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Prevalence of mandibular asymmetries in growing patients

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SUMMARY The aim of the present study was to determine the prevalence of mandibular asymmetries during the mixed dentition in growing children. For this purpose, a retrospective study was designed where various measurements were performed on the right and left sides of the mandible of panoramic radiographs of 327 children (males: 169; females: 158), 8–12 years old. Four linear measurements, mandibular ramus height, ramus width, corpus height, and corpus length, and two angles, mandibular gonial (Go) and mandibular condyle (Co), and the developmental stage of the permanent lower second molar were analysed. All measurements were adjusted for the magnification factor. The final data were then processed for the asymmetry index (AI) to determine the severity of the asymmetries and statistically analysed by Wilcoxon paired tests at the 95 per cent level of confidence.

A moderate-to-severe mandibular asymmetry for the linear dimensions when both sides of the mandible were contrasted was found in more than a half of the sample. There was also a high prevalence of moderate and severe asymmetries when comparing Go and Co angles on both sides of the mandible. No differences were observed in the developmental stage of the lower permanent second molar between either side. There was a high prevalence of both dimensional and angular mandibular asymmetries in the studied population.

Introduction

Facial symmetry refers to a state of balance, where the size, form, and arrangement of facial tissues and structures on the opposite sides of the median sagittal plane correspond. Thus, the right and left sides in the craniofacial complex, comprising identical structures, must similarly grow and develop to reach symmetry. Asymmetries between both sides of the mandible may be due to an adaptive response of the mandible to deviations during function, which may cause modelling of the condyle (CO) and glenoid fossa (Pirttiniemi and Kantomaa, 1992; Liu *et al.*, 2007), as well as remodelling and modelling of the mandibular bone (Turner, 1992; Pirttiniemi, 1994; Frost, 2004). Such a situation may lead to dimensional differences in size or shape between the right and left sides of the mandible, in other words, mandibular asymmetry. Anthropologic and cephalometric studies have reported the presence of asymmetries in normal facial features (Mulick, 1965; Letzer and Kronman, 1967; Vig and Hewitt, 1974, 1975), which leads to a general acceptance of the fact that asymmetries in some areas of the face may be normally present at some ages (Melnik, 1992; Duthie *et al.*, 2007). Nevertheless, studies investigating proportions in the craniofacial complex of normal subjects have shown that the dentoalveolar and mandibular regions are symmetrical on both sides (Shah and Joshi, 1978; Peck *et al.*, 1991).

Dimensional mandibular asymmetries have mainly been associated with crossbites (Pirttiniemi and Kantomaa, 1992; Hesse *et al.*, 1997; Lam *et al.*, 1999), Class II subdivision patients (Azevedo *et al.*, 2006; Sezgin *et al.*, 2007; Kurt *et al.*, 2008), and the right side predominating over the left when the dimensions of both hemimandibles are contrasted (Skvarilova, 1993; Kula *et al.*, 1998). Although mandibular asymmetries have been reported to be a common feature in growing patients (Melnik, 1992; Duthie *et al.*, 2007), a dimensional difference of more than 2–3 mm between the sides of the mandible has been considered as asymmetry, which may have clinical relevance (Lu, 1965; Kula *et al.*, 1998). Nevertheless, the prevalence and severity of mandibular asymmetries in a population in the mixed dentition has not been extensively studied.

Several methods, such as submento-vertical and posteroanterior radiographs (Forsberg *et al.*, 1984; Trpkova *et al.*, 2003), photography (Edler *et al.*, 2003), and the panoramic radiograph (Joondeph, 2000; Kambylafkas *et al.*, 2006), have been proposed to determine mandibular asymmetries. The panoramic radiograph offers a method to analyse the various structures of the mandible (e.g. CO, ramus, body) separately on the right and left sides (Larheim and Svanaes, 1986; Habets *et al.*, 1987; Liukkonen *et al.*, 2005), and even though it should be cautiously used when making absolute measurements or relative comparisons, the panoramic radiograph is reliable for determining mandibular asymmetries (Larheim and Svanaes, 1986; Habets *et al.*, 1987; Joondeph, 2000; Kambylafkas *et al.*, 2006; Laster *et al.*, 2006).

Therefore, the aim of the present study was to determine the prevalence of mandibular asymmetries in growing children in the mixed dentition. For this, linear and angular measurements, as well as a qualitative evaluation of the stage of second molar development, were performed.

Materials and methods

The present study was approved by the Marquette University Ethical Committee (HR-1523, 30 October 2007).

The dental records of 400 Caucasian subjects between 8 and 12 years old were randomly selected from those for whom a panoramic radiograph was taken for diagnostic purposes before restorative treatment at the Marquette University Pediatric Dental Clinic. From these dental records, four were missing the radiographs, and therefore, those subjects were not included in the study resulting in 396 panoramic radiographs initially selected. All radiographs were taken with the same X-ray machine (Ortopantomogram OP100; Instrumentarium Imaging, General Electric, Milwaukee, Wisconsin, USA) by two trained assistants, who followed the protocol for patient positioning established at the clinic.

Selection of the radiographs

Only those panoramic radiographs presenting no artefacts, the whole mandible fully captured on the radiograph, and the contrast on the radiograph sufficient to perform all the intended measurements were chosen. Sixty-nine radiographs were excluded because either the quality was poor or the mandible was cut-off at some point on the film. Thus, 327 radiographs of 169 boys and 158 girls without a history of trauma, craniofacial congenital disease, or orthodontic treatment recorded in their dental history were included in the study. Forty-one subjects were 8, 88 were 9, 69 were 10, 63 were 11, and 66 were 12 years of age.

The radiographs were digitally scanned (Epson Expression XL-Photo Scanner; Epson America, Long Beach, California, USA) at a resolution of 300 dpi. Two different sets of measurements (mandibular dimensions and mandibular angles) and a subjective evaluation (molar development) were recorded. All measurements and the subjective evaluation were performed on the digitized radiographs. Linear and angular measurements were undertaken using pre-calibrated morphometric analyser software (Scion Image; Scion Corp., Frederick, Maryland, USA). The software was pre-calibrated by means of a scale (18 mm in diameter) simultaneously scanned with each radiograph.

Mandibular dimensions

The following longitudinal measurements were undertaken on both sides of each panoramic radiograph (Figure 1):

Ramus height (RH): perpendicular distance between the deepest point of the mandibular ramus notch (R1) and the lower border of the mandible (R2) as described by Ricketts (1961).

Ramus width (RW): perpendicular distance between the deepest point of the anterior border of the mandibular ramus (R3) and the posterior border of the ramus (R4) as described by Ricketts (1961).

Corpus height (CH): perpendicular distance between the lowest mesial point of the permanent first lower molar at

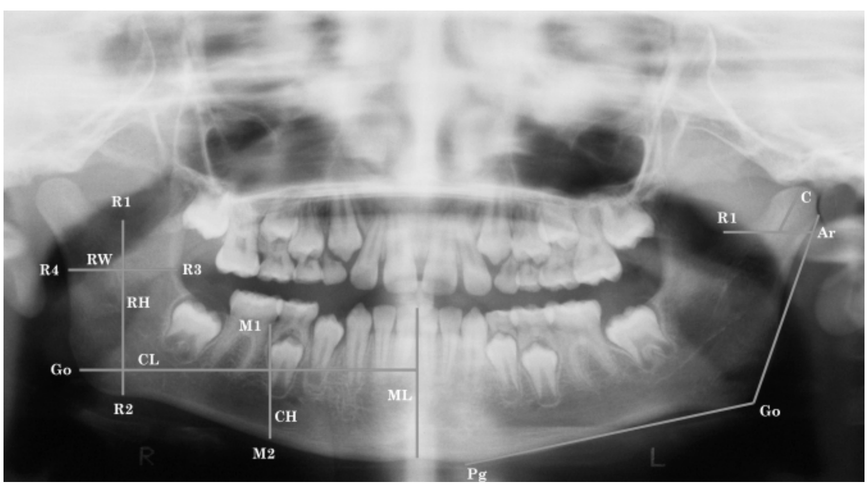


Figure 1 Panoramic radiograph showing the landmark points and linear and angular measurements used in this study. (R1–R4) Points described by Ricketts (1961) at the mandibular ramus: Go, gonion; M1, point at the cervical point of the first permanent molar; M2, corresponding perpendicular point to M1 at the inferior border of the mandible; Pg, pogonion; Ar, articulare; C, condylion; RW, ramus width; RH, ramus height; CL, corpus length; CH, corpus height; ML, midline.

the cemento-enamel junction (M1) and the lower border of the ramus (M2).

Corpus length (CL): distance between gonion intersection and pogonion (Pg), as recommended by Joondeph (2000). Gonion intersection was defined as the point of intersection of the mandibular plane (Go–Pg) and the plane of the posterior border of the mandibular ramus [articulare (Ar)–Go]; and Pg as the lowest point of the mental area on the mandibular midline.

Three co-authors (AS, EF, and KC) individually performed all measurements on both sides of all the panoramic radiographs and differences between them were determined by Spearman correlation coefficient analysis.

Calculation of the distortion factor of the panoramic radiograph

To determine the distortion the panoramic radiograph may have caused on the linear dimensions of the mandible on both sides, a distortion factor for each hemimandible was calculated. For this, 10 radiographs from the sample were randomly selected. The mesio-distal length of the four permanent first molars was measured on the study models. The same distances were then measured on the panoramic radiographs. The distortion factor was calculated by dividing the mesio-distal length on the cast by the mesio-distal length on the radiograph for each of the four permanent first molars. The average of the 20 distortion factors (10 upper and 10 lower molars on each side) was then separately computed for the right (0.62) and the left (0.69) sides and applied to the linear measurements. Thus, the distortion factors were applied to the initial results of the three investigators, and then, those results were processed to obtain the asymmetry index (AI) and submitted to statistical analysis.

AI for the linear measurements

For each of the linear measurements, the severity of the asymmetry that could be present in the mandible of each subject was determined by means of the AI. The index was calculated following the formula proposed by Saglam (2003):

$$\text{Asymmetry index (AI)} = \frac{\text{Right measurement} - \text{Left measurement}}{\text{Right measurement} + \text{Left measurement}} \times 100$$

The results were obtained as a percentage, where a positive result indicated that the right side was larger than the left, a negative result indicated that the left side was larger than the right, and a percentage equal to 0 indicated that both sides of the mandible were symmetric.

Based on the AI for each measurement on each radiograph, the results were classified into four categories of asymmetry: no significant (NS) asymmetry, when AI was between 0 and 2.99 per cent; light (L), when AI was between 3 and 5 per cent; moderate (M), when the index was greater than 5 per cent, but less than or equal to 10 per cent; and severe (S), when AI was more than 10 per cent.

Although the results for the severity of dimensional mandibular asymmetries are reported as a percentage, they may be measured in millimetres as follows: NS, a difference of 0–2 mm between both sides of the mandible; L, a difference of 2–3 mm; M, a difference of 3–5 mm; and S, a difference greater than 5 mm between both sides of the mandible for the correspondent measurement.

Mandibular angles

Two angles were measured for this study. Gonial (Go) angle was measured at the intersection of the planes formed by the posterior border of the mandibular ramus (Ar–Go on the mandibular ramus) and the lower border of the mandibular corpus (Go on the mandibular corpus–Pg). The second was condylar angle, which was measured by tracing a secant touching R1 on the ramus notch, running parallel to the Frankfort plane, and the long axis of the CO starting at condylion (C). The results are presented as angular degrees. Both mandibular angles measured for this study are shown in Figure 1.

Determination of asymmetry between mandibular angles

The difference between the right and left angle was used to determine the amount of asymmetry between the angles. The value of the left angle was subtracted from that of the right angle for both gonial and condylar angles. Thus, the severity of the asymmetry was determined as follows: NS, when the difference between the right and left angle was between 0 and 2.99 degrees; L, when the difference between both sides was between 3 and 5 degrees; M, when the difference was greater than 5 degrees but less than or equal to 10 degrees; and S, when that difference was more than 10 degrees.

Lower second molar development

The stages of development of the permanent lower second molars on both sides of the mandible were also compared and classified into one of the 14 stages proposed by Moorrees (1967), where stage 1 corresponds to the initial cusp formation and stage 14 to complete root formation and apical closure.

Subjective evaluation of the developmental stages of the permanent second molars was performed by three authors (AS, EF, and KC) at different times, and agreement between them was determined using the Spearman correlation coefficient analysis.

Agreement between investigators

Once all measurements were collected, the data were statistically compared with Spearman correlation coefficient analysis, a non-parametric correlation test, at the 95 per cent level of confidence. The correlation factor (*r*) was determined, which computes the agreement between the three results obtained for each measurement on each radiograph. The average from the three measurements for each dimension on each radiograph was then calculated and used as the final data.

Statistical analysis

The final data were statistically compared using Wilcoxon paired analysis, a non-parametric test, at the 95 per cent level of confidence. The data also were contrasted by age and gender.

Results

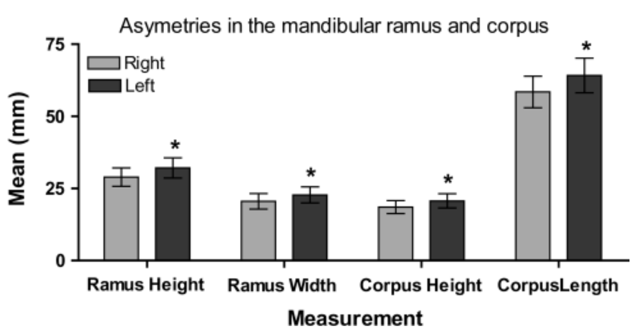
Investigator agreement

A high agreement (r = 0.88 or higher) was determined between the three investigators for the four longitudinal measurements. RH (r) was 0.91 for the right and 0.90 for the left side; RW (r) was 0.92 for the right and 0.90 for the left side; CH (r) was 0.89 for the right and 0.88 for the left side; and finally, CL (r) was 0.93 for the right and 0.95 for the left side.

For the mandibular angles, the agreement between investigators was high (right side $r = 0.88$; left side $r = 0.90$), whereas for molar development, it was very high (right side $r = 0.92$; left side $r = 0.91$).

Mandibular dimensions

Wilcoxon paired tests showed a statistically significant difference ($P < 0.05$) between both sides of the mandible for the four longitudinal measurements on the panoramic radiographs (RH, RW, CH, and CL). The means and standard deviation for each measurement are shown in Figure 2. The means for the right and left sides, respectively, were RH 28.90 ± 3.19 mm and 32.11 ± 3.51 mm; RW 20.52 ± 2.67 mm and 22.37 ± 2.78 mm; CH 18.54 ± 2.27 mm and 20.67 ± 2.47 mm; and CL 58.46 ± 5.47 mm and 64.15 ± 6.01 mm.



Q17 **Figure 2** Graph showing the means and standard deviation of the dimensional measurements performed on the panoramic radiographs to determine asymmetries between both hemimandibles, *$P < 0.05$.

For all four longitudinal measurements, the means were higher on the left side compared with the right side. Regarding age and gender, no significant differences were observed (data not shown).

Regarding the severity of the mandibular asymmetry calculated with the AI, a high percentage of the subjects presented moderate or severe asymmetry when both sides were compared. Thus, 165 of the 327 subjects were classified as M and 10 as S when considering RH. On the other hand, 146 subjects were classified as M and 45 as S when considering RW. Similarly, 170 subjects were classified as M and 23 as S when considering CH and 137 and 24 were classified as M and S, respectively, when considering CL. The results showed that more than a half of the sample had either moderate or severe asymmetry when comparing both sides of the mandible on the panoramic radiograph. The corresponding percentages for the severity of the asymmetry for each measurement are shown in Table 1.

The severity of the asymmetry regarding age is shown in Table 2. Moderate asymmetry was present in a high percentage of subjects at all ages for the four mandibular dimensions evaluated. The percentage of subjects for each type of asymmetry (NS, L, M, and S) was similar between females and males.

Mandibular angles

For both gonial and condylar angles, there was a statistically significant difference ($P < 0.05$) between the right and left sides. The means showed that the left gonial angle was more open (right 124 ± 6.59 degrees; left 126.6 ± 6.20 degrees), whereas it was the opposite for condylar angle (right 115.4 ± 22.93 degrees; left 113.7 ± 22.81 degrees). No significant differences were computed when the data were contrasted for age and gender.

When the severity of the asymmetry was calculated through subtraction of the left and right angles, 171 subjects were classified as NS for the gonial angle, 73 as L, 80 as M, and 3 as S. On the other hand, 158 subjects were classified as NS for the condylar angle, 65 as L, 79 as M, and 25 as S.

Table 1 Percentages for the severity of the asymmetry for the four linear and two angular measurements performed in this study; NS, no significant asymmetry; L, light asymmetry; M, moderate asymmetry; and S, severe asymmetry.

Severity/measurement	NS (%)	L (%)	M (%)	S (%)
Linear measurements				
Ramus height	14.37	32.41	49.23	3.97
Ramus width	23.85	18.04	44.65	13.45
Corpus height	16.21	24.77	51.99	7.03
Corpus length	31.8	20.79	41.59	5.81
Angular measurements				
Gonial angle	52.29	22.32	24.47	0.92
Condylar angle	48.31	19.87	24.17	7.65

The percentages for the severity of asymmetry for each angle are shown in Table 1.

Molar development

No significant differences were observed between the developmental stages of the permanent lower second molars when comparing both right and left mandible. Only 13 subjects showed a different developmental stage between both sides for those teeth under consideration. Ten subjects showed a difference of 1 developmental stage and three subjects a difference of 2 developmental stages between both sides (Table 3).

The permanent lower second molars were at different developmental stages at the various ages evaluated. Younger patients (8 years) had permanent lower second molars at developmental stages from 4 up to 9, and older patients (12 years) were between molar developmental Stages 7 and 13. Regarding gender, female subjects were at developmental stages from 5 to 12, whereas male subjects were at developmental stages from 4 up to 13.

Discussion

Craniofacial symmetry and balance is referred to as the 'state of equilibrium', where there is a correspondence in size, form, and arrangement of the various structures on the opposite sides of the median sagittal plane (Duthie *et al.*, 2007). The current study evaluated the prevalence of dimensional, angular, and tooth development asymmetries in the mandible of growing children in the mixed dentition. Although mandibular dimensional asymmetries have been observed in young patients by several authors, some of them consider it to be associated with growth periods and thus should not be considered relevant for treatment purposes (Kula *et al.*, 1998; Liukkonen *et al.*, 2005). However, the present results contradict that later statement, as a high percentage of the studied population, had significant dimensional asymmetry in the mandibular ramus and corpus, which appear to be associated with angular asymmetries.

The present results agree with those studies reporting that dimensional mandibular asymmetries are independent of gender and age (Ferrario *et al.*, 2001; Azevedo *et al.*, 2006). On the other hand, a controversy still exists as to whether dimensional mandibular asymmetries are considered normal at certain ages (Kula *et al.*, 1998) and how a malocclusion may be associated with the presence of mandibular asymmetries (Ferrario *et al.*, 2001; Kwon *et al.*, 2006; Haraguchi *et al.*, 2008). Asymmetries have been associated with periods of significant growth (Kula *et al.*, 1998), malocclusions (Hayashi *et al.*, 2004; Langberg *et al.*, 2005; Azevedo *et al.*, 2006), asymmetric development in some brain regions (Keles *et al.*, 1997), and temporomandibular joint internal derangement (Trpkova *et al.*, 2000). Lu (1965) and Kula *et al.* (1998) reported that mandibular dimensional asymmetries greater than 2–3 mm might affect facial appearance, whereas Skvarilová (1993) considered 4–5 mm as a range for normal asymmetry of facial dimensions. In the current study, moderate asymmetry was classified as a difference between both sides of the mandible from 3 to 5 mm, whereas severe asymmetry infers more than 5 mm difference. More than half of the subjects had moderate-to-severe asymmetry for both the height and width of the mandibular ramus and similarly for the height of the mandibular corpus, whereas almost a half of the subjects showed either moderate or severe asymmetry in CL. Thus, these results indicate that more than a half of the population studied had a considerable difference in dimensions between the two sides of the mandible. This investigation did not include either the sagittal or vertical relationships of dental

Table 2 Table showing the number of patients and the severity of asymmetry found for the four linear measurements performed in this study; L, light asymmetry; M, moderate asymmetry; NS, no significant asymmetry; and S, severe asymmetry.

Measurement	Age/severity	8	9	10	11	12	Total
Ramus height	NS	9	8	12	10	9	48
	L	11	30	17	17	29	104
	M	20	47	36	35	27	165
	S	1	3	4	1	1	10
Ramus width	NS	9	18	17	19	15	78
	L	7	14	14	11	12	58
	M	20	40	27	28	31	146
	S	5	16	11	5	8	45
Corpus height	NS	6	18	8	9	12	53
	L	8	25	17	15	16	81
	M	25	39	40	36	30	170
	S	2	6	4	3	8	23
Corpus length	NS	11	24	24	23	16	98
	L	6	17	11	19	15	68
	M	22	40	30	17	28	137
	S	2	7	4	4	7	24

Table 3 Differences in the developmental stages and developmental ranges for the second permanent molars in the population included in this study ($n = 327$).

Age	Molar development			
	No difference	+1 Stage	+2 Stages	Developmental range
8	38	3	0	4–9
9	86	0	2	5–11
10	64	5	0	5–11
11	60	2	1	5–12
12	66	0	0	7–13

Only 13 patients showed differences in the developmental stages between sides.

occlusion or chewing on the preferred side. The mandible adapts to mandibular deviations by modelling the CO and the glenoid fossa (Peck *et al.*, 1991; Pirttiniemi and Kantomaa, 1992; Liu *et al.*, 2007), suggesting that the asymmetry may be an adaptive response to functional demands (Shah and Joshi, 1978; Duthie *et al.*, 2007). Animal studies, as well as studies of humans with a crossbite, have shown that a functional shift can produce asymmetric mandibular growth (Poikela *et al.*, 1997; Thilander and Lennartsson, 2002; Kilic *et al.*, 2008). Therefore, the prevalence of mandibular asymmetries in young growing patients must be further studied, as well as the impact that those asymmetries may have on facial growth.

Another interesting finding of this investigation was the side predominance of mandibular asymmetries. Other studies have reported that the right side predominates over left when the size of both hemimandibles is considered (Skvarilová, 1993; Kula *et al.*, 1998). The results from the present research showed the opposite. The means of the four dimensional measurements, RH, RW, CH, and CL, were significantly larger for the left side of the mandible. Since those previous studies obtained more than a decade ago, the mixture between races has increased and more variables may have influenced growth and development of the mandible. Based on the present findings, it cannot be generalized that the right side always predominates when a mandibular asymmetry is present in young subjects. These results clearly show that there can be a left side predominance regarding dimensions when mandibular asymmetries are present.

Only a few studies have investigated angular asymmetries in the craniofacial complex. Some reported no statistically significant difference in gonial angle measurements between sides (Kwon *et al.*, 2006; Kurt *et al.*, 2008). The present results are contrary to those findings. It was found that more than 25 per cent of the population studied had either moderate or severe asymmetry when comparing left and right gonial angles. Furthermore, the angle formed by the longitudinal axis of the mandibular CO and the superior border of the ramus presented a high percentage of moderate and severe asymmetries between sides. Studies in rabbits have demonstrated that the angles of the condylar process with the inferior border of the mandible, as well as the dimensions of the mandible, are affected when masticatory function is altered (Poikela *et al.*, 1997). In that context, the current results support the hypothesis that the mandible responds with different amounts of growth at different sites and adjusts the angles between the various component parts (corpus, ramus, and condyles), so adapting to functional demands (Petrovic, 1994; Frost, 2004; Ramirez-Yañez *et al.*, 2004). Nevertheless, further studies are required to fully understand the effect of oral function on growth and development of the mandible in humans.

Regarding tooth development, the findings are in agreement with other studies showing no significant differences in tooth development between either side of the mandible (Moorrees, 1967). Even though only second permanent molar development was considered, no statistically significant difference was found in the various stages of that tooth's development. Therefore, it appears that the presence of mandibular dimensional and angular asymmetries of young subjects do not alter tooth development between the sides of the mandible.

Conclusions

This research found a high prevalence of dimensional and angular mandibular asymmetries in the population studied. The results showed no association between the presence of mandibular asymmetries with gender and age and that the presence of mandibular dimensional and angular asymmetries does not affect tooth development. Further studies are required to better understand the association between mandibular asymmetries and oral function.

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