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Size, shape and age-related changes of the mandibular condyle during childhood

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Abstract *Objective* To determine age-related differences in the size and shape of the mandibular condyle in children to establish anatomical reference values. *Methods* A total of 420 mandibular condyles in 210 children (mean age, 7years) were retrospectively analysed by using computed tomography (CT) imaging. The greatest left–right (LRD) and anterior–posterior (APD) diameters and the anteversion angles (AA) were measured by two readers. An APD/LRD ratio was calculated. The shape of the condyles was graded into three types on sagittal images. Correlations of parameters with the children's age were assessed by using Pearson's correlation analyses. *Results* The LRD (mean, 14.1±2.4mm), APD (mean, 7.3±1.0mm) and LRD/APD ratio (mean, 1.9±0.3) increased (r_{LRD}=0.70, $p<0.01$; r_{APD}=0.56, $p<0.01$; r_{rat}=0.28, $p<0.01$) while the AA (mean, 27±7°) decreased significantly (r_{antang}=−0.26, $p<0.001$) with age. The condylar shape as determined on sagittal images correlated significantly with age (r=0.69, $p<0.05$). Boys had significantly higher anteversion angles ($p<0.01$), greater LRDs ($p<0.05$) and greater mean ratios ($p<0.05$). *Conclusion* The mandibular condyle is subject to significant age-related changes in size and shape during childhood. As the size of the condyles increases with age, the anteversion angles decrease and the shape of the condyle turns from round to oval.

Keywords Temporomandibular joint · Computed tomography · Paediatric · TMJ · Mandibular condyle

Introduction

The temporomandibular joint (TMJ) is frequently subject to inflammatory disorders in children especially within the disease pattern of juvenile idiopathic arthritis (JIA) [1–9]. Arthritis of the TMJ, if not detected early and treated properly, may lead to bone destruction and osseous deformation of the mandibular condyle resulting in growth disturbances and dysmorphic facial features [2, 10–12]. Further on osseous deformations lead to an earlier onset of TMJ arthrosis. In order to detect abnormalities of the shape and size of the mandibular condyles in children of all ages it is necessary to be familiar with the normal appearance of the mandibular condyle in cross-sectional diagnostic imaging. However, to the best of our knowledge, only few data can be found on the normal size of the mandibular condyle in recent literature [13, 14] evaluating symptomatic TMJ disorders or including not only children but also adults in their study populations.

Therefore the purpose of our study was to evaluate the size, shape, gender- and age-related changes of the mandibular condyle in asymptomatic children in a retrospective analysis of multidetector computed tomography (CT) examinations.

Materials and methods

Patient population

A total of 210 children (mean age, 7 years; range, 0–17 years; 81 girls, 129 boys) were included in this cross-sectional study. The children underwent computed tomography (CT) of either the skull base (n=20, 9.5%), the cervical spine (n=30, 14.3%) or the head (n=160, 76.2%) between December 2008 and August 2009. None of the children included in this study underwent CT imaging for known or suspected disorders of the TMJ. The medical history of all children was reviewed and revealed that none of them was affected by rheumatological diseases or TMJ disorders. Indications for CT imaging included suspected intracranial bleeding or fractures after trauma to the head or cervical spine (n=96, 45.7%), suspected non-traumatic cerebral haemorrhage (n=29, 13.8%), evaluation for sinusitis or assessment of anatomical variants of the nasal cavity (n=38, 18.1%), follow-up or initial evaluations of hydrocephalus (n=31, 14.8%), suspected cerebral sinus venous thrombosis (n=4, 1.9%) and complicated mastoiditis (n=12, 5.7%).

All patients or their legal guardians gave consent consisting in a general waiver which allows the use of data from the hospital chart for retrospective scientific analysis. This approach is approved by the Institutional Ethics Review Board.

Computed tomography imaging

All CT examinations were performed on a commercially available 40-detector-row CT system (Brilliance CT 40, Philips Medical, Eindhoven, the Netherlands) with all children in the supine position, head first and with their mouth closed. For the CT protocols applied see Table 1.

Image analysis

Image analysis was performed upon multi-planar reconstructions (MPR) in transverse and sagittal imaging planes derived from axial-source CT images with a reconstruction slice thickness of 1.0 mm and a reconstruction increment of 0.5 mm.

Two radiologists (R1 and R2 with 4 and 3 years experience, respectively, of musculoskeletal and paediatric cross-sectional image interpretation) performed all image analysis on a commercially available post-processing software tool connected to the CT workstation (Philips Medical, Eindhoven, Netherlands).

At the level of the greatest left–right diameter of the mandibular condyles in the transverse imaging plane the greatest left-to-right diameter (LRD), the greatest anterior-to-posterior diameter (APD) and the anteversion angle (AA) of the mandibular condyles were measured (Fig. 1) separately for the left and right sides using an electronic calliper tool. The shape of the mandibular condyle was evaluated on sagittal imaging planes tilted to the long axis of the mandibular ramus and classified into three types (Fig. 2), which were defined by a panel of paediatric and musculoskeletal radiologists. In cases of disagreement, consensus reading was appended after 1 week. An APD/LRD ratio ($R_{APD/LRD}$) was calculated to classify the shape of the condyles in the transverse imaging plane into roundish or oval. A screen shot of all measurements was archived into the hospital's PACS (picture archive and communication system) for documentary purposes.

Statistical analysis

All quantitative variables are described as mean ± standard deviation. The data were descriptively reviewed and statistically analysed by using the Kolmogorov–Smirnov's test for normality.

Table 1 Imaging parameters for the acquisition of CT examinations of the skull, the skull base and the neck

	Skull	Skull base	Neck
Acquisition	Sequence	Spiral	
Tube voltage	120 kV (standard protocol) (80 kV in neonates)		
Tube current–time product (depending on children's age)	<3 months: 135 mAs	Low dose protocol: 75 mAs (bone evaluation)	Low dose protocol: 75 mAs (bone evaluation)
	3–12 months: 200 mAs	Standard protocol: 100 mAs (contrast enhanced)	Standard protocol: 100 mAs (contrast enhanced)
	1–5 years: 240 mAs		
	5–10 years: 260 mAs		
	10–15 years: 300 mAs		
Collimation	40×0.625 mm (16×0.625 mm in neonates)		40×0.625 mm
Pitch	–	1.125	
Gantry rotation time	0.75 s		
Window level setting	3,000/500 (bone)		400/100
	95/50 (brain)		
Matrix	512×512	768×768	512×512
Reconstruction thickness	5 mm	1 mm	1 mm
Reconstruction increment	10 mm	0.5 mm	0.5 mm

Fig. 1 Transverse computed tomography imaging plane showing the left-to-right (LRD, *longer black line*) and anterior-to-posterior (APD, *shorter black line*) diameters as well as the anteversion angle (AA) measurements (*white dotted lines*) of the mandibular condyles

The interobserver agreements for continuous variables (i.e. the LRD, APD and AA) were assessed according to the method of Bland and Altman and determined as the mean differences (bias) that are presented with corresponding limits of agreement.

Correlation between both readers' measurements was assessed by Pearson's correlation analysis. The interobserver agreement for the ordinal variable of condylar type (i.e. types I, II or III) was assessed by using *k* statistics and interpreted as follows: a *k* value greater than 0.81 corresponded to excellent agreement, a *k* value of 0.61 to 0.80 corresponded to very good interobserver agreement, a *k* value of 0.41 to 0.60 corresponded to good interobserver agreement, and a *k* value of 0.21 to 0.40 corresponded to moderate interobserver agreement.

Student's *t* test for independent samples was used to test for gender-specific differences between measurements of boys and girls.

Correlation between children's age and LRD, APD and AA measurements was assessed by using Pearson's correlation analysis. Results were demonstrated on scatter plots using cubic fitting. Correlation between children's age and condylar types on sagittal image reconstructions was assessed by using Spearman's correlation analysis. *P* values less than 0.05 were considered statistically significant. All statistical analyses were performed using commercially available software (SPSS, release 17.0, Chicago, IL, USA).

Results

Interobserver agreements of CT measurements

Bland–Altman analysis for testing the degree of agreement between the two readers revealed minimal mean differences, and all measurements were within close limits of agreement for all parameters. Correlation coefficients ranged from 0.68 to 0.89, as shown in Table 2. Because of excellent agreement regarding CT measurements, the means of both readers' measurements were taken for further analyses. Very good interobserver agreement was found for grading the condylar types with a *k* value of 0.67.

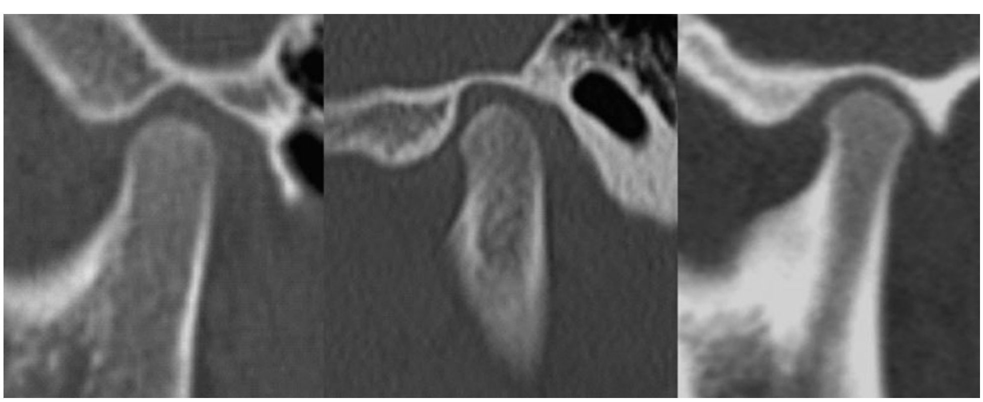

Fig. 2 Reformatted sagittal computed tomography images demonstrating the three different types of condylar shape as described in our study: type I (*left*) showing a smooth, round shape, which is most frequently seen in children aged 0–5 years; type II (*centre*) shows the beginning of the development of an anterior beak, which is mostly seen in type III shapes (*right*) together with a flattening of the condyle's anterior surface which can primarily be observed in children aged 10 and older

Table 2 Interobserver agreement for temporomandibular joint measurements of both readers

Parameter	Mean difference	95% CI	r*	p*
LRD	−0.4 mm	−2.8 to 2.0	0.89	<0.001
APD	−0.2 mm	−2.0 to 1.6	0.68	<0.001
AA	0.2°	−9.6 to 10.0	0.87	<0.001

LRD left-to-right diameter, *APD* anterior-to-posterior diameter, *AA* anteversion angle, *CI* confidence interval, *Pearson's correlation analysis

Condylar measurements and types

No gender-specific differences were found regarding anterior-to-posterior measurements. However, boys had significantly higher anteversion angles ($p<0.01$), greater left-to-right diameters ($p<0.05$) and greater mean $R_{APD/LRD}$ ($p<0.05$) compared to girls.

Statistically significant correlations were found between all measurements and the children's age. The LRD ($r_{LRD}=0.70$, $p<0.01$), APD ($r_{APD}=0.56$, $p<0.01$) and the $R_{APD/LRD}$ ($r_{rat}=0.28$, $p<0.01$) increased significantly while the anteversion angle decreased ($r_{antang}=-0.26$, $p<0.001$) with increasing age (Fig. 3).

The shape of the condyles on sagittal imaging planes was graded into three types by both readers (frequencies; R1/R2):

- Type I: R1, $n=48$ (11.5%); R2, $n=52$ (12.3%)
- Type II: R1, $n=156$ (37.1%); R2, $n=152$ (36.2%)
- Type III: R1, $n=216$ (51.4&); R2, $n=216$ (51.4%)

Children's age was significantly correlated with the condylar types observed (consensus evaluation: $r=0.69$, $p<0.05$).

Discussion

The purpose of this study was to evaluate the size, shape, gender- and age-related changes in the mandibular condyles in children without known or suspected disorders of the TMJ to create a standard of reference for future evaluations of osseous deformations of the mandibular condyles. We have found gender- and age-related changes of the mandibular condyles regarding their size, shape and position (by assessing the anteversion angle). Therefore we were able to demonstrate dynamic changes of the mandibular condyles during childhood growth and to establish reference values for the assessment by CT.

Deformations of the mandibular condyles represent well-known disorders in the elderly patient due to age-related osseous degeneration [15–18]. However with an increasing incidence of TMJ arthritis in children suffering from JIA [1, 19], erosions and osseous deformations are becoming more common in the TMJ of paediatric patients. Therefore, a description of the dynamic changes of the mandibular condyles' shape and size may be of interest to establish a reference for the evaluation of deformations. In the medical literature

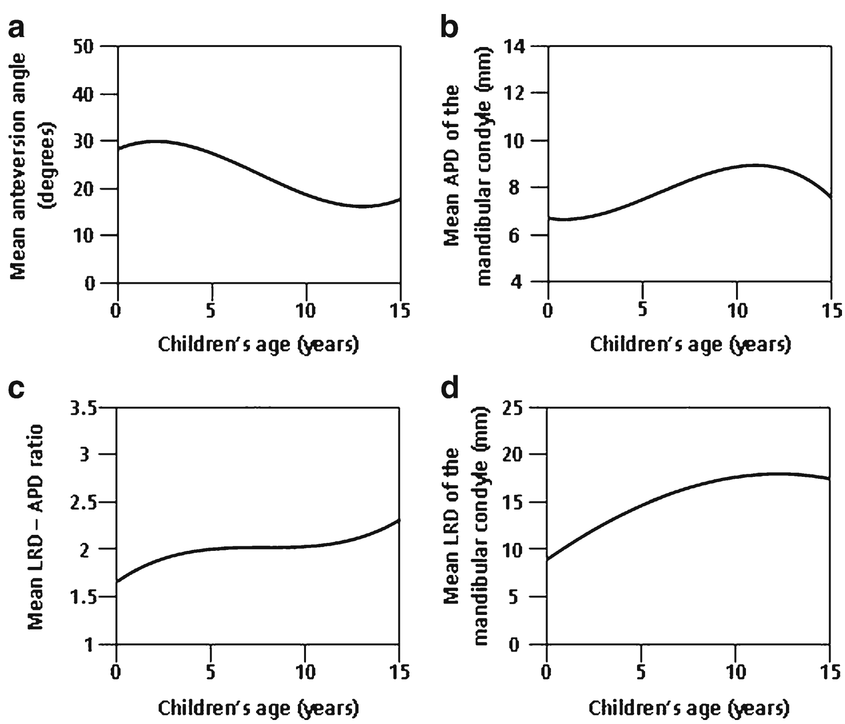

Fig. 3 Scatter plots correlating the mandibular condyle's anteversion angle (**a**), anterior-to-posterior diameter (APS, **b**), ratio (**c**) between the LRD and APD and left-to-right diameter (LRD, **d**) to the children's age

only few data can be found on the physiological size and shape of the mandibular condyle in children [13, 14]; however, these studies investigated the roof of the mandibular fossa in symptomatic patients [13] or evaluated the dynamic growth changes in the paediatric mandible without assessing for changes of the mandibular condyle [14], whereas multiple studies have discussed the articular eminence, the temporal fossa, differences between the paediatric and adult TMJ and growth-related remodelling of the TMJ in adults [13, 14, 20–25]. Some of the first to describe the shape and size of the mandibular condyle on CT were Christiansen et al. [26, 27] in 1987 who described the dimensions of the mandibular condyle in 53 adult patients. Meng et al. [20] discovered significant differences in TMJ morphology between child cadavers and adult volunteers, describing the shape of the paediatric condyles as rather round and small compared with the glenoid fossa. We are able to confirm this finding in our study with the ratios we have calculated.

Cascone [28] and his group presented a 3D model of the TMJ using simple software to perform reconstructions from CT and MRI data with an emphasis on anatomy and function. Ueda et al. [29] performed curvature analyses in 317 patients suffering from inner or middle ear disease with an age range from 4 to 89 years. These authors proposed curvature analyses as being a valuable tool for the depiction of the morphology of the mandibular condyles of various types. However no details of additional time requirements for this procedure were provided and its implementation into clinical routine may be associated with additional time-related expenses when reviewing or reconstructing CT images. We chose standard imaging planes to facilitate the assessment of the morphology of the mandibular condyles in clinical routine at no substantial extra time-related expense. Yale et al. were among the first to describe the shape of the mandibular condyle as one of four types: flattened, convex, angled and rounded [30–32]. A similar classification of the sagittal shape of the mandibular condyle was reported by Lemke et al. [33] in 2005, who investigated 320 temporomandibular joints in 184 patients (age range 12–86 years) upon MRI data and described four types of mandibular condyles in the sagittal imaging plane: round (normal), flat, osteophytic and with cortical thickening. However, they included patients between 12 and 86 years old with a mean age of 38.5 years. In our study, we have established three types of shape of mandibular condyles in the sagittal imaging plane, and were able to show that the shape of the condyle changes significantly during childhood growth (Fig. 2). Ishibashi [16] and his group evaluated 34 right-sided mandibular condyles obtained from autopsy, covering an age range of 16–92 years including only four specimens derived from patients under the age of 20 years. However no information was supplied about possible TMJ disorders in that study. In our study, none of the children was suffering from or was even suspected of suffering from TMJ disorders.

Our results demonstrate that the mandibular condyles are subject to significant changes in size and shape during childhood growth. As the size of the condyles increases, the anteversion angle decreases and therefore the position of the condyle within the TMJ changes. By calculating the ratio between the AP and LR diameters we were able to show that the shape of the mandibular condyles, as assessed on transverse images, turns from a round into an oval configuration. With our data obtained in healthy children, we are the first—to the best of our knowledge—to establish gender- and age-specific reference values for CT of the mandibular condyles. These age-related changes of the mandibular condyle need to be taken into consideration when assessing mandibular condyles using CT imaging.

Limitations

In this study we have not investigated the mandibular fossa, which might also undergo significant age-related changes. Also we have not assessed the angle between the mandibular condyle and the mandibular ramus in coronal imaging planes because the region of interest on our CT data sets was mostly limited to the skull base and therefore the mandibular ramus was not always included.

Conclusion

The mandibular condyle is subject to significant age-related changes in size and shape during childhood. As the size of the condyles increases with age, the anteversion angles decrease and the shape of the condyle turns from round to oval.

Conflict of interest All of the above mentioned authors have nothing to disclose.

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