Lower Dental Midline Stability: Effects of Primary Canine Loss

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of the Ohio State University

By

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ABSTRACT

**Purpose:** To compare changes in the lower dental midline position after premature unilateral loss of a lower primary canine with dental midline position after normal lower primary canine exfoliation. **Methods:** Dental casts were identified from growth studies at the University of Iowa and the University of Toronto. Two groups of dental casts were identified: premature unilateral loss and normal, asymmetric exfoliation of a single primary canine. The first set of casts displaying unilateral primary canine loss (Time 1) and the second casts displaying full permanent dentition (Time 2) were collected. The palatal rugae and palatal raphe were used to construct a median palatal plane (MPP). Dental midline position at each time point was measured from the MPP. **Results:** A total of 56 cases (15 early, 41 late) were identified. The mean lower dental midline changes from Time 1 to Time 2 for the early and late loss groups were 1.32 ± 0.83 mm and 0.97 ± 0.91 mm, respectively. This difference was not statistically significant with regard to group (p = 0.62), gender (p = 0.91), or the interaction effect of group and gender (p = 0.85). **Conclusions:** There was no significant difference in midline shift between individuals with early unilateral primary canine loss and those with normal, asymmetric unilateral loss of a primary canine.
I would like to dedicate this paper to my wonderful fiancé, Jen, for her patience and support during the past two years. I would also like to thank my parents, John and Lorie, for their encouragement and guidance during my journey.
Acknowledgements

I would first like to acknowledge Dr. John Christensen and Dr. Henry fields for their leadership and vision. 3Shape for their contribution, which allowed for this data to be collected and analyzed seamlessly. To the Ohio State University Orthodontic Department staff for their donation of time and services, and specifically to Dr. Beck for his analytic bequest.
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Fields of Study

Major Field: Dentistry

Specialty: Pediatric Dentistry
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Chapter 1: Introduction and Literature Review

Null Hypothesis:

\[ H_0: \text{The position of the lower dental midline after unilateral loss of a primary canine remains unchanged whether or not the primary canine is lost prematurely (greater than a year before the exfoliation of the contralateral primary canine).} \]

Mandibular Crowding and Canine Loss

The analysis of midline change must begin with a basic understanding of normal development and crowding. Previous studies have noted lower incisor crowding can be a normal stage of development, although the presence and severity of crowding cannot be properly noted until the permanent lateral incisors erupt.\(^1,2\)

Multiple factors influence eruption and alignment of lower incisors. These factors include, but are not limited to:\(^3\)

- Interdental spacing
- Intercanine distance
- Arch perimeter changes
- Size ratios between primary and permanent teeth

In cases when arch perimeter and intercanine distance are inadequate, there may be insufficient space mesiodistally for eruption of mandibular permanent incisors. The erupting permanent incisors may be blocked, completely or partially, by the primary canines leading to resorption of the mesial root surface of the canines. The ectopic eruption of the permanent lateral incisors can lead to premature unilateral and/or bilateral loss of primary canines. Premature loss of primary canines is not
limited to cases of ectopically erupting lateral incisors. Caries, trauma, and extraction can also result in early loss of the primary canine.

Regardless of the how the tooth was lost, premature loss of a lower primary canine and the need for treatment have been a topic of debate for many years. By some, it has been accepted as fact that the loss of a primary canine leads to an immediate midline shift. Whether a midline discrepancy will change as the dentition transitions from mixed into the permanent dentition and whether this will require early intervention is not clear.

Several studies and pediatric dental and orthodontic textbooks discuss lower incisor crowding and treatment of the lower dental midline shift in the early mixed dentition. Most recommend interceptive treatment for the crowding to minimize or correct the midline shift. While this is appealing to the practitioner, little evidence to supports these recommendations. Generally, recommended treatment is removal of the contralateral primary canine. Gianelly states that the removal of the opposing canine and placement of a lingual arch will control for symmetry and arch length. Others, like McDonald and Avery, believe the extraction of the contralateral canine will correct the midline deviation. Foley and Wright have created different treatments options based on the amount of crowding present. They recommend bilateral primary canine extraction when there is 4-9 mm of crowding. Foley and Wright suggest removal of the canines will allow for improved incisor alignment and will prevent the development of periodontal problems. The problem with these approaches is that the skeletal and dental relationships of the patient are not considered. Treatment options for a mandibular retrusive patient may differ from one with mandibular skeletal excess. Another problem with making decisions based only on crowding is that extraction of teeth may solve one problem for the clinician while creating another. For example, the Irregularity Index (a measure of contact discrepancies or tooth alignment) shows improvement when a contralateral canine is removed. However, there is a loss in arch length and arch perimeter. Therefore many clinicians recommend supporting
the incisors with a lower lingual holding arch after extraction of the canines to prevent arch length loss.\textsuperscript{3, 9}

Despite the general acceptance of contralateral canine extraction as the standard of care, insufficient evidence supports this theory. Gellin affirms that the primary incisors and canines are necessary for the process of alveolar growth, stating the presence of these teeth will allow for alleviation of crowding via increases in intercanine width.\textsuperscript{10} Hollander and Full reviewed the literature and believe the dental midline has the ability to self-correct, although they did not cite any supporting studies.\textsuperscript{11} Lee argues that primary canines act as proprioceptors to the forces guiding the movement of the permanent lateral incisors. He believes extraction of primary canines will discourage the mandibular arch from developing its optimal shape and size.\textsuperscript{12}

**Evaluation of the Dental Midline**

The position of the dental midline plays an important role in treatment planning for the pediatric dentist and orthodontist. The presence of a dental midline discrepancy has been documented in three-fourths of the population\textsuperscript{13} and is cited as a common cause for less than ideal finishes of orthodontic treatment.\textsuperscript{14} The three midlines most commonly evaluated in each patient are: the facial midline, the maxillary dental midline, and the mandibular dental midline. Jerrold and Lowenstein cite the mandibular dental midline as the most commonly discussed midline in the literature. They also suggest that studies about the correction of midline discrepancies often center around treatment of the mandibular dental midline.\textsuperscript{15}

Lewis proposed a set of questions for the practitioner to evaluate when presented with a midline discrepancy: (1) What has caused the midline deviation? (2) How does the deviation affect the occlusion? (3) Is it necessary to correct?\textsuperscript{16} Although many factors play a role in treatment decisions, one of the more important is the extent of deviation. Jerrold stated that a midline discrepancy can be
considered “very slight” when it is in the 1 to 2 mm range. These cases can often be managed, without creating functional problems, by tipping the anterior teeth or by interproximal reduction.

Beyer and Lindauer evaluated how discrepancies between the maxillary dental midline and the facial midline affected esthetics. The study evaluated the tolerance of midline discrepancies by general dentists, orthodontists, patients, and parents of patients. The authors determined a midline deviation of 2.2 ± 1.5 mm was the threshold for an acceptable midline deviation. Ker et al. conducted a similar study on esthetics and smile characteristics from the layperson’s perspective. The authors found mandibular midline deviations from the maxillary midline were esthetically acceptable until they exceeded 2.1 mm.

Much has been written regarding the dental midline position, but no conclusive data on what is considered a significant functional midline discrepancy is agreed upon. Despite this finding, the literature seems to agree that midline discrepancies less than 2 mm are not esthetically or clinically significant and can be managed with incisor tipping and interproximal reduction alone and without the risk of creating functional problems.

**Dental Cast Analysis**

Plaster dental models for orthodontic diagnosis have customarily been considered the gold standard. Traditionally, models have been analyzed using direct measuring methods, most commonly with calipers. Plaster models have proven to be a reliable and accurate representation of a patient’s dentition. The introduction of three-dimensional digital models over the past decade has changed the way cases are evaluated and treatment planned. The digital model has been shown to be reliable for diagnostic measurements and is as accurate in measurement as those taken from plaster casts.

The use of dental models in longitudinal studies has been investigated thoroughly. Dental models were obtained in many growth studies, but their use in
longitudinal analyses was hampered by the lack of stable landmarks. One of the first reports of a stable model landmark dates to 1955 when Lysell suggested the palatal rugae might serve as suitable landmarks for paternity identification. Two University of North Carolina evaluated the stability of the palatal rugae as landmarks for dental cast analysis. The studies specifically compared extraction versus non-extraction cases\textsuperscript{21} and the effects of headgear and functional appliances on rugae stability.\textsuperscript{22} The studies demonstrated that significant changes can be expected to the lateral points of the rugae. They concluded that the medial points of the third palatal rugae appear to be the most stable landmarks for the construction of anatomic reference points in longitudinal model analysis.\textsuperscript{21,22}

Dental Age Versus Chronologic Age

Dental age estimation charts have been used for decades in forensic science and dentistry to estimate age and maturity of individuals of unknown chronological age. Moorrees and Chadha first reviewed the literature available regarding dental development versus chronological age. They reported that combining early and late maturing children of the same chronologic age will disguise the amount of space loss during the transition from primary to permanent incisors.\textsuperscript{2} Late maturing children who have not lost all their primary incisors will mask the amount of space loss in other groups because they have not had to overcome incisor liability yet and have alignment of a partial complement of permanent teeth. Thus, it is vital to include dental age in the analysis of space loss.

The original gold standard of dental age estimation was based on tooth eruption sequence, although recently use of radiographic evidence of tooth development in the field of age estimation. Manjunatha and Soni suggested eruption sequence may not be as reliable as radiographic measures of tooth development to estimate age due to the influence of crowding and premature tooth loss.\textsuperscript{23} Despite these recent findings, numerous age estimation charts are available based on tooth eruption that have been thoroughly validated and used for many years. A 2014 study by AlQahtani et al. reviewed three of the most commonly used
estimation charts; Schour and Massler, Ubelaker, and the London Atlas. They revealed that all three charts underestimated the age of the individual, but that the London Atlas outperformed the Schour and Massler and the Ubelaker. Without standardized radiographs, the London Atlas appears to be the most reliable eruption based dental age estimation tool available.

**Background and Significance**

Every day pediatric dentists encounter early mixed dentition lower incisor crowding. Despite the daily presentation and some prevailing opinions, very little data are available regarding the changes in lower dental midline position over time. Important questions remain. Does the midline change if a single mandibular primary canine is lost prematurely? Does the midline change over time as permanent teeth erupt and is the movement in a direction back to the facial midline or does the midline continue to move away from the facial midline? Are the changes significant enough to influence future orthodontic treatment needs or esthetics? There are studies that describe the progression of crowding over time; however, none look at the change of the lower dental midline over time.

The position of the dental midline is an important factor in treatment planning. Little data provides guidance on whether to extract the antimere canine in cases with early unilateral primary canine loss, yet removal of the contralateral canine to correct a dental midline shift is taught in schools and textbooks.

The purpose of this project is to describe quantitative changes in the lower dental midline position for a cohort of dental casts over time after unilateral loss of a lower primary canine either prematurely or within normal limits. By identifying mean changes in the dental midline, this project may be able to provide more accurate information for clinicians on the long-term impact of canine loss and develop a treatment planning guideline for pediatric dentists and orthodontists. Sufficient evidence to support the null hypothesis would allow providers to be more conservative in treatment planning and reduce the number of pediatric surgical
procedures. A decrease in procedures and morbidity will decrease costs to patients and insurers.
Chapter 2: Materials and Methods

This project was exempt from review by the Institutional Review Board as it does not fit the definition of human subjects research. Dental casts and treatment records were obtained from growth studies conducted at the University of Iowa and the University of Toronto. Two types of dental casts were identified. The first group included casts with premature (more than 1 year prior loss of the contralateral tooth) unilateral loss of a primary canine. The second group included casts with unilateral loss of a primary canine due to normal, but asymmetric, exfoliation (less than 1 year prior to contralateral tooth eruption). Inclusion criteria were: dental casts revealing loss of one primary canine, no missing annual casts between loss of the first and contralateral canine, casts revealing full permanent dentition, no orthodontic treatment and no space maintainers for missing canines (band and loop off the lateral incisor or lower holding arch with spur for lateral incisor).

Two time periods were evaluated. Time 1 was the loss of one primary mandibular canine. Time 2 was the complete eruption of all permanent premolars. Each set of casts was scanned in a standardized manner using a 3Shape TRIOS intraoral scanner. The TRIOS intraoral scanner was shown to have the best balance of speed and accuracy in a 2016 review of 7 digital scanners. The scans were converted to three-dimensional images and data analysis was completed using digitized points within the 3Shape OrthoAnalyzer software. The OrthoAnalyzer software has been used in previous studies and was shown to adequately reproduce measurements taken manually from plaster casts.

The medial points of the third palatal rugae and palatal raphe were used as landmarks for baseline midline measurements. A median palatal plane
(MPP) was constructed on each maxillary cast using three points: RF1, RF2 and RF3.\textsuperscript{21,22} The RF1 landmark point is located on the median palatal raphe adjacent to the medial point of the right second palatal ruga. The RF2 and RF3 points were placed on the median palatal raphe distal to RF1 (See Figure 1). A perpendicular line from the MPP was drawn to the medial point of the right (RP3) and left (LP3) third palatal rugae, as the medial points of the third palatal rugae have been shown to be more stable than the first and second rugae.\textsuperscript{21,22} These measurements were used to confirm positioning of the MPP on all casts belonging to each case. The mandibular dental midline position was determined from these landmarks by measuring the distance of the mid-interproximal point of the mandibular central incisors to the MPP. The maxillary dental midline position was also measured from the MPP. In summary, the following measurements were made: right and left third palatal ruga to MPP, MPP to maxillary dental midline, and mandibular dental midline to MPP.

To determine reliability, all measurements of a random subset of 17.9\% (10 of 56) of casts were repeated 2 weeks later.\textsuperscript{20,29} After reliability was established, changes in the dental midline were evaluated for each set of casts. First, a determination was made to see if a midline shift occurred from time 1 to time 2. Second, a determination was made to evaluate the magnitude of the midline shift from time 1 to time 2. Third, the direction of midline shift was evaluated and recorded as either moving toward or away from the lost canine. Lastly, the deviation between maxillary and mandibular dental midlines was recorded at each time period (MAXMID1, MAXMID2) for all cases. Other data recorded included:

- Time elapsed between the first and second time periods (DTIME)
- Dental age at time of canine exfoliation (determined for each case using the London Atlas of tooth development and eruption)\textsuperscript{24} (DAGE)
- Race
- Sex
- Growth study group
Cases selected from each growth study that met inclusion criteria were assigned an identifier number that was separate from the identification system used by the growth studies. An electronic Excel file was kept in a password protected computer throughout the duration of the study.

Statistical Analysis and Sample Size Determination:

A post hoc power analysis with an effect size of 1.15 (i.e. a difference of midline deviation of ± 1mm), a non-directional alpha risk of 0.05, and a sample size of 15/41 yielded a power of 0.96.

Between group (early loss vs. late loss) analyses of age, dental age, time, and maxillary/mandibular deviations were made using the randomization test. The lower dental midline was assessed using a two-way mixed model analysis of variance with group (early loss vs. late loss) and gender as the independent variables. Maxillary/mandibular deviations and origin of the casts (Iowa, Ontario) were included as random variables.
Chapter 3: Manuscript

Lower Dental Midline Stability: Effects of Primary Canine Loss

ABSTRACT

Purpose: To compare changes in the lower dental midline position after premature unilateral loss of a lower primary canine with dental midline position after normal lower primary canine exfoliation. Methods: Dental casts were identified from growth studies at the University of Iowa and the University of Toronto. Two groups of dental casts were identified: premature unilateral loss and normal, asymmetric exfoliation of a single primary canine. The first set of casts displaying unilateral primary canine loss (Time 1) and the second casts displaying full permanent dentition (Time 2) were collected. The palatal rugae and palatal raphe were used to construct a median palatal plane (MPP). Dental midline position at each time point was measured from the MPP. Results: A total of 56 cases (15 early, 41 late) were identified. The mean lower dental midline changes from Time 1 to Time 2 for the early and late loss groups were 1.32 ± 0.83 mm and 0.97 ± 0.91 mm, respectively. This difference was not statistically significant with regard to group (p = 0.62), gender (p = 0.91), or the interaction effect of group and gender (p = 0.85). Conclusions: There was no significant difference in midline shift between individuals with early unilateral primary canine loss and those with normal, asymmetric unilateral loss of a primary canine.
INTRODUCTION

Mandibular Crowding and Canine Loss

Previous studies have noted lower incisor crowding can be a normal stage of development, although the presence and severity of crowding cannot be fully gauged until the permanent lateral incisors erupt.\textsuperscript{1,2}

Multiple factors influence eruption and alignment of lower incisors. These factors include dental variables such as interdental spacing, intercanine distance and change, arch perimeter changes and size ratios between primary and permanent teeth.\textsuperscript{3} Other factors such as sucking habits and muscle imbalances can change the position of the lower teeth.\textsuperscript{1,5}

In cases when arch perimeter and intercanine distance are inadequate, there may be insufficient space mesiodistally for eruption of mandibular permanent incisors. The erupting permanent incisors may be blocked by the primary canines leading to resorption of their mesial root surfaces. This ectopic eruption of the permanent lateral incisors can lead to premature unilateral or bilateral loss of primary canines. Premature loss of primary canines is not limited to cases of ectopically erupting lateral incisors. Caries, trauma, and extraction can also result in early loss of the primary canine.

Regardless of the how the tooth was lost, premature loss of a lower primary canine and the need for treatment have been a topic of debate for many years. By some, it has been accepted as fact that the loss of a primary canine leads to an immediate midline shift.\textsuperscript{4}
Several studies and pediatric dental and orthodontic textbooks discuss lower incisor crowding and treatment of the lower dental midline shift in the early mixed dentition.\(^1\) \(^4\) \(^5\) Most recommend interceptive treatment for the crowding to minimize or correct the midline shift. While this is appealing to the practitioner and parent, little evidence exists to supports these recommendations.

Generally, recommended treatment is removal of the contralateral primary canine.\(^4\) \(^6\) Gianelly states that the removal of the opposing canine and placement of a lingual arch will control for symmetry and arch length.\(^6\) Others, like McDonald and Avery, believe the extraction of the contralateral canine will correct the midline deviation.\(^4\) Foley and Wright have created different treatments options based on the amount of crowding present.\(^3\) However, it is important to realize extraction of teeth may solve one problem while creating another—dental irregularity and the midline may improve at the cost of reduced arch length.

Despite the general acceptance of contralateral canine extraction as the standard of care, other perspectives exist. Gellin affirmed that the primary incisors and canines are necessary for the process of alveolar growth and increases in intercanine width.\(^10\) Hollander and Full reviewed the literature and believed the dental midline had the ability to self-correct, although they did not cite any supporting studies.\(^11\) Lee argued that primary canines act as proprioceptors for the erupting permanent lateral incisors and are important for optimal mandibular arch shape and size.\(^12\)

**Evaluation of the Dental Midline**

The position of the dental midline plays an important role in treatment planning for the pediatric dentist and orthodontist. The presence of a dental midline discrepancy has been documented in three-fourths of the population\(^13\) and is cited as a common cause for less than ideal finishes of orthodontic treatment.\(^14\)

Although many factors play a role in treatment decisions, one of the more important is the extent of deviation. Jerrold stated that a midline discrepancy can be considered “very slight” when it is in the 1 to 2 mm range.\(^15\) These cases can
often be managed, without creating functional problems, by tipping the anterior teeth or by interproximal reduction.\textsuperscript{1,15}

Beyer and Lindauer evaluated how discrepancies between the maxillary dental midline and the facial midline affected esthetics. The study evaluated the tolerance of midline discrepancies by general dentists, orthodontists, patients, and parents of patients. The authors determined a midline deviation of $2.2 \pm 1.5$ mm was the esthetic threshold for an acceptable midline deviation.\textsuperscript{17} Ker et al. conducted a similar study solely from the layperson’s perspective and found mandibular midline deviations from the maxillary midline were esthetically acceptable until they exceeded $2.1$ mm.\textsuperscript{18}

In spite of divergent opinion, literature seems to agree that midline discrepancies less than $2$ mm are not esthetically or clinically significant and can be managed without the risk of creating functional problems.

**Dental Cast Analysis**

The use of dental models in longitudinal studies has been thoroughly investigated. Dental models were obtained in many growth studies, but their use in longitudinal analyses was hampered by the lack of stable landmarks. One of the first reports of a stable model landmark dates to 1955 when Lysell suggested the palatal rugae might serve as suitable landmarks for paternity identification. Two University of North Carolina studies evaluated the stability of the palatal rugae as landmarks for dental cast analysis. The studies specifically compared extraction versus non-extraction cases\textsuperscript{21} and the effects of headgear and functional appliances on rugae stability.\textsuperscript{22} The studies demonstrated that significant changes can be expected to the lateral points of the rugae while the medial points of the third palatal rugae appear to be the most stable landmarks for the construction of anatomic reference points in longitudinal model analysis.\textsuperscript{21,22}
Dental Age Versus Chronologic Age

Dental age estimation charts have been used for decades in forensic science and dentistry to estimate age and maturity of individuals of unknown chronological age. Moorrees and Chadha first reviewed the literature available regarding dental development versus chronological age. They reported that using chronologic age is deceptive because of early and late maturing individuals. It is vital to include dental age in the analysis of dental development dynamics.

Background and Significance

Every day pediatric dentists encounter early mixed dentition lower incisor crowding. Despite the daily presentation and some prevailing opinions, very little data are available regarding the changes in lower dental midline position over time. Important questions remain. Does the midline change if a single mandibular primary canine is lost prematurely? Does the midline change over time as permanent teeth erupt and is the movement in a direction back to the facial midline or does the midline continue to move away from the facial midline? Are the changes significant enough to influence future orthodontic treatment needs or esthetics? Although there are studies that describe the progression of crowding over time, none looks at the change of the lower dental midline over time.

The purpose of this project is to describe quantitative changes in the lower dental midline position for a cohort of dental casts over time after unilateral loss of a lower primary canine either prematurely or within normal limits. By identifying mean changes in the dental midline, this project may be able to provide guidance for treatment planning.

MATERIALS AND METHODS

This project was exempt from review by the Institutional Review Board as it does not fit the definition of human subjects research. Dental casts and treatment records were obtained from growth studies conducted at the University of Iowa and
the University of Toronto. Two types of dental casts were identified. The first group included casts with premature (more than 1 year prior loss of the contralateral tooth) unilateral loss of a primary canine. The second group included casts with unilateral loss of a primary canine due to normal, but asymmetric, exfoliation (less than 1 year prior to contralateral tooth eruption). Inclusion criteria were: dental casts revealing loss of one primary canine, no missing annual casts between loss of the first and contralateral canine, casts revealing full permanent dentition, no orthodontic treatment and no space maintainers for missing canines (band and loop off the lateral incisor or lower holding arch with spur for lateral incisor).

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incisors to the MPP. The maxillary dental midline position was also measured from the MPP. In summary, the following measurements were made: right and left third palatal ruga to MPP, MPP to maxillary dental midline, and mandibular dental midline to MPP.

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**Statistical Analysis and Sample Size Determination:**

A post hoc power analysis with an effect size of 1.15 (i.e. a difference of midline deviation of ± 1mm), a non-directional alpha risk of 0.05, and a sample size of 15/41 yielded a power of 0.96.
Between group (early loss vs. late loss) analyses of age, dental age, time, and maxillary/mandibular deviations were made using the randomization test. The lower dental midline was assessed using a two-way mixed model analysis of variance with group (early loss vs. late loss) and gender as the independent variables. Maxillary/mandibular deviations and origin of the casts (Iowa, Ontario) were included as random variables.

RESULTS

A total of 67 cases with unilateral canine loss were identified from the two studies (31 Iowa, 36 Toronto). Eleven cases were removed due to inadequate number of casts, orthodontic treatment, and/or space maintenance intervention (band-loops or holding arch with spurs off lateral incisors). Of the 56 cases that met all inclusion criteria, 15 were labelled premature loss and 41 as normal loss.

The examiner demonstrated good intra-examiner reliability with an ICC score of 0.96 (lower 95% confidence bound = 0.86; upper 95% confidence bound = 0.99).

The between-group comparisons showed statistically significant differences for mean chronological age (p = 0.001), dental age (p < 0.001), and elapsed time between Time 1 and Time 2 (p = 0.001; Table 1). The early loss group was not significantly different compared to the late loss group for maxillary-mandibular dental midline deviations at Time 1 (p = 0.11) or Time 2 (p = 0.09; Table 1). There were no significant differences in gender distribution or direction of midline shift and maxillary/mandibular midline differences at Time 1 or Time 2.

The mean lower dental midline changes from loss of the first primary canine (Time 1) to full permanent dentition (Time 2) for the early and late loss groups were 1.32 ± 0.83 mm and 0.97 ± 0.91 mm respectively (Table 2, Figure 2). This difference was not statistically significant for group (p = 0.62), gender (p = 0.91) or the interaction effect of group and gender (p = 0.85; Table 3). The median
midline shift for the early and late loss groups was 1.42 mm and 0.62 mm, respectively. The range for the early group was 0.07 – 2.61 mm and the range for the late group was 0.01 – 4.33 mm.

**DISCUSSION:**

Understanding the development of dental midline shifts can yield valuable insight into the potential need for early intervention. Previous reports and studies have discussed the topic of midline shifts, but to the best of our knowledge none have attempted to quantify it, outside of case reports. This study sought to understand one variable influencing midline shifts, the loss of a primary mandibular canine, and whether the timing of loss affects the magnitude of shift.

The mean lower dental midline shifts were calculated as the absolute shift from Time 1 to Time 2. The overall magnitude of midline shift for both groups was unexpectedly small. These changes were confirmed by the median changes, which were similar and eliminate group sample distributions as a confounding variable.

The group distribution was 26.8% (15) early canine loss and 73.2% (41) late canine loss. The gender distribution of the study was 33.9% male (19) and 66.1% female (37). Despite the large differences in sample sizes, no evidence suggests that group (p = 0.62), gender (p = 0.91), or their interaction (p = 0.85) affect the change in the lower dental midline from Time 1 to Time 2. An effect size of 1.15 (i.e. nearly 1 mm) was chosen because it gave the study a very high power (0.96) to detect a difference as small as 1 mm. Because of our effect size, we were not able to detect significant differences between the groups. Although we did not have the power to detect differences less than 1 mm, previous studies suggest that midline deviations are not esthetically or clinically significant until they are 2 mm or greater.15, 17, 18 Therefore, inability to discern differences between groups of less than 1 mm is irrelevant. Clinical decision making about differences less than 1 mm will not change treatment approaches in a meaningful way. The medians for each
group midline differences were also well below the 2 mm threshold for what is clinically and esthetically significant.

Five additional variables were compared between the two groups: Chronological age at Time 1, dental age at Time 1, time elapsed between Time 1 and Time 2, and maxillary/mandibular dental midline deviation at Time 1 and at Time 2. The average chronological age for the early and late loss groups, the average dental age and the average time elapsed between Time 1 and Time 2 were different for the longitudinal data collected over approximately 2 years and were expected.

The mean maxillary/mandibular dental midline deviation for the early and late groups at Time 1 was 1.53 ± 1.44 mm and 1.00 ± 0.93 mm (p = 0.11), respectively. The mean dental midline deviation at Time 2 for each group was 1.27 ± 0.93 mm and 0.83 ± 0.82 mm (p = 0.09), respectively. Neither the maxillary/mandibular dental midline deviation at Time 1 or Time 2 was significantly different between the early and late groups. The maxillary/mandibular dental midline deviation variable was included to account for possible dental midline deviations that were not recorded by only comparing the lower dental midline to the MPP. The potentially unstable maxillary dental midline and the static MPP provide two separate reference points for lower dental midline comparisons. This inclusion is significant because it lessens the potential impact of changes in occlusion as a confounding variable. The inclusion of the maxillary/mandibular dental midline comparison also allows a reference point for those not comfortable or familiar with the MPP and its validity as a stable reference point.

Interestingly, of the 56 cases, 40 (71.4%) showed an overall midline shift away from the side of early canine loss. This seems counterintuitive to current thought on early canine loss. One possible explanation for the direction of the shift is there was a midline shift that occurred prior to data collection for this study. Because models were obtained at specified intervals and not when the primary canine was first lost, there had to be a time interval between the loss of the primary canine and the patient’s next growth study appointment (Time 1). If a shift did
occur, was the shift all at one time or did the midline continue to shift similar to the space loss that occurs with the loss of a primary molar? Could most of the midline shift occur rapidly and then slow down (most movement occurs during the first few months), like with the loss of a permanent maxillary first molar? This is a question we were unable to answer. However, based on clinical experience, we must assume that some shift may have occurred during this time. This assumption means our Time 1 midline measurement does not include any initial midline shift toward the exfoliated canine. Our Time 1 to Time 2 measurements may have shown all midline movement except the initial shift.

If the initial midlines were identical, the magnitude of the initial shift would be small and clinically insignificant. Despite the inability to record these data, it is unlikely that its inclusion would significantly change our results in favor of clinical intervention. It is more likely that the inclusion of these missing data would further support the hypothesis that the overall midline shift is minimal and treatment should be limited to timely space maintenance and/or observation.

Finally, the range of the changes should be addressed. It is possible that sheer magnitude of some changes in the early loss group were masked by using measures of central tendency. This was not likely. The late loss group had a range 166% greater than the early loss group. The greater range was possible because the total crowding was manifest at the end of the transition.

CONCLUSION

1. The position of the lower dental midline after premature unilateral loss of a primary canine remains unpredictably and not a clinically meaningfully changed.

2. Our data suggest the long-standing theory that a significant midline deviation will occur and persist into the permanent dentition following premature unilateral primary canine exfoliation may not be accurate.
3. The nominal changes in midline position over time in this study suggest that not every patient with early unilateral primary canine loss will require intervention. Rather, each patient should be evaluated individually.

4. The findings of this study should encourage pediatric dentists and orthodontists to take a more conservative approach to treatment planning.
Chapter 4: Results

A total of 67 cases with unilateral canine loss were identified from the two studies (31 Iowa, 36 Toronto). Eleven cases were removed due to inadequate number of casts, orthodontic treatment, and/or space maintenance intervention (band-loops or holding arch with spurs off lateral incisors). Of the 56 cases that met all inclusion criteria, 15 were labelled premature loss and 41 as normal loss.

The examiner demonstrated good intra-examiner reliability with an ICC score of 0.96 (lower 95% confidence bound = 0.86; upper 95% confidence bound = 0.99).

The between-group comparisons showed statistically significant differences for mean chronological age (p = 0.001), dental age (p < 0.001), and elapsed time between Time 1 and Time 2 (p = 0.001; Table 1). The early loss group was not significantly different compared to the late loss group for maxillary-mandibular dental midline deviations at Time 1 (p = 0.11) or Time 2 (p = 0.09; Table 1). There were no significant differences in gender distribution or direction of midline shift and maxillary/mandibular midline differences at Time 1 or Time 2.

The mean lower dental midline changes from loss of the first primary canine (Time 1) to full permanent dentition (Time 2) for the early and late loss groups were 1.32 ± 0.83 mm and 0.97 ± 0.91 mm respectively (Table 2, Figure 2). This difference was not statistically significant for group (p = 0.62), gender (p = 0.91) or the interaction effect of group and gender (p = 0.85; Table 3). The median midline shift for the early and late loss groups was 1.42 mm and 0.62 mm, respectively. The range for the early group was 0.07 – 2.61 mm and the range for the late group was 0.01 – 4.33 mm.
Chapter 5: Discussion and Conclusions

DISCUSSION

Understanding the development of dental midline shifts can yield valuable insight into the potential need for early intervention. Previous reports and studies have discussed the topic of midline shifts, but to the best of our knowledge none have attempted to quantify it, outside of case reports. This study sought to understand one variable influencing midline shifts, the loss of a primary mandibular canine, and whether the timing of loss affects the magnitude of shift.

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CONCLUSION

Our findings support the null hypothesis that the position of the lower dental midline after unilateral loss of a primary canine remains unchanged. Our data suggest the long-standing theory that a significant midline deviation will occur and persist into the permanent dentition following premature unilateral primary canine exfoliation may not be accurate. The nominal changes in midline position over time in this study suggest that not every patient with early unilateral primary canine loss
will require intervention. Rather, each patient should be evaluated individually. The findings of this study should encourage pediatric dentists and orthodontists to take a more conservative approach to treatment planning.
Figure 1. Dental cast landmarks: 
RF1 (point on the median palatal raphe adjacent to the medial point of the right second palatal ruga); 
RF2 and RF3 (points on the median palatal raphe distally to RF1); 
LP3 (point on medial end of the left third palatal ruga); 
RP3 (point on the medial end of the right third palatal ruga); 
MPP (median palatal plane constructed by RF1, RF2, and RF3)
Figure 2. Comparison of lower dental midline shifts from Time 1 to Time 2.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Median</th>
<th>Quartile Range</th>
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<td>0.62</td>
<td>1.20</td>
<td>0.01</td>
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Table 1. Lower dental midline shift from Time 1 to Time 2.

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Table 2. ANOVA summary for independent variables of lower dental midline shift.
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Table 3. Between-group variable means. (AGE = chronological age; DAGE = dental age; DTIME = time elapsed between Time 1 and Time 2; MAXMID1 = maxillary/mandibular dental midline deviation at Time 1; MAXMID2 = maxillary/mandibular dental midline deviation at Time 2) (* = Between-group comparisons P value)
BIBLIOGRAPHY