COHORT STUDY O

The Effects of Primary Canine Loss on Permanent Lower Dental Midline Stability

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Abstract: ***Purpose:*** *The purpose of this study was to compare changes in the lower dental midline position after premature unilateral loss of a primary mandibular canine with dental midline position after normal primary mandibular 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: (1) premature unilateral loss; and (2) normal asymmetric exfoliation of a single primary mandibular canine. The first set of casts displaying unilateral primary canine loss (time one) and the second set of casts displaying full permanent dentition (time two) 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 premature, 41 normal) were identified. The mean lower dental midline changes from time one to time two for the premature and normal loss groups were 1.32±0.83 mm and 0.97±0.91 mm, respectively. This difference was not statistically significant regarding 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 the 15 individuals with premature unilateral primary canine loss and the 41 individuals with normal, asymmetric unilateral loss of a primary canine.* *(Pediatr Dent 2018;40(4):279-84) Received June 26, 2017 | Last Revision April 4, 2018 | Accepted May 17, 2018*

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Previous studies have noted that 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.[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.[3] Other factors, such as sucking habits and muscle imbalances, can change the position of the lower teeth.[1,4]

In cases when arch perimeter and intercanine distance are inadequate, there may be insufficient space mesiodistally for eruption of permanent mandibular incisors. The extraction of primary canines in the face of crowding can have variable outcomes. Sayin and Turkkahraman[5] looked at two groups with greater than or less than 1.6 mm of lower incisor crowding (incisor width compared to available space between the mesial surfaces of the primary canines); they found that, with extractions, the lower anteriors retruded but did not affect the arch length or width compared to the nonextraction group. In a different study, a sample of children with greater than six mm of incisor crowding, as determined by Little's irregularity index, were randomly assigned extraction or nonextraction treatment of the primary canines. The extraction group lost more arch length and had less incisor crowding, but the mandibular incisor inclination changes were similar.[6] These two studies had some overlapping subject types but different changes.

Alternatively, 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 primary mandibular 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.[7]

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.[1,4,7] 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 support these recommendations.

Generally, recommended treatment is removal of the contralateral primary canine.[7,8] Gianelly stated that the removal of the opposing canine and placement of a lingual arch will control for symmetry and arch length.[8] Others, like McDonald and Avery, believed the extraction of the contralateral canine will correct the midline deviation.[7] Foley and Wright have created different treatments options based on the amount of crowding present.[3] However, it is important to realize that extraction of teeth may solve one problem while creating another.

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.[9] Hollander and Full reviewed the literature and believed

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the dental midline had the ability to self-correct, although they did not cite any supporting studies.[10] Lee argued that primary canines act as proprioceptors for the erupting permanent lateral incisors and are important for optimal mandibular arch shape and size.[11]

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 75 percent of the population[12] and is cited as a common cause for less-than-ideal finishes of orthodontic treatment.[13] A midline discrepancy (maxillary or mandibular midline off the facial midline) is much more prevalent in the mandibular arch.[12]

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 one- to two-mm range.[14] These cases can often be managed, without creating functional problems, by tipping the anterior teeth or by interproximal reduction.[1,14]

Beyer and Lindauer evaluated how discrepancies between the maxillary dental midline and the facial midline affected esthetics. Their study evaluated the tolerance of midline discrepancies by general dentists, orthodontists, patients, and parents of patients. The authors determined that a midline deviation of 2.2±1.5 mm was the esthetic threshold for an acceptable midline deviation.[15] 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.[16]

In spite of divergent opinion, the literature seems to agree that midline discrepancies less than two 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 nonextraction cases[17] and the effects of headgear and functional appliances on rugae stability.[18] 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.[17,18]

Dental age versus chronologic age. Dental age estimation charts have been used for decades in forensic science and dentistry to estimate the 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 lower incisor crowding in the early mixed dentition.[19] 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 primary mandibular 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? Are changes affected by variables, such as chronological or dental age at the time of tooth loss, or by dental crowding? Although there are studies that describe the progression of crowding over time, none looks at the change of the lower dental midline over time.[2]

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

Methods

This project was exempt from review by an Institutional Review Board (no. IRB16-00284) at Nationwide Children's Hospital, Columbus, Ohio, as it does not fit the definition of human subjects research under 45 CFR part 46 or 21 CFR part 50. Dental casts and treatment records were obtained from growth studies conducted at the University of Iowa[20] and the University of Toronto.[21]

Two types of dental casts were identified. The first group included casts with premature (more than one year prior to 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 one 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); no clefts; and no crossbites. There was also no evidence or documentation suggesting the presence of a functional shift in any of the cases.

Two time periods were evaluated. Time one was the loss of one primary mandibular canine. Time two was the complete eruption of all permanent premolars. Each set of casts was scanned in a standardized manner using a 3Shape TRIOS (3Shape Trios A/S, Copenhagen, Denmark) intraoral scanner. The TRIOS intraoral scanner was shown to have the best balance of speed and accuracy in a 2016 review of seven digital scanners.[22] The scans were converted to three-dimensional images, and data analysis was completed using digitized points within the 3Shape OrthoAnalyzer (3Shape A/S, Copenhagen, Denmark) v. 2015 software. This software has been used in previous studies and was shown to adequately reproduce measurements taken manually from plaster casts.[23]

The medial points of the third palatal rugae and palatal raphe were used as landmarks for baseline midline measurements.[17,18,24] A median palatal plane (**MPP**) was constructed on each maxillary cast using three points: RF1; RF2; and RF3.[17,18] 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 posterior to RF1. The MPP was created by inserting a three-dimensional plane that intersected all RF

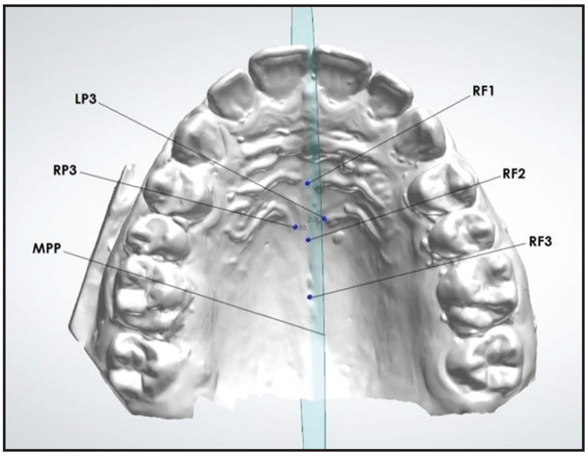

Figure 1. Dental cast landmarks. LP3: medial point of the left third palatal ruga perpendicular to the MPP. MPP: Median palatal plane. RF1: point on the median palatal raphe adjacent to the medial point of the right second palatal ruga. RF2: point on the median palatal raphe distal to RF1. RF3: point on the median palatal raphe distal to RF2. RP3: medial point of the right third palatal ruga perpendicular to the MPP.

points (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.[17,18] 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. All measurements were made by a single examiner.

To determine reliability, all measurements of a random subset of (10 of 56) casts were repeated at least two weeks later.[25,26] 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 one to time two. Second, a determination was made to evaluate the magnitude of the midline shift from time one to time two. Third, the direction of midline shift was evaluated and recorded as either moving toward or away from the lost canine. Lastly, the maxillary and mandibular dental midline deviations for time one and time two (**MXMNMID1** and **MXMNMID2**, respectively) was recorded 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; a **DAGE**)[27]; race; sex; growth study group (Iowa versus Toronto); amount of dental crowding (total arch length crowding as determined from a Tanaka-Johnston space analysis (**TJ**)[28]; and direct space analysis using all erupted permanent teeth.

Cases selected from each original growth study that met inclusion criteria for the current study were assigned an identifier number that was separate from the identification system used by the original 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 ±one mm), a nondirectional alpha risk of 0.05, and a sample size of 15 out of 41 yielded a power of 0.96. Estimated power calculations were done for the between group difference in midlines (i.e., time one to time two). The effect size of 1.15 was obtained by dividing one mm by the pooled standard deviation of the two groups. We did this to get an estimation for power if the observed difference between the groups had been one mm instead of the actual difference of 0.35 mm.

Between-group (premature unilateral loss versus normal asymmetric 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 (premature unilateral loss versus normal asymmetric loss) and gender as the independent variables. Maxillary/mandibular deviations and origin of the casts (Iowa, Ontario) were included as random variables. A similar analysis was done for the maxillary dental midline.

Intraexaminer measurement reliability was completed using an intraclass correlation coefficient (ICC) and 95 percent confidence intervals (95% CI). A Pearson correlation coefficient was used to relate the mandibular midline shift to the space analysis results.

A direct analysis of tooth size/arch length was calculated for both groups using the casts displaying full permanent dentition. A Pearson correlation coefficient was used to relate the total arch length to the mandibular midline shift.

All statistical analyses were done using SAS/STAT software, version 9.4 of the SAS System for X64_7PRO platform, Cary, N.C.; USA.

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 an 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 were labeled as normal loss.

The examiner demonstrated good intraexaminer reliability, with an ICC score of 0.71 (95% CI equals 0.25 to 0.91) to 0.97 (95% CI equals 0.71 to 0.97). The between-group comparisons showed statistically significant differences for mean chronological age (P=0.001; Table 1), dental age (P<0.001; Table 1), dental crowding (P=0.001; Table 1), Tanaka-Johnston space analysis (P=0.001; Table 1) and elapsed time between time one and time two (P=0.001, data not shown). The premature loss group was not significantly different compared to the normal asymmetric loss group for MXMNMID deviations at time one (P=0.11) or time two (P=0.09; Table 1).

The mean lower dental midline changes relative to the MPP from loss of the primary first canine (time one) to full permanent dentition (time two) for the premature and normal 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). The mean upper dental midline changes relative to the MPP from loss of the primary first canine (time one) to full permanent dentition (time two) for the premature and normal loss groups were 0.62±0.46 mm and 0.49±0.43 mm, respectively (Table 2). Again, this difference was not statistically significant for group (*P*=0.30), gender (*P*=0.14), or the interaction effect of group and gender (*P*=0.55).

There was no correlation between the magnitude of the midline shift and the results of the Tanaka-Johnston space analysis results (r equals -0.05, *P*=0.77; data not shown). There was also no correlation between the direct measured available space/arch length and the mandibular midline shift for either group (early: r equals 0.19, *P*=0.58; late: r equals -0.08, *P*=.66)

Table 1. BETWEEN-GROUP VARIABLE MEANS (PREMATURE UNILATERAL LOSS VS. NORMAL ASYMMETRIC LOSS)

Variable*	Group	N	Mean±SD	Median	Quartile range	Minimum	Maximum	*P*-value†
AGE	Premature	15	7.97±0.90	8.00	1.50	6.50	10.00	0.001
	Normal	41	9.02±0.99	9.00	1.50	7.00	11.50	
SEX N (%)	Premature	M F	8 (53) 7 (47)					0.0636
	Normal	M F	11 (27) 30 (73)					
DAGE	Premature	15	8.30±0.78	8.50	1.00	7.50	9.50	< 0.001
	Normal	41	9.87±1.12	9.50	1.00	7.50	11.50	
MXMNMID1	Premature	15	1.53±1.44	1.06	2.46	0.00	4.26	0.11
	Normal	41	1.00±0.93	0.71	1.14	0.04	3.49	
MXMNMID2	Premature	15	1.27±0.93	1.13	1.67	0.05	2.96	0.09
	Normal	41	0.83±0.82	0.53	0.96	0.01	3.66	
TJ	Premature	13	0.36±2.50	0.50	4.12	-4.16	3.81	0.001
	Normal	39	3.43±2.68	3.67	3.40	-2.01	8.41	

* AGE=chronological age, years; DAGE=dental age, years; MXMNMID1=maxillary/mandibular dental midline deviation at time one, mm; MXMNMID2=maxillary/mandibular dental midline deviation at time two, mm; TJ=Tanaka Johnson space analysis at T1 (crowding in mm).

† Between-group comparisons *P*-value. *P*-values for age, delta age, maxillary and mandibular shifts, and TJ were determined using the randomization test. Sex differences were evaluated using the chi-square test.

Table 2. DENTAL MIDLINE SHIFT (mm) RELATIVE TO MPP* FROM TIME 1 TO TIME 2

Midline	Group	N	Mean±SD	Median	Quartile range	Minimum	Maximum	*P*-value†
Lower	Premature	15	1.32±0.83	1.42	1.22	0.07	2.61	0.62
	Normal	41	0.97±0.91	0.62	1.20	0.01	4.33	
Upper	Premature	15	0.62±0.46	0.53	0.64	0.10	1.69	0.30
	Normal	41	0.49±0.43	0.43	0.51	0.00	2.30	

* MPP: Median palatal plane. † Analysis of variance.

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 and upper dental midline shifts were calculated as the absolute shift from time one to time two. The overall magnitude of midline shift for both groups was unexpectedly small. The group distribution was 26.8 percent (N equals 15) premature unilateral canine loss and 73.2 percent (N equals 41) normal asymmetric canine loss. The gender distribution of the study was 33.9 percent male (N equals 19) and 66.1 percent female (N equals 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 one to time two. An effect size of 1.15 (i.e., nearly one mm) was chosen, because it gave the study a very high power (0.96) to detect a difference as small as one mm. Although we did not have the power to detect differences less than one mm, previous studies suggest that midline deviations are not esthetically or clinically significant until they are two mm or greater.[14-16] Therefore, inability to discern differences between groups of less than one mm is irrelevant. Clinical decision-making about differences less than one mm will not change treatment approaches in a meaningful way. The medians for each group midline differences were also well below the two-mm threshold for what is clinically and esthetically significant.

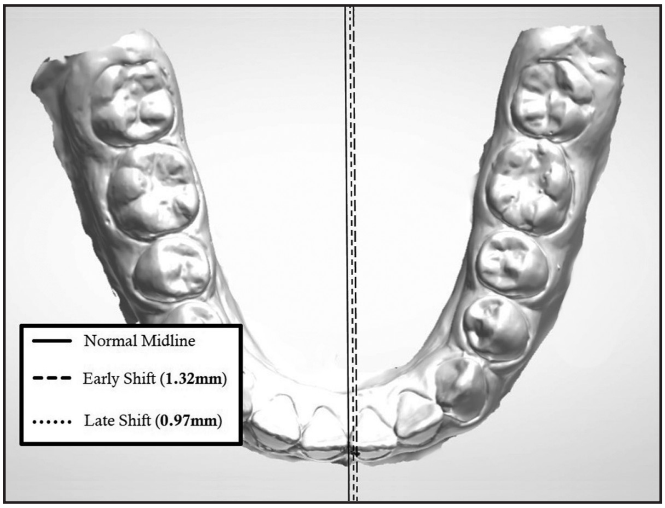

Figure 2. Comparison of lower dental midline shifts from Time 1 to Time 2.

The intraexaminer reliability was good, although there was a difference in the confidence intervals between the first and second reproducibility measurements. The difference in variability of the confidence intervals may be the result of experience.

It should be noted that, although previous studies report that dental midline deviations become esthetically and clinically significant after they surpass the two-mm threshold, there are obviously exceptions to the rule (i.e., cases with coincident dental midlines that are off the facial midline by greater than two mm).

To address this issue, the maxillary and mandibular midlines relative to the MPP were calculated at both time one and time two. There were no significant differences between the groups, and the magnitude of the deviations from the MPP were approximately 0.5 mm in the upper and one mm in the lower arches.

Seven additional variables were compared between the two groups: chronological age at time one; dental age at time one; time elapsed between time one and time two; Tanaka-Johnson space analysis at time one; and maxillary/mandibular dental midline deviation at time one and at time two. The average chronological age for the premature and normal loss groups, average dental age, and average time elapsed between time one and time two were different for the longitudinal data collected over approximately two years and were expected. The mean and median space analyses results showed both groups with adequate space, but significantly more space in the late asymmetric loss group. Transient crowding may have made the difference in tooth loss occur rather than overall crowding. Further, there was no correlation between the space analysis results and the amount of midline shift.

The mean maxillary/mandibular dental midline deviation for the premature and normal groups at time one were 1.53±1.44 mm and 1.00±0.93 mm (P=0.11), respectively. The mean dental midline deviation at time two for each group was 1.27±0.93 mm and 0.83±0.82 mm (P=0.09), respectively. 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. The average maxillary dental midline shift from the MPP was also included to give support to the maxillary/mandibular dental midline deviation as a stable reference point.

Interestingly, of the 56 cases, 40 (71.4 percent) showed an overall midline shift away from the side of premature canine loss. This seems counterintuitive to current thought on premature 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 one). 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), as with the loss of a permanent maxillary first molar?[29] These 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 one midline measurement does not include any initial midline shift toward or away from the exfoliated canine. Our time one to time two measurements may have shown all midline movement except the initial shift. If the initial midlines were coincident, 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.

A limitation of this study is the relatively low number of subjects in the premature loss group (15). Although we would have preferred a more balanced design, the data set yielded unequal cell sizes. This is unfortunate but unavoidable.

Some might argue that having these data prior to any tooth loss could have made this study more powerful. That is unlikely. Maxillary midlines are most likely close to the MPP.[12] Our maxillary midline to MPP data show approximately 0.5 mm discrepancy from that plane (Table 2), which confirms this previous finding. If one argues that our data missed early dramatic changes in the midline, then it had to be mitigated by dramatic moves away from the MMP and then back to it in the undocumented period of time. If that were the case, then the conclusion we reached that little, if any, intervention is warranted still stands, as the problem is self-correcting. On the other hand, it appears to be a relatively small problem, as we documented.

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

Conclusions

Based on this study's results, the following conclusions can be made:

1. The position of the lower dental midline after premature unilateral loss of a primary canine in 15 patients did not change significantly compared to the 41 control group patients.
2. Our data suggest that 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 premature unilateral primary canine loss will require intervention.

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