Raghavendra. Diagnostic features of Angle's Class II div 2 malocclusion. *Journal of International Society of Preventive & Community Dentistry*. 2015; 5(6):513-517

10. Prasad SERV, Indukuri RR, Singh R, Nooney A, Palagiri FB, Narayana V. Pathognomonic features of Angle's Class II division 2 malocclusion: A comparative cephalometric and arch width study. *Journal of International Society of Preventive & Community Dentistry*. 2014; 4(Suppl 2): S105-S109

11. Basdra EK, Kiokpasoglou M, Stellzig A. The Class II division 2 craniofacial type is associated with numerous congenital tooth anomalies. *Eur J Orthod* 2000; 22:529-535.

12. Moola S, Munn Z, Tufanaru C, Aromataris E, Sears K, Sfetcu R, Currie M, Qureshi R, Mattis P, Lisy K, Mu P-F. Chapter 7: Systematic reviews of etiology and risk. In: Aromataris E, Munn Z (Editors). *Joanna Briggs Institute Reviewer's Manual.* The Joanna Briggs Institute, 2017.

13. Harzer W, Seifert D, Mahdi Y. The orthodontic classification of impacted canines with special reference to the age at treatment, the angulation and dynamic occlusion. *Fortschr Kieferorthop*. 1994 Apr;55(2):47-53.
14. Al-Nimri K and Gharaibeh T. Space conditions and dental and occlusal features in patients with palatally impacted maxillary canines: an aetiological study. *European Journal of Orthodontics* 27 (2005) 461–465
15. Uslu O, Okan Akcam M, Evirgen S, Cebeci I. Prevalence of dental anomalies in various malocclusions. *American Journal of Orthodontics and Dentofacial Orthopedics* 2007; Vol 135, Number 3 17.
16. Pereira PM, Ferreira AP, Tavares P, Braga AC. Different manifestations of class II division 2 incisor retroclination and their association with dental anomalies. *Journal of Orthodontics*, 2013; 40:4, 299-306
17. Lüdicke G, Harzer W, Tausche E. Incisor Inclination – Risk Factor for Palatally-impacted Canines. *J Orofac Orthop* 2008;69: 357–64
18. Amini F, Shayesteh H, Mona HG, Vahid R. Associations between occlusion, jaw relationships, craniofacial dimensions and the occurrence of palatally-displaced canines. *Int Orthod*. 2017 Mar;15(1):69-81.
19. Mercuri E, Cassetta M, Cavallini C, Vicari D, Leonardi R, Barbato E. Skeletal features in patient affected by maxillary canine impaction. *Med Oral Patol Oral Cir Bucal*. 2013 Jul 1;18(4):e597-602.
20. Willems G, De Bruyne I, Verdonck A, Fieuws S, Carels C. Prevalence of dentofacial characteristics in a Belgian orthodontic population. *Clin Oral Invest* (2001) 5:220–226
21. Al-Amiri A1, Tabbaa S, Preston CB, Al-Jewair T. The prevalence of dental anomalies in orthodontic patients at the State University of New York at Buffalo. *J Contemp Dent Pract.* 2013 May 1;14(3):518-23.
22. Uribe F, Nanda R. Treatment of Class II, Division 2 Malocclusion in Adults: Biomechanical Considerations. *Journal of Clinical Orthodontics*. 2003. P.599
23. Scheid RC, Weiss G. *Woelfel's Dental Anatomy*. 2012. II;9, p.256
24. Hanson ML, Mason RM. *Orofacial Myology*. 2003, p.168

Chapter 3 - 3D Analysis of Maxillary Incisor Root Inclinations in Cases of Unilateral Maxillary Canine Impaction

Introduction

In the systematic review reported in Chapter 2, the association between CIID2 malocclusion and palatal maxillary canine impaction was discussed. It was suggested that the higher percentage of impactions seen in the CIID2 malocclusion could possibly have more to do with the root inclination of the maxillary incisors, rather than the overall CIID2 malocclusion characteristics *per se*.

There are multiple theories aimed at explaining the etiology for palatal canine impaction. One of the main schools of thought, coined "The Guidance Theory", suggests that the position of the maxillary lateral incisor's root has a direct influence on the neighboring canine's path of eruption [3,4]. In typical scenarios, the maxillary canine descends with a mesial angulation until it reaches the distal and palatal aspect of the maxillary lateral incisor [5], after which it utilizes the lateral incisor's root to upright itself towards normal eruption [6]. The Guidance theory posits that in cases where the lateral incisor's root is malformed or delayed in development due to genetic disturbances, the adjacent canine loses its typical mechanical guidance into the dental arch. Hence, the canine continues to erupt with a palatal direction and mesial angulation until it gets impacted somewhere in the maxilla. Using the same line of reasoning, if the lateral incisor root was abnormally buccally positioned, then the canine would follow a more palatal path into the dental arch guided by the palatally position incisor root. Pereira et al. reported differences in the prevalence of impaction between CII d2 malocclusion types A and B, which supports the Guidance theory.

The other primary theory, known as “The Genetic Theory” [7], suggests that the maxillary lateral incisor root does not directly influence the adjacent canine eruption. Instead, the theory proposes that there is a large genetic umbrella that simultaneously includes multiple disturbances, one being lateral incisor malformation/delayed development and another one being palatal canine impaction. To support this theory, Pereira et al. [1] suggested that retroclination of the four maxillary incisor crowns should be included in the overall genetic umbrella of the CIID2 malocclusion.

The current body of literature has delved into each theory, and valid points of the argument have been developed that offer support for each side; however, an overall consensus has not been reached [8]. Some authors [9] have concluded that the genetic theory is superior, stating that “in *52–57% of cases, palatally displaced canines are adjacent to normally developed incisors.”* However, the notion that incisor inclination can play a role in canine impaction has not been thoroughly investigated. While most of the existing research has analyzed the shape, size, and morphological development of the lateral incisor with respect to palatal maxillary canine impaction, only few attempts have focused on maxillary lateral incisor root inclination [1, 10]. The reason why previous studies have not explored this is likely because they would have needed to rely upon 2-dimensional cephalograms to quantify buccolingual incisor root inclination. Lateral cephalograms only assess the inclination of several superimposed incisors making a clear identification of the maxillary lateral root inclination of interest almost impossible. With the advent and increasing usage of 3-dimensional imaging, we now possess the opportunity to quantify root inclination of each individual maxillary incisor. Because the impacted palatal canine can be displaced medially to the extent that it approaches the midline of the maxillary dentition, CBCT imaging would allow assessment of the inclination of the maxillary central incisors as well.

The objective of this retrospective and observational study was to evaluate the association between maxillary lateral incisor root inclination and unilateral canine palatal impaction. Three-dimensional imaging was used to quantify buccolingual incisor root angulation as associated with the palatal maxillary canine impaction. Also, the distance and vertical position of the canine crown with respect to the adjacent lateral incisor root will be considered.

Research questions and hypotheses

Question #1

Do patients with palatally impacted maxillary canines exhibit differences in maxillary incisor root inclination compared to patients with buccally impacted or normally erupted canines?

Hypothesis

Patients with palatally impacted maxillary canines demonstrate buccally inclined roots of their maxillary incisors

- **Null hypothesis**:

  Patients with palatally impacted maxillary canines do not exhibit a statistically significant difference in maxillary lateral and central incisor root inclination when compared to patients with buccally impacted or non-impacted canines.

- **Alternative hypothesis**:

  Patients with palatally impacted maxillary canines do exhibit a statistically significant difference in maxillary lateral or central incisor root inclination when compared to patients with buccally impacted or non-impacted canines.

Question #2

Do patients with palatally or buccally impacted maxillary canines consistently exhibit differences in maxillary central or lateral incisor root inclination both ipsilaterally and contralaterally?

Hypothesis

A patient with an impacted maxillary canine will have a different inclination of the roots of the maxillary incisors on the side of the impaction compared to the unaffected side.

- **Null hypothesis**:

  Patients with palatally or buccally impacted maxillary canines do not exhibit a statistically significant difference in ipsilateral central or lateral incisor root inclination when compared to contralateral central or lateral incisor root inclination.

- **Alternative hypothesis**:

  Patients with palatally impacted maxillary canines do exhibit a statistically significant difference in ipsilateral central or lateral incisor root inclination when compared to contralateral central and lateral incisor root inclination.

Question #3

Does distance, vertical position, or impaction sector of the palatally or buccally impacted maxillary canine with respect to the adjacent lateral incisor have an association with the adjacent lateral incisor's root inclination?

Hypothesis

Factors pertaining to the impacted maxillary canine, such as its distance away from the adjacent lateral incisor, its vertical position with respect to the adjacent lateral incisor, and its impaction sector share an association with the root inclination of the adjacent lateral incisor

- **Null hypothesis**:

  Distance, vertical height, and impaction sector of the palatally or buccally impacted maxillary canine with respect to the adjacent lateral incisor have no association with the degree of the lateral incisor's root inclination.

- **Alternative hypothesis**:

  Distance, vertical height, or impaction sector of the palatally or buccally impacted canine crown is directly associated with the lateral incisor's root inclination.

Materials & methods

This retrospective cross-sectional study was approved by the ethics committee of the University of Alberta (ID: Pro00087314).

Patient Selection

All patients included in the study were patients of the University of Alberta Orthodontic Graduate Clinic, where the sample of patients was divided into 3 groups:

(1) Palatally impacted canines (from now on: group P)

(2) Buccally impacted canines (from now on: group B)

(3) Comparison/Control group: Normally erupted canines (from now on: group C)

To identify subjects for groups P and B, the principal investigator (NL) requested residents and instructors of the graduate clinic to identify patients under their care that they deemed were "impacted canine cases". Additionally, spreadsheets of resident cases from the current year (2020) going as far back as 2014 were collected (earlier spreadsheets were not available), where key phrases such as, "impaction", "canine", "cuspid", or "exposure" (as many patients with impacted canines were scheduled on the spreadsheet for surgical exposure) were scanned by the principal investigator (NL) to determine suitable patients for the study. Final patient selection was confirmed via examination of the orthodontic radiographic records in Dolphin Imaging 11.7 Premium (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). Patients in group C were selected through spreadsheets of patients belonging to particular instructor clinics that had a higher propensity for 3-D imaging as part of their general diagnostic examination.

Cases that the principal investigator (NL) experienced uncertainty in adopting the inclusion or exclusion criteria (listed below) were presented to the research supervisor (CFM) to make the final decision of whether or not to include them in our study.

Inclusion criteria:

- Patients that were in permanent dentition
    - Some patients that were mixed dentition were included as well. These were cases that were predicted to undergo abnormal canine eruption even before their average eruption period due to the position of tooth germ, tooth shape, direction of eruption, and available space, as per previous literature that classifies tooth impaction [11, 12]. Nevertheless, these cases were included provided that at least the first maxillary premolar erupted on the side of impaction
- Unerupted maxillary canines positioned either buccally or palatally to the dental arch
- Pre-treatment Cone-Beam Computed Tomographic (CBCT) images that included palatal plane and complete visualization of the anterior maxillary dentition (canines and incisors)

Exclusion criteria

- Canine impactions that were neither buccal nor palatal, but in line within the dental arch
- Bilateral canine impactions
- Unerupted permanent first maxillary premolars
- Pathology in the maxilla (cysts, odontoma, etc.)
- Patients presenting with at least one congenitally absent maxillary tooth other than the 3rd molar

- Severe root resorption, to the extent that the line of axis of at least one maxillary incisor was indistinguishable
- Patients that have reported a history of significant facial trauma
- Patients who have previously had orthodontic treatment

Measurement of Incisor Root Inclination

Because the vast majority of our retrospective sample consisted of small field of view images, the most relevant reference line to determine incisor angulation was the palatal plane, which is measured from Anterior Nasal Spine (ANS) to Posterior Nasal Spine (PNS) [13]. Using Dolphin Imaging Software, the two landmarks (ANS and PNS) were directly demarcated on 3D volume, after which they were confirmed on axial, sagittal, and coronal slices of the scan (Figure 3.1). Incisor root inclination is measured in relation to the ANS to PNS line through the line of axis of each maxillary incisor (Figure 3.2). The smaller the measured angle, the more forward the root of the incisor was inclined.

Measurement of the distance of impacted canine from lateral incisor root

Using Dolphin 3-D Imaging software, surrounding obstacles were spliced away to obtain the best view that allowed demarcation of the shortest distance between the canine crown and the root of the closest lateral incisor (Figure 3.3). The selection of the shortest distance was verified in sagittal and axial slices.

Measurement of the vertical height of impacted canine relative to lateral incisor root

The impacted canine's vertical position along the root of the adjacent lateral incisor was measured in the sagittal view and was recorded as a fractional value between two distances (Figure 3.4). The first distance was between the lateral incisor's cementoenamel junction (CEJ) and the point at which the canine was most proximal to the lateral incisor's root (the same landmark used above when measuring proximity). The second measurement was the length of the entire root of the incisor (from CEJ to apex).

Assessment of Impaction Zone

Using a CBCT-constructed orthopantomogram, medial crown position of the impacted canine within sectors 1-5 was recorded in the frontal view according to the method of Ericson and Kurol [14] (Figure 3.5).

Presence of deciduous canine

Presence or not of deciduous canine was noted.

Statistical analysis

Age and gender of patients in our sample were recorded. Malocclusion of each patient was diagnosed according to molar and canine relationship based on dental casts and intra-oral images, and cephalometric data (ANB). Diagnosis of the CLIID2 malocclusion specifically relied on the following criteria: (1) CLII molar relationship, (2) Increase overbite of >50%, (3) Retroclination of maxillary incisors (U1-SN <97 degrees), (4) Retrognathic mandible (ANB >3 degrees), and (5) Hypodivergent growth pattern (either MP-SN <27 degrees or MP-Occ plane

<11.6 degrees). Cephalometric reference values are based on one standard of deviation beyond the norm according to the Jarabak analysis. Fisher's exact test was used to ascertain if statistically significant associations existed between gender and malocclusion in the 3 groups, and a Kruskal-Wallis analyses was performed to determine if a significant association existed between the age of the patient and the respective group they belonged to.

<u>Reliability</u>

Intra-examiner reliability was assessed with the Intra-class Correlation Coefficient (ICC) using standard statistical software package (SPSS Statistics version 23 for Mac, IBM). ICC was chosen to assess the consistency and reproducibility of quantitative measurements taken 2 months apart by the principal investigator (NL) on 10 randomly selected patients. The repeatability of incisor root inclination for each maxillary incisor, the distance of the impacted canine from the adjacent lateral incisor, and the vertical position of the impacted canine with respect to the root of the lateral incisor was analyzed. Because the impaction sector is categorical, therefore being a more defined variable, intra-examiner reliability was not conducted. For statistical analysis, a single measure with absolute agreement under a two-way mixed model was chosen in SPSS to ensure all measurements and time points are in absolute agreement on the individual measurements rather than simply being correlated with each other on average.

<u>Research question #1 (Type of Canine Impaction and Incisor Root Inclination)</u>

The One-Way Analysis of Variance (ANOVA) was used to determine whether there were any differences between the 3 independent groups of impaction (Palatal, Buccal, and Comparison) in relation to the 4 continuous dependent variables of incisor root inclination for each maxillary incisor. Because patients in our study had either right or left maxillary canines being impacted, the incisors were divided as: (1) ipsilateral central incisor, (2) ipsilateral lateral incisor, (3) contralateral central incisor, and (4) contralateral lateral incisor.

Because patients in the comparison group did not have an impacted canine, we therefore do not have an objective "ipsilateral central and lateral incisor". Consequently, we randomly allocated half of the comparison group into "ipslateral" centrals and laterals, and the other half into "contralateral" centrals and laterals.

<u>Research question #2 (Ipsilateral vs. Contralateral Incisor Root Inclination)</u>

For groups P and B, our goal was to conduct a paired T-test to ascertain whether there is a significant difference in incisor root inclination between the ipsilateral and contralateral sides. One paired T-test was done to compare the lateral incisors, while another was done to compare the centrals.

To avoid the potential argument that the side of a person's face acts as a confounding variable towards incisor root inclination, paired T-tests were performed in group C as well. One test compared left vs. right lateral incisor root inclination, while another compared the centrals.

For a paired t-test, descriptive statistics and normality tests are performed not on the individual incisors, but on the vector difference between the root inclination of the incisor on the side of the canine impaction and that of its counterpart on the contralateral side.

Research question #3 (Distance, vertical height, and impaction sector of the impacted canine crown with respect to lateral incisor)

A Pearson correlation analysis was conducted for group P and group B subjects to determine the potential relationship between all three variables of the impacted canine crown with respect to the lateral incisor root, and the degree of the lateral incisor's root inclination. Our interpretations of correlation values went along with the conventions of Cohen (1988) [15].

Because an argument can potentially be made that a maxillary lateral incisor's root inclination can be influenced by the presence, or lack thereof, of the adjacent primary canine, this variable was also included in the Pearson analysis.

To address the potential confounding variable of peg-shaped or small maxillary lateral incisors in our study, we conducted the 3 research questions after removal of all patients demonstrating lateral incisors that were either peg-shaped or that had a smaller mesial-distal width of 5mm (there were three cases found in group P, two in group B, and one in group C).

Results

Sample size and demographics

After the application of inclusion and exclusion criteria, the sample consisted of 72 pre-treatment CBCT scans (27 palatal impactions, 15 buccal impactions, and 30 comparison patients).
Gender did not show a statistically significant association with any of the groups ($p = 0.491$), and the entire sample was made up of 45 females (62.5%) and 27 males (37.5%). Ages of patients

ranged from 10 years and 3 months to 49 years and 4 months, and patient's age did not demonstrate a statistically significant association with any of the groups (p = 0.259). Concerning malocclusion type per group, group P consisted of 55.6% CLI (n = 15), 22.2% CLII (n = 6), 11.1% CIID2 (n = 3), and 11.1% CLIII (n=3). Group B consisted of 53.3% CL1 (n = 8) and 46.7% CLII (n = 7), and did not contain any patients with the CLIID2 or CLIII malocclusion. Group C consisted of 50% CLI (n = 15), 33.3% CLII (n = 10), and 16.7% CLIII (n = 5), and did not contain any patients with the CLIID2 malocclusion. The entire sample consisted of 53% CLI (n = 38), 32% CLII (n = 23), 4.2% CLIID2 (n = 3), and 11% CLIII (n = 8), where all of the CLIID2 cases were found in group P only, and no statistically significant association was found between malocclusion and any of the groups (p = 0.214). Frequency statistics and results of the Fisher's and Kruskal Wallis tests can be seen in Appendices 3.1-3.3.

<u>Reliability</u>

The intra-examiner reliability of all 4 maxillary incisor root inclinations, canine vertical position, and canine proximity can be seen in Appendix 3.4. Incisor root inclination showed a statistically significant (p<0.0001) very high level of reliability with an ICC of 0.982 (CI 0.966, 0.991) and mean error of fewer than 0.5 degrees. ICC for the canine vertical position ratio was statistically significantly (p=0.001) high at 0.827 (CI 0.459, 0.954) with a mean error of 0.007. Lastly, reliability for distance of the impacted canine from the adjacent incisor root was statistically significantly (p=0.028) medium, with an ICC of 0.54 (CI -0.13, +0.856) and a mean error of 0.08mm. Individual stacked-line graphs offer a visualization of reliability for each measurement, which can be seen in Appendix 3.5.

Research question #1 (Type of Canine Impaction and Incisor Root Inclination)

Prior to ANOVA testing, homogeneity of variance with the Levene Statistic and multivariate normality using the Kolmogorov-Smirnov test was assessed separately within each patient group (Appendices 3.6-3.7) and outliers were visualized through a box plot (Appendix 3.8). Homogeneity of variance was violated by the ipsilateral lateral incisor (Statistic=7.93, p=0.001), but was not violated by the other incisors. This result was expected since the root inclination of the lateral incisor on the affected side tends to have the opposite consequence when comparing buccal to palatal canine impactions, where buccal impactions are associated with incisor crown proclination and palatal impactions with incisor crown retroclination. Because this violation of variance was expected, it was not deemed a hindrance for further statistical analysis.

Descriptive statistics for the mean values of root inclination for each maxillary incisor within each group can be viewed in Table 3.1 and are visualized though a boxplot, as seen in Appendix 3.8. There was only one outlier (patient #6) identified in our data set, which was a contralateral central incisor found within group P. In addition to being a statistical outlier, the principal investigator (NL) and supervisor (CFM) deemed this patient a clinical outlier as well. This was because her central incisor crown on the unaffected side was uncharacteristically more retroclined than that of the affected side by a margin of 4.5 degrees, which didn’t occur by half that extent in all other patients. For this reason, our analyses for research questions #1 and 2 were based on the results yielded without this outlier and our sample size in group P was therefore 26.

The results of the ANOVA (Table 3.2) lead to a rejection of our null hypothesis, offering evidence that patients with palatally impacted maxillary canines do exhibit a statistically significant difference in root inclination of the ipsilateral lateral incisor ($F=30.73$, $p<0.0001$) and ipsilateral central incisor ($F=7.193$, $p=0.001$) when compared to patients from the other groups. The multiple comparisons table represents the post-hoc LSD test employed in order to detail to what extent each maxillary incisor was implicated in our rejection of the null hypothesis (see Table 3.3). We divided up these results according to each incisor:

- Ipsilateral lateral incisor:
    - All groups demonstrated statistically significant differences in root inclination from one another ($p<0.0001$), where group P showed a mean difference of -10.3 degrees (more buccal root inclination) compared to group C (CI -15.1, -5.5), and group B showed a mean difference of +12.3 degrees (more palatal root inclination) compared to group C (CI 6.66, 17.98).
- Ipsilateral central incisor:
    - Group P showed statistically significant differences in root inclination from group B ($p<0.0001$) with a mean difference of -9.30 degrees (more buccal root inclination) (CI -14.33, -4.27) and from group C ($p=0.018$) with a mean difference of -5.03 degrees (more buccal root inclination) (CI -9.19, -0.88).
    - Group B failed to show statistically significant differences in root inclination from group C ($p=0.087$).
- Contralateral central incisor:

    - All groups failed to demonstrate statistically significant differences in root inclination from one another ($0.139<p<0.583$)
- Contralateral lateral incisor:
    - Group P showed statistically significant differences in root inclination from group B ($p=0.035$) with a mean difference of -4.61 degrees (more buccal root inclination) (CI -8.87, -0.34) but not from group C ($p=0.065$).
    - Group B failed to show statistically significant differences in root inclination from group C ($p=0.538$)

A visualization of these summarized findings can be seen in Figure 3.6. ANOVA results and the subsequent post hoc analysis before the removal of the outlier in group P (patient #6) can be seen in the Appendices 3.9-3.10.

<u>Research question #2 (Ipsilateral vs. Contralateral Incisor Root Inclination)</u>

For group P, descriptive statistics for the vector difference between ipsilateral and contralateral lateral and central incisors are summarized in Table 3.4, and is further visualized through a box plot (Appendix 3.11). Multivariate normality was assessed separately for lateral and central incisors using the Kolmogorov-Smirnov test (Appendix 3.12). There were no outliers and the assumption of normality was not violated both for lateral incisors (Statistic=0.093, $p=0.200$) and central incisors (Statistic=0.097, $p=0.200$).

The results of our paired T-tests show statistically significant differences in root inclination between the lateral incisors ($t=-9.185$, $p<0.0001$) with the ipsilateral side root being more buccally inclined than the contralateral by an average of 7.47 degrees. (CI -5.8, -9.1), as demonstrated in Table 3.5a. Similarly, the difference in root inclination between central incisors was statistically significant ($t=-5.907$, $p<0.0001$), where the ipsilateral side root tended to be more buccally inclined than the contralateral by an average of 2.95 degrees. (CI -1.92, -3.98), as shown in Table 3.5b. These findings lead to a rejection of our null hypothesis regarding both lateral and central ipsilateral incisors in group P, revealing that they do in fact exhibit statistically significant differences in root inclination compared to their contralateral counterparts.

Because the variances in our paired T-test are highly correlated (See appendices 3.13a-b), specifically a Pittman-Morgan analysis was performed to ensure homogeneity of variance was not violated. The results (Appendix 3.14) demonstrated that homogeneity of variance was not violated for lateral incisors ($t=0.98$, $p=0.33$) nor central incisors ($t=0.009$, $p=0.99$) in group P.

For group B, descriptive statistics for the vector difference between lateral incisor root inclinations are summarized in Table 3.6. The assumption of the Kolmogorov-Smirnov multivariate normality test (Appendix 3.15) was not violated (Statistic=0.144, $p=0.200$), and there were no outliers, as can be visualized in the constructed boxplot (Appendix 3.16). Statistically significant differences in root inclination are seen between the lateral incisors ($t=3.506$, $p=0.003$) where the ipsilateral side is more palatally inclined than the contralateral by an average of 10.5 degrees. (CI 4.1, 17.0), as seen in Table 3.7.

Concerning the vector difference between central incisors in group B, descriptive statistics can be seen in Table 3.8. The Kolmogorov-Smirnov test (Appendix 3.17) demonstrated that the assumption of multivariate normality for central incisors was violated (p=0.002), which is likely related to the two positive outliers seen in the constructed boxplot (Appendix 3.18). We performed a Wilcoxon Signed Ranks test, a non-parametric alternative to the paired t-test, which does not require the assumption of normality to be carried out. The results (Table 3.9a-b) showed an effect size of -0.55 (CI -0.735, +1.55) that was not statistically significant (Z=-0.682, p=0.495). For the sake of equality, the Signed Ranks test was also carried out for the lateral incisors in group B, which yielded the same conclusions as the paired t-test (see Appendix 3.19).

The results of the Pittman-Morgan analysis demonstrated that homogeneity of variance was not violated for lateral incisors (t=1.425, p=0.177) nor central incisors (t=0.887, p=0.391) in group B (see Appendix 3.20, and appendix 3.21 for correlation results).

Similar to the results for group P, the findings in group B also lead to a rejection of our null hypothesis. However, while for group P the null hypothesis was rejected for both central and lateral incisors, for group B the null hypothesis was rejected strictly for lateral incisors.

As mentioned above, the right and left incisors were contrasted in the comparison group to address the potential confounding variable. Descriptive statistics are seen in Table 3.10a-b for lateral and central incisors, where the constructed boxplot revealed no outliers (Appendix 3.22). The assumption of normality was not violated for either incisor (p=0.200, p=0.200) (Appendix 3.23). Results of the paired t-test concerning lateral incisors (Table 3.11a) were not statistically significant (t=-1.088, p=0.285), as was the case for the central incisors (t=-0.940, p=0.355) as seen in Table 3.11b.

The Pittman-Morgan analysis demonstrated that homogeneity of variance was not violated for lateral incisors (t=0.346, p=0.732) nor for central incisors (t=0.152, p=0.880) in group C (see Appendix 3.24, and see appendix 3.25a-b for correlation results).

These results reveal a lack of evidence towards the argument that a person's side of their face can contribute to statistically significant effects in maxillary incisor root inclination.

Research question #3 (Distance, vertical height, and impaction sector of the impacted canine crown with respect to lateral incisor)

Because this question involved the lateral incisors only, the outlier from the previous research questions (patient #6) was included, thereby making the sample size for group P at 27, while the sample size in group B remained at 15.

Descriptive statistics for continuous variables and frequencies for categorical variables in group P can be viewed in Tables 3.12 and 3.13 respectively. The Pearson analysis (see Table 3.14) suggests that the root inclination of the lateral incisor shares a statistically significant medium positive correlation both with the distance (+0.399, p=0.039) and vertical position (+0.402, p=0.039) of the adjacent palatally impacted maxillary canine with respect to the lateral incisor. Furthermore, within the measurements of the canine alone, distance shared a statistically significant medium positive correlation with vertical height (+0.452, p=0.016). A statistically significant medium negative correlation (-0.391, p=0.044) existed between the impaction sector of the palatally impacted canine and the root inclination of the adjacent lateral incisor. Lastly, our results showed that a statistically significant relationship does not exist between the presence/absence of the primary canine and the lateral incisor's root inclination (-0.172, p=0.39), thereby dismissing it as a potential confounding variable. Scatter plots were created to help visualize the statistically significant correlations (see Appendices 3.26-3.29).

Descriptive statistics for continuous variables and frequencies for categorical variables in group B can be seen in Tables 3.15 and 3.16 respectively. The Pearson analysis (Table 3.17) indicated a statistically significant (p<0.0001) very large positive correlation (+0.808) between the impaction sector of the buccally impacted canine and the root inclination of the adjacent lateral incisor. A statistically significant (p=0.042) large negative correlation between the impaction sector and distance of the canine from the lateral incisor (-0.514) existed as well. As in group P, a statistically significant relationship was not found between the presence/absence of the primary canine and the root inclination of the lateral incisor (0.004, p=0.988). Scatter plots were created to help visualize the statistically significant correlations (see Appendices 3.30-3.31).

To summarize our results from our 3rd research question: the null hypothesis was rejected for group P regarding all 3 variables (distance, vertical height, and impaction sector) with medium correlations, suggesting that they do share an association with the degree of the lateral incisor's root inclination. Group B also participated in rejecting the null hypothesis, but only with respect to the variable of impaction sector, which showed a high correlation.

<u>Peg laterals</u>

After the removal of the peg and small laterals from our samples, all three research questions of this chapter were performed. ANOVA results (Table 3.18) demonstrate that the overall outcome was maintained: statistically significant differences in root inclination existed between the 3 groups strictly in relation to the ipsilateral lateral incisor ($F=22.13$, $p<0.0001$) and ipsilateral central incisor ($F=4.03$, $p=0.023$). The new multivariable comparison, however, demonstrated two statistically significant differences in outcome after the removal of peg laterals (Table 3.19). One difference was seen in the ipsilateral central incisor, in which the difference between group P and group C was no longer statistically significant ($p=0.061$). The other difference was seen in relation to the contralateral lateral incisor, where group P was no longer statistically significantly different from group B ($p=0.162$). A visualization of these summarized findings can be seen in Figure 3.7.

There was an overarching difference seen in the multiple comparison chart pertaining to the mean differences of root inclination between the groups. Between groups P and C, all mean differences were increased (i.e. less negative), suggesting less buccal root inclination once peg/small laterals were removed. And between groups B and C, all mean differences were decreased, suggesting less palatal root inclination after removal of peg/small laterals. Descriptive statistics, normality tests, and homogeneity of variance after removal of peg/small laterals can be viewed in the Appendices 3.32-3.34.

The conclusions of our 2nd research question comparing ipsilateral to contralateral root inclination of lateral and central incisors remained unchanged after the removal of peg laterals. The details of this analysis can be seen in Appendices 3.35-3.41.

Concerning our 3rd research question, one statistically significant change seen from the removal of peg/small laterals was concerning the correlation between the impaction sector and lateral incisor root inclination in group P (Table 3.20). While the incisor root inclination continued to share a statistically significant medium positive correlation with distance (0.518, p=0.01) and vertical height (0.437, p=0.033), the correlation with the impaction sector was no longer statistically significant (-0.335, p=0.110). No statistically significant changes were seen in group B (see Appendix 3.42). Descriptive statistics and frequencies after removal of peg/small laterals can be seen in Appendices 3.43-3.44.

Discussion

The results suggest that patients with palatally impacted maxillary canines had more buccal root inclination of their ipsilateral maxillary incisors compared to patients from the buccal impaction and control groups. Patients with buccally impacted canines showed more palatal incisor root inclination on the side of the impacted canine. The overall findings suggest that patients with impacted maxillary canines, whether buccal or palatal, do not show generalized retroclination or proclination of all four maxillary incisor roots. Rather, changes in incisor root inclination were only ipsilateral to the impacted canine.

While group P demonstrated a statistically significant difference for both ipsilateral central and lateral incisor root inclination, group B displayed this only with the lateral incisor. We theorize that the reason why group B did not show a significant difference in central incisor root inclination is that the impacted canine rarely crossed over to the central incisor area in group B, where only 1 out of 15 cases (6.66%) had their impacted canine in sector 4, and the same value (6.66%) was seen for sector 5 (see Table 3.16). This was in stark contrast to group P that demonstrated 40.7% of their impacted canines (11/27) in sector 4, and 22.2% (6/27) in sector 5. (see Table 3.13) This rarity of buccally impacted canines crossing over into sectors 4-5 is supported by An et. al (2013) [16] who found that only 17% of total maxillary canine impactions overlapping the central incisors were buccal.

In group P, there was a statistically medium positive correlation (0.399) between the degree of inclination of the lateral incisor root and the proximity of the canine crown to the root. The closer the impacted canine crown was to the lateral incisor root, the more buccally inclined the root was. This could be interpreted to suggest that the canine crown places pressure on the lateral root resulting in buccal root movement.

There was a medium positive correlation (0.402) between the vertical position of the palatally impacted canine crown and the lateral incisor root's inclination. The more apical the impacted canine is situated with respect to the lateral incisor's root, the less buccally inclined the root will be. Recognizing that there was also a similar positive correlation between the distance of the canine and its vertical position (0.452) with respect to the lateral incisor roots, it could be interpreted that the higher up the canine is positioned, the farther away it is from the lateral incisor root. This again fits well within the suggestion that there exists an intrinsic relationship between how close the canine gets to the incisor and the amount of change in the incisor root's inclination.

The finding that a more apical position of an impacted canine places it farther away from the adjacent lateral incisor may relate to basic maxillary anatomy (Figure 3.8). In order to avoid the cortical plate of bone on the palatal aspect, an impacted canine crown will be forced to come closer to the lateral incisor in those cases where it is situated further down toward the alveolus.

It is tempting to rationalize a “cause and effect” relationship between canine impaction and the degree of inclination of the adjacent lateral incisor root. Is it the canine’s pre-programmed path of impaction that directly affects the inclination of the adjacent incisor(s)? Or is it the predetermined root inclinations of the adjacent incisor(s) that play a role in the canine’s path towards impaction? These questions, in essence, encapsulate the debate introduced above between the Genetic and Guidance theories. Nevertheless, the current methodology due to its cross-sectional nature cannot support an answer to this debate. It supports the concept that there is a strong association but that is everything that can be concluded.

When it comes to buccal impactions, it would seem irrational to suggest that the adjacent lateral incisor root was predestined to be significantly proclined for no apparent reason, thereby causing the canine to become impacted labially. Therefore, in group B it would be sensible to apply a “cause and effect” explanation, where the canine resting on top of the adjacent lateral incisor root directly influences the lateral incisor root to become more palatally inclined. This matches with the previous literature that suggests the primary etiology behind buccal impactions is a tooth-size to arch-length discrepancy, i.e. maxillary dental crowding. Again, the current methodology cannot assess “cause and effect”.

It would seem natural to apply this same reasoning to group P and suggest that palatal impactions are predetermined and that they are the inherent cause behind the effect of palatally positioned adjacent incisor crowns. This approach, which would follow the Genetic theory, is further strengthened by our results that revealed only incisors in proximity to the adjacent impacted canine show statistically significant changes in root inclination.

The findings of the present study do not necessarily refute the Guidance theory, which previously did not include the measurement of incisor root inclination. One possible explanation would be that incisor roots on only one side of the mouth can be genetically more buccally inclined than the other and thereby indirectly promote the adjacent canine to become impacted. But this would go against the results of our study where subjects in the comparison group did not demonstrate statistically significant differences in root inclination between right and left sides of the oral cavity. Furthermore, this suggestion would be different from what was reported by Baratieri et al. [17] who showed minimal intra-individual variability in central and lateral incisor root inclination between right and left sides of the mouth.

Another critical factor concerning the Guidance vs. Genetic debate is the existence of peg-shaped or small maxillary lateral incisors, that have been positively associated with palatally impacted maxillary canines [18]. Upon removal of peg/small lateral incisors from our sample, our results indicated that the root inclination of the central incisor adjacent to the palatally impacted canine was no longer statistically significantly different from that of the comparison group (Table 3.19). This possibly suggests that in the absence of peg laterals, the central incisor is not as significantly affected by the palatally impacted canine. A potential explanation for why this would occur is that patients with peg laterals may have a higher tendency for their canines to be displaced more medially in impaction sectors 4-5, the territory of the ipsilateral central incisor.

This theory is complemented by the fact that all 3 patients with peg laterals in group P had their impacted canines in sectors 4-5 (and one out of the two peg laterals in group B was in sector 4).

Another finding after the removal of peg/small laterals was concerning the mean difference values of root inclination across the groups. In palatal impactions, all maxillary incisors showed less buccal root inclination, and in buccal impactions, all maxillary incisors showed less palatal root inclination when compared to the comparison group. While further analysis is needed, this finding suggests that peg/small laterals show, on average, higher amounts of incisor root movement in the presence of impacted maxillary canines.

One other statistically significant change seen from the removal of peg/small laterals was concerning the correlation between the impaction sector and lateral incisor root inclination. Prior to the removal of peg laterals, our initial correlation analysis demonstrated that the impaction sector shares a statistically significant correlation with the degree of incisor root inclination in both types of canine impaction, where a medium negative relationship existed in group P (-0.391, $p=0.044$) and a high positive relationship (+0.808, $p<0.0001$) was seen in group B. What this translates into is that the more medially displaced the canine was (i.e. the larger the impaction sector), the more significant effect it would have on the inclination of the lateral incisor's root. Because in group P the incisors tended towards a more forward root position (i.e. decreased crown inclination), the relationship was negative, and vice versa in group B where lateral incisor roots were backwardly positioned (i.e. increased crown inclination). The high correlation in group B, however, should be evaluated with caution, as only 2 out of the 15 buccal impactions were found in impaction sectors 4-5.

While the correlation between the impaction sector and root inclination in group B did remain high even after the removal of peg laterals (+0.786, p=.001) (Appendix 3.42), this correlation was no longer statistically significant in group P (see Table 3.20). The fact that all peg/small laterals in group P were in sectors 4-5 may explain this statistically significant change after their removal.

What we can nevertheless conclude for the purposes of our study is that the presence of peg-shaped or small maxillary lateral incisors does not significantly affect the results of our findings, except in relation the inclination of the ipsilateral central incisor's root in comparison to group C.

Finally, two of our exclusion criteria require explanation. Concerning mid-alveolar canine impactions, there is a debate in the literature whether or not these in-line impactions are included within palatally impacted canines, or if they form an entirely new group of canine impaction [3, 19]. To avoid this point of argument, these cases were excluded from our study. Regarding bilateral cases, because our 2nd research question hinges on the comparison between incisors with an adjacent impacted canine to contralateral incisors that did not neighbor an impacted canine, bilateral canine impactions were excluded. Furthermore, the guidance theory acknowledges that bilateral canine impaction, in many instances, is genuinely genetic in nature [18]. In order to keep both sides of the debate equal, bilateral impactions were excluded.

<u>Limitations of the study</u>

One of the most significant obstacles in our research was that of a relatively small sample size. As mentioned above, the results of our correlation analysis in group B concerning the impaction sector may have little to offer, seeing that only two cases were situated in sectors 4-5. Furthermore, with respect to our 1st research question, a larger sample size will likely provide a more definitive outcome towards how significantly different group P's contralateral lateral incisor are from group C. Furthermore, because data was collected from a pre-existing readily available pool of patients, our study gleaned its results from a convenience sample as opposed to a representative or random sample of patients.

Another element of limitation to our correlation analysis was that we performed a Pearson correlation between continuous (root inclination, distance, vertical height) and categorical variables (the impaction sector, the existence of primary canine). The Pearson analysis is ideal when relating one or multiple continuous variables with other continuous variables, or between a continuous variable and a dichotomous categorical variable. While it was appropriate to use this test for correlating the existence of the primary canine, the categorical variable of the impaction sector is not dichotomous and our analysis was limited in that regard.

Another critical point to highlight is that in most cases we showed medium correlations that ranged from 0.391 to 0.452 in group P. While these correlations are not considered "low" in the conventions of Cohen cited above, when interpreting them as coefficients of determination, the results would indeed be considered "low". Using the coefficient of determination would mean that only 15.2-20.4% of the incisor root inclination can be explained by each of the variables (impaction sector, distance, and vertical height) on their own. While the coefficient of determination would still be relatively high in group B (65.3%), we have mentioned above that our correlations in group B are limited by the low sample size and having only two cases in impaction sectors 4-5.

The analysis of the sectors where the impacted canines were situated could have been done in three dimensions. Nevertheless, because the sector analysis was originally proposed using conventional panoramic radiographs and an accurate 3D depiction has not been validated yet it was decided to use the original sector analysis.

Lastly, while our reliability analysis garnered high correlation coefficients for our measurements of incisor root inclination and the vertical height of impacted canines, reliability was not as sharp when it came to measuring the distance between the impacted canine and the adjacent lateral incisor. This lower level of accuracy may have been an esential factor in the data we used to conduct our correlation analysis in our 3rd research question.

Conclusion

The results of our analysis suggest that patients with unilaterally impacted maxillary canines do not demonstrate significant differences in the root position of all four maxillary incisors, but rather only the incisors on the side of the impacted canine.

While palatal impactions are associated with buccally positioned roots of both the ipsilateral lateral and central incisors (with different degrees of inclination), buccal impactions are only associated with palatally positioned roots of the ipsilateral lateral incisors alone.

In the palatal group, a more buccal position of the lateral incisor's root was associated with a more proximally located, coronally positioned, and medially displaced adjacent impacted canine. Buccal impactions showed a high association between a palatal position of the lateral incisor root and a more medial displacement of the adjacent impacted canine, however this finding should be interpreted with caution as only 2 cases in group B found themselves in impaction sectors 4-5.

References

1. Pereira PM, Ferreira AP, Tavares P, Braga AC. Different manifestations of class II division 2 incisor retroclination and their association with dental anomalies. *Journal of Orthodontics*, 2013; 40:4, 299-306
2. Uslu O, Okan Akcam M, Evirgen S, Cebeci I. Prevalence of dental anomalies in various malocclusions. *American Journal of Orthodontics and Dentofacial Orthopedics* 2007; Vol 135, Number 3 17.
3. Becker A, Smith P, Behar R. The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids. Angle Orthod 1981; 51: 24–29
4. Becker A. In defense of the guidance theory of palatal canine displacement. Angle Orthod 1995; 65: 95–98
5. Coulter J, Richardson A. Normal eruption of the maxillary canine quantified in three dimensions. *European Journal of Orthodontics*, Vol 19, Issue 2, April 1997, p. 171–183,
6. Broadbent BH. Ontogenic Development of Occlusion. *Angle Orthod* 1 October 1941; 11 (4): 223–241.
7. Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod 1994; 64: 249–56
8. Litsas G, Acar A. A review of early displaced maxillary canines: etiology, diagnosis and interceptive treatment. *Open Dent J*. 2011;5:39–47. Published 2011 Mar 16
9. Leifert, S., Jonas, I. Dental Anomalies as a Microsymptom of Palatal Canine Displacement. *J Orofac Orthop* **64,** 108–120 (2003)
10. Lüdicke G, Harzer W, Tausche E. Incisor Inclination – Risk Factor for Palatally-impacted Canines. *J Orofac Orthop* 2008;69: 357–64

11. Andreasen J O, Petersen J K, Laskin D M 1997 Textbook and color atlas of tooth impactions, 1st edn. Munksguard, Copenhagen

12. Becker A 2007 The orthodontic treatment of impacted teeth, 2nd edn. Informa Healthcare, London

13. Nanda R. Esthetics and Biomechanics in Orthodontics (Textbook). 2nd edition. 2015. P. 26-27

14. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod. 1988; 10:283–95

15. Cohen, J. (1988) Statistical Power Analysis for the Behavioral Sciences, 2nd ed. Hillsdale, NJ: Erlbaum.

16. An S, Wang J, Li J, et al. Comparison of methods for localization of impacted maxillary canines by panoramic radiographs. *Dentomaxillofac Radiol*. 2013;42(8):20130129. doi:10.1259/dmfr.20130129

17. Baratieri C, Canongia AC, Bolognese AM. Relationship between maxillary canine intra-alveolar position and maxillary incisor angulation: a cone beam computed tomography study. *Braz Dent J*. 2011;22(2):146-150.

18. Becker A, Chaushu S. "Etiology of maxillary canine impaction: A review," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 148, no. 4, pp. 557–567, 2015.

19. Jacobs SG. The impacted maxillary canine. Further observations on aetiology, radiographic localization, prevention/interception of impaction, and when to suspect impaction. Aust Dent J. 1996 Oct;41(5):310-6.

Tables and figures

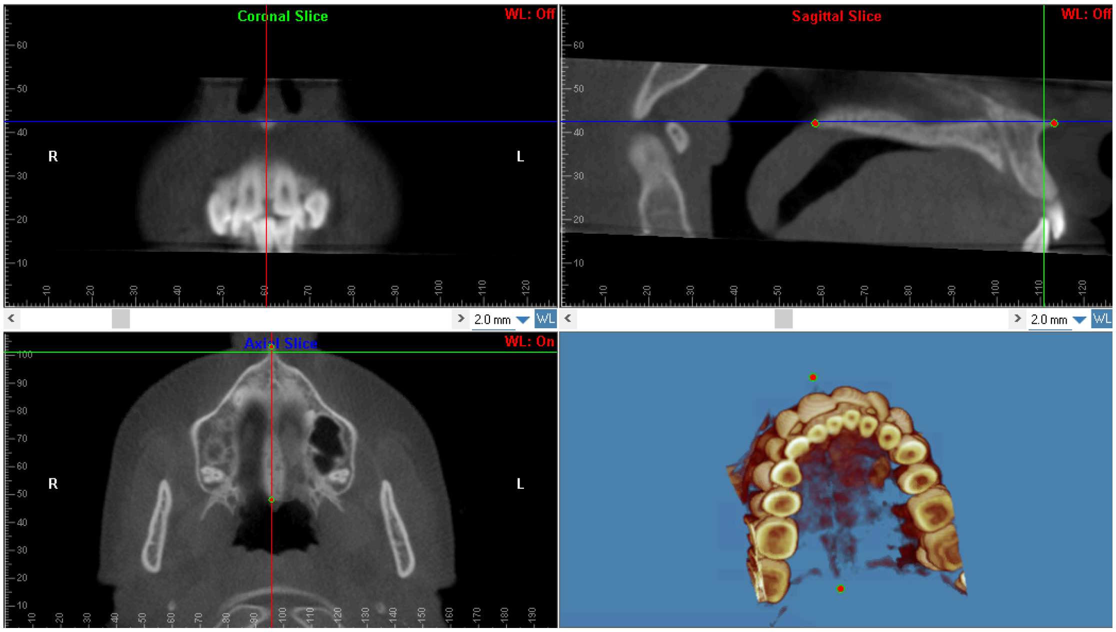


Figure 3.1. In the 3D image (bottom right), ANS and PNS were demarcated, after which the image is manipulated in all directions to verify the accuracy of the points. Landmarks were further verified by inspecting the axial (bottom left) and sagittal (top right) slices.

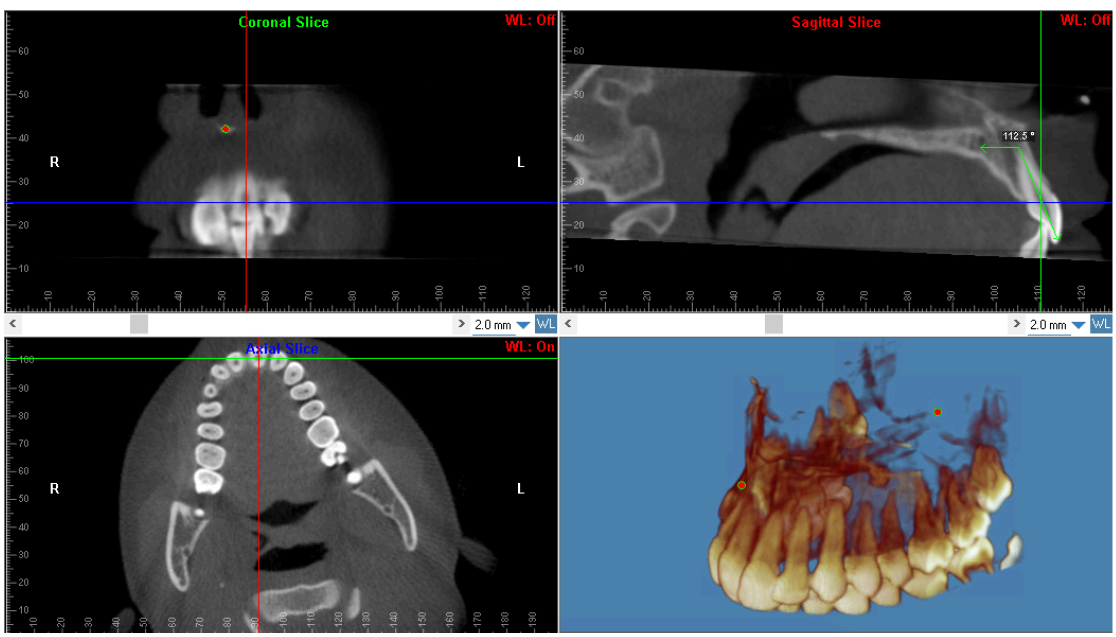


Figure 3.2. While staying parallel to palatal plane, the axial (blue) line is scrolled downwards in the coronal slice until the approximate location of the CEJ of the maxillary incisors (top left). The axial slice (bottom left) is then rotated in order for the sagittal (red) line to be positioned straight through the middle of the incisor being measured (bottom left). In the sagittal slice (top right), 3 points are demarcated in order to yield the angle of the incisor's line of axis with respect to the palatal plane. The same procedure is done for all 4 incisors.

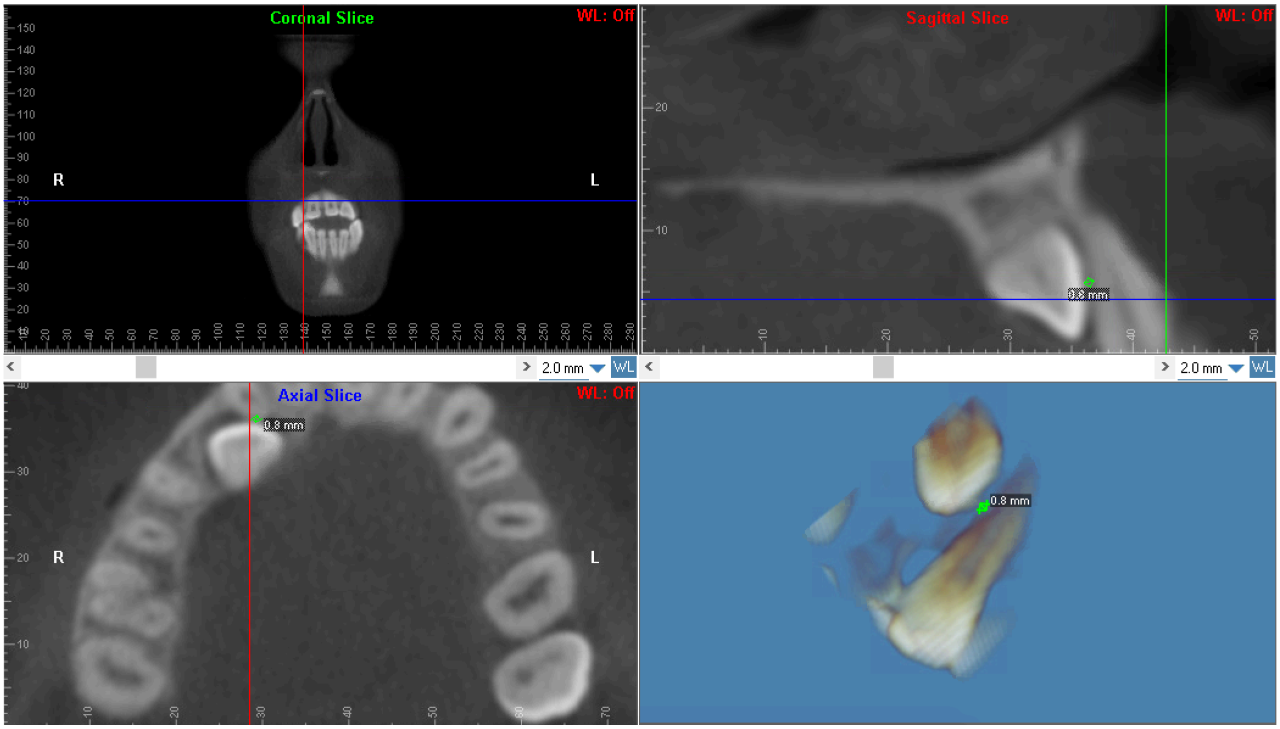


Figure 3.3. Surrounding objects are spliced away to allow for us to accurately locate the two points that represent the shortest distance between the crown of the impacted canine and the root of the closest incisor (lower right). The same process is done from the sagittal (top right) and axial (lower left) slices.

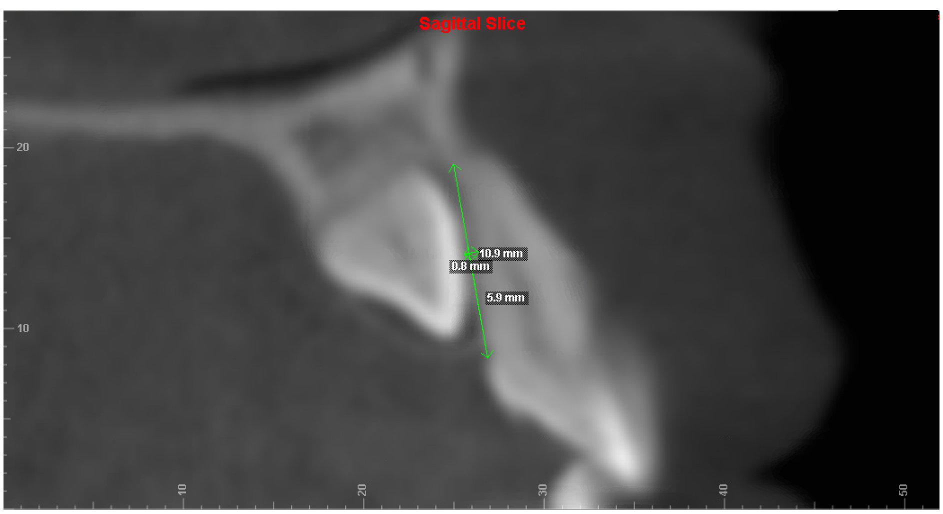


Figure 3.4. In the above image, the canine's vertical height would be recorded as 0.54, representing the fraction between the height at which the canine is closest to the incisor's root (5.9mm) and the entire length of the incisor's root (10.9mm). The measurement of 0.8mm is from the earlier distance measurement.

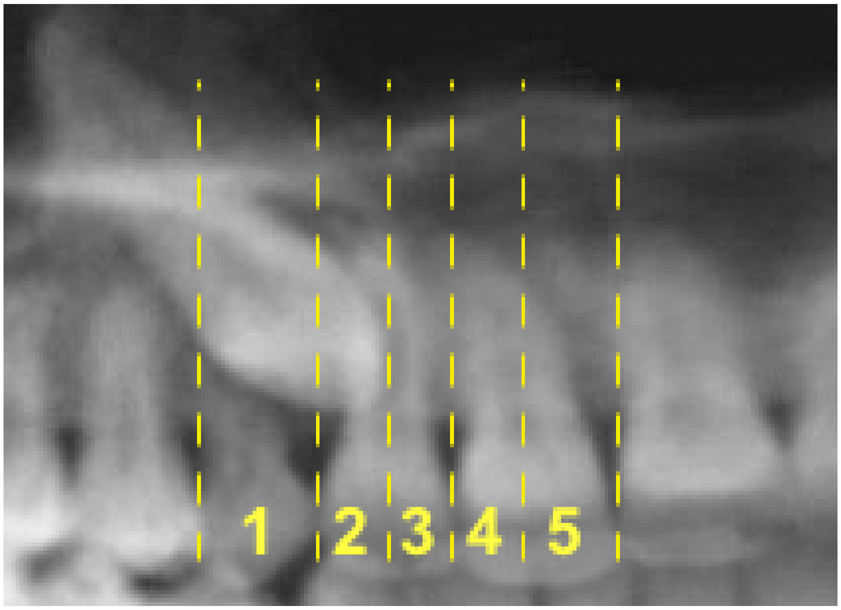


Figure 3.5. The above image is from a patient's CBCT-constructed panorex. The impacted canine would be located in sector 2 in this example

Results

RESEARCH QUESTION #1

Descriptive Statistics

Group		N	Range	Minimum	Maximum	Mean	Std. Deviation
P	IPSI_LATERAL	27	30.5	89.3	119.8	103.319	8.2204
	IPSI_CENTRAL	27	35.3	85.7	121.0	105.567	8.8782
	CONTRA_CENTRAL	27	45.1	81.3	126.4	108.244	9.5871
	CONTRA_LATERAL	27	21.6	98.7	120.3	110.652	6.9999
	Valid N (listwise)	27					
B	IPSI_LATERAL	15	37.6	109.9	147.5	126.267	13.2720
	IPSI_CENTRAL	15	18.0	105.3	123.3	115.633	5.5957
	CONTRA_CENTRAL	15	28.4	97.6	126.0	113.340	8.4693
	CONTRA_LATERAL	15	25.2	100.7	125.9	115.720	6.7184
	Valid N (listwise)	15					
C	IPSI_LATERAL	30	26.2	101.2	127.4	113.947	6.7376
	IPSI_CENTRAL	30	30.8	96.1	126.9	111.363	8.3670
	CONTRA_CENTRAL	30	31.5	97.0	128.5	111.880	8.5437
	CONTRA_LATERAL	30	27.7	103.5	131.2	114.430	6.4275
	Valid N (listwise)	30					

Table 3.1. Descriptive statistics for inclination of each maxillary incisor across the 3 groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
IPSI_LATERAL	Between Groups	4940.118	2	2470.059	30.730	.000
	Within Groups	5465.851	68	80.380		
	Total	10405.969	70			
IPSI_CENTRAL	Between Groups	869.146	2	434.573	7.193	.001
	Within Groups	4108.078	68	60.413		
	Total	4977.224	70			
CONTRA_CENTRAL	Between Groups	178.240	2	89.120	1.274	.286
	Within Groups	4756.904	68	69.954		
	Total	4935.145	70			
CONTRA_LATERAL	Between Groups	248.185	2	124.093	2.855	.064
	Within Groups	2955.614	68	43.465		
	Total	3203.799	70			

Table 3.2. ANOVA results test after the removal of the outlier in group P (patient #6)

Multiple Comparisons

LSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
IPSI_LATERAL	PDC	BDC	-22.6244*	2.9069	.000	-28.425	-16.824
		CTRL	-10.3044*	2.4023	.000	-15.098	-5.511
	BDC	PDC	22.6244*	2.9069	.000	16.824	28.425
		CTRL	12.3200*	2.8351	.000	6.663	17.977
	CTRL	PDC	10.3044*	2.4023	.000	5.511	15.098
		BDC	-12.3200*	2.8351	.000	-17.977	-6.663
IPSI_CENTRAL	PDC	BDC	-9.3026*	2.5201	.000	-14.331	-4.274
		CTRL	-5.0326*	2.0826	.018	-9.188	-.877
	BDC	PDC	9.3026*	2.5201	.000	4.274	14.331
		CTRL	4.2700	2.4579	.087	-.635	9.175
	CTRL	PDC	5.0326*	2.0826	.018	.877	9.188
		BDC	-4.2700	2.4579	.087	-9.175	.635
CONTRA_CENTRAL	PDC	BDC	-4.0592	2.7119	.139	-9.471	1.352
		CTRL	-2.5992	2.2411	.250	-7.071	1.873
	BDC	PDC	4.0592	2.7119	.139	-1.352	9.471
		CTRL	1.4600	2.6449	.583	-3.818	6.738
	CTRL	PDC	2.5992	2.2411	.250	-1.873	7.071
		BDC	-1.4600	2.6449	.583	-6.738	3.818
CONTRA_LATERAL	PDC	BDC	-4.6085*	2.1376	.035	-8.874	-.343
		CTRL	-3.3185	1.7665	065	-6.843	.207
	BDC	PDC	4.6085*	2.1376	.035	.343	8.874
		CTRL	1.2900	2.0848	.538	-2.870	5.450
	CTRL	PDC	3.3185	1.7665	.065	-.207	6.843
		BDC	-1.2900	2.0848	.538	-5.450	2.870

*. The mean difference is significant at the 0.05 level.

Table 3.3. Multiple comparisons generated using the LSD post-hoc test to the ANOVA analysis. *(PDC = group P, BDC = group B, and CTRL = group C)*

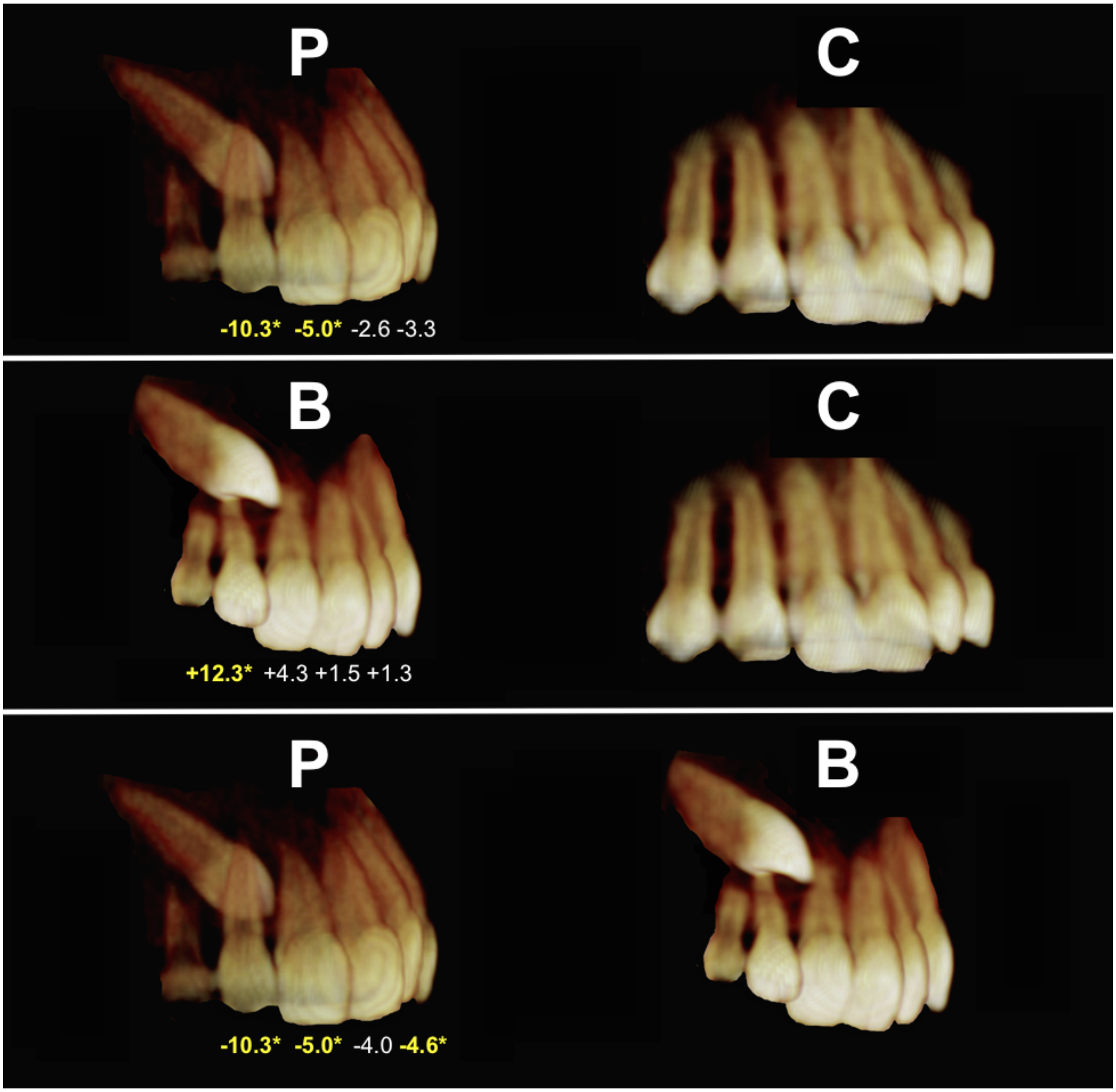


Figure 3.6. The above image contrasts the mean differences in incisor inclination for each respective maxillary incisor between patients with palatal (P) impactions and the comparison (C) group [top], patients with buccal (B) impactions and the comparison group (middle), and patients with palatal impaction and those with buccal impactions (bottom). Statistically significant values are highlighted in yellow with an asterisk.

RESEARCH QUESTION #2

Descriptives

			Statistic	Std. Error
Lateral_diff	Mean		-7.469	.8132
	95% Confidence Interval for Mean	Lower Bound	-9.144	
		Upper Bound	-5.795	
	5% Trimmed Mean		-7.420	
	Median		-6.900	
	Variance		17.192	
	Std. Deviation		4.1463	
	Minimum		-16.8	
	Maximum		1.6	
	Range		18.4	
	Interquartile Range		6.0	
	Skewness		-.288	.456
	Kurtosis		.344	.887
Central_Diff	Mean		-2.950	.4994
	95% Confidence Interval for Mean	Lower Bound	-3.979	
		Upper Bound	-1.921	
	5% Trimmed Mean		-2.950	
	Median		-3.200	
	Variance		6.484	
	Std. Deviation		2.5464	
	Minimum		-8.0	
	Maximum		2.0	
	Range		10.0	
	Interquartile Range		4.5	
	Skewness		.064	.456
	Kurtosis		-.761	.887

Table 3.4. Descriptive statistics for difference between ipsilateral and contralateral lateral (top) and central (bottom) incisor inclination in group P

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ipsi_Lateral - Contra_Lateral	-7.4692	4.1463	.8132	-9.1440	-5.7945	-9.185	25	.000

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ipsi_Central - Contra_Central	-2.9500	2.5464	.4994	-3.9785	-1.9215	-5.907	25	.000

Table 3.5a-b. Statistical results of the paired T-test conducted for (a) lateral incisors (top), and (b) central incisors (bottom) in group P.

Descriptives

			Statistic	Std. Error
DIFF_LAT	Mean		10.5467	3.00802
	95% Confidence Interval for Mean	Lower Bound	4.0951	
		Upper Bound	16.9982	
	5% Trimmed Mean		10.8407	
	Median		11.7000	
	Variance		135.723	
	Std. Deviation		11.65001	
	Minimum		-11.10	
	Maximum		26.90	
	Range		38.00	
	Interquartile Range		20.80	
	Skewness		-.286	.580
	Kurtosis		-.961	1.121

Table 3.6. Descriptive statistics for difference between ipsilateral and contralateral lateral incisor inclination in group B

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	IPSI_LAT_B - CONTRA_LAT_B	10.5467	11.6500	3.0080	4.0951	16.9982	3.506	14	.003

Table 3.7. Statistical results for paired T-test for lateral incisors in group B.

Descriptives

			Statistic	Std. Error
DIFF_CENT	Mean		2.2933	1.87488
	95% Confidence Interval for Mean	Lower Bound	-1.7279	
		Upper Bound	6.3146	
	5% Trimmed Mean		1.6370	
	Median		.1000	
	Variance		52.728	
	Std. Deviation		7.26139	
	Minimum		-4.50	
	Maximum		20.90	
	Range		25.40	
	Interquartile Range		5.40	
	Skewness		1.898	.580
	Kurtosis		3.059	1.121

Table 3.8. Descriptive statistics for the difference in inclination between central incisors in group B.

Confidence Interval Summary

Confidence Interval Type	Parameter	Estimate	95% Confidence Interval	
			Lower	Upper
Related-Samples Hodges-Lehman Median Difference	Median of the difference between IPSI_CENT_B and CONTRA_CENT_B.	-.550	-7.350	1.550

Total N	15
Test Statistic	48.000
Standard Error	17.603
Standardized Test Statistic	-.682
Asymptotic Sig. (2-sided test)	.495

Table 3.9. (a) Effect size and confidence intervals between central incisors in group B (left) (b) Results of the Wilcoxon Signed Ranks test between central incisors in group B (right)

Descriptives

			Statistic	Std. Error
Rlateral_Llateral	Mean		-.483	.4441
	95% Confidence Interval for Mean	Lower Bound	-1.392	
		Upper Bound	.425	
	5% Trimmed Mean		-.470	
	Median		-.600	
	Variance		5.917	
	Std. Deviation		2.4325	
	Minimum		-5.3	
	Maximum		4.3	
	Range		9.6	
	Interquartile Range		3.0	
	Skewness		-.042	.427
	Kurtosis		-.293	.833

			Statistic	Std. Error
Central_Diff	Mean		-.517	.5496
	95% Confidence Interval for Mean	Lower Bound	-1.641	
		Upper Bound	.607	
	5% Trimmed Mean		-.556	
	Median		-.650	
	Variance		9.061	
	Std. Deviation		3.0101	
	Minimum		-5.7	
	Maximum		5.5	
	Range		11.2	
	Interquartile Range		4.7	
	Skewness		.135	.427
	Kurtosis		-.799	.833

Table 3.10a-b. Descriptive statistics for the vector difference between (a) lateral incisors (top), and (b) central incisors (bottom) in group C.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	RLateral - LLateral	-.4833	2.4325	.4441	-1.3917	.4250	-1.088	29	.285

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	RCentral - LCentral	-.5167	3.0101	.5496	-1.6407	.6073	-.940	29	.355

Table 3.11a-b. Statistical results of the paired T-test conducted for (a) lateral incisors (top), and (b) central incisors (bottom) in group C.

RESEARCH QUESTION #3

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Ipsi_Lateralinclination	27	89.3	119.8	103.319	1.5820	8.2204	-.246	.448	-.775	.872
DISTANCE	27	.1	1.2	.448	.0502	.2607	.831	.448	1.097	.872
VERTICALHEIGHT	27	.19	1.00	.5164	.03723	.19347	.442	.448	-.217	.872
Valid N (listwise)	27									

Table 3.12. Descriptive Statistics for continuous variables (incisor inclination, distance, and vertical height) in group P.

IMPACTIONSECTOR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.0	3	10.7	11.1	11.1
	3.0	7	25.0	25.9	37.0
	4.0	11	39.3	40.7	77.8
	5.0	6	21.4	22.2	100.0
	Total	27	96.4	100.0	
Missing	System	1	3.6		
Total		28	100.0		

PRIMARYCANINE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	10	35.7	37.0	37.0
	1.0	17	60.7	63.0	100.0
	Total	27	96.4	100.0	
Missing	System	1	3.6		
Total		28	100.0		

Table 3.13. Frequency statistics for categorical variables of impaction sector (left) and presence of the primary canine (right) in group P. The value of "0" represents absence of the ipsilateral primary canine, and "1" signifies its presence.

Correlations

		Ipsi_Lateralinclination	PROXIMITY	VERTICALHEIGHT	IMPACTIONSECTOR	PRIMARYCANINE
Ipsi_Lateralinclination	Pearson Correlation	1	.399*	.402*	-.391*	-.172
	Sig. (2-tailed)		.039	.038	.044	.390
	N	27	27	27	27	27
DISTANCE	Pearson Correlation	.399*	1	.452*	.037	-.215
	Sig. (2-tailed)	.039		.016	.852	.281
	N	27	28	28	28	27
VERTICALHEIGHT	Pearson Correlation	.402*	.452*	1	.079	-.301
	Sig. (2-tailed)	.038	.016		.691	.127
	N	27	28	28	28	27
IMPACTIONSECTOR	Pearson Correlation	-.391*	.037	.079	1	.282
	Sig. (2-tailed)	.044	.852	.691		.154
	N	27	28	28	28	27
PRIMARYCANINE	Pearson Correlation	-.172	-.215	-.301	.282	1
	Sig. (2-tailed)	.390	.281	.127	.154	
	N	27	27	27	27	27

Table 3.14. Pearson correlation analysis for group P

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Ipsi_Lateralinclination	15	109.9	147.5	126.267	13.2720	.304	.580	-1.395	1.121
DISTANCE	15	.1	2.8	.640	.8450	2.129	.580	3.606	1.121
VERTICALHEIGHT	15	.39	1.00	.7349	.24184	-.266	.580	-1.450	1.121
Valid N (listwise)	15								

Table 3.15. Descriptive Statistics for continuous variables (incisor inclination, distance, and vertical height) in group B.

ImpactionSector

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	4	14.8	26.7	26.7
	2	2	7.4	13.3	40.0
	3	7	25.9	46.7	86.7
	4	1	3.7	6.7	93.3
	5	1	3.7	6.7	100.0
	Total	15	55.6	100.0	
Missing	System	12	44.4		
Total		27	100.0		

PrimaryCanine

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	4	14.8	26.7	26.7
	1	11	40.7	73.3	100.0
	Total	15	55.6	100.0	
Missing	System	12	44.4		
Total		27	100.0		

Table 3.16. Frequency statistics for categorical variables of impaction sector (left) and presence of the primary canine (right) in group B. The value of “0” represents absence of the ipsilateral primary canine, and “1” signifies its presence.

Correlations

		Ipsi_Lateralinclination	PROXIMITY	VERTICALHEIGHT	IMPACTIONSECTOR	PRIMARYCANINE
Ipsi_Lateralinclination	Pearson Correlation	1	-.319	-.348	.808**	.004
	Sig. (2-tailed)		.246	.204	.000	.988
	N	15	15	15	15	15
DISTANCE	Pearson Correlation	-.319	1	.495	-.514*	.214
	Sig. (2-tailed)	.246		.051	.042	.443
	N	15	16	16	16	15
VERTICALHEIGHT	Pearson Correlation	-.348	.495	1	-.291	.439
	Sig. (2-tailed)	.204	.051		.275	.102
	N	15	16	16	16	15
IMPACTIONSECTOR	Pearson Correlation	.808**	-.514*	-.291	1	-.114
	Sig. (2-tailed)	.000	.042	.275		.686
	N	15	16	16	16	15
PRIMARYCANINE	Pearson Correlation	.004	.214	.439	-.114	1
	Sig. (2-tailed)	.988	.443	.102	.686	
	N	15	15	15	15	15

Table 3.17. Pearson correlation analysis for group B

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
IPSI_LATERAL	Between Groups	3318.162	2	1659.081	22.131	.000
	Within Groups	4647.932	62	74.967		
	Total	7966.094	64			
IPSI_CENTRAL	Between Groups	502.545	2	251.273	4.029	.023
	Within Groups	3866.488	62	62.363		
	Total	4369.034	64			
CONTRA_CENTRAL	Between Groups	39.049	2	19.525	.283	.755
	Within Groups	4280.956	62	69.048		
	Total	4320.006	64			
CONTRA_LATERAL	Between Groups	108.033	2	54.016	1.298	.280
	Within Groups	2580.682	62	41.624		
	Total	2688.714	64			

Table 3.18. ANOVA results after removal of peg/small laterals

Multiple Comparisons

LSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
IPSI_LATERAL	1.0	2.0	-19.8110*	3.0043	.000	-25.817	-13.805
		3.0	-9.0612*	2.4175	.000	-13.894	-4.229
	2.0	1.0	19.8110*	3.0043	.000	13.805	25.817
		3.0	10.7499*	2.8899	.000	4.973	16.527
	3.0	1.0	9.0612*	2.4175	.000	4.229	13.894
		2.0	-10.7499*	2.8899	.000	-16.527	-4.973
IPSI_CENTRAL	1.0	2.0	-7.4963*	2.7402	.008	-12.974	-2.019
		3.0	-4.2003	2.2050	.061	-8.608	.207
	2.0	1.0	7.4963*	2.7402	.008	2.019	12.974
		3.0	3.2960	2.6358	.216	-1.973	8.565
	3.0	1.0	4.2003	2.2050	.061	-.207	8.608
		2.0	-3.2960	2.6358	.216	-8.565	1.973
CONTRA_CENTRAL	1.0	2.0	-1.4268	2.8833	.622	-7.190	4.337
		3.0	-1.6894	2.3201	.469	-6.327	2.949
	2.0	1.0	1.4268	2.8833	.622	-4.337	7.190
		3.0	-.2626	2.7735	.925	-5.807	5.282
	3.0	1.0	1.6894	2.3201	.469	-2.949	6.327
		2.0	.2626	2.7735	.925	-5.282	5.807
CONTRA_LATERAL	1.0	2.0	-3.1716	2.2387	.162	-7.647	1.303
		3.0	-2.3801	1.8014	.191	-5.981	1.221
	2.0	1.0	3.1716	2.2387	.162	-1.303	7.647
		3.0	.7915	2.1534	.714	-3.513	5.096
	3.0	1.0	2.3801	1.8014	.191	-1.221	5.981
		2.0	-.7915	2.1534	.714	-5.096	3.513

Table 3.19. LSD Post Hoc test after removal of peg/small laterals (1 = group P, 2 = group B, and 3 = group C)

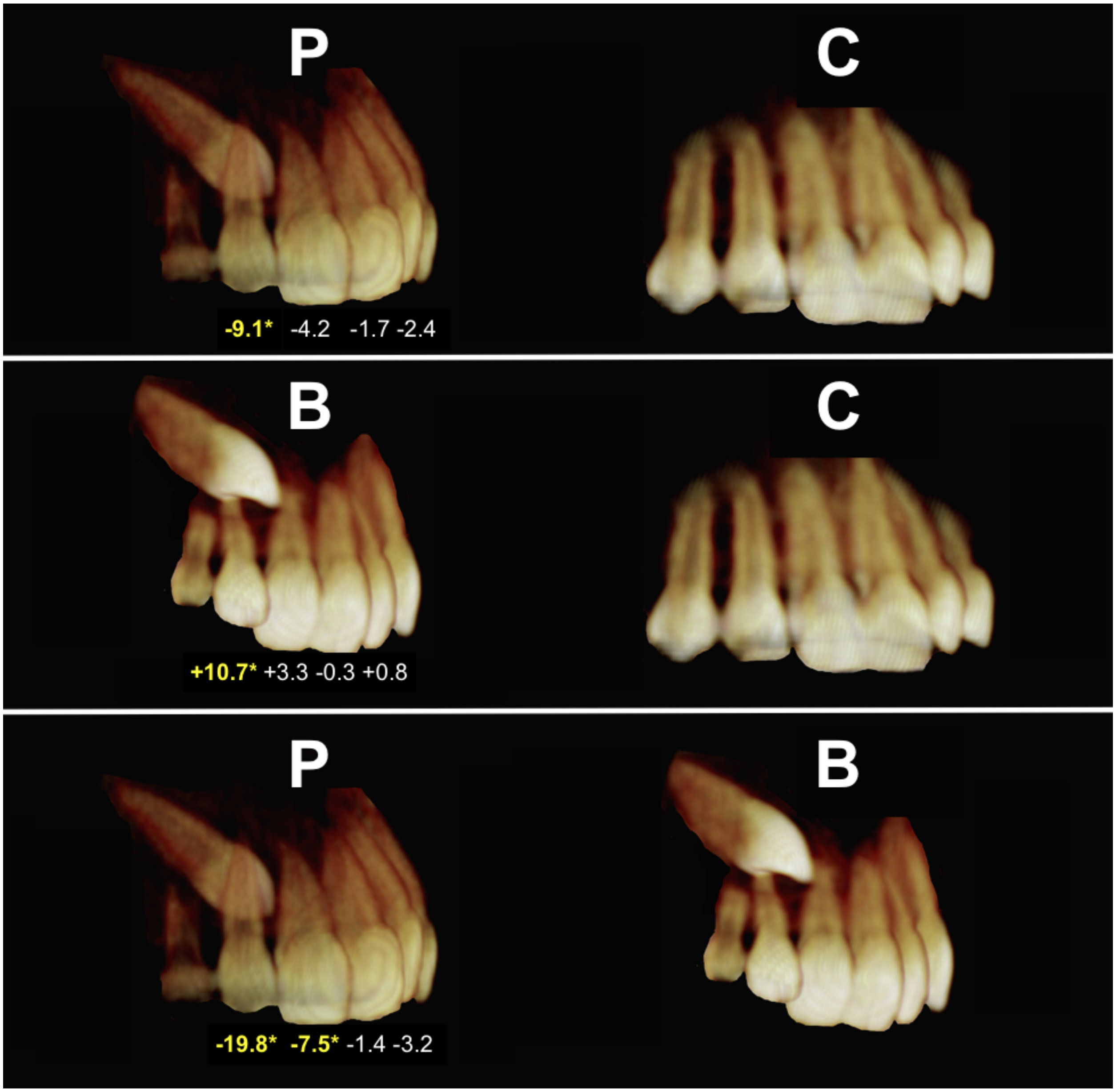


Figure 3.7. The above image contrasts the mean differences in incisor inclination between the groups after removal of peg laterals. Statistically significant values are highlighted in yellow with an asterisk.

Correlations

		Ipsi_Lateralinclination	DISTANCE	VERTICALHEIGHT	IMPACTIONSECTOR	PRIMARYCANINE
Ipsi_Lateralinclination	Pearson Correlation	1	.518**	.437*	-.335	-.351
	Sig. (2-tailed)		.010	.033	.110	.093
	N	24	24	24	24	24
DISTANCE	Pearson Correlation	.518**	1	.513*	-.006	-.210
	Sig. (2-tailed)	.010		.010	.980	.326
	N	24	24	24	24	24
VERTICALHEIGHT	Pearson Correlation	.437*	.513*	1	.124	-.298
	Sig. (2-tailed)	.033	.010		.564	.157
	N	24	24	24	24	24
IMPACTIONSECTOR	Pearson Correlation	-.335	-.006	.124	1	.406*
	Sig. (2-tailed)	.110	.980	.564		.049
	N	24	24	24	24	24
PRIMARYCANINE	Pearson Correlation	-.351	-.210	-.298	.406*	1
	Sig. (2-tailed)	.093	.326	.157	.049	
	N	24	24	24	24	24

Table 3.20. Pearson correlation analysis for group P after the removal of peg/small laterals

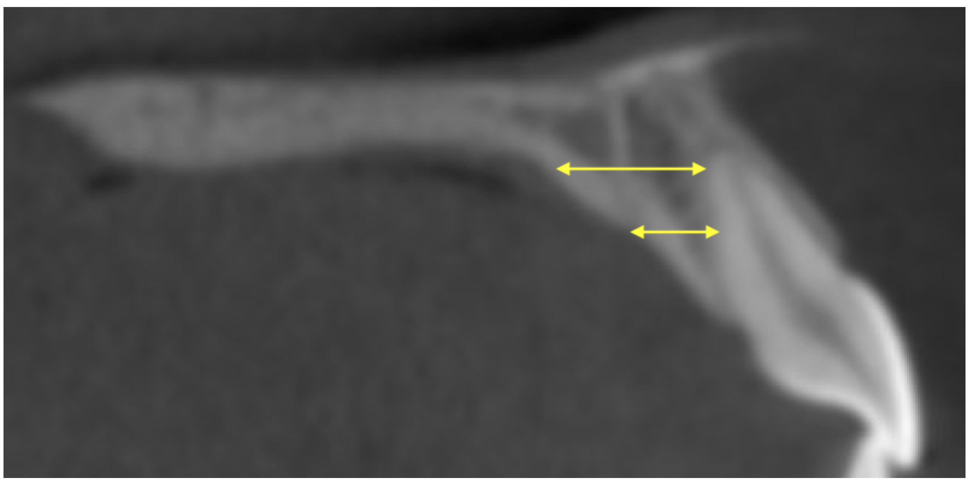


Figure 3.8. A sagittal slice of the palatine process of the maxilla. Yellow arrows demonstrate how it thins out as it move occlusally, thereby forcing the impacted canine closer to the adjacent incisor(s).

Chapter 4 - Overall Conclusions and Future Research Directions

The overall goal of this thesis was to assess the association degree between impacted maxillary canines and their effect on the maxillary incisor root position. An association was identified where the unilateral palatally impacted canine was linked to buccally displaced roots for the closest incisor, whereas the unilateral buccally impacted canine was linked to palatally displaced roots for the closest incisor. These associations were mostly circumscribed to the closest incisor roots.

The thesis first focused on the proposition that there is a higher prevalence of maxillary canine impactions among Class II Division 2 (CIID2) cases. For this question, it was decided to complete a systematic assessment of the published literature in this regard (Chapter 2).
Of the few existing studies that assess the prevalence between palatal maxillary canine impaction and the Class II division 2 malocclusion, the systematic review suggested that inadequate diagnosis of the malocclusion was present in each study. Future research that involves maxillary canine impactions and CIID2 would greatly benefit from using a unified and complete set of diagnostic criteria to identify the CIID2 cases, where a later systematic review can garner more definitive conclusions.

Keeping in mind the significant potential basis of incorrect malocclusion classification, of the handful of articles that were included in our review, the prevalence of the CIID2 malocclusion in patients with palatal impactions stood at approximately 45%, in contrast to the prevalence of palatal impactions in patients displaying the CIID2 malocclusion, which ranged from 0-20%.

With respect to the latter, it was argued that the conflicting reports of the prevalence of palatal impactions in the CIID2 malocclusion might be clarified if CIID2 subdivisions were to have been considered. In that sense, it was noted that the 0% prevalence pertained to the subgroup of the malocclusion displaying retroclined central incisors and normal or proclined lateral incisors. In comparison, the 20% prevalence belonged to patients that demonstrated retroclination of all four maxillary incisor crowns. These findings hinted at a potential link to the inclination of the maxillary incisors, most likely laterals, in relation to palatal maxillary canine impactions, which became the basis for the thesis research questions (Chapter 3).

The article [1] that assessed palatal impactions in the two sub-groupings of the CIID2 malocclusion had 78.3% (18/23) of its palatal impactions as unilateral, implying that unilateral canine impactions may still be associated with bilateral retroclination of maxillary lateral incisors. Our current thesis, which had the advantage of using 3D craniofacial imaging, was able to measure the individual root inclination of all four maxillary incisors, hence allowing the exploration of this concept to ascertain if this could be confirmed. As per our results, patients with palatal maxillary canine impaction do not display generalized retroclination of all four maxillary incisor crowns, rather significant buccal root inclination (associated with retroclination of the incisor crown) was seen in the ipsilateral central and lateral incisors alone. When compared to patients in the comparison group, lateral incisors on the side of the palatally impacted canine showed an average of approximately 10 degrees more buccal root inclination, and central incisors on the affected side averaged around 5 degrees more buccal root inclination. Within the group of palatal impactions, the ipsilateral lateral incisor averaged approximately 7.5 more degrees of buccal root inclination than their contralateral counterpart, while the central incisor on the affected side averaged around 3 degrees more buccal root inclination than that of the contralateral side.

Our study had the further advantage of assessing buccal impactions of the maxillary canine and its relationship to the root inclination of the maxillary incisors. Our study showed that differences in root inclination among the four maxillary incisors were something that existed in buccal maxillary canine impactions as well. However, unlike palatal impactions, buccal impactions showed significant differences in the ipsilateral lateral incisor alone, which averaged approximately 12 more degrees of palatal root inclination (associated with proclination of the incisor crown) compared to the normally positioned canine group. When compared to the contralateral side, the lateral incisor immediately adjacent to the buccally impacted canine displayed an average of approximately 10.5 degrees more palatal root inclination.

To the best of our knowledge, this study is the first attempt in the existing literature to use 3D imaging to assess buccolingual root inclination of incisors in patients displaying unilateral maxillary canine impaction. It is suggested that the identified differences provide meaningful information to be applied in a clinical setting. For the dental practitioner assessing a child's mouth, these significant differences in root inclination would be presented as unilateral retroclination of the incisor crown(s) in palatal impactions and proclination in buccal impactions. When unilateral apparent differences in the crown inclination of maxillary incisors are noted and a reasonable justification is not evident (i.e., increased localized crowding in the side of the incisor crown displacement) appropriate imaging to assess the potential canine impaction probability would be justified. These findings potentially act as a screening guide for orthodontists, pediatric dentists, and general practitioners to recognize how the differences in maxillary incisor crown inclination in a patient may likely be a warning sign of maxillary canine impaction. These results may also provide the dental practitioner with pertinent information that allows them to estimate with a higher degree of confidence the likely buccolingual position of the canine embedded within the maxilla without the need for 3D imaging that may not be available. While the results suggest statistical significance, the level of clinical relevance and at what stages of the patient's dental development potential benefits from this information apply, could be topics that future research should address.

Another assessment of the current 3D analysis was the association between incisor root inclination and multiple related factors pertaining to the impacted maxillary canine. We suggested that the root inclination of the lateral incisor shared a medium correlation with relative distance and vertical position of the palatally impacted canine. Concerning vertical height, the variability in length of incisor roots between patients may have influenced the linear measurements of the vertical position of the impacted canine. Future studies can potentially avoid this limitation by using linear measurements that would contrast with measurements of the contralateral side of the patient's mouth to check for outliers. Alternatively, vertical position of canines can be recorded based on a linear measurement between the cusp tip of maxillary canine and a 3-Dimensionally constructed plane. This latter approach would allow vertical positioning of maxillary canine be measured even in the comparison groups.

Regarding the relationship between the impaction sector and inclination of the ipsilateral lateral incisor, which showed a medium negative correlation in palatal impactions and a large positive correlation in buccal impactions, a limitation is to be noted in that the impaction sector was recorded on 2D reconstructions of CBCT imaging. Future studies could include a 3D assessment of the canine's impaction sector concerning the root inclinations of the maxillary incisors.

A further area of future 3D exploration that would be most useful, in addition to larger, balanced, and more representative sample sizes across groups, is the simultaneous analysis of all three planes of space when measuring the root inclination of the maxillary incisors. Furthermore, if the root inclination of the impacted canine itself was measured in all three planes of space it would provide another layer of insight in the relationship between the impacted canine and the ipsilateral maxillary incisors. This 3D analysis could be enhanced if measurements of the inclination of the adjacent maxillary first premolar were included as well.

The current results also offered potential avenues for future research in relation to peg-shaped and small lateral incisors within the context of impacted maxillary canines. Future studies with higher sample sizes will hopefully be able to yield definitive conclusions regarding the interplay between peg/small laterals, canine impaction sector, and incisor root inclination in palatal and buccal impactions of the maxillary canine when assessed through 3D imaging.

In conclusion, it is our hope that the present study will aid future researchers in further exploring the intimate relationship between the impacted maxillary canine and the adjacent maxillary incisors, with the ultimate goal of providing dental practitioners with clinical information that will aid them in the overall management of the phenomenon of maxillary canine impaction.

BIBLIOGRAPHY

(All references have been listed below in alphabetical order)

Bass TB. Observations on the misplaced upper canine tooth. *Dent Pract Dent Rec.* 1967; 18:25–33.

Becker A, Chaushu S. “Etiology of maxillary canine impaction: A review,” *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 148, no. 4, pp. 557–567, 2015.

Al-Amiri A1, Tabbaa S, Preston CB, Al-Jewair T. The prevalence of dental anomalies in orthodontic patients at the State University of New York at Buffalo. *J Contemp Dent Pract.* 2013 May 1;14(3):518-23.

Al-Nimri K and Gharaibeh T. Space conditions and dental and occlusal features in patients with palatally impacted maxillary canines: an aetiological study. *European Journal of Orthodontics* 27 (2005) 461–465

Alqerban A, Jacobs R, Lambrechts P, Loozen G, Willems G. Root resorption of the maxillary lateral incisor caused by impacted canine: a literature review. *Clin Oral Investig* 2009; 13: 247–255

Alves MJ, Baratieri C, Nojima LI. Assessment of mini-implant displacement using cone beam computed tomography. Clin Oral Impl Res 2011 [DOI: 10.1111/J1600-0501.2010.02092.x. -Epub ahead of print].

Amini F, Shayesteh H, Mona HG, Vahid R. Associations between occlusion, jaw relationships, craniofacial dimensions and the occurrence of palatally-displaced canines. *Int Orthod*. 2017 Mar;15(1):69-81.

An S, Wang J, Li J, et al. Comparison of methods for localization of impacted maxillary canines by panoramic radiographs. *Dentomaxillofac Radiol*. 2013;42(8):20130129. doi:10.1259/dmfr.20130129

Andreasen J O, Petersen J K, Laskin D M 1997. *Textbook and color atlas of tooth impactions, 1st edn*. Munksguard, Copenhagen

Baccetti T, Mucedero M, Leonardi M, Cozza P. Interceptive treatment of palatal impaction of maxillary canines with rapid maxillary expansion: a randomized clinical trial. *American Journal of Orthodontics & Dentofacial Orthopedics* 2009;136(5):657-61

Baratieri C, Canongia AC, Bolognese AM. Relationship between maxillary canine intra-alveolar position and maxillary incisor angulation: a cone beam computed tomography study. *Braz Dent J*. 2011;22(2):146-150.

Basdra EK, Kiokpasoglou M, Stellzig A. The Class II division 2 craniofacial type is associated with numerous congenital tooth anomalies. *Eur J Orthod* 2000; 22:529-535

Becker A 2007 The orthodontic treatment of impacted teeth, 2nd edn. Informa Healthcare, London

Becker A, Chaushu S. Dental age in maxillary canine ectopia. *Am J Orthod Dentofac Orthop* 2000; 117:657-662.

Becker A, Smith P, Behar R 1981 The incidence of anomalous lateral incisors in relation to palatally displaced cuspid. *Angle Orthodontist* 51: 24–29

Becker A. In defense of the guidance theory of palatal canine displacement. Angle Orthod 1995; 65: 95–98

Broadbent BH. A new x-ray technique and its application to orthodontics. Angle Orthod 1931;1:45-66.

Broadbent BH. Ontogenic Development of Occlusion. *Angle Orthod* 1 October 1941; 11 (4): 223–241.

Cohen, J. (1988) Statistical Power Analysis for the Behavioral Sciences, 2nd ed. Hillsdale, NJ: Erlbaum.

Coulter J, Richardson A. Normal eruption of the maxillary canine quantified in three dimensions. *European Journal of Orthodontics*, Vol 19, Issue 2, April 1997, p. 171–183,

Dodda KK, Prasad SERV, Kanuru RK, Nalluri S, Mittapalli R, Raghavendra. Diagnostic features of Angle's Class II div 2 malocclusion. *Journal of International Society of Preventive & Community Dentistry*. 2015; 5(6):513-517

Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. *Eur J Orthod* 1988; 10:283-295.

Hanson ML, Mason RM. *Orofacial Myology*. 2003, p.168

Harzer W, Seifert D, Mahdi Y. The orthodontic classification of impacted canines with special reference to the age at treatment, the angulation and dynamic occlusion. *Fortschr Kieferorthop*. 1994 Apr;55(2):47-53.

Iramaneerat S, Cunningham SJ, Horrocks EN. The effect of two alternative methods of canine exposure upon subsequent duration of orthodontic treatment. *International Journal of Paediatric Dentistry* 1998;8(2):123-9.

Jacobs SG. The impacted maxillary canine. Further observations on aetiology, radiographic localization, prevention/interception of impaction, and when to suspect impaction. Aust Dent J. 1996 Oct;41(5):310-6.

Jacoby H 1983 The etiology of maxillary canine impactions. *American Journal of Orthodontics* 84: 125–132

Leifert, S., Jonas, I. Dental Anomalies as a Microsymptom of Palatal Canine Displacement. *J Orofac Orthop* **64,** 108–120 (2003)

Leonardi M, Armi P, Franchi L, et al: Two interceptive approaches to palatally displaced canines: a prospective longitudinal study. *The Angle Orthodontist* 74(5): 581-6, October 2004

Litsas G, Acar A. A review of early displaced maxillary canines: etiology, diagnosis and interceptive treatment. *Open Dent J*. 2011;5:39–47. Published 2011 Mar 16

Lüdicke G, Harzer W, Tausche E. Incisor Inclination – Risk Factor for Palatally-impacted Canines. *J Orofac Orthop* 2008;69: 357–64

McConnell T L, Hoffman D L, Forbes D P, Jensen E K, Wientraub N H. 1996. Maxillary canine impaction in patients with transverse maxillary deficiency. *Journal of Dentistry for Children* 63: 190–195

Mercuri E, Cassetta M, Cavallini C, Vicari D, Leonardi R, Barbato E. Skeletal features in patient affected by maxillary canine impaction. *Med Oral Patol Oral Cir Bucal*. 2013 Jul 1;18(4):e597-602.

Moola S, Munn Z, Tufanaru C, Aromataris E, Sears K, Sfetcu R, Currie M, Qureshi R, Mattis P, Lisy K, Mu P-F. Chapter 7: Systematic reviews of etiology and risk. In: Aromataris E, Munn Z (Editors). *Joanna Briggs Institute Reviewer's Manual.* The Joanna Briggs Institute, 2017.

Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, Farman AG. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone- beam computed tomography. Am J Orthod Dentofacial Orthop 2007;132:550-560.

Nanda R. Esthetics and Biomechanics in Orthodontics (Textbook). 2nd edition. 2015. P. 26-27

Nordenram A, Stromberg C 1966 Positional variation of impacted upper canine. *Oral Surgery, Oral Medicine, Oral Pathology* 22: 711–714

Oliveira CAP, Meurer MI, Pascoalato C, Silva SRC. Cone-beam computed tomography analysis of the apical third of curved roots after mechanical preparation with different automated systems. Braz Dent J 2009;20:376-381.

Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. *Angle Orthod* 1994; 64:249-256.

Pereira PM, Ferreira AP, Tavares P, Braga AC. Different manifestations of class II division 2 incisor retroclination and their association with dental anomalies. *Journal of Orthodontics*, 2013; 40:4, 299-306

Power SM, Short MB. An investigation into the response of palatally displaced canines to the removal of deciduous canines and an assessment of factors contributing to favourable eruption. Br J Orthod 1993;20:215–23

Prasad SERV, Indukuri RR, Singh R, Nooney A, Palagiri FB, Narayana V. Pathognomonic features of Angle's Class II division 2 malocclusion: A comparative cephalometric and arch width study. *Journal of International Society of Preventive & Community Dentistry*. 2014; 4(Suppl 2): S105-S109

Scheid RC, Weiss G. *Woelfel's Dental Anatomy*. 2012. II;9, p.256

Sigler, Lauren M. et al. Effect of rapid maxillary expansion and transpalatal arch treatment associated with deciduous canine extraction on the eruption of palatally displaced canines: A 2-center prospective study. *American Journal of Orthodontics and Dentofacial Orthopedics*, Volume 139, Issue 3, e235 - e244

Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsh E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133.

Silvola AS, Arvonen P, Julku J, Lahdesmaki R, Kantomaa T, Pirttiniemi P. Early headgear effects on the eruption pattern of the maxillary canines. *Angle Orthodontist O* 2009;79(3):540-5

Stellzig A, Basdra E K, Komposch G 1994 The etiology of canine impaction–space analysis. *Fortschritte der Kieferorthopädie* 55: 97–103

Uribe F, Nanda R. Treatment of Class II, Division 2 Malocclusion in Adults: Biomechanical Considerations. *Journal of Clinical Orthodontics*. 2003. P.599

Uslu O, Okan Akcam M, Evirgen S, Cebeci I. Prevalence of dental anomalies in various malocclusions. *American Journal of Orthodontics and Dentofacial Orthopedics* 2007; Vol 135, Number 3 17.

Warford JH, Grandi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. *Am J Orthod Dentofac Orthop* 2003; 124:651-655.

Willems G, De Bruyne I, Verdonck A, Fieuws S, Carels C. Prevalence of dentofacial characteristics in a Belgian orthodontic population. *Clin Oral Invest* (2001) 5:220–226

APPENDICES

Appendix 2.1: Search Strategy for PubMed

Steps	Combination words
1	malocclusion, angle class II
2	malocclusion, angle class 2
3	tooth, impacted
4	tooth impaction
5	Canine tooth
6	cuspid
7	1 OR 2
8	3 OR 4 OR 5 OR 6
10	7 AND 8

Appendix 2.2: Search Strategy for Medline

Steps	Combination words
1	malocclusion, angle class II
2	tooth, impacted
3	tooth impaction
4	Canine tooth
5	cuspid
6	2 OR 3 OR 4 OR 5
7	1 AND 6

Appendix 2.3: Search Strategy for Cochrane

Steps	Combination words
1	malocclusion, angle class II
2	tooth, impacted
3	tooth impaction
4	Canine tooth
5	cuspid
6	2 OR 3 OR 4 OR 5
7	1 AND 6

Appendix 2.4: Search Strategy for Embase

Steps	Combination words
1	malocclusion, angle class II
2	tooth, impacted
3	tooth impaction
4	Canine tooth
5	cuspid
6	2 OR 3
7	4 OR 5
8	1 AND 6
9	1 AND 7

Appendix 2.5: Search Strategy for Web of Science

Steps	Combination words
1	malocclusion, angle class II
2	tooth, impacted
3	tooth impaction
4	Canine tooth
5	cuspid
6	2 OR 3
7	4 OR 5
8	1 AND 6
9	1 AND 7

Appendix 2.6: Search Strategy for Lilacs

Steps	Combination words
1	malocclusion, angle class II
2	tooth, impacted
3	tooth impaction
4	Canine tooth
5	cuspid
6	2 OR 3
7	4 OR 5
8	1 AND 6
9	1 AND 7

Gender

Group			Frequency	Percent	Valid Percent	Cumulative Percent
1.0	Valid	f	19	70.4	70.4	70.4
		m	8	29.6	29.6	100.0
		Total	27	100.0	100.0	
2.0	Valid	f	8	53.3	53.3	53.3
		m	7	46.7	46.7	100.0
		Total	15	100.0	100.0	
3.0	Valid	f	18	60.0	60.0	60.0
		m	12	40.0	40.0	100.0
		Total	30	100.0	100.0	

Malocclusion

Group			Frequency	Percent	Valid Percent	Cumulative Percent
1.0	Valid	CL1	15	55.6	55.6	55.6
		CL2	6	22.2	22.2	77.8
		CL2D2	3	11.1	11.1	88.9
		CL3	3	11.1	11.1	100.0
		Total	27	100.0	100.0	
2.0	Valid	CL1	8	53.3	53.3	53.3
		CL2	7	46.7	46.7	100.0
		Total	15	100.0	100.0	
3.0	Valid	CL1	15	50.0	50.0	50.0
		CL2	10	33.3	33.3	83.3
		CL3	5	16.7	16.7	100.0
		Total	30	100.0	100.0	

Appendix 3.1. Frequency statistics for gender (left) and malocclusion (right) per group. f = female, m = male, 1.0 = group P, 2.0 = group B, and 3.0 = group C.

Group * Gender

Crosstab

			Gender		Total
			f	m	
Group	1.0	Count	19	8	27
		Expected Count	16.9	10.1	27.0
	2.0	Count	8	7	15
		Expected Count	9.4	5.6	15.0
	3.0	Count	18	12	30
		Expected Count	18.8	11.3	30.0
Total		Count	45	27	72
		Expected Count	45.0	27.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	1.331[a]	2	.514	.491
Likelihood Ratio	1.341	2	.511	.518
Fisher's Exact Test	1.375			.491
N of Valid Cases	72			

Group * Malocclusion

Crosstab

			Malocclusion				Total
			CL1	CL2	CL2D2	CL3	
Group	1.0	Count	15	6	3	3	27
		Expected Count	14.3	8.6	1.1	3.0	27.0
	2.0	Count	8	7	0	0	15
		Expected Count	7.9	4.8	.6	1.7	15.0
	3.0	Count	15	10	0	5	30
		Expected Count	15.8	9.6	1.3	3.3	30.0
Total		Count	38	23	3	8	72
		Expected Count	38.0	23.0	3.0	8.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)
Pearson Chi-Square	9.419[a]	6	.151	.142
Likelihood Ratio	11.827	6	.066	.095
Fisher's Exact Test	7.649			.214
N of Valid Cases	72			

Appendix 3.2. Results of the Fisher's test for gender (left) and malocclusion (right) per group. f = female, m = male, 1.0 = group P, 2.0 = group B, and 3.0 = group C.

Kruskal-Wallis Test

Ranks

	Group	N	Mean Rank
Age	1.0	27	41.72
	2.0	15	33.77
	3.0	30	33.17
	Total	72	

Test Statistics[a,b]

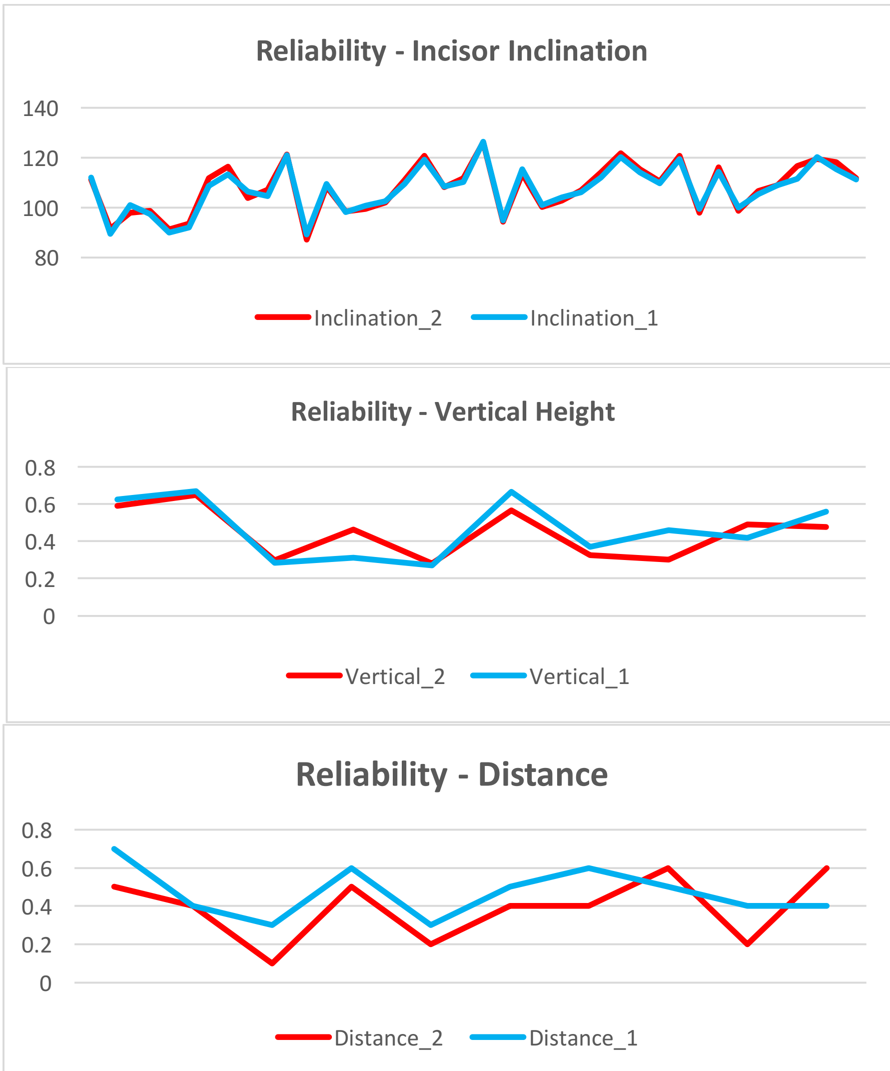
	Age
Chi-Square	2.699
df	2
Asymp. Sig.	.259

Appendix 3.3. Results of the Kruskal-Wallis test for age per group. 1.0 = group P, 2.0 = group B, and 3.0 = group C.

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Incisor Inclination	.982	.966	.991	116.638	39	39	.000
Vertical Height	.827	.459	.954	10.037	9	9	.001
Distance	.540	-.013	.856	3.886	9	9	.028

Appendix 3.4. ICC for measurements of incisor inclination for all 4 maxillary incisors, vertical height and distance of the impacted canine with respect to the lateral incisor root



Appendix 3.5. Visualization of Reliability analyses for incisor inclination (top), distance (middle), and vertical height (bottom). Blue lines represent the measurements taken at time point 1, and red lines represent the measurements taken 2 months afterward.

Test of Homogeneity of Variances

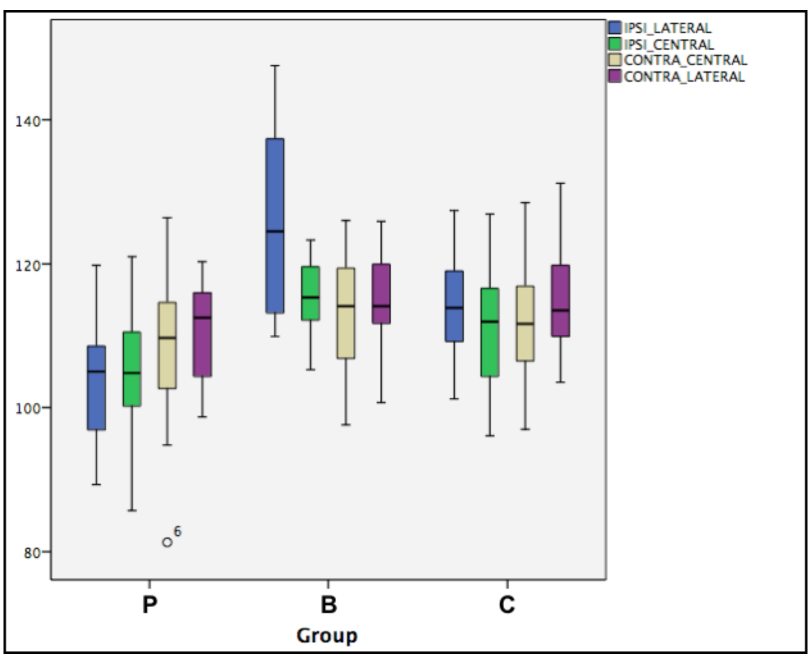
	Levene Statistic	df1	df2	Sig.
IPSI_LATERAL	7.934	2	69	.001
IPSI_CENTRAL	1.349	2	69	.266
CONTRA_CENTRAL	.158	2	69	.854
CONTRA_LATERAL	.444	2	69	.643

Appendix 3.6. Homogeneity of variance of each maxillary incisor

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
IPSI_LATERAL	P	.148	27	.133	.946	27	.171
	B	.167	15	.200*	.909	15	.131
	C	.130	30	.200*	.977	30	.736
IPSI_CENTRAL	P	.086	27	.200*	.975	27	.741
	B	.162	15	.200*	.949	15	.510
	C	.130	30	.200*	.968	30	.485
CONTRA_CENTRAL	P	.116	27	.200*	.972	27	.666
	B	.167	15	.200*	.952	15	.556
	C	.146	30	.101	.964	30	.395
CONTRA_LATERAL	P	.129	27	.200*	.925	27	.052
	B	.129	15	.200*	.949	15	.503
	C	.141	30	.130	.966	30	.436

Appendix 3.7. Individual assessments of normality of each maxillary incisor across the 3 groups



Appendix 3.8. Box plot visualizing inclination for each individual maxillary incisor across the 3 groups. Patient #6 presented as a contralateral central incisor outlier in group P.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
IPSI_LATERAL	Between Groups	5181.636	2	2590.818	32.272	.000
	Within Groups	5539.449	69	80.282		
	Total	10721.084	71			
IPSI_CENTRAL	Between Groups	1061.996	2	530.998	8.110	.001
	Within Groups	4517.943	69	65.477		
	Total	5579.939	71			
CONTRA_CENTRAL	Between Groups	308.068	2	154.034	1.929	.153
	Within Groups	5510.831	69	79.867		
	Total	5818.899	71			
CONTRA_LATERAL	Between Groups	315.472	2	157.736	3.506	.035
	Within Groups	3103.954	69	44.985		
	Total	3419.427	71			

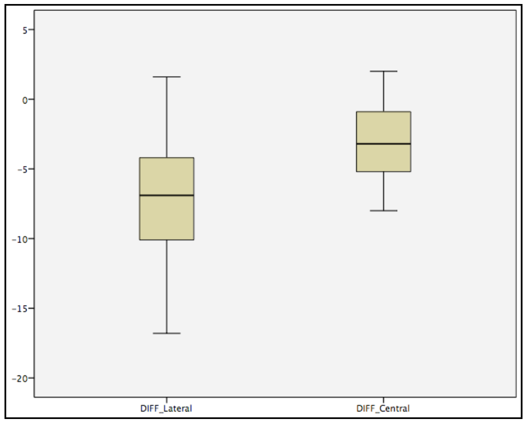
Appendix 3.9. ANOVA results prior to the removal of the outlier in group P (patient #6).

Multiple Comparisons

LSD

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
IPSI_LATERAL	1.0	2.0	-22.9481*	2.8854	.000	-28.704	-17.192
		3.0	-10.6281*	2.3769	.000	-15.370	-5.886
	2.0	1.0	22.9481*	2.8854	.000	17.192	28.704
		3.0	12.3200*	2.8334	.000	6.668	17.972
	3.0	1.0	10.6281*	2.3769	.000	5.886	15.370
		2.0	-12.3200*	2.8334	.000	-17.972	-6.668
IPSI_CENTRAL	1.0	2.0	-10.0667*	2.6058	.000	-15.265	-4.868
		3.0	-5.7967*	2.1465	.009	-10.079	-1.514
	2.0	1.0	10.0667*	2.6058	.000	4.868	15.265
		3.0	4.2700	2.5589	.100	-.835	9.375
	3.0	1.0	5.7967*	2.1465	.009	1.514	10.079
		2.0	-4.2700	2.5589	.100	-9.375	.835
CONTRA_CENTRAL	1.0	2.0	-5.0956	2.8779	.081	-10.837	.646
		3.0	-3.6356	2.3707	.130	-8.365	1.094
	2.0	1.0	5.0956	2.8779	.081	-.646	10.837
		3.0	1.4600	2.8261	.607	-4.178	7.098
	3.0	1.0	3.6356	2.3707	.130	-1.094	8.365
		2.0	-1.4600	2.8261	.607	-7.098	4.178
CONTRA_LATERAL	1.0	2.0	-5.0681*	2.1599	.022	-9.377	-.759
		3.0	-3.7781*	1.7792	.037	-7.328	-.229
	2.0	1.0	5.0681*	2.1599	.022	.759	9.377
		3.0	1.2900	2.1210	.545	-2.941	5.521
	3.0	1.0	3.7781*	1.7792	.037	.229	7.328
		2.0	-1.2900	2.1210	.545	-5.521	2.941

Appendix 3.10. Post-Hoc results of ANOVA prior to removing outlier (patient #6)
(1 = group P, 2 = group B, 3 = group C)



Appendix 3.11. Boxplot of the vector difference between ipsilateral and contralateral lateral (left) and central (right) incisors in group P

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Lateral_diff	.093	26	.200*	.980	26	.868

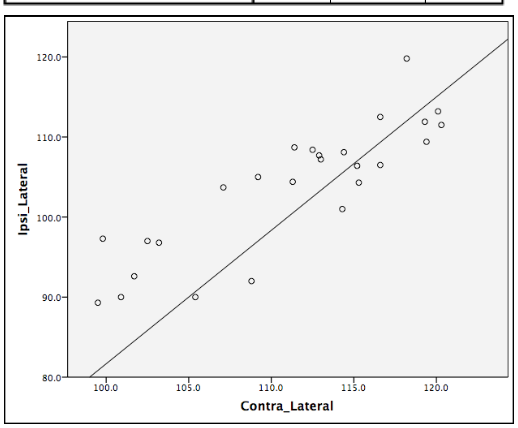
Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Central_Diff	.097	26	.200*	.979	26	.843

Appendix 3.12. Normality tests for the vector difference of lateral incisors (left) and central incisors (right) in group P

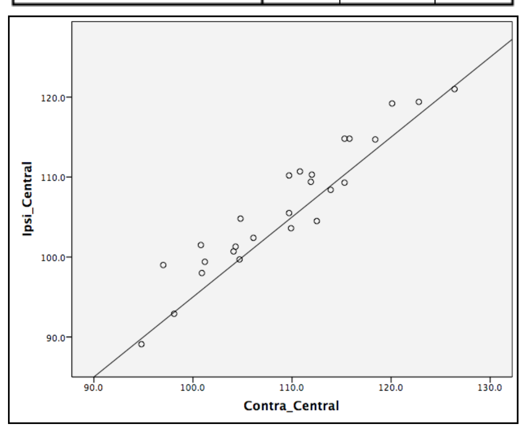
Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Ipsi_Lateral & Contra_Lateral	26	.864	.000



Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Ipsi_Central & Contra_Central	26	.951	.000



Appendix 3.13a-b. Correlations between (a) ipsilateral and contralateral lateral incisors (left), and (b) between ipsilateral and contralateral central incisors (right) in group P

	Pitman-Morgan Test
	Enter Data
variance 1	8
variance 2	7
sample size	26
correlation	1
	Results Option 1
t value	0.9806
df	24
sig.	0.3366

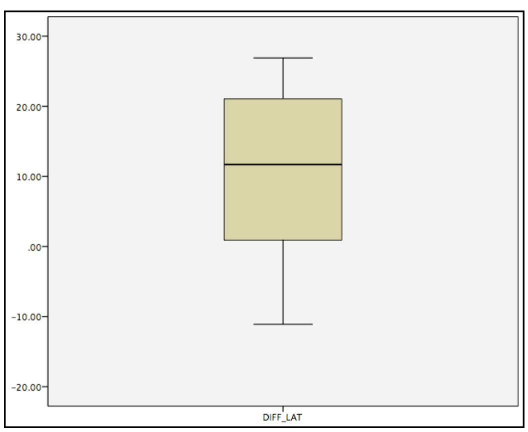
	Pitman-Morgan Test
	Enter Data
variance 1	8
variance 2	8
sample size	26
correlation	1
	Results Option 1
t value	0.0089
df	24
sig.	0.9930

Appendix 3.14. Results of the Pittman-Morgan test for homogeneity of variance concerning the lateral (left) and central (right) incisors in group P.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DIFF_LAT	.144	15	.200*	.956	15	.619

Appendix 3.15. Normality test for the vector difference between lateral incisors in group B.



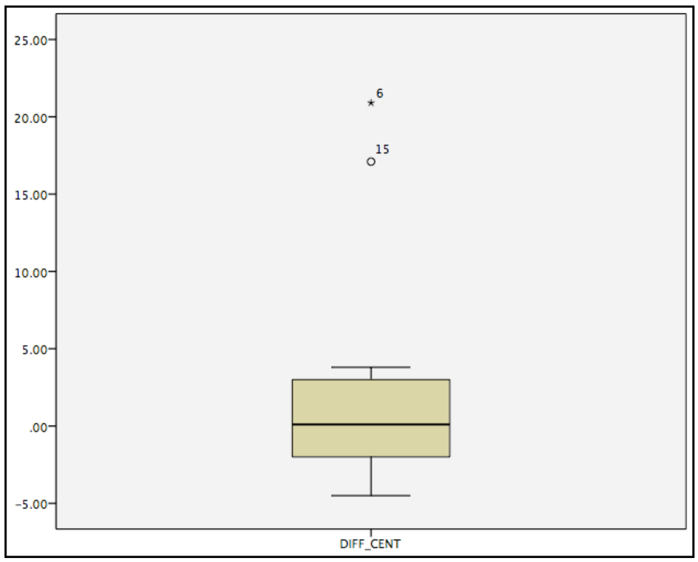
Appendix 3.16. Boxplot of the vector difference between lateral incisors in group B

B

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DIFF_CENT	.284	15	.002	.747	15	.001

Appendix 3.17. Test of normality for difference in inclination between central incisors in group B. A violation of normality is seen (p=0.001).



Appendix 3.18. Boxplot of the vector differences between central incisors in group B

Confidence Interval Summary

Confidence Interval Type	Parameter	Estimate	95% Confidence Interval	
			Lower	Upper
Related-Samples Hodges-Lehman Median Difference	Median of the difference between IPSI_LAT_B and CONTRA_LAT_B.	-10.975	-17.700	-4.100

Total N	15
Test Statistic	14.000
Standard Error	17.607
Standardized Test Statistic	-2.613
Asymptotic Sig. (2-sided test)	.009

Appendix 3.19. (a) Effect size and confidence intervals between lateral incisors in group B (left) (b) Results of the Wilcoxon Signed Ranks test between lateral incisors in group B (right)

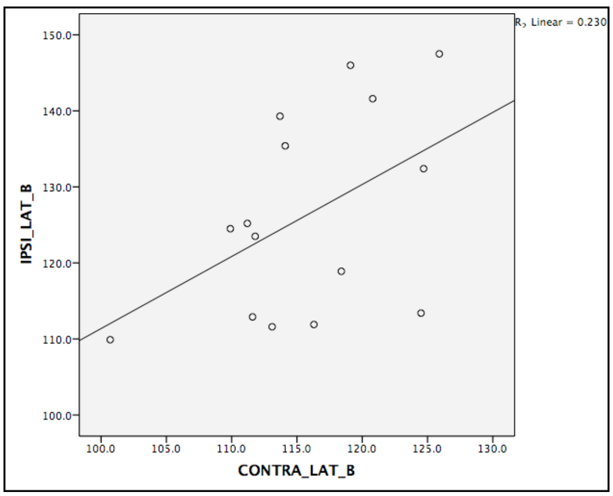
	Pitman-Morgan Test
variance 1	13
variance 2	7
sample size	15
correlation	0
	Results Option 1
t value	1.4254
df	13
sig.	0.1776

	Pitman-Morgan Test
variance 1	8
variance 2	6
sample size	15
correlation	1
	Results Option 1
t value	0.8866
df	13
sig.	0.3914

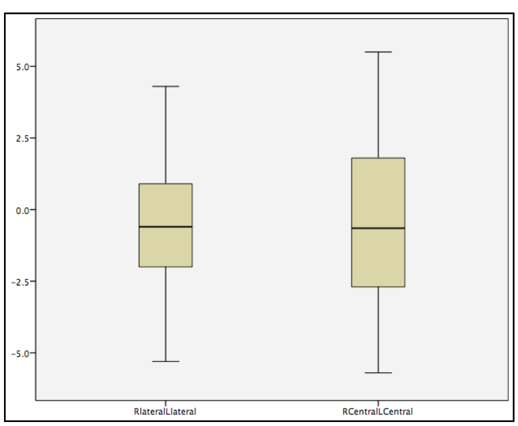
Appendix 3.20. Results of the Pittman-Morgan test for homogeneity of variance concerning the lateral (left) and central (right) incisors in group B.

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	IPSI_LAT_B & CONTRA_LAT_B	15	.480	.070



Appendix 3.21. Correlation (+0.48) between lateral incisors in group B



Appendix 3.22. Boxplots of vector differences between lateral and central incisors in group C

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Rlateral_Llateral	.077	30	.200*	.984	30	.917

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Central_Diff	.069	30	.200*	.978	30	.774

Appendix 3.23. Normality tests for lateral (above) and central (below) incisors in group C

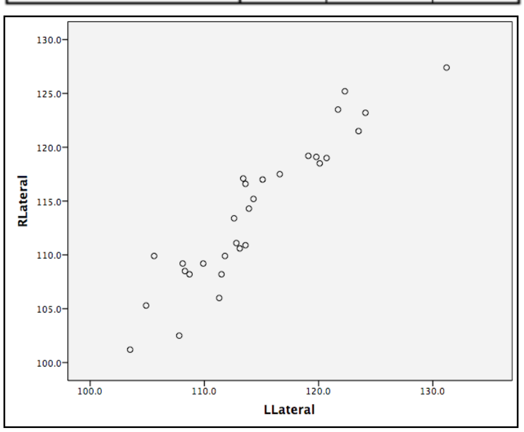
	Pitman-Morgan Test
variance 1	7
variance 2	6
sample size	30
correlation	1
	Results Option 1
t value	0.3462
df	28
sig.	0.7318

	Pitman-Morgan Test
variance 1	9
variance 2	8
sample size	30
correlation	1
	Results Option 1
t value	0.1523
df	28
sig.	0.8801

Appendix 3.24. Results of the Pittman-Morgan test for homogeneity of variance concerning the lateral (left) and central (right) incisors in group C.

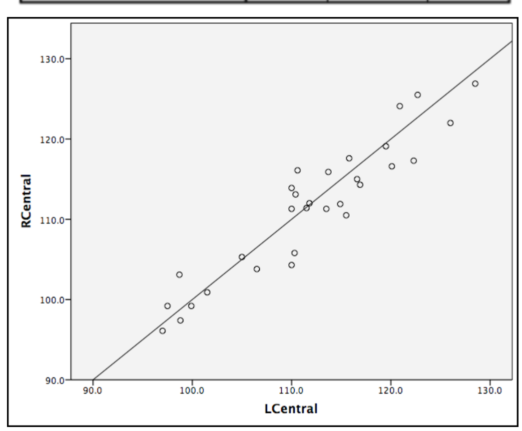
Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	RLateral & LLateral	30	.933	.000

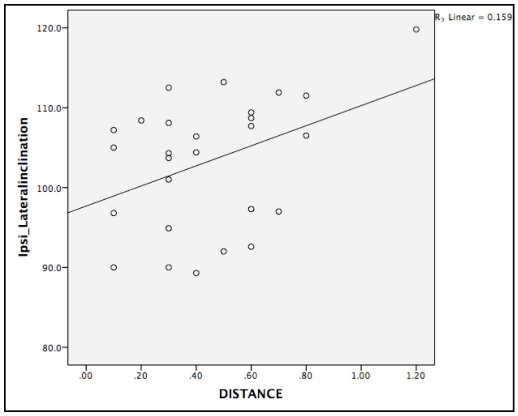


Paired Samples Correlations

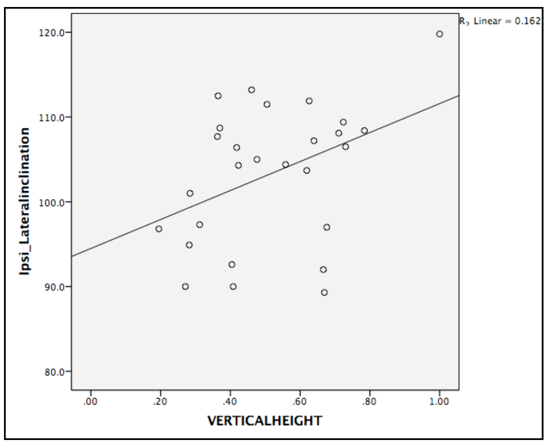
		N	Correlation	Sig.
Pair 1	RCentral & LCentral	30	.937	.000



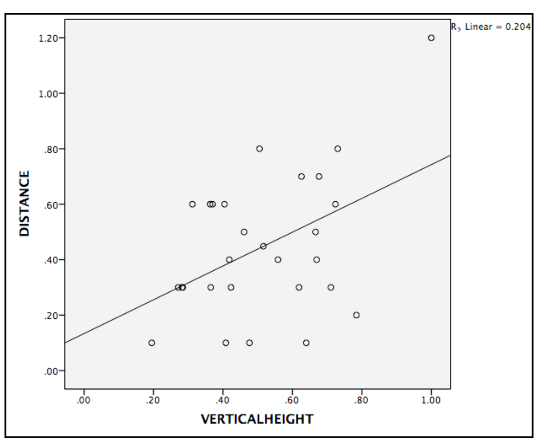
Appendix 3.25a-b. Correlations between (a) ipsilateral and contralateral lateral incisors (left), and (b) between ipsilateral and contralateral central incisors (right) in group C



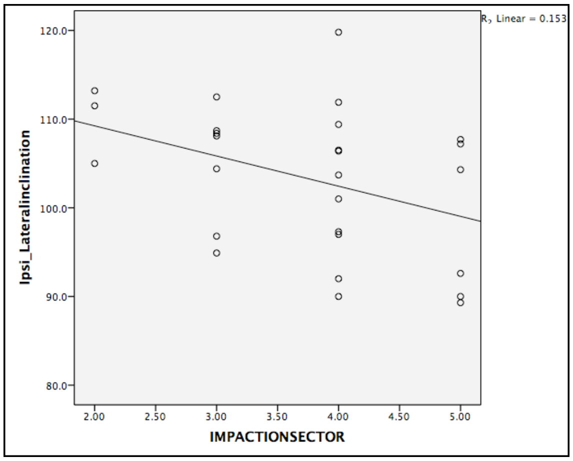
Appendix 3.26. Scatter plot representations of the correlation (+0.399) between lateral incisor inclination and distance away from the palatally impacted canine



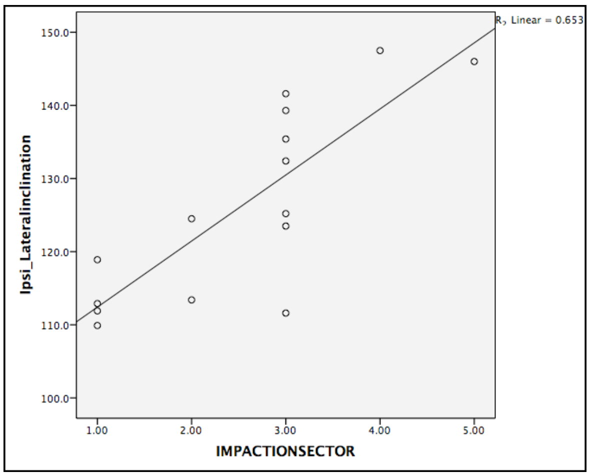
Appendix 3.27. Scatter plot representations of the correlation (+0.402) between lateral incisor inclination and vertical height of the palatally impacted canine



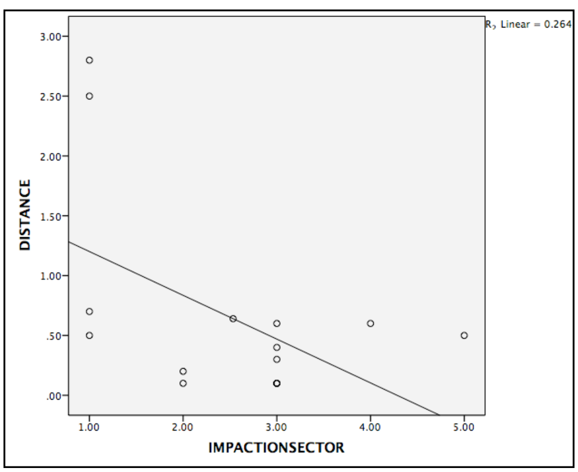
Appendix 3.28. Scatter plot representations of the correlation (+0.452) between distance and vertical height of the palatally impacted canine with respect to the lateral incisor



Appendix 3.29. Scatter plot representations of the correlation (-0.391) between lateral incisor inclination and impaction sector of the palatally impacted canine



Appendix 3.30. Scatter plot representations of the correlation (+0.808) between lateral incisor inclination and impaction sector of the buccally impacted canine



Appendix 3.31. Scatter plot representations of the correlation (-0.514) between impaction sector and distance of the buccally impacted canine with respect to the lateral incisor

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
IPSI_LATERAL	1.0	23	104.904	7.8306	1.6328	101.518	108.291	89.3	119.8
	2.0	13	124.715	12.8542	3.5651	116.948	132.483	109.9	146.0
	3.0	29	113.966	6.8560	1.2731	111.358	116.573	101.2	127.4
	Total	65	112.909	11.1566	1.3838	110.145	115.674	89.3	146.0
IPSI_CENTRAL	1.0	23	107.165	8.2313	1.7164	103.606	110.725	89.1	121.0
	2.0	13	114.662	5.3673	1.4886	111.418	117.905	105.3	123.3
	3.0	29	111.366	8.5151	1.5812	108.127	114.604	96.1	126.9
	Total	65	110.538	8.2623	1.0248	108.491	112.586	89.1	126.9
CONTRA_CENTRAL	1.0	23	110.135	8.1837	1.7064	106.596	113.674	94.8	126.4
	2.0	13	111.562	7.6016	2.1083	106.968	116.155	97.6	124.3
	3.0	29	111.824	8.6894	1.6136	108.519	115.129	97.0	128.5
	Total	65	111.174	8.2158	1.0190	109.138	113.210	94.8	128.5
CONTRA_LATERAL	1.0	23	112.113	6.3269	1.3193	109.377	114.849	99.5	120.3
	2.0	13	115.285	6.4897	1.7999	111.363	119.206	100.7	124.7
	3.0	29	114.493	6.5318	1.2129	112.009	116.978	103.5	131.2
	Total	65	113.809	6.4816	.8039	112.203	115.415	99.5	131.2

Appendix 3.32. Descriptive statistics of incisor inclination across all maxillary incisors after removal of peg/small laterals (1 = group P, 2 = group B, 3 = group C)

Tests of Normality

Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
P	IPSI_LATERAL	.178	23	.057	.925	23	.085
	IPSI_CENTRAL	.081	23	.200*	.975	23	.801
	CONTRA_CENTRAL	.131	23	.200*	.981	23	.922
	CONTRA_LATERAL	.145	23	.200*	.927	23	.093
B	IPSI_LATERAL	.195	13	.187	.897	13	.120
	IPSI_CENTRAL	.147	13	.200*	.966	13	.840
	CONTRA_CENTRAL	.175	13	.200*	.965	13	.823
	CONTRA_LATERAL	.131	13	.200*	.949	13	.587
C	IPSI_LATERAL	.145	29	.124	.972	29	.603
	IPSI_CENTRAL	.118	29	.200*	.966	29	.464
	CONTRA_CENTRAL	.141	29	.146	.963	29	.394
	CONTRA_LATERAL	.132	29	.200*	.968	29	.511

Appendix 3.33. Normality tests for incisor inclination of al maxillary incisors across the 3 groups after removal of peg/small laterals

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
IPSI_LATERAL	6.379	2	62	.003
IPSI_CENTRAL	1.613	2	62	.208
CONTRA_CENTRAL	.076	2	62	.927
CONTRA_LATERAL	.015	2	62	.985

Appendix 3.34. Homogeneity of variance after removal of peg/small laterals

Descriptives

			Statistic	Std. Error
DIFF_Lat	Mean		-7.2087	.78752
	95% Confidence Interval for Mean	Lower Bound	-8.8419	
		Upper Bound	-5.5755	
	5% Trimmed Mean		-7.2271	
	Median		-6.9000	
	Variance		14.264	
	Std. Deviation		3.77683	
	Minimum		-15.40	
	Maximum		1.60	
	Range		17.00	
	Interquartile Range		5.90	
	Skewness		-.024	.481
	Kurtosis		.488	.935
DIFF_Cent	Mean		-2.9696	.56269
	95% Confidence Interval for Mean	Lower Bound	-4.1365	
		Upper Bound	-1.8026	
	5% Trimmed Mean		-2.9691	
	Median		-3.4000	
	Variance		7.282	
	Std. Deviation		2.69856	
	Minimum		-8.00	
	Maximum		2.00	
	Range		10.00	
	Interquartile Range		4.90	
	Skewness		.083	.481
	Kurtosis		-1.003	.935

Appendix 3.35. Descriptive statistics for the vector difference of lateral and central incisors in group P after removal of peg/small laterals

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DIFF_Lat	.098	23	.200*	.982	23	.940
DIFF_Cent	.122	23	.200*	.965	23	.568

Appendix 3.36. Normality test for vector difference of lateral and central incisors in group P after removal of peg/small laterals

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	IPSI_LATERAL	104.904	23	7.8306	1.6328
	CONTRA_LATERAL	112.113	23	6.3269	1.3193

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	IPSI_LATERAL & CONTRA_LATERAL	23	.879	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	IPSI_LATERAL - CONTRA_LATERAL	-7.2087	3.7768	.7875	-8.8419	-5.5755	-9.154	22	.000

Appendix 3.37. Results of paired t test for lateral incisors in group P after removal of peg/small laterals

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	IPSI_CENTRAL	107.165	23	8.2313	1.7164
	CONTRA_CENTRAL	110.135	23	8.1837	1.7064

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	IPSI_CENTRAL & CONTRA_CENTRAL	23	.946	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	IPSI_CENTRAL - CONTRA_CENTRAL	-2.9696	2.6986	.5627	-4.1365	-1.8026	-5.277	22	.000

Appendix 3.38. Results of paired t test for central incisors in group P after removal of peg/small laterals

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DIFF_LAT	.134	13	.200*	.960	13	.750
DIFF_CENT	.309	13	.001	.765	13	.003

Appendix 3.39. Normality test for lateral and central incisors in group B after removal of peg/small laterals

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	IPSI_LAT_B	124.715	13	12.8542	3.5651
	CONTRA_LAT_B	115.285	13	6.4897	1.7999

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	IPSI_LAT_B & CONTRA_LAT_B	13	.369	.215

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	IPSI_LAT_B - CONTRA_LAT_B	9.4308	12.0756	3.3492	2.1336	16.7280	2.816	12	.016

Appendix 3.40. Results of paired t test for lateral incisors in group B after removal of peg/small laterals

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between IPSI_CENT_B and CONTRA_CENT_B equals 0.	Related-Samples Wilcoxon Signed Rank Test	.196	Retain the null hypothesis.

Confidence Interval Summary

Confidence Interval Type	Parameter	Estimate	95% Confidence Interval	
			Lower	Upper
Related-Samples Hodges-Lehman Median Difference	Median of the difference between IPSI_CENT_B and CONTRA_CENT_B.	-1.100	-9.200	1.150

Appendix 3.41. Results of Wilcoxon Signed Rank test for central incisors in group B after removal of peg/small laterals

Correlations

		Ipsi_Lateralinclination	PROXIMITY	VERTICALHEIGHT	IMPACTIONSECTOR	PRIMARYCANINE
Ipsi_Lateralinclination	Pearson Correlation	1	-.353	-.212	.786**	-.079
	Sig. (2-tailed)		.236	.486	.001	.798
	N	13	13	13	13	13
PROXIMITY	Pearson Correlation	-.353	1	.577*	-.531	.259
	Sig. (2-tailed)	.236		.039	.062	.394
	N	13	13	13	13	13
VERTICALHEIGHT	Pearson Correlation	-.212	.577*	1	-.205	.544
	Sig. (2-tailed)	.486	.039		.501	.055
	N	13	13	13	13	13
IMPACTIONSECTOR	Pearson Correlation	.786**	-.531	-.205	1	-.213
	Sig. (2-tailed)	.001	.062	.501		.486
	N	13	13	13	13	13
PRIMARYCANINE	Pearson Correlation	-.079	.259	.544	-.213	1
	Sig. (2-tailed)	.798	.394	.055	.486	
	N	13	13	13	13	13

Appendix 3.42. Pearson correlation for group B after removal of peg/small laterals

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Ipsi_Lateralinclination	24	89.3	119.8	104.488	7.9261
PROXIMITY	24	.1	1.2	.433	.2729
VERTICALHEIGHT	24	.19	1.00	.5233	.19728
Valid N (listwise)	24				

IMPACTIONSECTOR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.0	3	12.5	12.5	12.5
	3.0	7	29.2	29.2	41.7
	4.0	9	37.5	37.5	79.2
	5.0	5	20.8	20.8	100.0
	Total	24	100.0	100.0	

PRIMARYCANINE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.0	8	33.3	33.3	33.3
	1.0	16	66.7	66.7	100.0
	Total	24	100.0	100.0	

Appendix 3.43. Descriptive statistics (left) and frequencies (right) for variables in group P after removal of peg/small laterals

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Ipsi_Lateralinclination	13	109.9	146.0	124.715	12.8542
PROXIMITY	13	.1	2.8	.685	.8980
VERTICALHEIGHT	13	.39	1.00	.7505	.23680
Valid N (listwise)	13				

IMPACTIONSECTOR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	4	16.7	30.8	30.8
	2	2	8.3	15.4	46.2
	3	6	25.0	46.2	92.3
	5	1	4.2	7.7	100.0
	Total	13	54.2	100.0	
Missing	System	11	45.8		
Total		24	100.0		

PRIMARYCANINE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	4	16.7	30.8	30.8
	1	9	37.5	69.2	100.0
	Total	13	54.2	100.0	
Missing	System	11	45.8		
Total		24	100.0		

Appendix 3.44. Descriptive staistics (left) and frequencies (right) for variables in group B after removal of peg/small laterals