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Evaluation of mandibular geometry in healthy children aged 0–1 year – a pilot study

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Purpose: The main aim of the research was the three-dimensional morphological assessment of the mandible in children. *Materials and Methods*: The research group consisted of 34 infants from 21 to 417 days of age (0–13 months). Models of the mandibles were developed on the basis of tomographic images. Characteristic anatomical points were marked on the models, on the basis of which characteristic distances and angles were calculated, determining the length, width and height of the mandible as well as its proportion and symmetry. Based on the obtained database, 3D models of mandibular growth in the first year of life were also developed. *Conclusions*: The analysis of the results revealed some significant objective information on the growth and development of the normal mandible.

Key words: *anthropometry, asymmetry, computed tomography (CT), morphological measurements, mandibular indices, model of growth*

1. Introduction

The development of the mandible begins in the 6th week of gestation. On the basis of Meckel's cartilage, two symmetrical parts are formed in the following weeks, joined in the midline by the mandibular symphysis (symphysis menti). After birth, the mental symphysis fuses by the end of the first year of life [2]. The mandible changes its size, shape and location along with the postnatal development of the skull. The mandible of a newborn is characterized by the occlusion plane passing through the head of the condylar process, a large opening of the mandibular angle, prominent projections and short condylar processes, which is the optimal structure of the masticatory apparatus for the suction function. With the appearance of deciduous teeth (around 6 months of age), the shape of the lower jaw changes; the occlusal plane lowers, the posterior edge of the branch becomes more vertical, and the lower edge of the mandibular body becomes more horizontal. As a result, the gonial angle becomes smaller [3], [5], [6], [17]. After childbirth, the growth rate of the head accelerates. Head circumference increases by 17% during the first three months of life, and then by 25% up to the 6th month of life [32]. Although research into the development of the masticatory apparatus is scarce, mandibular growth also appears to be the fastest in infancy and early childhood [19]. In the second year of a child's life, the mandible reaches about 70% of its final size [20].

Increasing the size of the mandible and its movement to the front of the face is due to the apposition and resorption of bone tissue [8]. This process dynamically builds up the outer part of the bone and, at the same time, destroys the opposite inner part of the cortex. As a consequence, there is an increase in the area of the

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mandibular branch, the alveolar process, and the movement of articular and pitted processes to the rear. The next process of formation takes place within the cartilage on the head of the articular condyle. Throughout the period of mandibular growth, the mandibular condyle along with articular cartilage is highly susceptible to mechanical, functional and hormonal stimuli [2], favoring the upward and backward growth of the mandible, while increasing the transverse dimension is associated with the adaptive abilities of the condylar processes to the widening base of the skull with receding pits [11]. Two-sided symmetry is a characteristic feature of the human morphological structure. Despite the action of molecular mechanisms responsible for the equal development of both parts of the body, perfect symmetry is not present, and a certain degree of asymmetry is observed from birth. Various authors group the factors responsible for shaping it [28], for example, factors acting in the fetal period (congenital, of prenatal origin) as well as developmental factors arising during development and of unknown etiology. The types of morphological asymmetry are directional asymmetry (which is responsible for the action of genes) and fluctuating asymmetry (which is caused by environmental factors). Directional asymmetry shows a constant direction, and the distribution of differences between the right and left sides in the population shows a clear skew, while the manifestation of fluctuating asymmetry is the normal distribution of differences [10].

There are only few studies on the morphology of the mandible in the first years of a child's life and databases containing measurement data are often unavailable. The reasons for this may be seen in the ethical limitations of avoiding the irradiation of infants, whether using X-ray or CT. Such material most often comes from the examination of corpses [13], fossil materials or CT and X-ray examinations performed for diagnostic purposes for other reasons [4], [19], [32]. Knowledge about the correct growth trends is necessary to make a reliable diagnosis of abnormalities in the development of the mandible and to plan procedures, e.g., for future surgical procedures [7], [18]. Some possibilities of analyzing the morphology and anatomy are provided by the predictive approach using parametric models developed for the growth of the mandible, for width, height and length dimensions. The aim of the study was to assess of mandibular dimensions based on measurements and anthropometric indicators of the lower jaw in children in the first year of life, taking into account asymmetry. In addition, parametric models of mandibular growth were created, which allow for the identification and analysis of growth patterns of individual parts of the mandible and their correct growth dynamics.

2. Materials and methods

The research group consisted of 34 infants (16 females and 18 males) aged from 1 month (21 days) to 13 months (417 days), patients of the Upper Silesian Child Health Center in Katowice at the Department of Pediatric Neurosurgery. All babies were born on time, from single pregnancies, without any complications. Routine diagnostic CT examination of the head was performed in children, due to suspicion of neurological, oncological or other problems, but skeletal defects and diseases were excluded. In previous work on changes in the cranial structure with age, this group was a control group [14], [32]. In this study, the available scans of the mandible were also used. In the analyzes, the material was divided into 4 age groups, according to the quarters of life (Table 1). First group consisted of 10 children, second group – of 9 children, third group – of 8 children and fourth group – of 7 children.

Table 1. Characteristics of research group

Age [months]	Age [days]	Number of female/male	Total number
0–3	21–118	7/3	10
4–6	122–202	2/7	9
7–9	216–316	3/5	8
10–13	324–417	4/3	7

In all children, CT scans were conducted as a part of the routine diagnosis of various diseases. The examinations were performed with a Philips Brilliant 64 tomograph with the following parameters: slice thickness: 0.5 mm, pixel size: 0.3–0.4 mm, resolution 512×512 px.

Characteristic anatomical points were manually marked on the models. To avoid the intraobserver errors, only one person was responsible for this task.

2.1. Analyzed parameters

Based on the CT scans of each child, 3D models of the lower jaw were created using the Mimics software. Then, 10 characteristic anatomical points were marked on the models (Fig. 1). Having the coordinates of individual points, it was possible to calculate the distances and angles between them (Table 2). In order to compare the dimensions of the jaws of children from different age groups, the Kruskal–Wallis test was used (the Shapiro–Wilk test used earlier showed skewed distributions for individual measurements, data not shown).

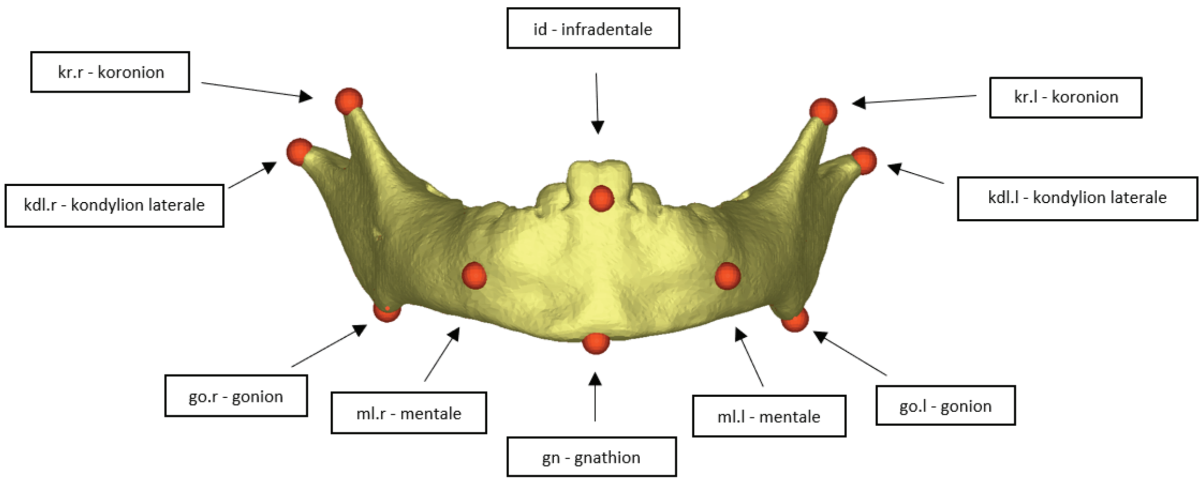


Fig. 1. Three-dimensional model of the mandible and anthropometric points (for odd points: r – right side, l – left side)

Table 2. Standard anthropometric measurements and angles

Length	Dimension	Description
|gn-go| (even)	mandibular body length	lower jaw base line; the most distal point of the mandible on the midline and the point of the angle of the mandible
|go-go| (odd)	bigonial breadth	distance between points on the mandibular angles on the right and left
|id-gn| (odd)	height of the mandibular symphysis	the distance between the bottommost symphysis point of the mandible and the point centrally between the lower incisors
|kdl-kdl| (odd)	bicondylar breadth external	distance between the most posterior points on the right and left condylar process
|go-kdl| (even)	height of ramus	distance between the point on the mandibular angle and the most posterior point on the condylar process
|gn-kdl| (even)	total length of mandible	distance between the innermost point of the mandible on the midline and the most lateral point on the articular process
|kr-kr| (odd)	bicoronial breadth	distance between points at the tip of the coronoid process of the mandible
|ml-ml| (odd)	bimental breadth	distance between the two mental foramina
Angles		
<go-gn-go (odd)	the angle of the mandible	the angle between the lines defining the mandibular body length on the right and left
gonial (alfa) (even)	gonial angle	the obtuse angle at the back of the mandible formed by the intersection of the vertical and horizontal portions of the jaw

For even distances, the asymmetry index (AI) was calculated according to the recommendations of Habets et al. 1987:

$$AI = \left| \frac{\text{right measurement} - \text{left measurement}}{\text{right measurement} + \text{left measurement}} \right| \times 100 .$$

AI index equal to 0 indicated that both sides of the mandible were symmetrical, a negative value indicated that the left side was larger than the right, a positive value indicated that the right side was larger than the left. To assess the degree of asymmetry, accordingly to Ramirez-Yañez et al. [24], the following classification was applied: no significant (NS) asymmetry – when AI was between 0 and 2.99 percent; light (L) – when AI was between 3 and 5 percent; moderate (M) – when the index was greater than 5 percent but less than or equal to 10 percent; and severe (S) – when AI was more than 10 percent. Asymmetry in the gonial angle was evaluated by subtracting the value of the left angle from that of the right angle. The intensity of asymmetry was defined as no significant (NS) – when the difference between the right and left angle was from 0 to 2.99 degrees; light (L) – when the difference between both sides was from 3 to 5 degrees; moderate (M) – when the difference was greater than 5 degrees but smaller or equal to 10 degrees; severe (S) – when the difference was greater than 10 degrees [14]. Moreover,

Table 3. Analyzed indices of proportions

Formula	Proportion	Description
$i_1 = \frac{go.l - go.r}{kdl.r - kdl.r} \times 100$	ratio of bigonial breadth (lower jaw) to bicondylar breadth external (upper mandible)	the lower the value, the narrower the lower part of the mandible
$i_2 = \frac{go.l - go.r}{gn - kdl} \times 100$	ratio of bigonial breadth and total length of mandible	the higher the value, the shorter the mandible
$i_3 = \frac{gn - go}{gn - kdl} \times 100$	ratio of mandibular body length and total length of mandible	the higher the value, the shorter the mandibular body
$i_4 = \frac{gn - id}{gn - go} \times 100$	ratio of height of the mandibular symphysis and mandibular body length	the higher the value, the higher the mandibular symphysis

the distribution of differences between the measurements made on the left and right side was estimated; if the distribution of differences shows a statistically significant skewness, the mandibles show directional asymmetry, if the distribution of differences is normal, the differences between the right and left sides are a symptom of fluctuating asymmetry [10].

Then, on the basis of selected distances, indicators determining the shape and proportions of the mandible were calculated (Table 3).

2.1. Model of mandible growth in the first year of life

The distances between the distinguished anthropometric points on the mandible of children constituted a set of variables on the basis of which the growth curves for the latitude, height and length directions were determined. For each set of variables, the following statistical model was selected:

$$y = \frac{a}{(1 + b \times e^{cx})}, \quad (1)$$

where: y – vector of growth, a, b, c – parameters of model, x – child's age [days].

The proposed curve (exponential/logarithmic) corresponds to the dimensional variation representing the directions of the mandible growth. This curve is characterized by significant properties: it is positively marked in the set of positive values of the variables (postnatal age), it is dynamically increasing in the early development of the child and it is limited from the top by the horizontal asymptote (the values approach the limit value, which in this study results from the age of the examined children – 13 months).

All available data, i.e., from the 21st day to the 417th day of life, were used to develop the growth curves. In search of the best suited model parameters for each set of dimensions, the method of non-linear estimation was used, while analyzing and assessing their fit to the database on the basis of the degree of correlation, i.e., the measure of the relationship between two variables/empirical data (the dimension of the mandible and the age of the child). The models with the best fit of parameters were considered representative, which allowed for the identification and analysis of the growth patterns of individual parts of the mandible and their correct growth dynamics.

3. Results

The assessment of the jaw dimensions in children in the first year of life was carried out in two stages. First, the size of changes with age in width, length and height dimensions as well as angles of the mandible in four age groups was estimated. The values of indicators describing the shape and proportions of the mandible were also analyzed and the size of the asymmetry was assessed. In the second stage, models of the mandible growth in the first year of life were built. Bigonial breadth (go-go), mandibular body length (gn-go), total length of mandible (gnkdl), height of the mandibular symphysis (id-gn), height of ramus (go-kdl) were included. To develop models describing the growth of the mandible, average distances between selected points were used that represent the dimensions of the mandible in three main directions: anteroposterior, vertical and lateral. In the selection of model/function parameters, non-linear estimation was used, and the choice of the model was determined by the degree of correlation.

3.1. The size, shape and proportions of the lower jaws in the first year of life

In Table 4, the values of mean and standard deviations of height, width and length dimensions as well as mandibular angles, separately for boys, girls and both

Table 4. Mandibular size during the first year of postnatal life

Age	1–3 months 1st quarter of the year (Q1)		4–6 months 2nd quarter of the year (Q2)		7–9 months 3th quarter of the year (Q3)		10–13 months 4th quarter of the year (Q4)		Kruskal–Wallis test
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	H; *p*
MALES									
Width dimensions [mm]									
go.l-go.r	56.05	4.36	58.61	1.09	58.00	2.57	58.62	2.21	1.23; 0.7453
kdl.l-kdl.r	70.37	3.75	76.06	2.58	76.28	3.41	78.86	4.33	4.34; 0.2268
kr.l-kr.r	61.85	6.02	67.17	2.76	66.31	3.31	67.22	2.36	5.34; 0.1484
ml.l-ml.r	27.35	6.82	29.92	5.38	30.12	2.90	34.33	2.03	4.17; 0.2428
Length dimensions [mm]									
gn-go.l	43.58	3.46	45.32	3.45	45.85	2.33	49.36	1.52	7.14; 0.0675
gn-go.r	43.11	2.11	44.81	2.66	45.37	1.59	47.90	2.06	8.45; 0.0376
gn-kdl.l	62.86	1.25	66.58	1.37	69.21	2.54	73.92	2.06	11.88; 0.0078
gn-kdl.r	63.80	4.55	66.97	1.71	70.27	2.49	74.59	2.60	11.54; 0.0091
Height dimensions [mm]									
id-gn	16.39	1.62	17.04	1.57	18.60	0.83	20.58	1.10	11.67; 0.0086
go.r-kdl.r	68.23	0.90	72.51	0.90	73.34	3.37	75.13	2.80	6.84; 0.0772
go.l-kdl.l	67.67	2.69	72.26	1.54	73.39	2.80	75.84	1.71	9.00; 0.0292
Angles [°]									
alpha L	133.26	2.82	133.47	2.51	131.08	3.45	130.53	4.16	2.27; 0.5177
alpha R	132.48	4.30	133.12	1.87	130.21	3.23	131.93	4.72	2.72; 0.4375
go-gn-go	80.77	5.96	81.53	5.82	79.07	4.28	74.34	5.87	3.66; 0.3003
FEMALES									
Width dimensions [mm]									
go-go	49.76	4.85	56.05	0.09	59.81	1.74	60.01	3.40	10.70; 0.0135
kdl-kdl	66.48	3.41	70.72	1.59	75.21	1.85	80.35	3.91	12.91; 0.0048
kr-kr	57.37	3.28	60.95	1.04	66.22	1.14	67.18	4.38	11.08; 0.0113
ml-ml	24.14	2.97	26.95	7.17	28.57	2.37	33.96	4.65	8.05; 0.0449
Length dimensions [mm]									
gn-go.l	36.91	4.10	41.21	0.74	44.40	0.34	46.10	2.70	10.34; 0.0159
gn-go.r	36.81	4.59	42.07	1.05	44.42	0.71	45.18	3.27	8.62; 0.0348
gn-kdl.l	55.74	4.76	61.35	2.33	68.60	1.27	72.85	2.34	12.60; 0.0056
gn-kdl.r	55.46	5.14	61.94	2.65	67.79	1.55	73.04	2.21	12.60; 0.0056
Height dimensions [mm]									
id-gn	14.63	2.20	18.06	1.11	16.19	0.01	19.40	1.24	11.33; 0.0101
go.r-kdl.r	61.73	4.21	68.44	1.73	73.81	2.36	77.91	2.49	12.91; 0.0048
go.l-kdl.l	62.14	4.49	67.82	0.38	74.16	1.77	77.34	3.55	12.32; 0.0064
Angles [°]									
alpha L	135.37	5.17	130.23	0.87	129.11	0.14	131.33	2.52	3.56; 0.3126
alpha R	135.32	4.50	129.83	1.48	130.94	1.73	129.64	3.52	4.77; 0.1896
go-gn-go	85.30	6.75	84.62	2.07	84.66	1.81	82.42	5.44	0.63; 0.8889
WHOLE GROUP									
Width dimensions [mm]									
go-go	51.64	5.40	58.04	1.47	58.31	2.58	59.14	2.80	11.73; 0.0084
kdl-kdl	67.65	4.35	74.88	3.30	75.85	3.33	79.70	3.92	20.84; 0.0001
kr-kr	58.72	3.90	65.79	3.66	66.54	2.86	67.51	3.43	16.95; 0.0007
ml-ml	25.10	3.61	29.26	5.46	29.78	2.93	34.10	3.52	14.66; 0.0021
Length dimensions [mm]									
gn-go.l	38.91	4.67	44.41	3.51	44.96	1.83	47.60	2.70	15.89; 0.0012
gn-go.r	38.70	4.90	44.21	2.63	44.87	1.52	46.72	2.86	14.12; 0.0027
gn-kdl.l	57.88	5.45	65.42	2.72	68.73	2.36	73.55	2.11	27.26; 0.0001
gn-kdl.r	57.96	6.02	65.85	2.83	69.16	2.74	73.93	2.31	25.88; 0.0001
Height dimensions [mm]									
id-gn	15.16	2.01	17.26	1.48	17.85	1.48	20.00	1.24	21.57; 0.0001
go.l-kdl.l	63.80	5.01	71.28	2.37	73.44	2.69	76.44	2.78	23.77; 0.0001
go.r-kdl.r	63.68	5.14	71.60	2.05	73.27	3.28	76.55	2.80	23.25; 0.0001
Angles [°]									
alpha L	134.74	4.47	132.75	2.62	130.95	3.00	131.53	3.25	4.80; 0.1872
alpha R	134.47	4.05	132.39	2.24	130.63	2.86	131.35	3.85	5.61; 0.1322
go-gn-go	83.94	7.22	82.22	5.27	81.07	4.52	78.02	6.32	3.05; 0.3839

Table 5. Percentage differences in mandibular size in quarters of first year of life

Percentage difference between quarters	Q2–Q1 [%]	Q3–Q2 [%]	Q4–Q3 [%]	Q4–Q1 [%]
Width dimensions				
go-go	12.39	0.46	1.44	14.52
kdl-kdl	10.69	1.30	5.08	17.82
kr-kr	12.04	1.15	1.45	14.97
ml-ml	16.55	1.80	14.48	35.83
Length dimensions				
gn-go.l	14.14	1.23	5.88	22.33
gn-go.r	14.23	1.49	4.14	20.73
gn-kdl.l	13.04	5.06	7.02	27.08
gn-kdl.r	13.61	5.02	6.90	27.55
Height dimensions				
id-gn	13.91	3.41	12.02	31.95
go.r-kdl.r	12.44	2.32	4.48	20.22
go.l-kdl.l	11.72	3.03	4.08	19.81
Angles				
alpha L	–1.47	–1.36	0.44	–2.38
alpha R	–1.55	–1.33	0.55	–2.31
go-gn-go	–2.06	–1.40	–3.76	–7.06

sexes together, are contained. The percentage change in individual dimensions in the quarters of life of the examined infants is presented in Table 5. As could be expected, the dimensions of the lower jaws increased with age, reaching statistical significance in most cases for female children and for the entire material. At the same time, in the first year of life, a decrease in the value of the mandibular angles (gonial, alpha) and the angle of no significant changes with age in the lower jaw angle was observed.

Comparing changes in the values of average length, width and height measurements in various quarters of life (Q4–Q1, Table 4), it was noticed that the total increase in the values of width measurements in the first year of life amounted to, from 14.5% (go-go) to even 35.83% (ml-ml l), for length measurements 20.7% (gn-go, mandibular body length) to 27% (gn-kdl, total mandibular length). The change in mandibular symphysis height (id-gn) in the 1st year of life was 32%. The highest dynamics of growth was recorded in the first quarter (Q2–Q1) – the changes amounted to as much as 16% for the width of the mandible between two formats (ml) and over 13% for length measurements. In the following quarters, the changes were clearly smaller, usually by a few percent. Changes in the values of the designated alpha (gonial) angles were smaller and range from <1% to 4% in quarters, while in the first year the total change fluctuated around 2.3%. In the first year of life, the angle of the mandible (go-gn-go) decreased by 7%, which was a consequence of faster elongation of the mandibular body in relation to changes in the width of the mandible.

3.2. Proportions of the lower jaw in age groups

Comparison of the values of the mandibular proportions indexes (Table 6) showed that not all areas of the mandible grew at the same rate, leading to changes in the shape of the mandible. The decreasing value of the i1 index with age indicates faster separation of the articular processes (kdl-kdl) compared to points on the mandibular angles (go-go). The decreasing values of i2 and i3 indices with age also indicate greater changes within the mandibular branch (branch elongation) compared to the body. The symphysis of the mandible increased at a similar rate as the length of the mandibular body (i4). In summary, the length dimensions increased faster than the width and height dimensions, and changes in the branches and articular condyles were relatively larger than changes in the mandibular body.

3.3. The degree of mandibular asymmetry

For all age groups, indices of asymmetry (AI) for selected even dimensions were calculated (Table 4). The mean values of the asymmetry index did not exceed 3%, which indicated no abnormalities in the dimensions between the right and left sides of the mandible. The occurring differences were assessed as fluctuation asymmetry, because the distributions of differences be-

Table 6. Mean values of proportional indices and asymmetry indices in age groups

Index	1–3 months 1st quarter of the year	4–6 months 2nd quarter of the year	7–9 months 3th quarter of the year	10–13 months 4th quarter of the year
$i_1 = \frac{go.l - go.r}{kdl.r - kdl.r} \times 100$	76.95 (SD 5.35)	77.62 (SD 3.17)	76.94 (SD 3.60)	74.32 (SD 4.14)
$i_2 = \frac{go.l - go.r}{gn - kdl} \times 100$	90.22 (SD 6.51)	88.50 (SD 2.10)	84.59 (SD 2.62)	80.23 (SD 3.39)
$i_3 = \frac{gn - go}{gn - kdl} \times 100$	66.89 (SD 4.73)	67.51 (SD 3.01)	65.16 (SD 1.82)	63.97 (SD 2.65)
$i_4 = \frac{gn - id}{gn - go} \times 100$	39.05 (SD 3.58)	39.11 (SD 4.02)	39.76 (SD 2.95)	42.47 (SD 2.43)
AI of mandibular angle	0.26 (SD 0.16)	0.40 (SD 0.30)	0.54 (SD 0.52)	0.57 (SD 0.58)
AI of go – kdl	0.45 (SD 0.31)	0.60 (SD 0.49)	0.42 (SD 0.43)	0.72 (SD 0.48)
AI of gn – kdl	0.77 (SD 0.62)	0.66 (SD 0.29)	0.74 (SD 0.42)	0.36 (SD 0.29)
AI of gn – go	2.11 (SD 1.25)	1.27 (SD 0.70)	0.80 (SD 0.77)	1.32 (SD 0.90)

Table 7. The differences between the left and right sides and the assessment of the normality of the distribution

Even measurements	Mean	SD	Skewness	Kurtosis	Shapiro–Wilk test
alpha	–0.276	1.54	–0.057	1.001	0.977 / $p = 0.669$
go – kdl	0.050	1.02	0.023	–0.230	0.981 / $p = 0.891$
gn – kdl	0.316	0.91	–0.637	0.086	0.958 / $p = 0.220$
gn – go	–0.364	1.57	0.324	–0.340	0.974 / $p = 0.590$

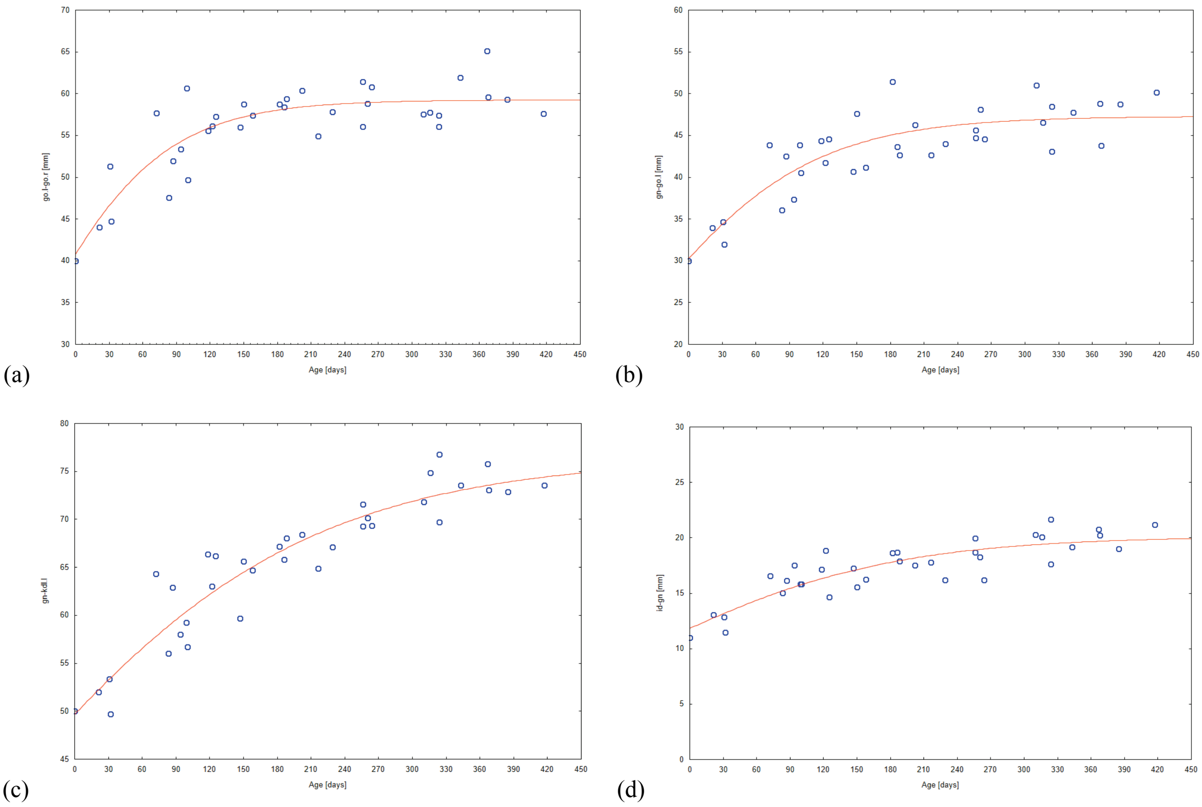
tween the dimensions of the pages did not differ significantly from the normal distribution (Table 7).

3.4. Model of mandible growth in the first year of life

To reflect the mutual relationship between the morphometric data of the mandible and the age of the child, an exponential/logarithmic function was used to show the mandible growth in a given direction. The obtained functions describe changes in the width, length and height of the mandible and make it possible to predict the size of the mandible according to the analyzed age of the child. From the course of the designated functions, the greatest increase in the mandible in the first quarter is noticeable in the anteroposterior direction, i.e., the length of the mandible (Fig. 2a), followed by an increase in its height (Fig. 2b, c), and the smallest increase is manifested in its width (Fig. 2d, e). The values of the function, which measure the proportional change in the size of the mandible during the child's development, are consistent with literature reports [13] and indicate a dy-

Table 8. Values of parameters of growth's models (a, b, c, according to equation (1) and values of correlation index (R) for calculated models

Dimension	Factor			
	a	*b*	*c*	R
Width measurements				
go.l – go.r	59.26206	0.453296	–0.017000	0.85719
kdl.l – kdl.r	36.29560	–0.457275	0.000504	0.75537
ml.l – ml.r	35.23283	0.675561	–0.007072	0.69656
Length measurements				
gn – go.l	47.29850	0.564021	–0.013411	0.85695
gn – kdl.l	76.48351	0.540054	–0.007109	0.93988
Height measurements				
id – gn	20.14944	0.703119	–0.009269	0.87005
go.l – kdl.l	77.08207	0.436626	–0.010156	0.90493



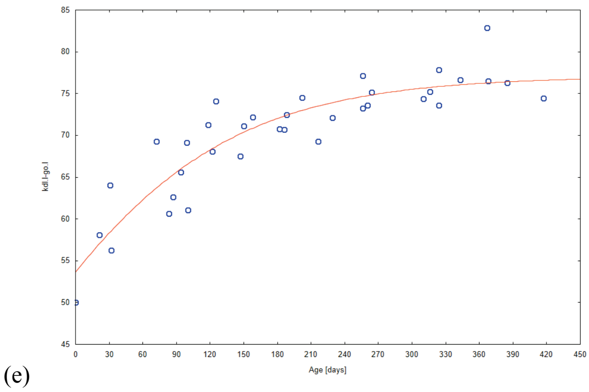


Fig. 2. Model of growth based on dimensions:
(a) width go-go, (b) length gn-go, (c) length gn-kdl.l,
(d) height id-gn, (e) height kdl-go

namic growth in the first months of life after stagnation in the fetal period. In the following quarters/periods of life, a further increase in the length of the mandible can be noticed with a slight change in its height and width.

The parameters of the mandible growth model and the correlation coefficient are presented in Table 8. The models allow for the analysis of the growth patterns of individual parts of the mandible and their correct growth dynamics.

4. Discussion

Pediatricians and head surgeons often point out the lack of accurate measurement data of the head and its individual elements in infants. While the basic dimensions of the cranium and their changes with age are described [22], [24], [27], the mandible is rarely studied. Difficulties in obtaining data on the size of the correct dimensions of the mandibles of healthy children result from ethical reasons, avoiding unnecessary irradiation of the child in order to conduct scientific research. The opportunity to perform measurements of the mandible are CT images of the head taken for other reasons not related to the mandible (injuries, accidents, oncological and neurological suspicions). The greater number of measurements made in children of different ages also allows the use of mathematical modeling to determine the direction of developmental changes with age. In this paper, CT scans of 34 infants were used, and the variability of the size, shape and proportion of the mandibles in the first year of life was presented. The degree of asymmetry in three dimensions and angles between the right and left sides of the mandible was also estimated. The asymmetry described in this study was small, statistically insignificant and had the character of a fluctuating asymmetry. This means that the existing differences between the right and left sides of the mandible were due to environmental influences, unrelated to developmental and genetic disorders. This confirms the good quality sampling for the analysis of the variation of mandibular size and proportions with age and the absence in the study group of children with developmental abnormalities in the head.

The first year of a child's life is a period of very dynamic changes in the dimensions of the whole body, which includes the head and mandible. Schipper et al. [25] showed that the greatest growth of the mandible occurrs during the first 6 months. The present study confirmed nonlinear mandibular growth in first year of age. In addition, changes in mandibular dimensions were not uniform across areas. Immediately after birth, the mandibles of newborns are characterized by low branches and a short and low body, in older children, the elongation of the mandibular body was faster than changes in the width of the mandible. In contrast, the smallest change occurred in the mandibular symphysis (height of the mandibular body). After a period of intense change in the first six months, the growth rate slows down in the following years, accelerating again in adolescence [1], [21]. Finally, the mandible completes its growth with the completion of the pubertal jump and the establishment of the final body height, in girls after the age of 16, and in boys not much later [16], [20].

The dimensions and proportions of the whole head, as well as the mandible, of adults show sexual dimorphism [26]. In contrast, publications on sex differences in the size of the head and mandible at younger ages do not show consistent results. Some studies found no significant sex differences in the measurements and proportions of craniofacial and cerebral cranium [23], [31], while others showed differences in some measurements [12], [33]. A widely accepted opinion was given by [9], who suggested that girls and boys do not differ in facial characteristics until about 13 years of age [1]. Tutkuviene et al. [29] obtained differences in mandibular width (go-go) in European children of 3–6 years, with boys' mandibles being on average by 1.7–2.7 mm wider than girls'. In contrast, Ursi et al. [30] found that the mandibular effective lengths are dimorphic from 9 year of life. In the present study, due to the small numbers in the sex and age subgroups, dimorphic differences in the course of changes in mandibular dimensions were not analyzed. Although the mandibular dimensions of boys were slightly larger than those of girls, the observation of the mean values of width, height and length dimensions of children in the first year of life are in line with Kelly et al. [15] finding that growth of mandible followed a similar trajectory for both sexes.

5. Conclusions

It can be concluded that the greatest growth rate of the mandible in children in the first year of life occurs in the first three months. The changes are usually more than 10%, and the largest changes are in the length dimensions of the mandible body and the length of the entire mandible. The average values obtained indicate that there is no significant asymmetry. The slight differences between the measurements of the right and left sides are a manifestation of fluctuating asymmetry, resulting from the influence of environmental factors.

The results complete the knowledge of changes with age in the dimensions and shapes of the mandible by the period of the first year of life. Most of the work on this issue concerns older children and teenagers, while measurements of newborns and infants are rarely available. Improving knowledge of development and growth of craniofacial structures, especially in early life, is important for all pediatric specialists, clinicians, head surgeons or orthodontists. It is essential to know the ranges of normal dimensions, the regularities of development, the rate and dynamics of the changes taking place, in order to make diagnoses correctly and have a point of reference during the treatment processes.

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