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ORIGINAL RESEARCH

Panorametric study in a paediatric population in Madrid

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Abstract

The aim of the study was to establish the normality ranges of the linear and angular measurements that can be carried out in orthopantomographies (OPGs) of a paediatric sample from Madrid, according to sex and dentition. OPGs performed in the Radiology Service of the Faculty of Dentistry of the Complutense University of Madrid (UCM) from caucasic children between 4–14 years old were selected. A total of 44 measurements were made in the OPGs, and the sex and type of dentition of each child were recorded. Panoramic Mandibular Index and Antegonial Index were also calculated. Statistical tests were performed with a confidence level of 95% ($p < 0.05$) and bilateral significance to analyse the differences between sex and type of dentition, and the correlation between the measurements of the right and left sides. A total sample of 160 OPGs (50% boys, 50% girls) were analysed. 16.25% of the sample was in primary dentition, 50% in first phase mixed dentition, 17.5% in second phase mixed dentition and 16.25% in permanent dentition. Statistically significant differences were found with respect to the sex of the subjects in 11 of the measurements; and 44 in relation to the dentition stages of the subjects. A strong correlation is found between the measurements on the right and left sides. The application of panoramic measurements as indicators of normality can help in the detection of craniofacial alterations in growth and development of the lower facial third.

Keywords

Pantomography; Orthopantomography; Panoramic radiography; Anatomy; Growth; Development

1. Introduction

Anthropometry is the science based on the study of human dimensions and measurements with the purpose of assessing the physical changes that occur throughout the development and growth. By means of a systematized technique based on measurements and observations in the human body, anthropometry can be carried out directly on the subject himself (per example measure of height or weight) or thought complementary records like x-rays or photographs [1].

Craniofacial growth and development are a complex physiological process that includes a dynamic series of events that begins at fertilization and continues, both in the prenatal and postnatal stages of the child [2]. In Paediatric Dentistry, the anthropometric study of the characteristics and magnitude of bone growth at the orofacial level, especially in the maxillary and mandibular bone, allows us to determine growth models or patterns in healthy children. Growth alterations, both in pattern and rate, indicate the development of an abnormal skeletal morphology of the face that may lead to associated dental and/or skeletal malocclusion [3–5].

The orthopantomography (OPG) or panoramic radiography is an extraoral radiological technique that allows the professional to observe a great area of the upper maxilla and the mandible in a single image [6]. The OPG complements the intraoral radiographs in dental diagnosis, without replacing them. The dental professional must evaluate the benefits and disadvantages that each type of radiography provides, especially the amount of radiation received by the patient, and choose the most convenient in each case [6]. When performing an OPG, it is important to pay special attention that the spine, Frankfort plane, lips and tongue are correctly positioned and that the person remains still to avoid movement errors [7].

A systematized analysis of the OPG allows us to reach an adequate interpretation, so it is important to carry out an exhaustive analysis of the radiograph, confirming belonging to the subject, the position of the patient, symmetry, artifacts, technical errors (exposure, contrast, blurred areas, *etc.*), pathological or abnormal findings, among others. Puricelli, in 2009 [8], proposed a method called “panorametry” to make measurements in the mandible, using OPG. The author proposed a series of linear and angular measurements, ant their main objective was to compare the mandible bilaterally. Since then, many other authors such as Frascino *et al.* [9] in 2019 or Sghaireen *et al.* [10] in 2020, have used this type of radiographs to perform bone metric studies. However, we have not found the description of a standardized pattern to analyse OPGs that allows assessing mandibular growth. The aims of this study were to determine the measurements that can be carried out in OPG to create a panorametry and to establish their mean values in a Madrid paediatric sample to create reference tables with normality ranges.

2. Materials and methods

A retrospective cross-sectional study was conducted. All the digital OPGs of children treated in the master's degree in paediatric dentistry at the Complutense University of Madrid (UCM) between 2011 and 2021 were selected, obtaining an initial study universe of 311 records that were requested for diagnostic purposes other than research. All radiographs were taken by the same X-ray technician and the same OPG machine (Instrumentarium Orthopantomograph® OP30) and parameters (frequency 100–130 kHz, voltage tube 2.8 mm AI, current tube 9/10 mA, nominal voltage 100/115 VAC or 220/230/240 VAC, 50/60 Hz), with a known image magnification of 25%. To obtain the final study sample, OPGs from children with normal growth and development of the mandible aged between 4 and 14 years of age and Caucasian race (first and second degree European relatives, respectively parents and grandparents) were selected. The selection criteria regarding race was imposed to avoid the presence of anatomical pattern biases or craniofacial development associated with the children's race. Regarding the age of the children, the minimum age was set at 4 years since we do not systematically perform OPG on younger children, and the maximum at 14 years because it is the pediatric age limit stipulated in Spain and therefore the maximum age of patients in our pediatric dentistry service. It was decided to select children of all ages between 4 and 14 years with the aim of carrying out an evaluation of the method at different ages and dentition stages.

Records of patients with a history of premature birth, craniofacial trauma, dental malocclusion and/or orthodontic-orthopaedic treatment, craniofacial pathologies, syndromes, or altered growth and development were excluded. OPGs were also excluded for reasons of poor radiographic quality, image distortion, or the presence of radiographic artifacts. After discarding 151 radiographic records, the final study sample was composed of 160 OPGs.

The Sakura® Software (version 2.0, Madrid, Spain) was used for the visualization and measurement of the OPG. Through its "Anonymize Selected Study" tool, the confidentiality of patients' personal data was protected while recording the case history number, date of birth, and date of OPG performance. In those cases, in which the child had more than one OPG performed on different dates, all those that met the selection criteria were included as independent samples. The observation of the OPGs allowed us to establish four groups depending on the patient's dentition: group 1 (primary dentition), group 2 (mixed dentition—first phase), group 3 (mixed dentition—second phase) and group 4 (permanent dentition). A distinction was made between first phase mixed dentition (eruption of first permanent molars and replacement of temporary incisors by permanent ones) and second phase (replacement of primary molars and canines by permanent premolars and canines, respectively). The anatomical points that we have used to carry out our measurements are collected in Table 1 [8, 11–13]. Given Ladeira's results, which show that the intergonial distance does not affect the horizontal and vertical measurements, groups were not differentiated based on the distance between the Gonion anatomical point [14]. Linear and angular measurements were made, 34 linear and 10 angular (Table 2) [8, 11–13]. A total of 34 linear measurements were made up of 10 vertical (A1–A10) (Fig. 1), 10 horizontal (B1–B10) (Fig. 2) and 14 oblique (C1–C14) (Fig. 3) [8, 11–13]. 10 angular measurements were carried out (D1–D10) (Fig. 4) [8, 12]. With these data, the Panoramic Mandibular Index (PMI) or Klemetti Index (assessment of osteoporosis) and the Antegonial Index (AGI) were calculated bilaterally (Table 2). PMI is the quotient between the distance between AMinf and the lower edge of the mandibular body, and the width of the cortex of the lower edge of the mandibular body. AGI is the thickness of the lower cortex of the mandible [15].

TABLE 1. Description of the anatomical references used to trace the panorametry [8, 11–13].

Anatomical References	Location
ACsup	Most superior point of the coronoid process
AM	Mental foramen
AMant	Most anterior point of the mental foramen
AMinf	Most inferior point of the mental foramen
AMpost	Most posterior point of the mental foramen
CM	Mandibular body
CMinf	Lower border of the mandibular body
CMsup	Upper border of the mandibular body
Co	Most superior point of the mandibular condyle
Copost	Most posterior point of the mandibular condyle
ESinf	Deepest point of the mandibular sigmoid notch
Go	Most posterior and inferior point of the mandibular external angle
H	Vertical line perpendicular to the edge of the radiograph and passing through the centre of the nasal bones
rMx	Right most posteroinferior point of the maxilla
lMx	Left most posteroinferior point of the maxilla
RM	Mandibular ramus
RMant	Most anterior point of the posterior border of the mandibular ramus
RMpost	Most posterior point of the anterior border of the mandibular ramus

TABLE 2. Measurements and indexes made with the panoramic tracing [8, 11–13].

Acronym	Description
Vertical Measurements [8]	
rCo-ESinf (A1)	Distance from Co right to ESinf right
lCo-ESinf (A2)	Distance from Co left to ESinf left
rACsup-ESinf (A3)	Distance from ACsup right to ESinf right
lACsup-ESinf (A4)	Distance from ACsup left to ESinf left
rESinf-Go (A5)	Distance from ESinf right and Go right
lESinf-Go (A6)	Distance from ESinf left and Go left
rCo-Go (A7)	Distance from Co right to Go right (A1 + A5)
lCo-Go (A8)	Distance from Left Co to Left Go (A2 + A6)
rCMlower-CMupper (A9)	Distance between the lower and upper edges of the right CM that has left AMant as tangential point
lCMlower-CMupper (A10)	Distance between the lower and upper edges of the left CM that has left AMant as tangential point
Horizontal Measurements [8]	
rMx-H (B1)	Distance between point rMx and H
lMx-H (B2)	Distance between point lMx and H
rCo-H (B3)	Distance from Co right to H (B5 + B9)
lCo-H (B4)	Distance from left Co to H (B6 + B10)
rACsup-H (B5)	Distance from ACsup right to H
lACsup-H (B6)	Distance from ACsup left to H
rGo-H (B7)	Distance from Go right to H
lGo-H (B8)	Distance from Go left to H
rCo-ACsup (B9)	Distance between the right points Co and ACsup
lCo-ACsup (B10)	Distance between left points Co and ACsup
Oblique Measurements [11–13]	
rCo-Go (C1)	Distance between right Co and Go points
lCo-Go (C2)	Distance between left Co and Go points
rACtop-Go (C3)	Distance between right ACtop and Go points
lACsup-Go (C4)	Distance between left ACsup and Go points
rCopost-Go (C5)	Distance between right Copost and Go
lCopost-Go (C6)	Distance between left Copost and Go
rCo-SMinf (C7)	Distance between right Co and SMinf
lCo-SMinf (C8)	Distance between left Co and Sminf
rRMant-RMpost (C9)	Distance between right RMant and RMpost points
lRMant-RMpost (C10)	Distance between left RMant and RMpost points
rAMinf-CMlower (C11)	Distance between right AMinf and the lower edge CM
lAMinf-CMlower (C12)	Distance between left AMinf and the lower edge CM
rCMlower (C13)	Cortical width of the lower border of the right CM
lCMlower (C14)	Width of the cortex of the lower border of the left CM

TABLE 2. Continued.

Acronym	Description
Angular Measurements [8, 12]	
rCM-MR (D1)	Angle formed between the tangent passing through the most prominent points of the right CM and the tangent passing through the most prominent points of the right MR
lCM-MR (D2)	Angle formed between the tangent passing through the most salient points of the left CM and the tangent passing through the most salient points of the left MR
rCo-AM-C2 (D3)	Angle between the line joining Co and the most posterior point of AM and C2 on the right side
lCo-AM-C2 (D4)	Angle between the line joining Co and the most posterior point of AM and C2 on the left side
rCo-AMpost-Go (D5)	Angle between the line joining Co and AMpost and the line joining AMpost and Go on the right side
lCo-AMpost-Go (D6)	Angle between the line joining Co and AMpost and the line joining AMpost and Go on the left side
rC6-AMpost-Go (D7)	Angle between the line joining C6 and the line joining AMpost and Go on the right side
lC6-AMpost-Go (D8)	Angle included between the line joining C6 and the line joining point AMpost and Go on the left side
rC2-AMpost-Go (D9)	Angle between line C2 and the line joining AMpost and Go on the right side
lC2-AMpost-Go (D10)	Angle between line C2 and the line joining AMpost and Go on the left side
Indexes [15]	
PMIR	Right panoramic mandibular index = C11/C13
PMIL	Left panoramic mandibular index = C12/14
AGIR	Right antegonial index = C13
AGIL	Left antegonial index = C14

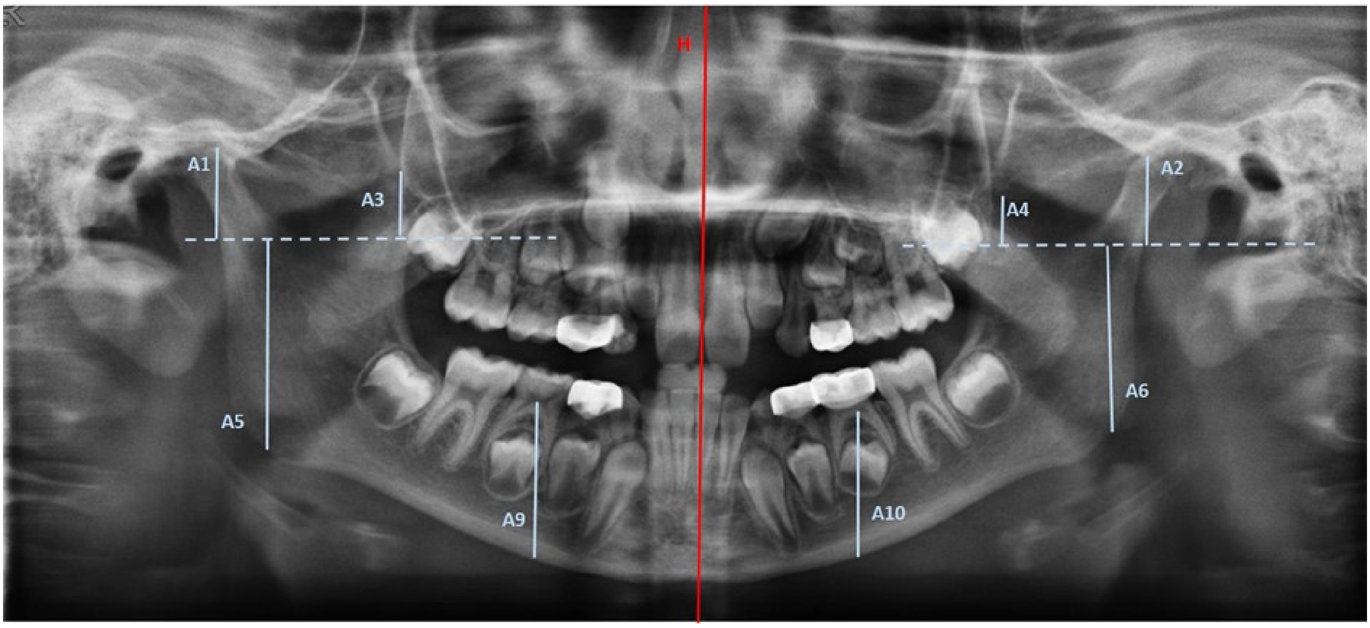

FIGURE 1. Vertical linear measurements made in the OPG from a 9 years/1 month boy.

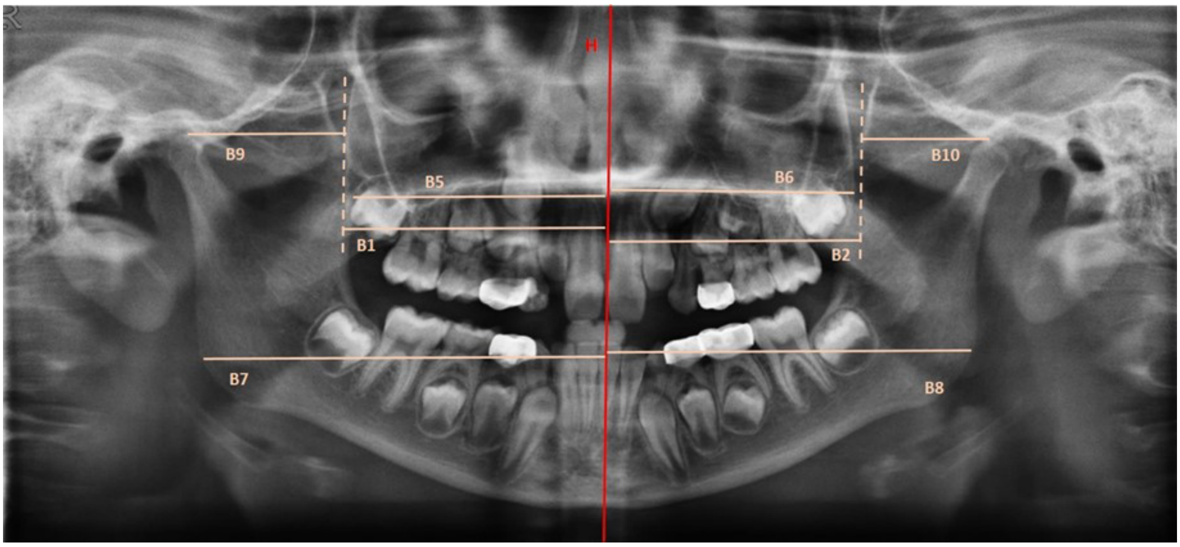

FIGURE 2. **Horizontal linear measurements made in the OPG from a 9 years/1 month boy.**

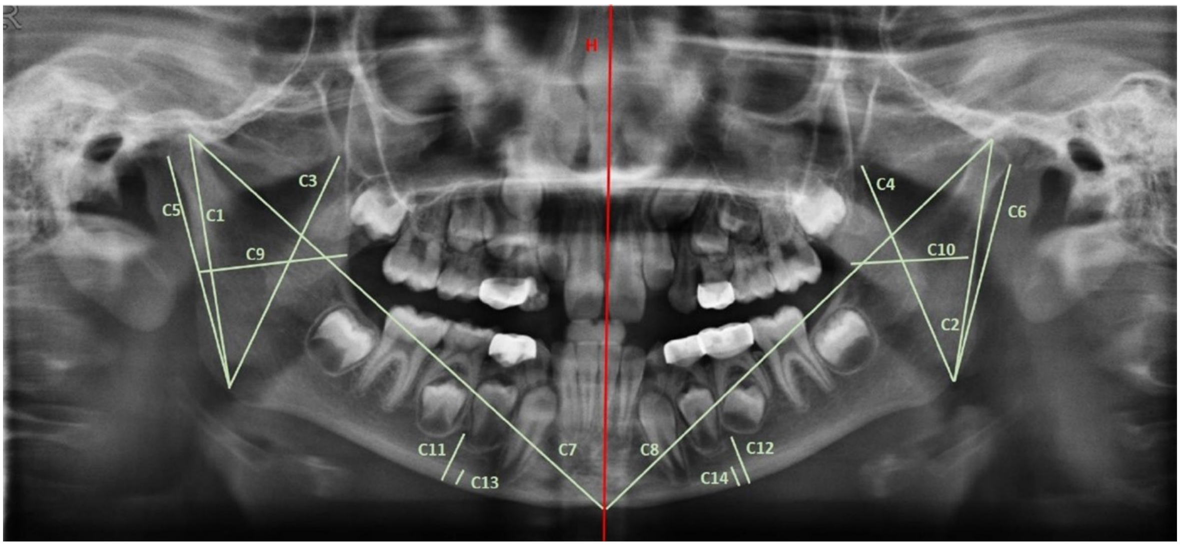

FIGURE 3. **Oblique linear measurements made in the OPG from a 9 years/1 month boy.**

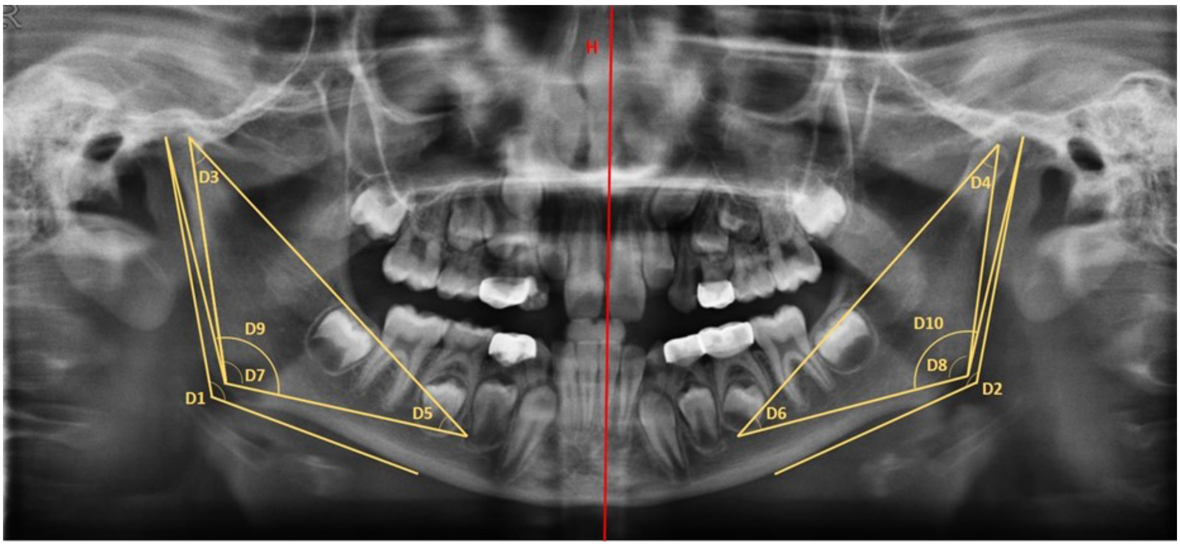

FIGURE 4. **Angular measurements made in the OPG from a 9 years/1 month boy.**

The order of the measurements was vertical, horizontal, oblique and angular. Finally, the indices were determined. Fig. 1 shows an example of the panoramic tracing made in each OPG. Measurements were performed by two calibrated examiners, and intra- and inter-examiner agreement was determined by re-evaluating 20% of the sample, on randomly chosen OPGs, two months after their first measurement. A maximum of 10 radiographs per session were measured, always under the following conditions: with natural light, without using any type of image magnification, using the same computer located in the same place.

Statistical analysis was performed with SPSS 24® Software (version 24.0, Armonk, N.Y., USA) with a confidence level of 95% ($p \leq 0.05$) and asymptotic or bilateral significance. Intra- and inter-examiner agreement was assessed using the intraclass correlation coefficient (ICC), and interpreted as poor (value <0.40), fair (value 0.4–0.59), good (value 0.6–0.74) or excellent agreement (value 0.75–1) [16]. The descriptive statistics was made up of the calculation of the mean, standard deviation, maximum and minimum of the variables studied. The normality test (Kolmogorov-Smirnov test with Lilliefors correction) of the variables was performed to select the type of inferential test to be performed. The T-Student and Anova tests were performed for parametric variables and the Mann-Whitney and Kruskal-Wallis U tests for non-parametric variables in the hypothesis contrast. Correlation between left and right sides measurements was analysed using Pearson's Correlation Coefficient.

3. Results

The study sample consisted of 160 OPGs (80 boys and 80 girls), of which 16.25% had primary dentition (Group 1), 50% first phase mixed dentition (Group 2), 17.50% second phase mixed dentition (Group 3) and 16. 25% permanent dentition (Group 4) (Table 3). The distribution of the general sample by gender was homogeneous ($p - \chi^2 = 0.874$) but statistically significant differences were found analysing the distribution of the type of dentition ($p - \chi^2 = 0.000$). However, the distribution according to simultaneal to sex and type of dentition was simultaneously homogeneous ($p - \chi^2 = 0.725$) although Group 2 continues to be more numerous than the rest of the groups by type of dentition.

Inter-examiner agreement was almost perfect or excellent in 21 of the variables studied, good in 19 variables, and moderate or fair in 5 variables. However, in B9 we found a poor degree of agreement (ICC = 0.163), and in PMIL and AGIR they showed a poor degree of agreement (ICC = 0.340 and ICC = 0.386, respectively). Intra-examiner agreement was almost perfect or excellent in 41 of the variables, good in three variables, moderate or fair in three variables, and poor in D1 (ICC = 0.002) (**Supplementary Table 1**).

Means and standard deviations of all measurements were calculated. A table was created for boys and girls (Table 4), divided by type of dentition. According to the Kolmogorov-Smirnov test, only 20 of the measurements follow a normal distribution, while 28 measurements do not meet normality criteria (**Supplementary Table 1**).

The differences between the measurements with respect to the sex were analysed. The measurements are higher in girls than in boys, obtaining statistically significant differences (p-value ≤ 0.05) in four vertical measures (right and left ESinf-Go, and right and left CMlower-CMupper), six horizontal measures (right and left MX-H, rCo-H, right and left ACsup-H and rGo-H) and an oblique measure (lACsup-Go) (**Supplementary Table 1**).

Regarding the type of dentition, statistically significant differences (p-value ≤ 0.05) were obtained in 44 of the 48 proposed measures (**Supplementary Table 2**) increasing the measures as the dentition stage advances. Only in the 4 measures (right and left CM-MR, lCo-AM-C2 and PMIR) no differences were found between the type of dentition and the measurements performed. *Post-hoc* tests were performed, indicating that differences were found in the measurements between all the dentition groups in practically all the variables studied. Regarding the *post hoc* tests, there is a general tendency towards the presence of statistically significant differences between the temporary dentition and the rest of the groups (specifically the second phase mixed dentition and the permanent dentition) and the absence of significant differences between the second phase mixed dentition. phase and permanent dentition.

Finally, the behaviour of the measures on the right side with their analogous contralateral measures was analysed, showing a strong or very strong degree of agreement in almost all the parameters (Pearson's correlation coefficient >0.5), except for the pairs of measures rCo-ACsup (B9–B10) (Pearson's correlation coefficient = 0.467) and PMIR-PMIL (Pearson's correlation coefficient = 0.470).

The analysis of the data obtained in the total sample has allowed the creation of model tables for the panoramic tracing of OPGs for boys and girls. In this normality tables, the means and standard deviations of the results obtained in this study are included in different columns (differentiated according to the type of dentition), as a reference of normality (**Supplementary Table 2**).

TABLE 3. Distribution of the sample according to the type of dentition and sex.

Sample	Group 1		Group 2		Group 3		Group 4		Total	
	Primary dentition		1st Mixed dentition		2nd Mixed dentition		Permanent Dentition			
	n	%	n	%	n	%	n	%	n	%
Boys	14	8.75%	40	25%	15	9.38%	11	6.88%	80	50%
Girls	12	7.50%	40	25%	13	8.13%	15	9.38%	80	50%
Total	26	16.25%	80	50%	28	17.50%	26	16.25%	160	100%

TABLE 4. Values of the mean (cm) and standard deviation of the measurements, according to Table 2 acronyms.

Measure	Male				Female			
	Dentition				Dentition			
	Primary	1st Mixed	2nd Mixed	Permanent	Primary	1st Mixed	2nd Mixed	Permanent
A1[b]	1.45 ± 0.22	1.38 ± 0.31	1.77 ± 0.26	1.95 ± 0.30	1.52 ± 0.42	1.43 ± 0.33	1.73 ± 0.31	1.94 ± 0.44
A2[b]	1.45 ± 0.33	1.39 ± 0.28	1.80 ± 0.37	1.89 ± 0.40	1.50 ± 0.38	1.49 ± 0.31	1.88 ± 0.40	1.95 ± 0.42
A3[b]	1.09 ± 0.22	1.17 ± 0.24	1.25 ± 0.23	1.01 ± 0.32	0.90 ± 0.32	1.18 ± 0.23	1.20 ± 0.27	1.28 ± 0.28
A4[b]	1.05 ± 0.27	1.17 ± 0.19	1.32 ± 0.22	1.12 ± 0.32	0.87 ± 0.25	1.17 ± 0.27	1.20 ± 0.22	1.17 ± 0.19
A5[a,b]	3.97 ± 0.63	4.08 ± 0.41	4.67 ± 0.38	4.63 ± 0.56	3.45 ± 0.56	3.91 ± 0.36	4.22 ± 0.40	4.61 ± 0.38
A6[a,b]	3.97 ± 0.34	4.27 ± 0.37	4.86 ± 0.34	4.85 ± 0.46	3.69 ± 0.59	4.03 ± 0.43	4.47 ± 0.39	4.83 ± 0.36
A7[b]	5.42 ± 0.80	5.46 ± 0.50	6.44 ± 0.51	6.58 ± 0.46	4.97 ± 0.90	5.34 ± 0.47	5.95 ± 0.49	6.55 ± 0.42
A8[b]	5.42 ± 0.47	5.66 ± 0.53	6.66 ± 0.52	6.74 ± 0.51	5.19 ± 0.93	5.52 ± 0.49	6.35 ± 0.58	6.78 ± 0.52
A9[a,b]	3.08 ± 0.22	3.26 ± 0.28	3.67 ± 0.29	3.61 ± 0.27	2.76 ± 0.51	3.15 ± 0.27	3.39 ± 0.40	3.59 ± 0.34
A10[a,b]	3.10 ± 0.22	3.26 ± 0.28	3.67 ± 0.29	3.61 ± 0.27	2.76 ± 0.51	3.15 ± 0.27	3.39 ± 0.40	3.59 ± 0.34
B1[a,b]	6.30 ± 0.51	6.47 ± 0.67	6.95 ± 0.46	6.74 ± 0.82	5.51 ± 1.17	6.18 ± 0.58	6.32 ± 0.42	6.46 ± 0.61
B2[a,b]	6.37 ± 0.50	6.45 ± 0.72	6.82 ± 0.46	6.58 ± 1.20	5.53 ± 1.16	6.18 ± 0.56	6.35 ± 0.51	6.64 ± 0.52
B3[a,b]	9.98 ± 0.76	10.31 ± 0.76	10.90 ± 0.70	10.54 ± 1.13	8.85 ± 1.66	10.06 ± 0.76	10.43 ± 0.76	10.27 ± 0.65
B4[b]	9.90 ± 0.55	10.08 ± 1.29	10.34 ± 0.93	10.71 ± 0.70	8.88 ± 1.79	10.00 ± 0.74	10.36 ± 0.22	10.38 ± 0.67
B5[a,b]	6.74 ± 0.44	7.00 ± 0.66	7.46 ± 0.52	7.11 ± 0.80	5.94 ± 1.10	6.77 ± 0.63	6.95 ± 0.45	6.78 ± 0.68
B6[a,b]	6.81 ± 0.49	6.90 ± 0.57	7.28 ± 0.62	7.26 ± 0.56	5.99 ± 1.19	6.83 ± 0.58	6.97 ± 0.44	6.88 ± 0.52
B7[a,b]	8.71 ± 0.85	9.16 ± 0.76	9.89 ± 0.41	9.51 ± 0.69	7.91 ± 1.44	8.88 ± 0.68	9.24 ± 0.68	9.42 ± 0.63
B8[b]	8.49 ± 0.72	8.55 ± 1.21	9.29 ± 0.54	9.50 ± 0.45	7.73 ± 1.57	8.39 ± 1.01	9.01 ± 0.83	9.27 ± 0.68
B9[b]	3.25 ± 0.43	3.31 ± 0.31	3.44 ± 0.45	3.44 ± 0.45	2.91 ± 0.61	3.29 ± 0.28	3.47 ± 0.31	3.49 ± 0.32
B10[b]	3.08 ± 0.22	3.35 ± 0.96	3.30 ± 0.51	3.45 ± 0.32	2.89 ± 0.66	3.17 ± 0.31	3.39 ± 0.41	3.49 ± 0.35
C1[b]	5.45 ± 0.38	5.52 ± 0.44	6.50 ± 0.45	6.53 ± 0.36	5.11 ± 0.89	5.46 ± 0.42	6.06 ± 0.36	6.56 ± 0.40
C2[b]	5.60 ± 0.38	5.83 ± 0.44	6.73 ± 0.49	6.73 ± 0.50	5.34 ± 0.99	5.73 ± 0.39	6.39 ± 0.53	6.81 ± 0.48
C3[b]	5.28 ± 0.48	5.59 ± 0.42	6.37 ± 0.36	6.14 ± 0.53	4.76 ± 0.77	5.45 ± 0.42	5.88 ± 0.59	6.46 ± 0.39
C4[a,b]	5.37 ± 0.41	5.64 ± 0.41	6.46 ± 0.41	6.34 ± 0.54	4.91 ± 0.86	5.44 ± 0.41	6.00 ± 0.52	6.44 ± 0.41
C5[b]	5.02 ± 0.33	5.08 ± 0.39	5.96 ± 0.42	5.98 ± 0.36	4.86 ± 0.84	5.01 ± 0.38	5.59 ± 0.31	5.98 ± 0.39
C6[b]	5.24 ± 0.37	5.42 ± 0.40	6.24 ± 0.43	6.20 ± 0.47	4.92 ± 0.90	5.33 ± 0.37	5.38 ± 0.50	6.25 ± 0.49
C7[b]	12.85 ± 0.84	13.07 ± 0.86	14.57 ± 0.80	14.58 ± 0.70	11.80 ± 2.15	12.86 ± 0.79	13.85 ± 0.83	14.29 ± 0.70
C8[b]	12.83 ± 0.71	13.04 ± 0.88	14.43 ± 0.84	14.72 ± 0.64	11.92 ± 2.32	12.73 ± 1.77	14.09 ± 1.19	14.40 ± 0.78
C9[b]	3.18 ± 0.40	3.29 ± 0.31	3.36 ± 0.40	3.39 ± 0.41	2.91 ± 0.55	3.22 ± 0.28	3.29 ± 0.34	3.40 ± 0.31
C10[b]	3.11 ± 0.31	3.21 ± 0.34	3.31 ± 0.38	3.49 ± 0.32	2.98 ± 0.61	3.07 ± 0.44	3.13 ± 0.79	3.36 ± 0.46

TABLE 4. Continued.

Measure	Male				Female			
	Dentition				Dentition			
	Primary	1st Mixed	2nd Mixed	Permanent	Primary	1st Mixed	2nd Mixed	Permanent
C11[b]	0.88 ± 0.13	1.00 ± 0.18	1.25 ± 0.17	1.33 ± 0.26	0.75 ± 0.14	0.98 ± 0.19	1.16 ± 0.17	1.22 ± 0.27
C12[b]	0.87 ± 0.07	0.96 ± 0.21	1.15 ± 0.17	1.31 ± 0.21	0.77 ± 0.15	0.96 ± 0.18	1.16 ± 0.13	1.25 ± 0.18
C13[b]	0.33 ± 0.03	0.36 ± 0.09	0.38 ± 0.07	0.39 ± 0.08	0.26 ± 0.08	0.35 ± 0.06	0.37 ± 0.07	0.46 ± 0.09
C14[b]	0.33 ± 0.04	0.34 ± 0.05	0.37 ± 0.09	0.40 ± 0.08	0.29 ± 0.07	0.35 ± 0.05	0.38 ± 0.07	0.46 ± 0.08
D1	128.21 ± 5.95	126.63 ± 5.55	124.38 ± 5.84	126.64 ± 7.03	127.00 ± 5.82	127.35 ± 4.39	127.00 ± 4.69	124.00 ± 6.21
D2	128.07 ± 5.24	126.45 ± 5.68	124.50 ± 5.42	126.00 ± 6.03	125.75 ± 4.52	127.27 ± 4.80	128.00 ± 5.19	124.33 ± 6.67
D3	32.36 ± 3.03	35.00 ± 2.84	34.69 ± 2.39	33.55 ± 3.42	32.33 ± 2.77	33.80 ± 2.39	33.50 ± 3.42	34.33 ± 3.68
D4	32.00 ± 3.64	33.55 ± 2.93	32.19 ± 3.15	33.45 ± 2.66	32.08 ± 2.31	32.55 ± 2.86	32.50 ± 2.61	33.87 ± 3.38
D5[b]	31.57 ± 2.21	31.33 ± 3.13	33.63 ± 3.36	34.27 ± 3.23	31.92 ± 2.81	31.35 ± 2.75	32.00 ± 1.95	34.00 ± 2.33
D6[b]	33.00 ± 2.32	33.40 ± 3.28	36.19 ± 3.12	36.55 ± 3.14	33.92 ± 2.78	22.55 ± 2.41	34.75 ± 2.14	36.87 ± 2.90
D7[b]	121.93 ± 4.55	119.57 ± 5.37	117.50 ± 7.11	118.18 ± 5.88	121.58 ± 4.87	120.57 ± 3.80	119.67 ± 4.11	116.93 ± 4.57
D8[b]	121.57 ± 4.94	119.88 ± 5.58	118.06 ± 6.22	116.36 ± 5.87	120.50 ± 4.12	120.57 ± 4.69	119.67 ± 4.50	115.53 ± 5.69
D9[b]	115.21 ± 4.54	113.10 ± 5.08	110.94 ± 5.50	111.64 ± 5.33	115.00 ± 4.39	114.00 ± 3.47	114.08 ± 4.12	110.87 ± 4.37
D10[b]	115.36 ± 4.73	113.20 ± 5.23	112.00 ± 5.01	111.45 ± 4.30	113.92 ± 3.80	114.00 ± 3.47	114.08 ± 4.12	110 .87 ± 4.37
PMIR	2.29 ± 0.62	2.35 ± 0.66	2.88 ± 0.72	3.00 ± 1.48	2.58 ± 1.08	2.40 ± 0.71	2.75 ± 0.75	2.53 ± 1.13
PMIL[b]	2.29 ± 0.61	2.38 ± 0.59	2.81 ± 0.75	3.00± 0.89	2.25 ± 0.45	2.33 ± 0.62	2.58 ± 0.67	2.33 ± 0.72
AGIR[b]	0.33 ± 0.33	0.36 ± 0.09	0.38 ± 0.07	0.39 ± 0.08	0.26 ± 0.08	0.35 ± 0.06	0.37 ± 0.07	0.46 ± 0.09
AGIL[b]	0.33 ± 0.04	0.34 ± 0.05	0.37 ± 0.09	0.40 ± 0.08	0.33 ± 0.04	0.34 ± 0.05	0.37 ± 0.09	0.40 ± 0.08

[a] *Statistically significant for intragroup comparison (sex).*
[b] *Statistically significant for intragroup comparison (dentition).*

4. Discussion

There is little literature on the use of OPGs to quantify bone growth and assess facial and lower third face bone symmetry. Possibly, this may be due to the poor quality offered by these radiographs, which used to be distorted both at the bone and dental levels. However, improvements in the radiographic technique in recent years and their digitization make it possible to consider their use for this purpose.

Regarding the sample studied and the sample of the analysed articles, they are generally retrospective cross-sectional studies. It is important to note that, in our sample, the lower age limit was set at four years because this type of radiography is not usually performed on younger children, and the upper limit was set at 14 years because we were interested in assessing possible growth patterns in children in the widest possible age range. Most of the articles analysed were studies carried out in healthy children, but older than 15 years or in adulthood [10, 11, 15, 17, 18].

Although we have found some studies that include child samples [9, 12, 19], we found the drawback that they are children with systemic pathologies and/or with growth alterations, therefore this prevents their use to obtain reference values applicable to the general population and therefore comparisons with our results. For this reason, we would like to emphasize that in this study data are provided on the normal development of the jaws in a wide age range and that they can serve as a guide to compare it with other samples of childish age, from different groups and populations.

Regarding the methodology, the origin of our research arises from the one carried out by Edela Puricelli, in 2009 [8], on measurements in OPG. This author proposed a method, "panorametry", which consists of making a series of linear and angular measurements from a series of reference points and planes. Their objective was to compare the mandible bilaterally, also including certain dental measurements.

Based on the main objective of the present manuscript (assess bone parameters of growth and development), we have not carried out the dental measurements proposed by Puricelli [8]; in addition, it should be considered that the dental measurements proposed by Puricelli included the second and third permanent molars, which had not erupted in our patients, and for this reason we dispensed with these measurements. There are certain reference points and measurements that both works have in common, such as the gonion or the mental foramen. It should be noted that these references are widely used in other works reviewed [8, 11, 12, 20]. Other characteristics in common between the "Panorametry" studied by Puricelli and this one is that a vertical line perpendicular to the centre of the nostrils is marked as a reference, which serves as an anatomical reference [8]. However, all the measurements made by Puricelli [8] were oblique lines and angles focused on the mandibular angle. We also study other measures, such as the angles related to the condyle. Although Puricelli's [8] study is very complete, as we have said before, there are points and lines taken from his study, but we decided to simplify the methodology.

Also noteworthy is the work of Lopatiene *et al*. [11] (2018) who studied condylar symmetry and the mandibular ramus in children with crossbite. We have measured the condylar height and the mandibular ramus in the same way, obtaining similar results, although slightly higher than those obtained by Lopatiene *et al*. [11] in his control group without malocclusion (42.83 cm ± 1.93 and 42.91 cm ± 1.91, in the left and right side, respectively). Furthermore, it is interesting to consider that in the comparison of the group with malocclusion, the measurements on the non-crossbite side were significatively increased compared to the crossbite side, increasing the asymmetry index.

Other authors [13, 14, 21, 22], took as reference oblique lines tangent to the outermost edges of the mandibular lower body and the outer edge of the mandibular ascending ramus. Likewise, they assessed the maximum width of the mandibular ramus, minimum angle of the mandibular ramus and bigonial width. These references are similar to the present study if we look at the oblique measurements. In addition, we decided to carry out different types of linear, vertical, and horizontal measurements, to make a more exhaustive mandibular analysis. Frascino *et al*. [9] carried out a study in which they analyzed mineral density by measuring the mandibular cortex in survivors of pediatric hematopoietic stem-cell transplantation. In their results, they find a width of the mandibular cortex of 3.307 mm, similar to our results, and a significantly lower width in the children of the study group.

Regarding the calculation of mandibular indexes, we mainly rely on Dagistan *et al*. [15]. These authors, as well as other subsequent investigations, considered the values of the AGI, the mental index, the PMI and the mandibular cortical index in OPG [9, 10, 15, 17, 19, 23–25]. We also included the calculation of the AGI, which is defined as the thickness of the lower mandibular cortical bone in the antegonial area and the MPI or Klemetti, which is calculated with the ratio between the height of the mandibular cortical bone and the distance between the mental foramen and the lower edge of the mandible [15, 26]. Again, we find authors who have used this index in their research, but not in healthy populations, so it is not possible to compare results. Thus, Limeira *et al*. [27], analysed it in adults with type 1 Diabetes Mellitus and Apolinário *et al*. [28], in a paediatric sample with Osteogenesis Imperfecta. The study carried out by Apolinario *et al*. [28] in children reports a mandibular cortical index of 3.5–3.7 mm in children with a non-narrow cortex, and of 2.5–2.8 in those categorized as having a narrow cortex. The results obtained in our study (AGIR and AGIL) are close to those obtained by Apolinário in children with OI but with a non-narrow mandibular cortex, but superior to children with altered dimension of this cortex, as expected.

Other authors, on the contrary, focused on evaluating other aspects. We highlight those studies that analysed the mandibular symmetry [18], the location of the mental foramen [20], and from a morphodensitometric point of view, the canal of the inferior alveolar nerve [29–31]. All these measurements have been included in our panoramic layout.

As we have been mentioning, the comparison of our work with other studies has been of great complexity, since there are no previous investigations that use the same methodology. Therefore, although we have analysed some aspects, the originality of this study prevents us from carrying out an exhaustive discussion with the data obtained by other authors. In a study carried out in children with Fragile X Syndrome (FXS) [12], the researchers found measurements of the mandibular angle (rCM-MR and lCM-MR) similar to our study in the control group (122.7º ± 7 and 123º ± 6.3 in the respective right and left side), although they reported that in children and adolescents with FXS this angle is significantly increased.

Regarding the results, we can observe that the measurements obtained increase as the stage of dentition advances and therefore the age of the children. In relation to sex, most of the results obtained are quite similar between men and women. Even so, statistically significant differences are found in some variables. The significance tests show that in the linear and angular measurements there are relevant differences in terms of sex, specifically in 11 measurements, and in terms of the stage of dentition in 44 measurements. In the previous literature, we have not found studies that found differences in measurements and sex, except the study of Tassoker *et al*. [13] carried out in adults, which revealed that males have a larger mandibular morphology in almost all evaluated parameters in OPGs except gonial angles measurements that are almost equal in males and females. In a study carried out with OPGs [31] it is confirmed that the mandible shows a great sexual dimorphism that can be determined by analyzing the geometry and the allometry relationship between the body and the ascending ramus of the mandible. Sexual dimorphism in bone structures can be observed from an early age, with differences observed in young children with immature jaws with a reliability of 81% in determining sex [32]. In addition, more robust jaws are observed in boys than in girls at an early age and even during the eruption of the primary dentition [33]. In addition, it is considerable that the distribution of our sample was not homogeneous in terms of stage of dental replacement, and therefore age. In Spain it is estimated that pubertal growth begins at 8–13 years in girls and 10–15 in boys [34]. This advancement of pubertal growth in girls with respect to boys is probably acting on our data, and for this reason we found higher measurements in some of the variables studied.

With respect to the differences obtained related to the stage of dentition in the measurements, our results coincide with most of the studies analysed, that also obtained statistically significant differences in terms of the stage of dentition [13, 14, 18, 21, 22]; although no differences were found with respect to the skeletal classes [18].

Tassoker *et al*. [13] carried out a research reporting that changes were also detected between the different age groups. In addition, they agree with our study group that these works can serve as a basis for future studies comparing populations of children, with or without special needs, and determine differences between them. Sabbagh-Haddad *et al*. [12] found a weak correlation between age and mandibular angle. These studies could be used as a very useful tool even for forensic and anthropometric purposes of identification establishing growth patterns [13, 22, 31].

With the data obtained in our research, we have created normality tables, differentiated by sex and dentition stage, where the means and standard deviations have been included. This could serve as the mean values to apply them in the future to children to be able to study its growth by means of a panorametry made in a OPG. As explained above, it could be considered very interesting to extrapolate these tables to other populations or apply this panoramic study to children with special needs to make a comparison. Similar tables have not been found in other articles reviewed, so it has not been possible to compare. Therefore, this opens the possibility of developing many new lines of research.

Finally, regarding the indices that we have studied, the Antegonial Index (AGI) [23] and the Panoramic mandibular Index (PMI) using the Klemetti technique, we decided to include them in our study since they are considered the best predictive agents since they are the most standardized and used in case of possible future loss of bone mass [10, 15, 17, 24]. Its study, together with the mental index, has been repeated on numerous occasions in the selected articles [10, 15, 17, 20, 24], being carried out above all in populations with special needs, such as patients with osteoporosis [15, 19], or Diabetes Mellitus [27], and finding differences statistically significant. In the present study, no statistically significant differences were found in the analysis of the four selected indexes in terms of sex or dentition stages. This may make sense since these indexes are designed to assess bone loss in patients with osteoporotic diseases and our sample was made up of healthy children. Thereby, other studies such as Dagistan *et al*. [15] have shown that the change in cortical bone measurement in the antegonial region is inversely proportional to age, and the values are smaller in females than in males. Despite this, it was decided to include the indexes to find normality ranges that could be extrapolated to other collective with special needs. On the other hand, other articles detail other ways of measuring cortical bone width [9], or bone mineral density [19] in patients with osteoporotic problems [25], finding relevant results, although without consensus. Allen *et al*. [19], in 2016, for example, found a very weak association.

This study presents some limitations that have been justified by previous studies on the subject. On the one hand, OPGs have less precision than intraoral radiographs [6, 35] but allows the dental professional to have a global view of the structures of the lower third of the face. It has many shortcomings related to the reliability and accuracy of size, location and form of the images created [36]. The degree of distortion and magnification, greater in the horizontal plane [37] depends on the X-ray device [8, 38] and on other factors associated to the patient (malocclusion, bone asymmetries, *etc.*) or the technique (patient position or mobility among others). In addition, it has been seen that the distortion is greater in the anterior region than in the posterior region [14], and therefore, most of our measurements are in the posterior sector. Authors wishing to carry out measurements on OPG should take this magnification into account when making linear measurements. Despite this limitations, the use of this radiographs have been shown to be valid for the performance of measurements [37, 39, 40] and the estimation of age in forensic medicine [41]. We have avoided this limitation using always the same X-ray machine (with a known magnification of 25%) and being carried out by only one operator. On the other hand, the number of children in first mixed dentition were higher than in the other study groups, although the distribution of children by sex and type of dentition were homogeneous. This is secondary that the age of first OPG is frequently six years old in order to discard dental agenesis and to carry out orthodontic study for orthopedic or interceptive orthodontic. It is also important to consider that cranial growth is influenced by epigenetics and hormones, among others, so there is slight intersubject variability inherent to human heterogeneity. for this reason, the OPG can be considered helpful for the diagnosis of craniofacial alterations, but nevertheless, other complementary tests will be needed to support the diagnosis.

Despite these limitations, our research has some strengths. All the measurements analysed had an inter and intra-examiner agreement between good and almost perfect, except five measures (moderate agreement), showing the validity and the accuracy of our method. All the radiographs were made with the same X-ray equipment and the same operating technician, so we consider that there is standardization in the patient's position during the acquisition of the radiographic image. This fact also minimizes possible biases in terms of patient positioning or image quality, considering that all the images were taken under the same conditions and the same environment. The homogeneous distribution of the sample in sex, race and age makes our results reliable. Although OPGs are one of the most widely used radiographs in initial dental diagnosis, taking measurements on them is not a popular practice. The novelty of this method is the unification and simplification of the measurements proposed by other authors, tested in children of different age ranges and types of dentition.

In would be interesting, in future investigations, to use this method in other population groups (different age and race), in order to evaluate its utility. The use of this method in special needs children could help in the diagnosis of face asymmetries or growth disturbances, being of great help in therapeutic planning and counseling for families. In addition, since our method is a modification of Puricelli's original, it would be interesting to carry out a study in which both methods are compared, to evaluate both their simplicity in performing the method, and in the evaluation of craniofacial growth. Also, it could be of great interest to analyse longitudinal changes in the OPG measurements, although some authors [42] stablish that it is not recommended to use OPGs analysis of individual longitudinal changes in vertical facial and dentoalveolar parameters because a change in head inclination results in blurring, distortion, or enlargement of those areas, since the head position change becomes located outside the imaging plane. We also believe in our research group that it would be relevant to be able to create and test measures in OPGs that evaluate and monitor growth at the level of the upper jaw. Regarding the distortion that occurs in extraoral radiography equipment, given the latest advances and improvements in the field, it would be interesting to carry out studies that evaluate the distortion in the three planes of space in order to better determine the dimensional changes. between the patient and his radiograph.

5. Conclusions

With our results we can state that the OPG are useful to determine relevant measures proposed previously in the scientific literature to analyse the development of the craniofacial structures of the lower facial third of children, although larger population studies would be necessary. The measurements increase significantly with the stage of dentition, and are greater in females in comparison to males. It is possible to make tables in order to determine a panoramic pattern from the mean values and standard deviations of the analysed measurements. There is a correlation between the measurements on the right and left sides, so to simplify the procedure, it is proposed to perform it only unilaterally.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article (and supplementary material).

AUTHOR CONTRIBUTIONS

JNGJ and NEGLN—Conceptualization, validation and supervision; EPM—methodology, resources; AMV—software and data curation; EPM and AMV—formal analysis; EPM, JNGJ and NEGLN—investigation; AMCZ—writing-original draft preparation; AMCZ, AMV, AGP and NEGLN—writing review and editing; EPM and AGP—visualization; JNGJ—project administration. All authors have read and agreed to the published version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective cross-sectional study was approved by the Research Ethics Committee of the San Carlos Clinical Hospital in Madrid (ref: 22/068-E), according to the guidelines established by the Declaration of Helsinki for human research and current regulations regarding the protection of personal data. The parent/legal guardian of the patients signed a written consent for the use of records for purposes investigations.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1697507072644399104/attachment/Supplementary%20material.docx.

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