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Comparative dimensional study between panoramic X-ray (OPG) and cone beam CT (CBCT)

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ABSTRACT

During daily practice, we find various situations in which the 1/1 correspondence between panoramic x-ray (OPG) and reality seems not to be respected. In the studied literature, there are articles on this subject, but our study was made based on cases in a highly frequented dental imaging clinic in Bucharest. The study was carried out on a number of 24 patients selected from the radiology department. Using Romexis Viewer software, with soft's specific feature, measurements have been made (in approximately horizontal and approximately vertical axis) in three different areas: anterior, bicuspid and molar. Various results have been obtained, depending on the studied area. CBCT measured length of anterior teeth was higher than that measured on OPG, in the majority of cases. Molar width (mesio-distal distance) parameter variation was very small between OPG and CBCT.

Keywords: panoramic radiography, CBCT, dimensional measurements

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Introduction

In our daily practice, in various fields (endodontics, surgery, implantology), we are often in the position to perform OPG measurements. We encounter situations in which the 1/1 correspondence between the panoramic X-ray and reality seems not to be respected. There are other methods of dimensional measurement to correct the errors (retroalveolar radiography, apex locator or CT). For the above reasons we consider that the present study is useful to daily practice.

In the specialty literature there are articles which tackle this issue. A comparative study which analyzed the data obtained by CBCT and by 2D digital imaging methods emphasized significant dimensional differences in the central incisors and the canines [1]. Another study comparing CBCT and OPG, nevertheless, does not find significant dimensional differences between the techniques used [2].

The decision to perform a radiography prior to surgery relies on the ALARA (As Low As Reasonably Achievable) assumption, which implies exposure to the lowest radiation dose that allows for the necessary information. According to a study carried out by

Ghaeminia, CBCT imaging is more suitable for pre-surgical planning, compared to OPG [3].

Hörner [4], cited by Brüllmann [2], states that CBCT offers a 500- micron visibility of details. Thus, in clinical use, practitioners should not expect an accuracy of over 0.5 mm, at best. If in doubt, they should avoid the submillimeter measurements and accept an error limit in planning the procedure [5,6].

Materials and methods

24 de patients who came to the Radiology Department associated to "Prof. Dr. Dan Theodorescu" Hospital in Bucharest were selected for the present study. The patients called at the department for investigations preceding the implanto-prosthetic treatment. The selection of the cases was made depending on the imaging exploration techniques used. OPG and CBCT explorations using the same piece of equipment – Planmeca ProMax 3D Mid with a maximum power of 90 kw and a maximum intensity of 14 mA – were applied to these patients. Using the Romexis Viewer programme, measurements in three different areas – frontal, premolar and molar – were performed with the ruler in the soft, in horizontal and vertical axes. Clear morphologic landmarks (e.g. the cusps tips, the radiologic apex) were preferred, even if the resulting measurement axis is not (in a strictly mathematical sense) horizontal/vertical, because of the dental inclination. On both images the maximal width (coronal mesiodistal distance) and the maximal length (from the apex of the largest root to the tip of the highest cusp) were measured in a molar, premolar and front tooth of each of the 24 patients. 68 teeth were measured in total, because there were 4 cases of edentations for which the examiners could not perform the measurements.

Table I Teeth on which the measurements were performed

No	Frontal area	Premolar area	Molar area
1	4.2	4.5	3.7
2	1.2	1.5	2.7
3	2.2	1.5	2.7
4	1.2	1.5	1.7
5	1.2	1.5	1.6
6	1.2	1.5	2.6
7	4.3	1.5	1.6
8	1.3	1.5	1.6
9	1.2	1.5	1.6
10	4.2	4.4	1.7
11	1.3	4.5	1.8
12	1.1	2.4	1.8
13	2.1		2.6
14	2.1	3.4	2.6
15		3.5	2.8
16	2.3	2.5	1.7
17	3.3	3.5	
18	3.2	4.4	1.7
19	3.3		3.7
20	3.3	3.5	4.8
21	4.1	4.5	1.7
22	3.3	3.5	3.6
23	1.2	2.5	1.7
24	1.1	1.5	4.6

The teeth selected for measurement in each topographic dental arch varied according to the clinical case. This variation is determined both by the edentations which limited the selection, and to certain inclinations, positions or anomalies of shape because of which the measurements were inaccurate. After the data were gathered, they were included in tables and then statistically analyzed, using the Microsoft Excel 2007 program, part of Microsoft Open Office, produced by the Microsoft Corporation.

An example of the analysis of the clinical cases:

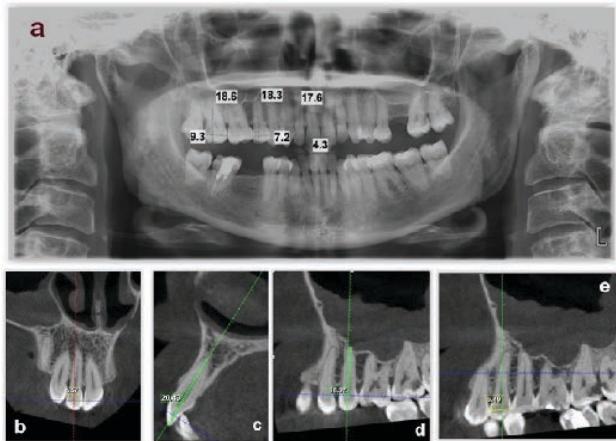


Figure 1. The measurements performed (in example 1) on OPG (a), compared to the ones on CBCT: maximal mesiodistal width (M-D) 12 in coronal acquisition (b), height 12 on sagittal acquisition (c), height (d) and M-D width (e) 25 in sagittal acquisition

Table II was drawn up using the measurements obtained from the OPG and CBCT images and the Microsoft Excel program.

Analysis: After the measurements were performed, a variable Δ was set, which represents the difference between the length and the width of the tooth, measured on CBCT and the length and width of the same tooth measured on OPG. 6 Δ variables ($\Delta 1$, $\Delta 2$, $\Delta 3$, $\Delta 4$, $\Delta 5$, $\Delta 6$) were obtained in this way, which were calculated using predefined Excel functions. In the end, we made a graphic representation of the values obtained, so as to observe their evolution. A graph for each Δ was made, so in the end there were six graphs in total. When Δ has a positive value, this means that the length/width of the tooth measured on CBCT was greater than the same length/width measured on OPG. When Δ has a negative value, this means that the length/width measured on OPG has a

Table II Information gathered from measurements

No	Initials of name and first name	OPG mm						CBCT mm					
		I l	I w	P l	P w	M l	M w	I l	I w	P l	P w	M l	M w
1	C. P.	19.7	4.5	20.8	7	18.8	10.2	19.02	4.71	20.8	6.74	18.89	10.06
2	E.D	24.6	6	20.6	6.4	20.1	9.8	26.56	6.81	20.57	6.35	19.52	10.2
3	M.C	19.2	4.3	17.2	6.5	16.5	9.2	19.36	5.71	15.71	5.85	16.12	9.07
4	C.M	17.3	4.3	18.3	7.2	18.6	9.3	20.17	5.4	18.6	6.9	17.51	9.06
5	C.G	18.1	4.6	17.9	5.5	16.9	8.8	19.68	5.85	19	6.16	18.06	9.76
6	S.A	23	5.6	22.7	7.8	21.1	11.5	23.8	5.92	24.09	6.77	22.89	9.91
7	P.I	27	6	23.2	6.4	17.4	10.6	26.27	6.15	22.67	6.6	23.21	9.86
8	S.P	21.7	5.6	18.8	6	18.1	10	27.16	7.52	18.91	6.15	18.31	10.05
9	N.E	21.5	4.7	19.9	6.9	17.5	10.6	22.08	6.45	18.96	6.34	20.3	9.76
10	N.M	20.7	4.3	21.3	6.3	20.1	8.8	19.81	5.25	20.27	6.3	18.51	8.4
11	L.L	20.7	6.3	19.7	7.3	14.3	8.6	23.48	7.35	19.34	6.51	16.27	7.92
12	P.A	23.5	7.2	20.1	6.7	19.4	10.8	23.1	7.5	20.1	6.34	21.21	9.45
13	C.A	19.6	6.4			18.8	9.2	19.55	6.4			18.4	10.52
14	D.D	20.9	8.4	22.8	7.2	20.7	9.8	20.9	9.4	23.15	7.07	19.8	9.6
15	M.M			21.4	7.1	20	9.3			21.36	7.06	19.92	8.72
16	I.I	21.7	6.1	20.2	6.9	19.6	11.6	21.87	6.16	20	8.56	18.95	11.4
17	C.G	23.4	4.9	24	7.5			23.4	5.4	22.15	7.01		
18	H.V	15.9	4.1	18.4	5.4	18.9	9.1	20.53	4.8	15.5	4.5	18.27	9.75
19	D.L	21	5.9			19.9	9.6	20.6	6.27			18.4	9.61
20	G.A	22.6	4.6	21.4	7	20.7	10.4	22.22	5.57	21.6	5.6	18.5	9.68
21	D.S	15.5	4	17.8	6.7	19.9	10.2	18.8	4.8	17.57	6.8	19.6	8.8
22	R.C	22.2	5.3	19.6	6	18.9	11.1	22.52	5.8	19.22	6.8	18.45	10.8
23	G.M	20	5.7	20.1	7	18.5	10.7	20.9	5.7	20.1	6.4	19.5	10.2
24	C.M	23.5	6.9	19.9	6.7	21.2	11.2	23.48	8.8	19.24	6.9	19.89	11.2

greater value than the one measured on CBCT. When the value of Δ is 0, this means that the values obtained by OPG and CBCT measurements were equal.

$\Delta 1$ – the difference between the sizes measured on the vertical axis in the frontal area

$\Delta 2$ – the difference between the sizes measured on the horizontal axis in the frontal area

$\Delta 3$ – the difference between the sizes measured on the vertical axis in the premolar area

$\Delta 4$ – the difference between the sizes measured on the horizontal axis in the premolar area

$\Delta 5$ – the difference between the sizes measured on the vertical axis in the molar area

$\Delta 6$ – the difference between the sizes measured on the horizontal axis in the molar area

Table III Differences between OPG and CBCT measurements

Nr.crt	$\Delta 1$	$\Delta 2$	$\Delta 3$	$\Delta 4$	$\Delta 5$	$\Delta 6$
1	-0.68	0.21	0	-0.26	0.09	-0.14
2	1.96	0.81	-0.03	-0.05	-0.58	0.4
3	0.16	1.41	-1.49	-0.65	-0.38	-0.13
4	2.87	1.1	0.3	-0.3	-1.09	-0.24
5	1.58	1.25	1.1	0.66	1.16	0.96
6	0.8	0.32	1.39	-1.03	1.79	-1.59
7	-0.73	0.15	-0.53	0.2	5.81	-0.74
8	5.46	1.92	0.11	0.15	0.21	0.05
9	0.58	1.75	-0.94	-0.56	2.8	-0.84
10	-0.89	0.95	-1.03	0	-1.59	-0.4
11	2.78	1.05	-0.36	-0.79	1.97	-0.68
12	-0.4	0.3	0	-0.36	1.81	-1.35
13	-0.05	0			-0.4	1.32
14	0	1	0.35	-0.13	-0.9	-0.2
15			-0.04	-0.04	-0.08	-0.58
16	0.17	0.06	-0.2	1.66	-0.65	-0.2
17	0	0.5	-1.85	-0.49		
18	4.63	0.7	-2.9	-0.9	-0.63	0.65
19	-0.4	0.37			-1.5	0.01
20	-0.38	0.97	0.2	-1.4	-2.2	-0.72
21	3.3	0.8	-0.23	0.1	-0.3	-1.4
22	0.32	0.5	-0.38	0.8	-0.45	-0.3
23	0.9	0	0	-0.6	1	-0.5
24	-0.02	1.9	-0.66	0.2	-1.31	0

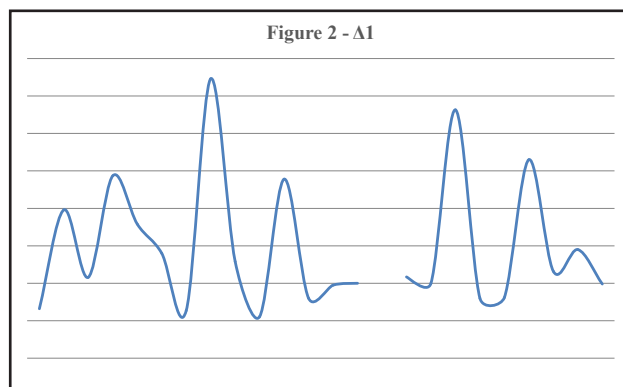


Figure 2 emphasizes the fact that the variations of the $\Delta 1 = H_{CBCT} - H_{OPG}$ parameter in the front teeth, (where H = vertical length) are predominantly positive, the greatest ones even exceeding 5mm.

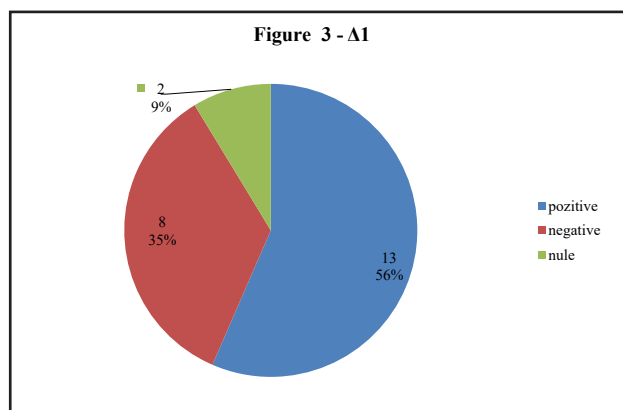


Figure 3 shows the percentage ratio of positive, negative and null values of $\Delta 1$

Therefore, the length of the front teeth determined on CBCT was, in most cases, greater than the same length measured on OPG. This finding can be determined by the fact that the front teeth have an oro-vestibular inclination of varying degrees, which explains their shorter image on OPG

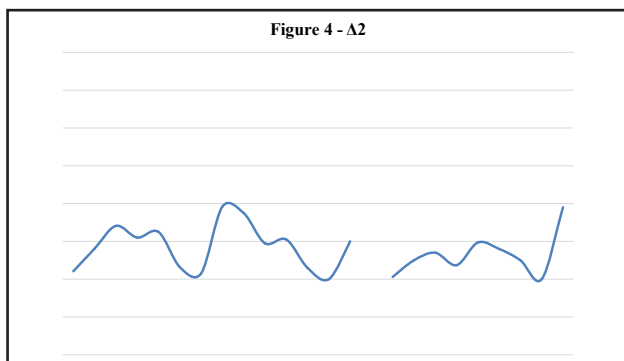


Figure 4 The variation of the $\Delta 2 = \text{LCBCT-LOPG}$ parameter in the front teeth, where L= width, in a horizontal sense (mesio-distal), shows that the values obtained for this variable are positive and null, without any negative values.

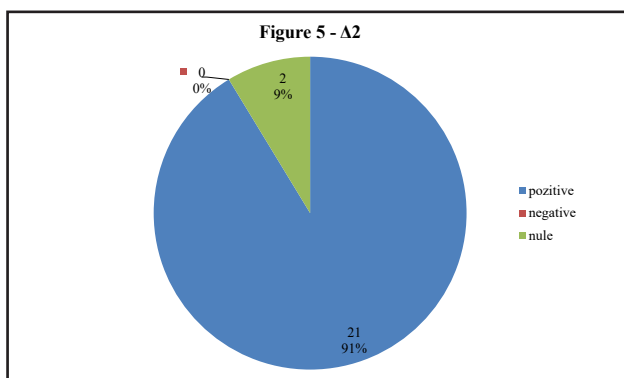


Figure 5 shows the percentage distribution of the $\Delta 2$ values.

Therefore, the width of the front teeth measured on CBCT was, in most cases, greater than the same width measured on OPG, and in 3 cases the values of the two types of measurements were equal. The causes of this difference can be found in: changes of the position of teeth, rotated teeth, impacted teeth (which made it impossible for the OPG to determine their real width, the difference from the shape of the arch) and the semicircle described by the rotation of the apparatus.

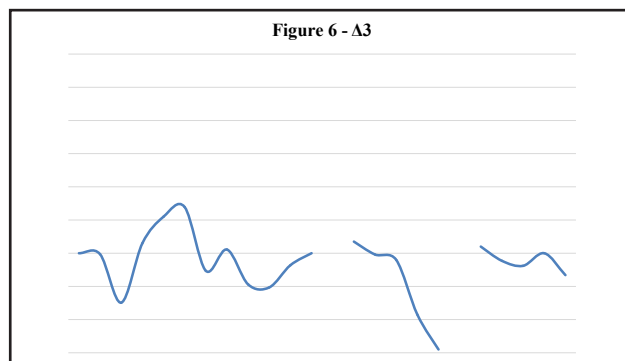


Figure 6 shows that positive, negative and null values were obtained for $\Delta 3$

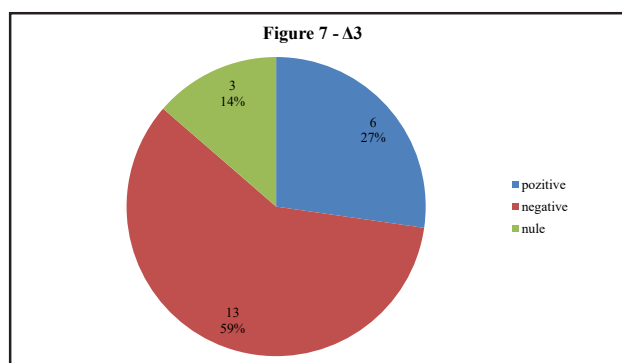


Figure 7 presents the percentage distribution of the positive, negative and null values of the $\Delta 3$ parameter, where $\Delta 3 = \text{HCBCT- HOPG}$ (H= vertical length of the premolar). In half of the cases, the length obtained on the OPG was greater than the same length measured on CBCT

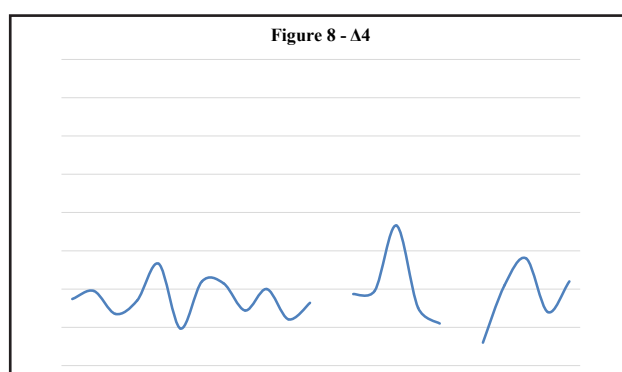


Figure 8 shows the variation of the $\Delta 4$ parameter = LCBCT-LOPG (L= width of the premolar in a mesio-distal direction), with positive, negative and null values for $\Delta 4$. In half of the cases $\Delta 4$ is negative, which means the fact that the values obtained for the measurement of OPG were greater than the ones obtained on CBCT

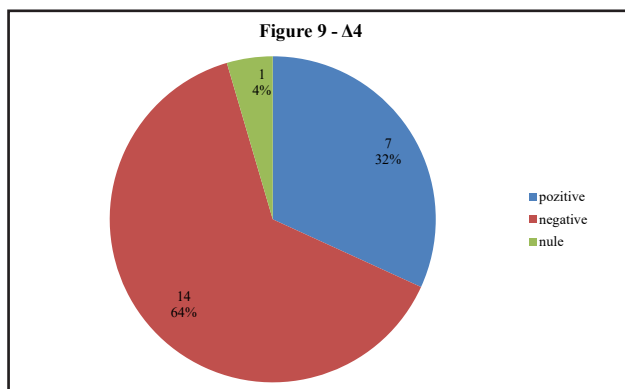


Figure 9 shows the percentage distribution of the values obtained for parameter $\Delta 4$

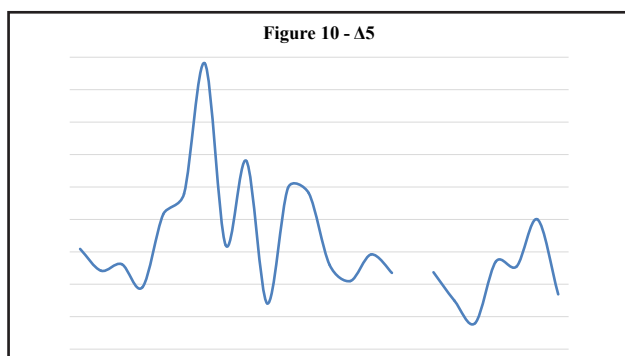


Figure 10 shows the variation of the $\Delta 5$ parameter = HCBCT-HOPG (H= vertical length of the molar), has an irregular aspect, with both positive and negative values, and a positive peak, which corresponds to a value of almost 6 mm.

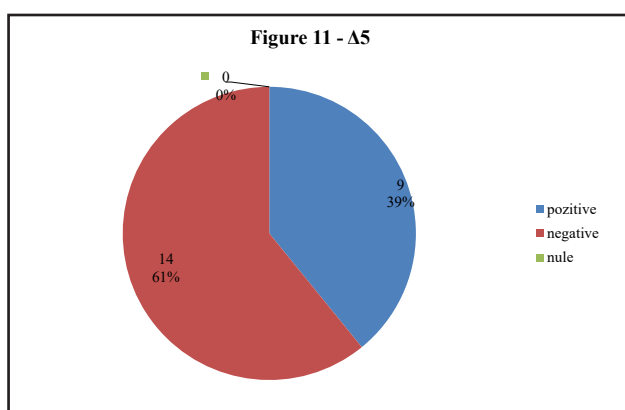


Figure 11 shows the percedntage distribution of the negative and positive values obtained for $\Delta 5$. There were no null values, and the majority of the values of $\Delta 5$ are negative

Therefore, the values measured on the two types of techniques were, in most cases, quite similar, with the exception of 6 measurements, whre the differences found were greater. The cause for these great differences can be the lack of visibility of the palatal root on the OPG, in the case of upper molars, where the inter-radicular bone is denser and hides the root.

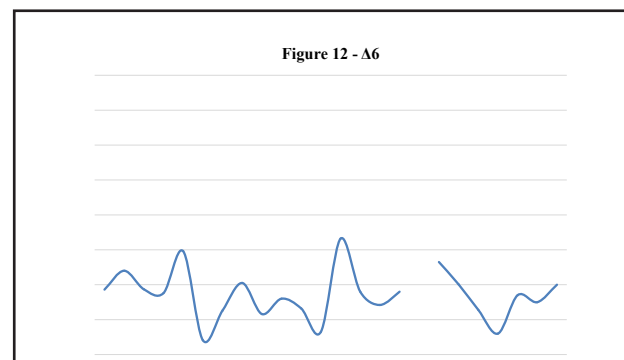


Figure 11 The variation of the $\Delta 6$ parameter

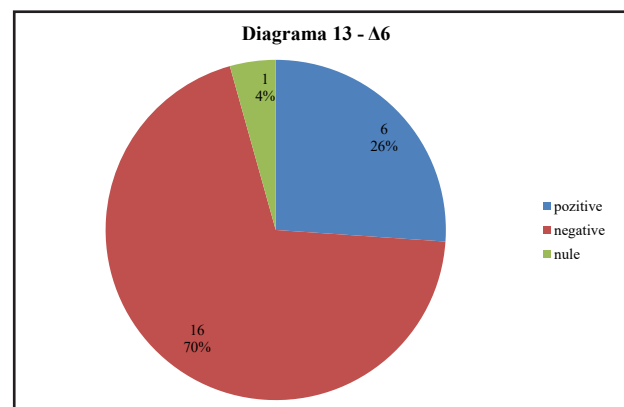


Figure 13 shows the percentage distribution of the $\Delta 6$ parameter

The variation of the $\Delta 6$ parameter = LCBCT-LOPG, where L= width (mesio-distal distance) of the molar, shows that the values measured on the two radiographs were quite similar, taking into account that the positive maximum is 1.32 mm, and the negative minimum is -1,5 mm (Figure 12). These differences could occur because of the malpositions of the teeth.

Conclusions

1. The length of the front teeth found on CBCT was, in most cases, greater than the same length measured on the OPG. This could be due to the fact that front teeth have an oro-vestibular inclination in varying degrees, which is why they appear shorter on the OPG.

2. The width of the front teeth measured on CBCT was, in most cases, greater than the same width measured on the OPG. The causes of these differences could be found in: changes of the position of teeth, rotated teeth, impacted teeth, which made it impossible for the OPG to determine their real width, since the difference in the shape of the arch and the semicircle described by the rotation of the apparatus was evident.

3. In half of the cases, the length of the premolar obtained by OPG measurement was greater than the same length measured on the CBCT.

4. Most often, the width of the premolars was greater on the OPG than the one on the CBCT.

5. The values of the molar length measured by the two techniques were, in most cases, quite similar, with the exception of 6 measurements, where greater differences were found. The cause of these great differences could be the lack of visibility of the palatal root on the OPG in the case of the upper molars, where the inter-radicular bone is denser and hides the root.

6. The variation of the parameter width of the molar (mesio-distal distance) is very small on the OPG compared to the one on the CBCT.

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