Location of the Mandibular Lingula in Pediatric Patients using CBCT Images

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Abstract

Location of the mandibular lingula in pediatric patients on CBCT Images

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Purpose: To determine the position of the mandibular lingula in a sample of CBCTs taken on pediatric patients, with a focus on implications for administration of local anesthesia.

Methods: A sample of 280 outpatient CBCT (i-CAT) scans (153 males and 127 females) (UW-SoD dept. of pediatric dentistry) were divided into age groups: 6-9 year olds (N=103), 10-13 year olds (N=103), and 14-18 year olds (N=74). An ANOVA test was used to compare across age groups, with significance level set to $P<.05$. A calibrated investigator assessed all images using InVivo5 (Anatomage) software. The position of the lingula was determined relative to the anterior and posterior border of the ramus, the mandibular notch, the inferior border of the mandible and the mandibular plane. The mandibular angle was also recorded.

Results: The average distance for all positional measurements was significantly greater in 14-18 year-olds when compared with 6-9 year-olds. In the oldest age group, the mandibular angle was significantly more acute. Significant differences in distances were noted bilaterally across all

age groups in boys (1) and girls (2) for distance from lingula to: (1) posterior border of ramus, (1,2) mandibular notch, (1,2) inferior border mandible and (1,2) occlusal plane.

Conclusions: The average distance from the mandibular lingula to anatomic markers increases with patient age. On average, the needle for inferior alveolar nerve blocks should be directed 3mm above the occlusal plane in 6-9 year-olds, 5mm above the occlusal plane in 10-13 year-olds, and 7mm above the occlusal plane in 14-18 year olds.

Introduction

It has been reported that the failure rate of the inferior alveolar nerve block (IANB) is 15-20% [5, 8]. This high failure rate can be attributed to a high degree of variation in the anatomical structures near the IAN nerve, psychological fears, or pathological reasons. However, the most common reason for failure is due to poor technique [7]. The most commonly used technique is called the direct approach (also known as the Halsted block), which involves inserting the needle into the pterygomandibular space by piercing the buccinator muscle [6]. Once in this space, the goal is to deposit the local anesthetic just superior to the lingula in order to anesthetize the inferior alveolar nerve before it enters the mandibular foramen. The mandibular lingula is a tongue-like bony protrusion located on the medial aspect of the ramus protecting the mandibular foramen and it is often used to approximate the position of the mandibular foramen. The inferior alveolar nerve travels through the mandibular foramen to innervate the mandibular alveoli and buccal gingiva anteriorly to the midline, along with the pulp tissue of all mandibular teeth on that side.

The body grows in a cephalocaudal gradient, meaning that the pattern of growth over time increases from head to foot. In regards to facial growth, the maxilla completes its growth early whereas the mandible tends to continue to grow more and finishes growth at a later time [10]. It is not surprising to see a mandibular surge in adolescents whereas maxillary growth is hardly evident after 11 to 12 years of age [9]. The growth of the mandible is such that it is translated downward and forward due to growth at the mandibular condyle and along the posterior surface of the ramus [1]. Knowledge of how the mandibular lingula changes position with age can lead to increased success in local anesthesia. Past studies have shown that the position of the mandibular lingula in relation to the occlusal plane increases from 6mm in 7-8

year olds to 10mm in 9 to 10-year olds [5]. The mandibular angle has been shown to decrease with age in both males and females [12]. Differences between the lingula and mandibular ramal landmarks from the right and left sides have been reported to be statistically significant in a patient population aged 9 to 18 years [4]. The position of the lingula is important for many oral and maxillofacial surgical procedures including bilateral sagittal split osteotomies and mandibular trauma management.

Cone Beam Computed Tomography (CBCT) is ideal for three-dimensional imaging of hard tissues (e.g. bone and teeth). CBCT images are superior to panoramic radiographs in visualizing mandibular landmarks [2]. Additionally, compared to a multi-slice CT (medical CT), a CBCT results in a lower radiation dose for patients. The latter is especially important when treating young patients, who require three dimensional imaging for dentomaxillofacial complications (e.g. aberrant developing dentition, dento-alveolar trauma, orthognathic surgical planning and follow-up [13]). The advantages of CBCTs are that they have offer rapid scan time and easy reconstruction of data [3]. Routine use of CBCTs, however, is not acceptable clinical practice, as the estimated effective dose is, depending on the field of view, 5-300 microSieverts (μSv), versus merely 24 μSv for a panoramic radiograph [1]. Additionally, children are more prone to potential stochastic effects from ionizing radiation as their tissues grow at a faster rate (higher mitotic activity) and thus are more vulnerable to DNA damage [1].

Multiple studies have been published about anatomical variations found on CBCT images taken in adult patients, but very sparse research exists on anatomy using CBCTs from a pediatric population. The latter can be attributed to the fact that in general, fewer children are submitted to CBCT investigations than adults.

The present study is unique in that it is, to our knowledge, the first study that has examined and reviewed CBCT images in a population of American children aged 6 to 18 years. The objectives of this study are to determine the average distances from the mandibular lingula to mandibular ramal landmarks, and the average mandibular angle between and across age groups and sexes.

Materials and Methods:

A cross-sectional study was performed using a convenience sample of patients who received a CBCT at the Center for Pediatric Dentistry (CPD) (University of Washington, Seattle, Washington) from January 1, 2014 through December 31, 2015. A total of 280 images were reviewed. Children were categorized according to age: 6-9, 10-13 and 14-18 years. This study was approved by the Institutional Review Board (IRB) of the University of Washington, in Seattle, Washington (IRB-45968).

Images were obtained with the i-CAT Next Generation® (Imaging Sciences International, LLC, Hatfield, PA, USA). Inclusion criteria were patients who were 6 to 18 years old at the time of CBCT investigation, not subjected to prior orthodontic treatment or orthognathic surgery and had good quality CBCT images available that included the entire mandible. The images were then viewed with Invivo5® (Anatomage, San Jose, CA, USA).

Three dimensionally surface rendered, direct right and left side views, were used for the measurements in Invivo5®, not allowing for rotations of the mandible. Opacity, brightness and contrast were altered on the images in order to clarify the location of the mandibular lingula and other anatomical landmarks. The left view was always measured first.

The angle of the mandible was measured by placing a point on the most posterior aspect of the condyle, a point at the most posterior and inferior aspect of the mandible, and on the most anterior and inferior point of the chin. All measurements from the mandibular lingula originated from a single point at the most posterior and superior aspect of the lingula (Fig. 1). Straight lines were used to measure all the distances between the lingula and the various ramal landmarks: the most anterior aspect of the ramus, the most posterior border of the ramus, the most superior aspect of the mandibular notch, and the most inferior aspect of the border of the ramus. The occlusal plane was defined as a line from the most anterior lingual cusp available in that quadrant of the mandible (e.g. first primary molar or a first permanent premolar) to the most posterior lingual cusp in that same quadrant (e.g. second permanent molar or second primary molar) . Subsequently, a straight line was dropped and measured from the most posterior and superior aspect of the lingula to the occlusal plane.

The principal investigator (LYG) was calibrated before the study using benchmarks set by an oral and maxillofacial radiologist (JA). Two calibration exercises of five patients each (of CBCTs not taken from 2014-2015) were performed. Both investigators were blinded to the measurements from the other investigator. An interrater correlation (ICC) of > 75% was achieved. Midway through data collection, five additional patients were chosen at random for calibration, which resulted in the same interrater correlation.

The data were entered into REDCap® (6.16.3) (Institute of Translational Health Services, Vanderbilt University, Nashville, TN, USA) and exported into Stata (13.1)® (StataCorp LP, College Station, TX, USA) for analysis. Statistical significance was determined at the level of $p < 0.05$.

Descriptive statistics (means, standard deviations, counts, and percentages) were calculated for all patient data. ANOVA tests were used to compare the three age categories, 2-sample t-tests were used to compare boys versus girls, while paired t-tests were used to compare the right versus the left side.

Results:

A total of 280 patients from the CBCT database were eligible to be included in the study. The majority were boys (54.6%), and most of the patients were between 6 and 13 years old (73.6%). Table 1 contains information regarding the subjects in this study. Tables 2 and 3 show the mean values of the measurements for the respective genders, age groups and mandibular sides.

Angle of the mandible

Across all ages, the right angle of the mandible ranged from 109.4 – 140.1 degrees, while on the left it ranged from 106.7 to 140.4 degrees. Measures for the mandibular angle were more acute with increasing age. On the right, there is on average a decrease of 3.01 degrees (p-value = 0.001) in children aged 14-18 years of age in comparison to those who are 6-9 years old. On the left, there is a decrease of 3.58 degrees (p-value < 0.001). (Table 2) In boys, a significant difference was observed in the oldest age group, compared to the youngest age group (p = 0.009), while in girls this significant decrease was found when the oldest age group was compared with the middle age group (p = 0.022). (Table 3) The left mandibular angle in boys appears to decrease significantly when the oldest age group is compared to both younger age groups (p = 0.001), while for girls the latter was only true when the oldest age group was compared to the middle age group (p = 0.011). (Table 3)

Distance from the anterior border of the ramus

Irrespective of age, the distances measured in boys are significantly greater than in girls (0.63mm greater for the right side ($p = 0.023$) and 0.59mm greater for the left side ($p = 0.025$)). (Table 3) Measurements for 14-18 year old boys were 1.31 mm greater than girls from the same age group. ($p = 0.037$). (Table 3) Neither boys nor girls demonstrated a significant change in this measurement as age increased.

Distance from the posterior border of ramus

Table 2 shows that when gender is not taken into account, a significantly greater distance of 0.77mm on the right side in the oldest age group was noticed when compared to the youngest group ($p = 0.015$). For the left side this was true for the oldest age group compared to either other age group ($p < 0.001$). In the 14 to 18 year olds the left side was, on average, 0.38mm greater compared to the right side ($p =0.018$). In boys this distance increased significantly with age bilaterally ($p < 0.001$ for both sides). (Table 3) Irrespective of their age, this distance in boys, compared to girls, is significantly greater on the on the right side by an average of 0.65mm ($p = 0.002$). For the oldest age group it was observed that this distance was significantly greater in boys than in girls (1.54mm greater on the right, 1.49mm on the left) ($p < 0.001$). (Table 3)

Distance from the mandibular notch

Table 2 illustrates that if gender and age are not considered, this distance was significantly greater on the right side of the mandible by 0.40mm ($p < 0.001$). Similar findings

were observed for the 6 to 9 and 10 to 13 year olds ($p = 0.004$ and $p = 0.005$ respectively). From Tables 2 and 3, this distance increases bilaterally with age in both genders ($p < 0.001$ for all).

Distance from inferior border of the ramus

Irrespective of age and gender, this distance is significantly greater on the left side by 0.22mm ($p = 0.040$) (Table 2). Across age groups, this distance increased significantly with age ($p < 0.001$ for both sides) and for both genders ($p < 0.001$). (Tables 2 and 3) The range of measurements was greater in the older age groups in comparison to the younger age groups. In the 14-18 year olds, the range was approximately 20mm. When age is not considered, this distance on the left side of the mandible was significantly greater in boys versus girls by 1.10mm ($p = 0.033$). In the oldest age group, the distance is significantly greater in boys than girls (by 4.38mm on the right, and 4.4mm on the left) ($p < 0.001$ for both sides). (Table 3)

Distance from 1st molar occlusal plane

Table 2 shows that in some patients, the lingula is located below the occlusal plane, yielding a negative distance. Additionally, the location can be up to 13 mm different within the same age group (14-18 year olds). Table 2 shows that this distance significantly increases bilaterally with age (right side increases 3.53mm from the youngest to the oldest age group, and left side increases 3.62mm from the youngest to the oldest age group) ($p < 0.001$ for both sides). (Table 2) This distance is significantly greater on the right side ($p < 0.001$) in every age group, irrespective of gender ($p = 0.005$, $p = 0.001$ and $p = 0.010$ for the age groups respectively). A similar finding was observed comparing the right to left side in boys 10 to 13 years of age, the right side was on average 0.78mm greater distance than the left ($p = 0.027$). (Data not shown in

tables) For girls, irrespective of age (0.73mm greater in the right versus the left side; $p = 0.048$) and in all 3 age groups the same finding was observed (($p = 0.037$, $p = 0.016$ and $p = 0.048$ for the age groups respectively). (Data not shown in tables) When genders are compared, irrespective of age, girls have a greater distance than boys (1.11mm greater on the right; $p = 0.003$ and 1.03mm greater on the left; $p = 0.006$). (Table 3)

Discussion:

When comparing 6-9 year-old children to 14-18 year-old children, there are significant differences in all measurements except for the distance to the anterior border of the ramus. This result is in line with the fact that mandibular growth occurs mostly on the posterior border of the ramus, and not the anterior aspect of the ramus. All measurements increased in value with the exception of the mandibular angle (which decreased), leading to a more acute angle with age. These findings are to be expected since they are related to mandibular growth.

Findik et al. performed a small CBCT study looking at 27 patients ages 9 through 18 years of age [4]. The differences between the right and left measurements from the lingula to the anterior border of the ramus were statistically significant. In the present study, significant differences between the sides occurred, but the differences were very minimal (less than a 1mm difference in all comparisons). Significant differences between boys and girls occurred, but these were on average less than 2 mm difference other than a difference of 4-5mm in the 14-18 year old age group when examining the distance between inferior border of the mandible to the lingula. These results can be interpreted as being of little clinical relevance due to the small differences noted. However, considering the range of measurements (minimal and maximal values that were measured), it appears that there was substantial individual variation in subjects,

which could explain why some individuals are difficult to anesthetize in the mandible. The position of the mandibular lingula with respect to the anterior or posterior edge of the ramus of the mandible can be up to a 10mm difference between subjects within the same age group. The variation in distance from the mandibular lingula to the occlusal plane also varied substantially across and within age groups.

The results of this study suggest that clinicians should recognize that there is a great deal of individual anatomic variability, and the position of the lingula changes in relative position with age. This has strong implications for successful administration of a conventional mandibular block. On average, in 6-9 year-olds, the lingula is 3mm above the occlusal plane, in 10-13 year-olds, 5mm above the occlusal plane, and in 14-18 year olds, 7mm above the occlusal plane. These results differ from a previous study [5] which found the location of the lingula to be 6mm above the occlusal plane in 7-8 year olds, and 10mm in 9-10 year olds in measuring these values from panoramic radiographs.

In Fig. 2, one can see the ideal insertion height for a mandibular block for each age category. The needle should then be advanced to the point where it passes just over the lingua and is adjacent to the inferior alveolar nerve. On average, this point is 18 mm from the anterior edge of the ramus and 15 mm from the posterior edge of the ramus. According to our findings, clinicians should aim at the maximum value (14mm across all age groups) from the occlusal plane in order to capture the inferior alveolar nerve. Aiming for the maximum value above the occlusal plane as opposed to the mean value would prevent the provider from too low of an insertion and potentially missing the block. The downside of aiming too high would be the potential of blocking the mandibular division V3 block of the trigeminal nerve if the needle was positioned too far posteriorly and superiorly near the condylar neck, through the Gow-Gates

technique. In this technique, mandibular anesthesia is obtained in which more nerves are anesthetized than in the inferior alveolar block, including the inferior alveolar, mental, incisive, lingual, mylohyoid, auriculotemporal and buccal nerve (in 75% of patients) [8]. The Gow-Gates technique would still allow for patient comfort for mandibular procedures, and usually has very few post-injection complications.

Others have reported measurements for the lingula that were quite different than we observed. Serkerci et al. examined the anatomy and position of the lingula in 269 Turkish children between six and twelve years old using CBCTs. The authors found that the lingula had a mean (± standard deviation) distance of 13.3±2.3 mm from the anterior border of the mandibular ramus, 10.2±1.6 mm from the posterior border of the ramus, and 11.4±2.5 mm from the mandibular notch [11]. In comparing our 2 age categories encompassing ages 6-13 years, all of these measurements were roughly 4 to 5 mm greater in our present study. This may be due to the fact that our population was comprised of American children, while they studied Turkish children.

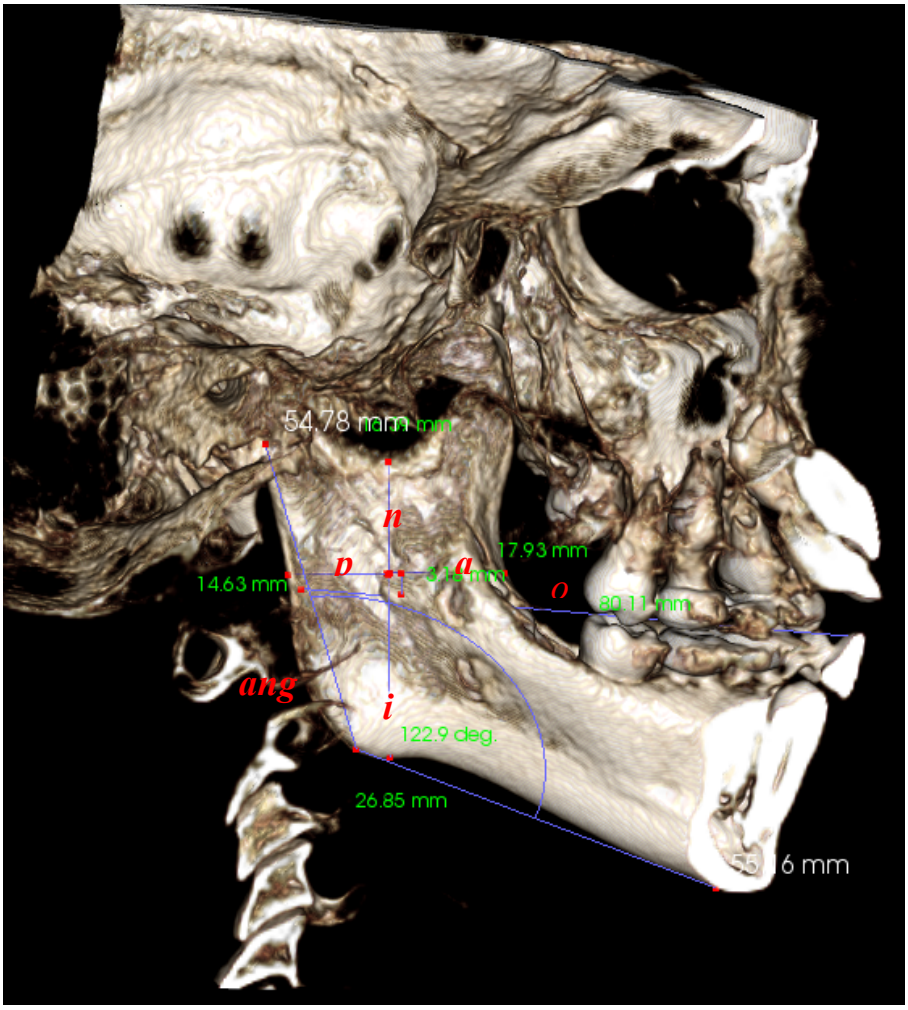
Out of the 280 patients that we measured, 27 patients had the left lingula at or below the occlusal plane and 23 patients had their right lingulas positioned at or below the occlusal plane (Table 4). From the same table, one can appreciate that with increasing age, the position of the lingula changes and appears to be located superior to the occlusal plane. The clinical significance of this statement is that when administering the IAN block one should aim above the occlusal plane, as illustrated in Figure 2.

This study has a few limitations. We designed our study so that one investigator recorded all of the measurements. The CBCT image was altered through opacity and brightness so that the lingula was able to be fully visualized. This allowed for repeatable results and high intra-

investigator reproducibility, but if this study were replicated, there could be differences in the way the image is altered in identifying the points of measurements. Another limitation of this study relates to individual variations in anatomy. Some patients had a very pronounced point gonion, leading to a larger mandibular angle. Some patients also appeared to have distinctly different lingula morphology on either side. Such anatomical variations may confound the resulting measurements, and also explain why there are large ranges for each measurement. Furthermore, the ethnic and racial backgrounds of the patients are unknown as this data was not recorded at the study clinic. The patient population at the Center for Pediatric Dentistry of the University of Washington is very diverse and it should be assumed that significant ethnic diversity existed in the study population.

Conclusion:

These results help to clarify the location of the mandibular lingula and can inform dentists regarding the appropriate insertion point for conventional inferior alveolar nerve block in children. On average, in 6-9 year-olds, the lingula is 3mm above the occlusal plane, in 10-13 year-olds, 5mm above the occlusal plane, and in 14-18 year olds, 7mm above the occlusal plane. Retrospective three-dimensional studies should continue to be conducted as the use of cone beam computed topography becomes more accepted and used more frequently in the dental field. There is still much to learn about dental anatomy and the individual variations that occur.



ang	Angle of the mandible
a	Distance from anterior border of the ramus
p	Distance from posterior border of the ramus
n	Distance from mandibular notch
i	Distance from inferior border of the ramus
o	Distance from 1st molar occlusal plane

Fig. 1 Left lateral view in Invivo5® (Anatomage) with distances measured in mm, and the mandibular angle measured in degrees

Table 1: Patient Characteristics

	N = 280
Child Demographics	N (%)
Child's gender	
Male	153 (54.6%)
Female	127 (45.4%)
Child's age at time of CBCT	
6-9 years old	103 (36.8 %)
10-13 years old	103 (36.8%)
14-18 years old	74 (26.4%)

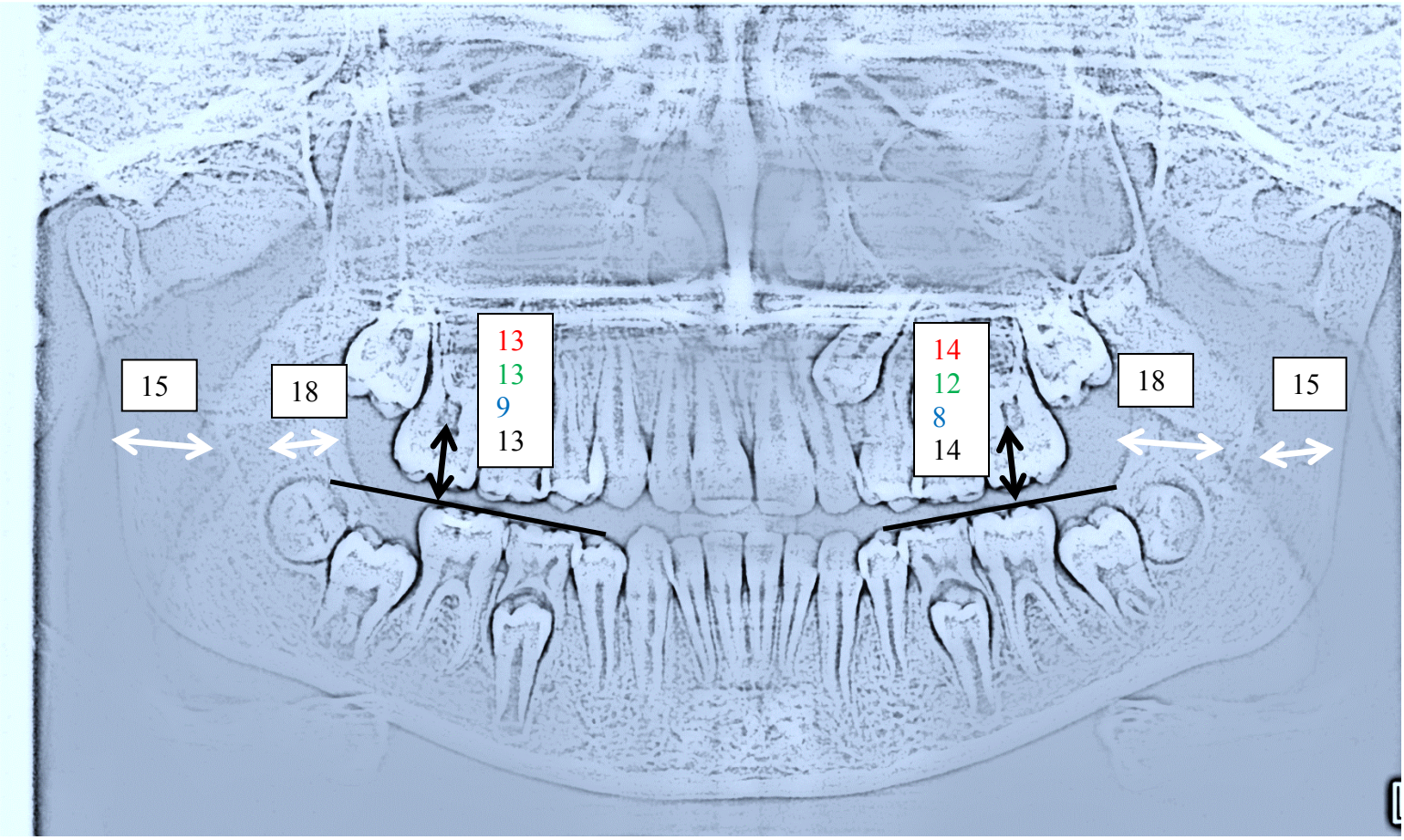


Fig. 2 Average measurements of distances (in mm) from anterior and posterior borders of the ramus to the lingula and maximum values of distance from the occlusal plane by age groups (black: inclusive of all age groups, blue: 6-9 year olds, green: 10-13 year olds, red: 14-18 year olds)

Table 2: Measurements for all patients and patient groups, irrespective of gender

	All ages (N=280)	**6-9 years (N=103)**	**10-13 years (N=103)**	**14-18 years (N=74)**	
	mean (SD) [min, max]	mean (SD) [min, max]	mean (SD) [min, max]	mean (SD) [min, max]	*p-value**
Angle of the mandible (degrees)					
Right	126.3 (5.4) [109.40, 140.10]	127.32 (5.18)[1] [115.50, 137.70]	126.69 (5.44)[2] [109.40, 140.10]	124.31 (5.13)[1,2] [109.9, 136.5]	<0.001
Left	126.5 (5.5) [106.70, 140.40]	127.61 (4.91)[1] [112.60, 138.10]	127.15 (5.25)[2] [106.70, 140.40]	124.03 (5.88)[1,2] [111.3, 137.40]	<0.001
*p-value***	0.291	0.351	0.158	0.479	
Distance from anterior border of ramus (mm)					
Right	18.02 (2.31) [11.81, 25.19]	17.68 (2.11) [12.46, 24.96]	18.23 (2.25) [12.96, 25.10]	18.21 (2.60) [11.81, 25.19]	0.172
Left	18.12 (2.17) [11.58, 25.56]	17.83 (1.79) [13.68, 22.03]	18.32 (2.07) [13.92, 23.85]	18.24 (2.71) [11.58, 25.56]	0.237
*p-value***	0.270	0.352	0.489	0.860	
Distance from posterior border of ramus (mm)					
Right	14.89 (1.80) [10.01, 20.42]	14.63 (1.66)[1] [10.01, 18.67]	14.79 (2.89) [10.42, 20.42]	15.40 (2.04)[1] [10.01, 19.97]	0.015
Left	14.97 (1.86) [10.1, 20.88]	14.47 (1.64)[1] [10.10, 18.26]	14.90 (1.78)[2] [10.81, 20.88]	15.78 (2.00)[1,2] [10.51, 20.29]	<0.001
*p-value***	0.296	0.216	0.355	0.018	
Distance from mandibular notch (mm)					
Right	15.91 (2.45) [9.82, 25.82]	14.96 (2.01)[1,3] [10.41, 23.66]	15.84 (2.26)[2,3] [9.82, 20.94]	17.34 (2.61)[1,2] [11.68, 25.82]	<0.001
Left	15.51 (2.36) [10.62, 23.79]	14.51 (1.95)[1,3] [11.01, 19.01]	15.41 (2.10)[2,3] [10.62, 19.59]	17.02 (2.49)[1,2] [11.58, 23.79]	<0.001
*p-value***	<0.001	0.004	0.005	0.129	
Distance from inferior border of the ramus (mm)					
Right	27.16 (4.24) [18.07, 41.99]	24.32 (2.87)[1,3] [18.07, 32.03]	27.37 (3.27)[2,3] [19.68, 36.57]	30.82 (4.13)[1,2] [18.48, 41.99]	<0.001
Left	27.38 (4.30) [17.28, 40.93]	24.49 (3.10)[1,3] [17.28, 31.34]	27.71 (3.43)[2,3] [20.07, 36.83]	30.95 (4.00)[1,2] [20.83, 40.93]	< 0.001
*p-value***	0.040	0.298	0.064	0.577	
Distance from 1st molar occlusal plane (mm)					
Right	5.11 (3.16) [-2.77, 13.29]	3.53 (2.60)[1,3] [-2.61, 9.10]	5.30 (2.91)[2,3] [-2.77, 13.12]	7.06 (3.08)[1,2] [0.00, 13.29]	<0.001
Left	4.43 (3.12) [-5.93, 13.65]	2.83 (2.60)[1,3] [-5.93, 7.86]	4.58 (2.74)[2,3] [-1.15, 11.60]	6.45 (3.10)[1,2] [-0.69, 13.65]	< 0.001
*p-value***	<0.001	0.005	0.001	0.010	

*P-values to test for differences across age groups were calculated using ANOVA. Superscripts are to show which groups are significantly different from the others. For example, 1,2 indicates that the value is significantly different between the group that also has a superscript of 1, and the other group that has a superscript of 2.
**P-values to test for differences across right and left side were calculated using a paired t-test.

Table 3: Comparisons of measurements in males and females and per age category and per side

Side	Gender	All ages	6-9 years	10-13 years	14-18 years	*p-value**
Angle of the mandible (degrees)						
Right	M	125.97 (5.39) [109.40, 137.70]	127.22 (5.01)[1] [116.50, 137.70]	125.72 (5.65) [109.40, 137.00]	123.97 (5.21)[1] [109.9, 132.6]	0.011
	F	126.68 (5.38) [115.50, 140.10]	127.50 (5.56) [115.50, 135.90]	127.53 (5.16)[1] [117.30, 140.10]	124.64 (5.10)[1] [115.50, 136.50]	0.022
*p-value***		0.270	0.798	0.092	0.579	
Left	M	126.21 (5.10) [106.70, 137.00]	127.62 (4.43)[1] [117.20, 137.00]	126.19 (4.99)[2] [106.70, 134.90]	123.68 (5.53)[1,2] [111.30, 134.00]	0.001
	F	126.84 (6.00) [112.60, 140.40]	127.61 (5.80) [112.60, 138.10]	128.00 (5.57)[1] [116.30, 140.40]	124.39 (6.25)[1] [112.90, 137.40]	0.011
*p-value***		0.349	0.9997	0.088	0.606	
Distance from anterior border of ramus (mm)						
Right	M	18.31 (2.39) [11.81, 25.19]	17.90 (2.26) [12.46, 24.96]	18.52 (2.21) [12.96, 23.03]	18.77 (2.75) [11.81, 25.19]	0.291
	F	17.68 (2.17) [13.80, 25.10]	17.26 (1.75) [14.05, 20.82]	17.97 (2.27) [14.95, 25.10]	17.65 (2.34) [13.80, 22.94]	0.322
*p-value***		0.023	0.148	0.213	0.062	
Left	M	18.39 (2.22) [12.27, 25.56]	17.91 (1.73) [13.68, 21.03]	18.66 (2.14) [13.92, 22.81]	18.89 (2.92) [12.27, 25.56]	0.055
	F	17.80 (2.07) [11.58, 24.06]	17.68 (1.93) [14.14, 22.03]	18.03 (1.98) [14.10, 23.85]	17.58 (2.34) [11.58, 24.06]	0.561
*p-value***		0.025	0.538	0.120	0.037	
Distance from posterior border of ramus (mm)						
Right	M	15.19 (1.71) [11.51, 19.97]	14.75 (1.61)[1] [11.41, 18.67]	15.06 (1.33)[2] [12.02, 17.43]	16.17 (1.95)[1,2] [12.40, 19.97]	<0.001
	F	14.54 (1.85) [10.01, 20.42]	14.41 (1.74) [10.01, 16.83]	14.56 (1.95) [10.42, 20.42]	14.63 (1.84) [10.01, 17.92]	0.876
*p-value***		0.002	0.323	0.137	<0.001	
Left	M	15.15 (1.79) [10.10, 20.29]	14.56 (1.60)[1] [10.10, 18.26]	14.94 (1.45)[2] [11.41, 18.58]	16.52 (1.83)[1,2] [12.98, 20.29]	<0.001
	F	14.76 (1.93) [10.11, 20.88]	14.29 (1.71) [10.11, 18.17]	14.87 (2.05) [10.81, 20.88]	15.03 (1.91) [10.51, 20.22]	0.226
*p-value***		0.078	0.433	0.852	<0.001	
Distance from mandibular notch (mm)						
Right	M	16.00 (2.70) [10.72, 25.82]	15.07 (2.18)[1] [10.72, 23.66]	15.99 (2.46)[2] [11.65, 20.94]	17.71 (3.05)[1,2] [11.68, 25.82]	<0.001
	F	15.81 (2.12) [9.82, 21.51]	14.77 (1.65)[1] [10.41, 17.48]	15.71 (2.09)[2] [9.82, 19.31]	16.96 (2.04)[1,2] [13.42, 21.51]	<0.001
*p-value***		0.537	0.954	0.523	0.221	
Left	M	15.55 (2.48) [10.62, 23.79]	14.52 (1.97)[1] [11.23, 19.01]	15.50 (2.22)[2] [10.62, 19.46]	17.53 (2.50)[1,2] [11.58, 23.79]	<0.001
	F	15.45 (2.23) [11.01, 22.11]	14.50 (1.95)[1] [11.01, 18.36]	15.34 (2.00)[2] [11.27, 19.59]	16.51 (2.40)[1,2] [12.19, 22.11]	<0.001
*p-value***		0.711	0.450	0.709	0.078	
Distance from inferior border of the ramus (mm)						
Right	M	27.57 (4.66) [19.68, 41.99]	24.52 (2.66)[1,3] [20.14, 32.03]	27.70 (3.45)[2,3] [19.68, 36.57]	33.01 (3.88)[1,2] [24.58, 41.99]	<0.001
	F	26.67 (3.61) [18.07, 34.70]	23.94 (3.23)[1,2] [18.07, 31.08]	27.08 (3.12)[1,3] [21.38, 34.70]	28.63 (3.13)[2,3] [18.48, 34.38]	<0.001
*p-value***		0.076	0.334	0.344	<0.001	
Left	M	27.88 (4.63) [18.47, 40.93]	24.82 (2.83)1,3 [18.47, 29.81]	28.14 (3.52)[2,3] [22.13, 36.83]	33.17 (3.59)[1,2] [25.35, 40.93]	<0.001
	F	26.78 (3.80) [17.28, 35.63]	23.85 (3.53)[1,2] [17.28, 31.34]	27.34 (3.32)[1] [20.07, 35.63]	28.73 (3.08)[2] [20.83, 35.51]	<0.001
*p-value***		0.033	0.135	0.235	<0.001	
Distance from 1st molar occlusal plane (mm)						

Right	M	4.61 (3.27) [-2.77, 13.29]	3.31 (2.77)[1] [-2.61, 9.10]	4.23 (2.52)[2] [-2.77, 11.40]	7.47 (3.30)[1,2] [0.65, 13.29]	<0.001
	F	5.72 (2.92) [-1.84, 13.12]	3.95 (2.20)[1,2] [-1.30, 7.19]	6.23 (2.94)[1] [-1.84, 13.12]	6.66 (2.83)[2] [0.00, 11.18]	<0.001
*p-value***		0.003	0.239	<0.001	0.260	
Left	M	3.96 (3.20) [-5.93, 13.65]	2.74 (2.72)[1] [-5.93, 7.86]	3.45 (2.25)[2] [-0.80, 8.60]	6.88 (3.30)[1,2] [-0.69, 13.65]	<0.001
	F	4.99 (2.95) [-1.81, 11.60]	2.99 (2.38)[1,2] [-1.81, 7.77]	5.57 (2.76)[1] [-1.15, 11.60]	6.02 (2.86)[2] [0.65, 10.19]	<0.001
*p-value***		0.006	0.640	<0.001	0.239	

*P-values to test for differences across age groups were calculated using ANOVA. Superscripts are to show which groups are significantly different from the others. For example, 1,2 indicates that the value is significantly different between the group that also has a superscript of 1, and the other group that has a superscript of 2.
**P-values to test for differences between males and females were calculated using 2-sample t-tests

Table 4: The position of the lingula at or below the occlusal plane per age category and per side

	Males and Females (N)	Males (N)	Females (N)
Left lingula (all ages)	27	20	7
Left lingula (6-9 years)	17	12	5
Left lingula (10-13 years)	9	7	2
Left lingula (14-18 years)	1	1	0
Right lingula (all ages)	23	15	8
Right lingula (6-9 years)	17	12	5
Right lingula (10-13 years)	5	3	2
Right lingula (14-18 years)	1	0	1

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