

LOWER INCISORS' PROCLINATION ASSESSMENT ON PANORAMIC RADIOGRAPHY

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ABSTRACT

Aim of the study: The evaluation of the lower incisors proclination before orthodontic treatments is classically done on profile telerradiography, usually used in orthodontics, but it is also important in the diagnosis and treatment of complex cases by prosthodontists and periodontists. The present study analysed a method to evaluate the incisor proclination based exclusively on panoramic radiography, commonly present at the beginning of any treatment.

Materials and methods: We deduced a mathematical formula for determining the proclination of the lower incisors based on the ratio of the incisor to premolar's image. The theoretically proposed calculation formula was then verified on a sample of n=104 cases. **Results:** The statistical results showed that the formula offered consistent results to the condition that the positioning error by tilting the head is limited (to the range of 0-10 degrees = 86.475% and for a tilt of 0-5 degrees = 95.45%). The values obtained were not dependent on the type of OPG (occlusion or disocclusion) (Sig=0.705). **Conclusions:** Further research studies on larger groups with various positioning errors and diversified growth patterns would be necessary to validate and improve this method.

Key words: lower incisors proclination, incisor mandibular plane angle, panoramic radiography assessment

INTRODUCTION

Panoramic radiography is the radiologic examination of choice recommended for all patients, both for treatment planning and for monitoring the patient's evolution over time. This is why it is important to obtain as much information as possible from panoramic radiography. Usually, panoramic radiography is requested because it provides information about the patient's dentition, but it can be recommended as a screening method for many other pathologies such as periodontal disease, large bone lesions, tooth eruption disorders, TMJ disorders or sinus pathology. [1]

Despite the wide range of pathologies that

can be diagnosed on panoramic radiography, for craniofacial development analysis and diagnosis of potential associated anomalies, lateral telerradiography (teleRx) remains the radiologic examination of choice. [2]

Based on previous studies confirming the effectiveness of panoramic radiography in the assessment of facial divergence by measuring the FMA (Frankfurt Mandibular plane Angle) [3,4], the present study aims to evaluate the possibilities of determining the IMPA (Incisor Mandibular Plane Angle) on panoramic radiography.

Of course, a dentist, looking at the OPG, may immediately notice the appearance of the

lower incisors and suspect proclination. However, we would like to see objective criteria included in an AI software that utilizes all the data from the OPG and instantly calculates incisor proclination. This, in the context of rapid AI development can greatly facilitate diagnostic work.

Software such as Diagnocat (LLC Diagnocat, Moscow, Russia) that analyse panoramic radiographs for diagnostic purposes are already state-of-the-art and allow detection of: caries, dental calculus, missing teeth, periapical lesions, periodontal bone loss, dental fillings, prosthetic restorations or endodontically treated teeth. [5] Similarly, artificial intelligence is also used for cephalometric landmark detection, cephalometric tracing, measurements, and cephalometric analysis. [6]

Although the incisors' proclination is of utmost interest in orthodontics, it can also have implications in other dental specialties (prosthodontics and periodontology). There is a proven link between the patient's occlusion and the masticatory force generated by the patient. Patients with Angle Class I or II malocclusion develop higher masticatory forces than those with Angle Class III malocclusion. [7] Thus, those with normal or accentuated incisor proclination develop increased molar occlusal forces compared to patients with retroclined incisors. [8]

Malocclusions involving an increased proclination of the lower incisors associate changes in gingival thickness, dimensional changes of the alveolar bone processes as well as altered overjet and overbite. [9] An exaggerated lower incisor inclination is often correlated with crowding, representing an important risk factor in the development of periodontal disease. [10] Also, an increased proclination of the lower incisors poses problems in closing the lips and may predispose the patient to traumatic accidents. [9]

Dehiscence type alveolar defects occur more frequently to the mandibular incisors and predominantly affect the buccal cortical plate in all 3 classes of malocclusion. [11] Also, even in retroclinations associated with class III malocclusion, periodontal support may be deficient. These patients show a predisposition for bone resorption in the lower incisor region. [12].

There is a proven correlation between lower incisor position and alveolar process morphology. [13,14] This is of importance also if postextractional implants are to be applied. [15]

The methods to assess incisor proclination on panoramic radiographs could be additional diagnostic tools also suitable for AI software for analysing radiological images.

Moreover, antemortem panoramic X-rays can be compared with postmortem X-rays as a tool of great importance in the identification of remains from victims of crime or in the context of mass disasters. [16,17]

The aim of our study is to determine the proclination of the lower incisors relative to the base of the mandible using OPG exclusively. This has predictive diagnostic and even forensic identification importance.

MATERIALS AND METHODS

Patients who presented to a clinic for an orthodontic consultation were selected.

The inclusion criteria were: good quality radiographs and the existence for the same patient of a panoramic radiography and a profile telerradiography.

Exclusion criteria were: poor quality of radiographs (clarity, contrast, severe positioning errors) and patients in whom the apices of the lower incisors and premolars were not closed (immature teeth). Also, there were excluded radiographs with severe crowding and consequent overlapping of tooth images.

These radiographs were taken digitally. Consent for participation in the study and publication was obtained in the initial

agreement signed by the patient.

Two types of measurements were carried out on these radiographs. These were performed by two independent observers using ImageJ (National Institutes of Health, University of Wisconsin) and AutoCAD (Autodesk, California) software, respectively. After the first measurement,

The roles of the two observers were then reversed. Where the measurements differed or were unclear, the third author stepped in to clarify the situation and reduce the risk of error.

The following measurements were made for each patient (Figure 1a, 1b):

On the OPG: mean lower incisor length, mean premolar length, $\angle$ FMA (Frankfurt Mandibular Angle), $\angle$ β angle (angle between the patient's Frankfurt plane and the horizontal plane of the X-ray film, showing the angular deviation of the patient's positioning from the horizontal plane). When cephalic extremity was positioned in flexion relative to the ideal position, $\angle$ β was assigned positive values, whereas for incorrect positioning with the cephalic extremity in extension, $\angle$ β was assigned negative values. The $\angle$ FMA angle was measured on the panoramic radiograph by drawing two representative straight lines for the Frankfurt plane (by joining the Orbitale and Porion anthropometric points) and the mandibular basal plane (the line tangent to the mandibular base).

On the profile teleradiography: $\angle$ IMPA angle (Incisor Mandibular Plane Angle), the angle between the lower incisors' axis and the mandibular base.

All these values were entered into a Microsoft Excel 2019 table (Microsoft, Washington) and imported to SPSS 16.0 (IBM, New York) for statistical analysis.

The purpose of these measurements was to compare the calculated $\angle$ IMPA angle determined on OPG with the actual $\angle$ IMPA angle measured on teleradiography. This comparison was intended to validate the calculation formula.

IMPA angle is not directly measurable on the OPG, in contrast to profile teleradiography. By projecting the incisors onto the X-ray film, the shorter the image formed, the more

proclined the incisors are. This principle is the basis for the calculation formula to determine the $\angle$ IMPA angle on OPG.

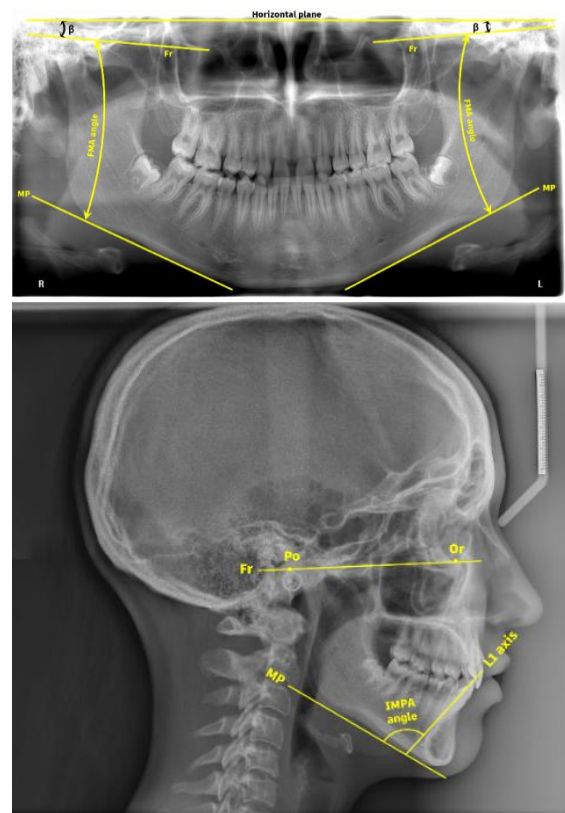


Figure 1 a, b - Example of the angular measurements on OPG and teleRx (Fr - Frankfurt plane, MP - mandibular plane)

In order to determine the calculation formula, we next present the geometric reasoning.

We imagine a lower central incisor in 3 hypothetical positions in the sagittal plane (Figure 2). The 3 positions are geometrically represented as segments as follows:

- **Position 1:** AD – incisor in vertical position (incisor axis parallel to the X-ray film and perpendicular to the Frankfurt plane);
- **Position 2:** BD – incisor axis perpendicular to the mandibular base ($\angle$ IMPA=90°);
- **Position 3:** CD – large random proclination (for which we aim to determine the $\angle$ IMPA value).

$$[AD]=[BD]=[CD]=\text{anatomical incisor length}$$

The diagram illustrates the Frankfort Plane, a horizontal reference plane in cephalometric radiography. It shows the relationship between the Frankfort Plane and the Mandibular Plane. Key points and lines include:

- Frankfort Plane:** A horizontal line passing through the external acoustic meatus (A) and the upper incisor (P).
- Mandibular Plane:** A line passing through the upper incisor (P) and the mandibular incisor (D).
- Angles:**
 - FMA (Frankfort-Mandibular Angle):** The angle between the Frankfort Plane and the Mandibular Plane, marked at point A.
 - IMPA (Incisor-Mandibular Plane Angle):** The angle between the upper incisor (P) and the Mandibular Plane, marked at point D.
- Points:** A (external acoustic meatus), B (orbit), C (upper incisor), D (mandibular incisor), E (upper incisor), F (upper incisor), G (upper incisor), H (upper incisor), I (upper incisor), J (upper incisor), K (upper incisor), L (upper incisor), M (upper incisor), N (upper incisor), O (upper incisor), P (upper incisor), Q (upper incisor), R (upper incisor), S (upper incisor), T (upper incisor), U (upper incisor), V (upper incisor), W (upper incisor), X (upper incisor), Y (upper incisor), Z (upper incisor).
- Lines:** 1 (vertical line), 2 (line from A to P), 3 (line from D to P).

To find the value of $\angle\text{IMPA}$, the first step is to find the value of the angle that the incisor axis makes with the vertical line. We denote this angle by $\angle\alpha$.

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were analysed.

RESULTS

For the n=104 patients analysed, we obtained various differences between measured and calculated values. The distribution of these values can be seen in

Table 1. Almost all patients had the $\angle \beta$ angle positive, meaning the possible positioning error was by slight head flexion. As can be seen, the differences are dependent on the patient's positioning at the time of radiography

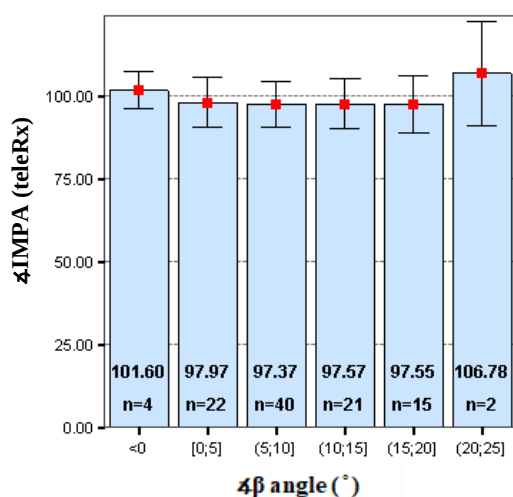
	$\angle \beta$ range	No. patients / group	No. patients - acceptable differences ($\leq 10^\circ$)	Percentage of acceptable differences ($\leq 10^\circ$)
Group 1	$<0^\circ$	4	2	50.00 %
Group 2	$[0^\circ ; 5^\circ)$	22	21	95.45 %
Group 3	$[5^\circ ; 10^\circ]$	40	31	77.50 %
Group 4	$(10^\circ ; 15^\circ)$	21	10	47.62 %
Group 5	$[15^\circ ; 20^\circ)$	15	4	26.67 %
Group 6	$\geq 20^\circ$	2	0	0.00 %
Total		104	68	

Table 1 - Differences between IMPA (teleRX) - IMPA (OPG) according to the values of the β angle (patient positioning at the time of radiography)

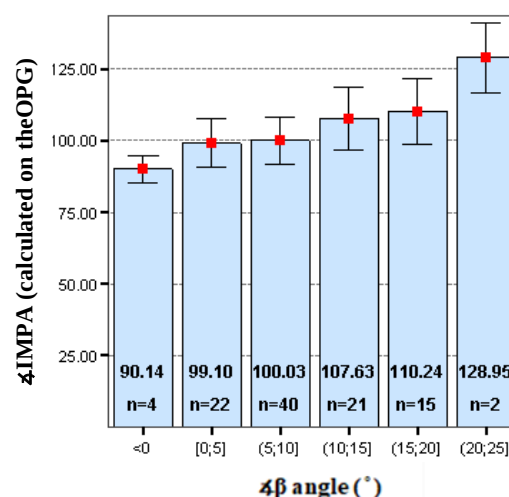
($\angle \beta$). Only for small deviations from the horizontal positioning ($\angle \beta \leq 10^\circ$) do we have mostly acceptable differences between the calculated $\angle$ IMPA and the measured $\angle$ IMPA ($\leq 10^\circ$).

Averaging groups 2 and 3 with $\angle \beta$ angle $[0^\circ ; 5^\circ)$ and $[5^\circ ; 10^\circ]$ we obtain the value of 86.475% for the $[0^\circ ; 10^\circ]$ interval.

Therefore, we selected from the initial table only the cases in which the patient was



correctly positioned on the radiograph (n= 62), with $\angle \beta \leq 10^\circ$. This choice is also confirmed by other statistical methods (Figure 3a,b). We note that negative $\angle \beta$ values were only n=4, insignificant to the overwhelming majority of cases (n=100) having positive values.



Box and Whiskas plot shows that the statistical scheme formed from the 62 patients is compact and valid. There are no outliers and no extremes. The values calculated on OPG span on a slightly wider range than those measured by teleRx, which is normal because

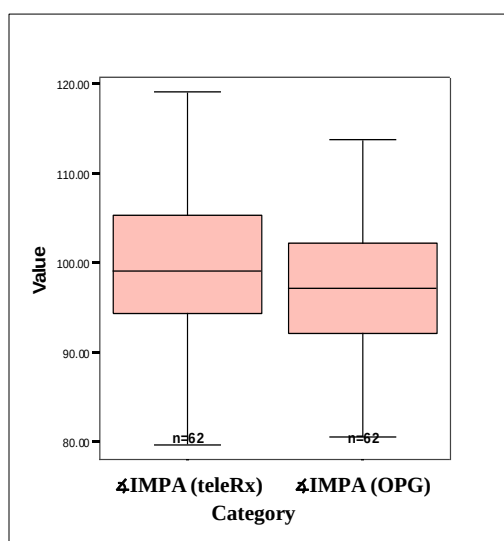


Figure 4 – Box plot of values in the selected range $\alpha \beta [0^\circ - 10^\circ]$ for α IMPA (OPG) and α IMPA (teleRx)

teleRx is more accurate. (Fig. 4)

For this group of patients, we also calculated the Pearson correlation index between the α IMPA values measured on the profile teleradiography and the α IMPA values determined by calculation on the OPG.

Between α IMPA (teleRx) and α IMPA (OPG) there is a good positive correlation $r=0.705$, statistically significant, Sig <0.001. (Fig. 5) Also, between α IMPA (OPG) and I/PM ratio there is a good negative correlation $r = -0.784$, statistically significant Sig <0.001, which justifies the use of this ratio in determining the proclination of lower incisors. (Fig. 6)

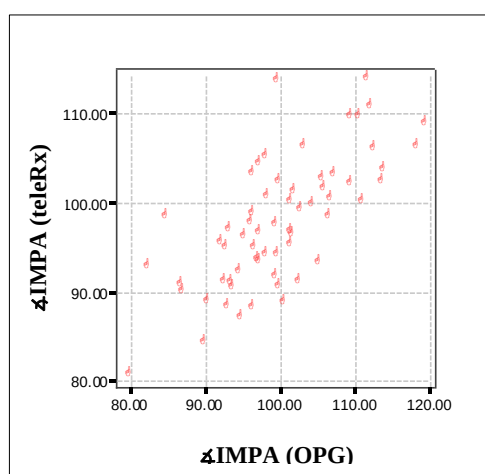


Figure 5 – Correlation between α IMPA (teleRX) and α IMPA (OPG) values

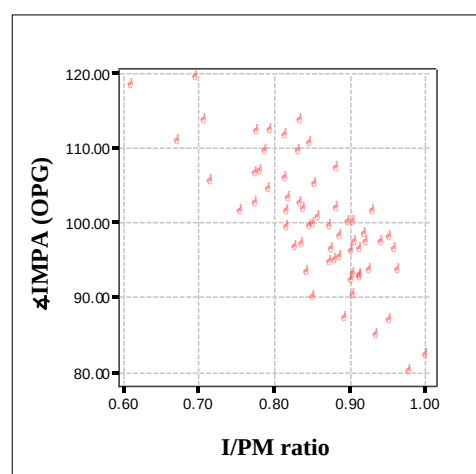


Figure 6 – Correlation between I/PM ratio and α IMPA values (OPG)

	OPG occlusion	Standard deviation	OPG disocclusion	Standard deviation
Mean value of α IMPA calculated on OPG	100.09 °	$\pm 7.06^\circ$	99.28 °	$\pm 9.62^\circ$
Mean value of α IMPA measured on teleRx	97.59 °	$\pm 6.43^\circ$	97.59 °	$\pm 7.96^\circ$

Table 2 - Mean α IMPA values according to the type of panoramic radiograph (in occlusion vs. in disocclusion)

ANOVA Table

		Sum of Squares	df	Mean Square	F	Sig.
IMPA (calculat pe OPG)	Between Groups (Combined)	10.184	1	10.184	.144	.705
* Ocluzie	Within Groups	4229.880	60	70.498		
	Total	4240.064	61			

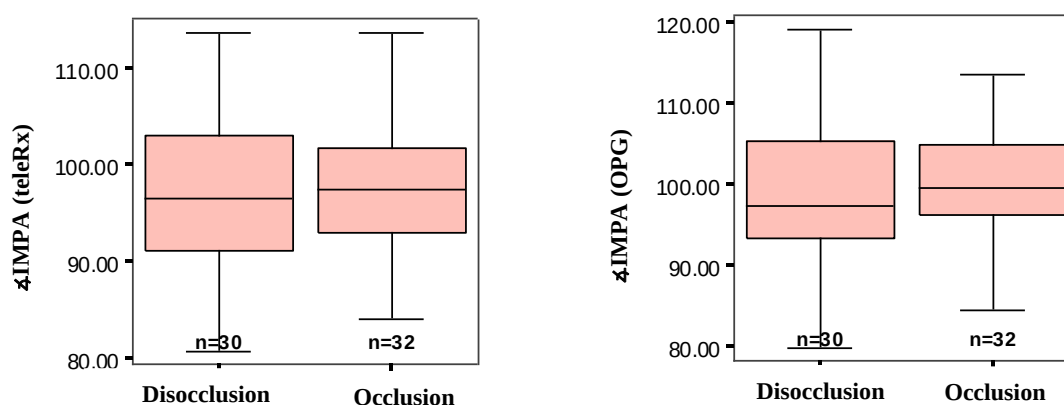
Table 3 - ANOVA analysis for Δ IMPA (OPG), occlusion vs disocclusion

We further evaluated the possibility that the type of panoramic radiograph (in occlusion or disocclusion) might influence the results obtained (Table 2).

ANOVA analysis confirms that there is no statistically significant difference between patients with panoramic radiographs in occlusion and those in disocclusion for

Δ IMPA (OPG) – Sig=0.705 (Table 3).

We then divided patients by growth pattern into 3 groups according to FMA angle values. For each group, we similarly evaluated the mean differences Δ IMPA teleRx – Δ IMPA OPG and found that regardless of the patient's growth pattern, the formula yields similar results (Table 4).

**Figure 7 – Box plots for Δ IMPA (teleRx) and Δ IMPA (OPG) occlusion vs. disocclusion**

Growth pattern	Δ FMA value	No. patients	IMPA teleRx – IMPA OPG difference (absolute value)	Sig
Hypodivergent	< 22 °	34	5.46	0.507
Normodivergent	22 ° - 28 °	22	5.20	
Hyperdivergent	> 28 °	6	3.51	

Table 4 - Mean differences IMPA teleRx - IMPA OPG according to patients' growth pattern

DISCUSSIONS

The study of the position of the lower incisors appears as a constant in the dental literature of all times and continues quite intensively nowadays. This underlines the importance that all clinicians and researchers attribute to this subject.

Qualitative assessment of incisor position is a matter of functionality and aesthetics. The subjectivity of both the patient and the observer's comes into play here. There is, however, a measurable assessment that has been made over the years on profile teleradiography, study models or computerized tomography.

There are many methods based on the use of profile teleradiography and they date back as far as the use of this type of incidence in practice. [21]

A relatively recent systematic review [20] that focused on the optimal incisor position (in relation to orthodontic treatments), studied the methods described in orthodontics starting with Tweed (1954), Steiner (1953), Downs (1956) and up to Web (2016) and Masoud (2017) using profile teleradiographs. These studies have in common the recognition of the correct position of the lower incisors as 87-94° to mandibular plane. But the optimal incisal position remains debatable because of the great heterogeneity that was found in terms of subject characteristics and measurement methods. It is still stated (2022) that "future research should address the need for standardization of lines and reference points".

In addition to the classic cephalometric analysis performed on profile teleradiography, there are also cephalometric measurements that can be performed on CBCT images. A systematic review from 2023 concludes that the diagnostic accuracy and reproducibility of cone-beam CT-synthesized lateral cephalograms are comparable with conventional lateral cephalograms in the context of cephalometric analysis. [22]

A study from 2024 (Majd Elias et al)

measures both lower and upper incisor proclination in order to analyse their influence on lip position and thickness. The advantages that CBCT images present in this case being the high accuracy of the measurements and the elimination of overlaps. [23]

By searching the electronic archives (PubMed, Google Academic) for terms such as "CBCT cephalometry" or "CBCT lower incisor position assessment" we found that in CBCT imaging, the particular matter of lower incisor position assessment is poorly addressed. The studies obtained from the search mostly focus on different methods of integrating CBCT into orthodontic treatment planning [24], on changes in incisor position before and after orthodontic treatment [25] or on the influence that orthodontic treatment may have on soft tissue morphology [26, 23].

Even if the analysis on CBCT is accurate, a CBCT is not routinely performed in every patient, instead a panoramic radiograph is required. [1]

Regarding evaluation on study designs, this has been used in the past. For example, in 1998 Stephen Richmond et al proposed the use of a "Tooth Inclination Protractor" device to determine the inclination of incisor crowns relative to the occlusal plane on study casts. [27] However, such methods cannot relate incisor position to stable skeletal landmarks (such as the mandibular basal plane) and cannot integrate incisor position into the patient's cranial morphology.

Nowadays study casts are being replaced by 3D images obtained by intraoral scanning, on which measurements can also be made. These measurements can be performed with similar accuracy on both plaster study casts and digital or 3D-printed casts. [28, 29] These images can also be coupled with computed tomography through dedicated software, integrating also facial scans for a complete reconstruction of the "virtual patient" [30, 31]

Intraoral scanning is however performed more for the aesthetic and functional appreciation of the position of the lower incisors than for measuring tooth proclination. [32, 33]

We explored the literature in order to identify similar studies that geometrically described the position of the lower incisors based on panoramic radiographs. We accessed the PubMed database and searched for a number of MeSH terms such as:

- Geometry of orthopantomography / OPG / panoramic x-ray / panoramic radiography (31 results)
- Mandibular incisor proclination OPG / orthopantomography / panoramic x-ray / panoramic radiography (7 results)
- IMPA angle orthopantomography / OPG / panoramic x-ray / panoramic radiography (4 results)
- Incisor mandibular plane angle OPG / orthopantomography / panoramic x-ray / panoramic radiography (18 results)
- Tweed triangle orthopantomography / OPG / panoramic x-ray / panoramic radiography (0 results)
- OPG cephalometry (17 results)
- Orthopantomography cephalometry (915 results).

For none of the options we have identified any article proposing a similar method to assess the position of the lower incisors.

Our proposed method for calculating the IMPA angle using only OPG has an accuracy dependent on patient positioning during radiography. It is known that manufacturers of such devices recommend positioning the patient with the Frankfurt plane parallel to the ground, with the orthopantomograph presenting bright guide lines to standardize this position. [34]. It is expected that failure to follow this recommendation may lead to some errors.

The strength of this study is due to the actual verification on tele-radiography of the incisor proclination angle, which can be deduced by a mathematical calculation using only the panoramic radiograph.

The main limitation relates to the fact that

the study was performed on a limited number of cases (pilot study). Further research with studies on larger groups with various positioning errors and diversified growth patterns would be necessary.

CONCLUSIONS

1. The calculation method proposed for the mandibular incisor axis inclination, proved to be a valid method, but it is dependent on the patient's positioning at the time of the radiograph ($\angle\beta$ angle), requiring correct positioning.
2. Almost all patients studied, if they had any errors in head positioning at the time of the radiograph, these were due to slight head flexion.
3. The ratio of average I/PM lengths has proven statistically useful for the determinations made.
4. Performing OPG in occlusion or disocclusion does not produce statistically significant differences.
5. This method could be useful in many situations: for the initial radiological evaluation, for the comparison of successive orthopantomographies and at the end of a prosthetic or periodontal treatment. Also the need for rapid forensic identification of subjects or mandibular fragments using OPG from the dentist's database could be considered.

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