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RESEARCH

Influence of the intergonial distance on image distortion in panoramic radiographs

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Objectives: The aim of this study was to evaluate the influence of the intergonial distance during the formation of panoramic radiographic images by means of horizontal and vertical measurements.
Methods: 30 macerated mandibles were categorized into 3 different groups ($n=10$) according to their intergonial distances as follows: G1, mean distance 8.2 cm, G2, mean distance 9.0 cm and G3, mean distance 9.6 cm. Three metal spheres 0.198 cm in diameter and placed at an incline using an isosceles triangle were separately placed over the internal and external surfaces of the mandibles before radiographic exposure for the purpose of taking the horizontal and vertical measurements. The occlusal planes of the mandibles were horizontally placed on the chin rest of the panoramic machine Orthopantomograph® OP 100 (Instrumentarium Imaging, Tuusula, Finland) and were then radiographed. In the panoramic radiographs, an expert radiologist measured the distances between the metal spheres in the horizontal and vertical directions using a digital caliper. The data were tabled and statistically analysed by Student's *t*-test and analysis of variance with Tukey post-test ($\alpha=0.05$).
Results: In all three groups magnification of the distances between spheres was observed when compared with the real distance in both horizontal and vertical measurements ($p < 0.05$). Differences in both horizontal and vertical measurements were observed between the different regions ($p < 0.05$), however there were no differences between groups in the same region ($p > 0.05$). Differences between horizontal and vertical measurements were observed in different regions in all evaluated groups ($p < 0.05$).
Conclusion: The intergonial distance is a factor that had no influence on image formation in the panoramic radiograph.
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Keywords: radiography; panoramic; radiographic magnification; diagnostic imaging

Introduction

Despite the new imaging diagnostic methods that have recently been introduced in dentistry, conventional panoramic radiography is still widely used[1] because of the ability to record the entire maxillomandibular region on a single film.

Several specialties in dentistry,[2–4] such as orthodontology, implant dentistry and buccomaxillofacial surgery, which need precise images to make reliable measurements for treatment planning, have used this technique indiscriminately,[5] making linear and angular measurements.[6,7] Thus, panoramic radiography has been used for evaluating mandibular asymmetry,[8,9] bone width for implant placement[10–12] and cephalometric analysis,[9] among others.[13,14]

In a panoramic image there is an inherent magnification derived from the distance between the patient and the film;[13] however, the anatomical variations of each patient, according to their facial patterns, may establish a larger or smaller degree of distortion in images caused by the position of the jaws in the image layer of the

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machine. Consequently, to obtain an image without distortion, all anatomical structures must be positioned in the centre of the image layer of the X-ray machine,[12,15,16] which can be difficult because the image layer is virtual.

Image distortion is a recognized phenomenon in panoramic radiography[11,13] and can induce diagnostic inaccuracy when disregarded clinically. The main limitation of this technique is its ability to determine the current dimensions in the panoramic image.[11] Therefore, it is very important to know the outcome of the radiographic image and define the type of distortion that each unit provides, according to the position of the anatomical structures of each patient. Therefore, the aim of this study was to evaluate the influence of the intergonial distance during image formation in panoramic radiographs by means of horizontal and vertical measurements.

Materials and methods

After this project was approved by the Human Research Ethics Committee, register number 096/2007, 30 human adult macerated mandibles were randomly selected. The selected mandibles had similar mandibular arch shape but were different in size. The intergonial distances of the macerated mandibles were measured using a digital caliper (167 series; Mitutoyo Sul Americana Ltda, São Paulo, Brazil). They were then categorized into three different groups ($n=10$) according to the measured distances as follows: G1, mean distance 8.2 cm (range 7.4–8.7 cm), G2, mean distance 9.0 cm (range 8.8–9.2 cm) and G3, mean distance 9.6 cm (range 9.3–9.9 cm).

Three metal spheres, 0.198 cm in diameter, were placed at an incline using an isosceles triangle with a horizontal side 1 cm wide and a vertical side 1 cm high. Five sets of isosceles triangles were separately placed on the surfaces of the mandibles before radiographic exposure for the purpose of taking horizontal and vertical measurements. Images were separately obtained with the sets placed on the internal and external surfaces of the mandibles, as illustrated in Figure 1. Each isosceles triangle was placed at a distance of 0.5 cm from the mandibular base, with the horizontal side of the isosceles triangle parallel to the occlusal and horizontal planes, in one of the following anatomical regions: incisor, canine/premolar, molar, mandibular angle and ramus.

The occlusal planes of mandibles were horizontally placed on the chin rest of the panoramic machine Orthopantomograph® OP 100 (Instrumentarium Imaging, Tuusula, Finland) and were then radiographed. The Orthopantomograph OP 100 panoramic machine has a focal size of 0.5×0.5 mm, total filtration to 3.2 mm of aluminum and an exposure time ranging from 2.7 s to

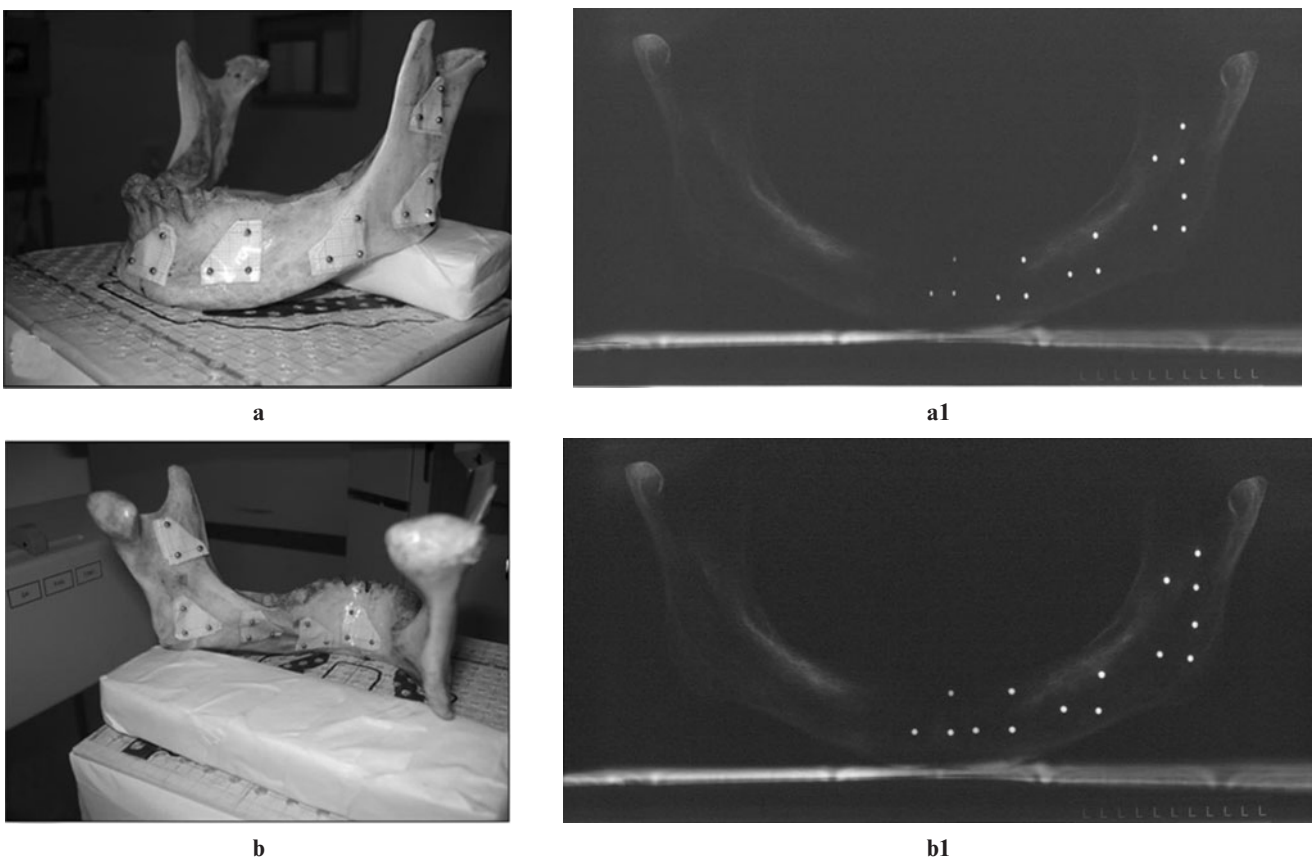

Figure 1 Mandibles placed on the chin rest of the panoramic machine. (a) Isosceles triangles placed on the external surface of mandible. (a1) Panoramic radiograph obtained. (b) Isosceles triangles placed on the internal surface of mandible. (b1) Panoramic radiograph obtained

17.6 s. For panoramic radiographic image formation, the magnification factor is constant at 1.3 as reported by the machine manufacturer. The X-ray tube was operated with settings of 57 kVp, 3.2 mA and an exposure time of 17.6 s. The metal cassette was used with Lanex® regular screen and T-Mat G X-ray film (Eastman Kodak Company, São Paulo, Brazil). After radiographic exposure all films were processed in an automatic processor Macrotec MX-2 (Macrotec, São Paulo, Brazil) with Picker RP type-S processing chemistry (Eastman Kodak Company, Rochester, NY).

In the panoramic radiographs, the distances between images of the metal spheres were measured in the horizontal and vertical directions using a digital caliper. A trained radiologist (DBSL) assessed all panoramic radiographs twice, with interval of 2 weeks between analyses, to verify the reliability of the measurements. The reliability was statistically controlled by the intraclass correlation coefficient with $r > 0.99$ as acceptable. Measurements were acquired using a viewing box with a constant light intensity of 1700 lux in a secluded room where light intensity was 20 lux. Light intensity from the viewing box and procedure room was measured by a Photometer 07–621 (Fluke Biomedical, Cleveland, OH).

The median between the internal and external measurements was calculated, with the value of the mandible as the central position, and was used for statistical analysis.

The data were tabled and statistically analysed using Student's *t*-test and analysis of variance with Tukey post-test ($\alpha = 0.05$).

Results

The results for the vertical measurements in the different groups and regions are shown in Table 1. In all groups, a magnification of the distances between spheres was observed when compared with the real distance ($p < 0.05$). Statistical differences ($p < 0.05$) were observed between the different regions, which showed a greater magnification in the anterior region and diminished towards the posterior region. There were no differences ($p > 0.05$) between the groups of mandibles in the same region.

Table 2 shows the results of the horizontal measurements in the different groups and regions. Similarly to the results mentioned for the vertical measurements, all groups showed a magnification of distances between spheres ($p < 0.05$). Differences in magnification were observed between different regions ($p < 0.05$), with decreasing magnification towards the posterior regions, but there were no differences between groups of mandibles in the same region ($p > 0.05$).

During comparison of the vertical and horizontal measurements, different magnifications were observed between these axes in same region ($p < 0.05$). Table 3 shows the measurements of the group G1 and differences were observed in the regions of the incisors and mandibular angle and ramus. For G2, differences were observed in the incisors, mandibular angle and ramus and molar region (Table 4) and in G3 differences were observed in the above-mentioned regions (Table 5).

Table 1 Mean (standard deviation) of vertical linear measurements of triangles for the different mandibular groups

	Groups		
Region	*G1*	*G2*	*G3*
Incisors	1.300 [a](0.049)Aa	1.263 [a](0.053)Aab	1.305 [a](0.037)Aa
Canines/premolars	1.305 [a](0.023)Aa	1.285 [a](0.038)Aa	1.283 [a](0.043)Aab
Molars	1.245 [a](0.059)Aab	1.258 [a](0.044)Ab	1.215 [a](0.032)Abc
Mandibular angle	1.210 [a](0.046)Abc	1.180 [a](0.042)Ac	1.218 [a](0.047)Abc
Mandibular ramus	1.155 [a](0.054)Ac	1.148 [a](0.073)Ac	1.188 [a](0.024)Ac

Letters represent horizontal/vertical comparison of regions within each position (uppercase letters=horizontal; lowercase=vertical) and differences were measured using Tukey's test ($p \leq 0.05$).
[a]Indicates a value that differs from 1.00 cm by *t*-test for a mean ($p \leq 0.05$).

Discussion

Irrespective of the regions and mandibular groups evaluated, considering only one side of the triangle, all individual measurements were magnified in comparison with the actual measurements. There is an inherent magnification factor in the panoramic radiography technique;[2,11,17] however, magnification is an equivalent increase in horizontal and vertical axes without change in image shape. When the increases of the horizontal and vertical axes are independent, there is image distortion with changes in image shape.[17–19] Only the regions of the canines/premolars and molars in groups G1 and G3 showed magnification while the regions of the incisors, mandibular angle and ramus showed distortion. In group G2, only the regions of the

Table 2 Mean (standard deviation) of horizontal linear measurements of triangles for the different mandibular groups

	Groups		
Region	*G1*	*G2*	*G3*
Incisors	1.838 [a](0.119)Aa	1.855 [a](0.141)Aa	1.875 [a](0.135)Aa
Canines/premolars	1.333 [a](0.047)Ab	1.328 [a](0.053)Ab	1.325 [a](0.060)Ab
Molars	1.235 [a](0.036)Ac	1.190 [a](0.054)Ac	1.178 [a](0.051)Ac
Mandibular angle	1.108 [a](0.055)Ad	1.058 [a](0.047)Ad	1.045 [a](0.059)Ad
Mandibular ramus	1.103 [a](0.055)Ad	1.033 [a](0.041)Ad	1.043 [a](0.073)Ad

Letters represent horizontal/vertical comparison of regions within each position (uppercase letters=horizontal; lowercase=vertical) and differences were measured using Tukey's test ($p \leq 0.05$).
[a]Indicates a value that differs from 1.00 cm by *t*-test for a mean ($p \leq 0.05$).

Table 3 Mean (standard deviation) of linear measurements of triangles for group G1

	Measurements	
Region	*Vertical*	*Horizontal*
Incisors	1.300 (0.049)B	1.838 (0.119)A
Canines/premolars	1.305 (0.023)A	1.333 (0.047)A
Molars	1.245 (0.059)A	1.235 (0.036)A
Mandibular angle	1.210 (0.046)A	1.108 (0.055)B
Mandibular ramus	1.155 (0.054)A	1.103 (0.055)B

Letters represent horizontal differences using Tukey's test ($p \leq 0.05$).

Table 5 Mean (standard deviation) of linear measurements of triangles for group G3

	Measurements	
Region	*Vertical*	*Horizontal*
Incisors	1.305 (0.037)B	1.875 (0.135)A
Canines/premolars	1.283 (0.043)A	1.325 (0.060)A
Molars	1.215 (0.032)A	1.178 (0.051)A
Mandibular angle	1.218 (0.047)A	1.045 (0.059)B
Mandibular ramus	1.188 (0.024)A	1.043 (0.073)B

Letters represent horizontal differences using Tukey's test ($p \leq 0.05$).

canines/premolars showed magnification. These results could be related to the sample used, which by the mandibular shape established a specific position within the image layer of the X-ray machine.[20]

Considering the independent analyses of vertical measurements, each region produced a different magnification, shown to be greater in the anterior and smaller in the posterior regions, similar to the results found in previous studies.[11,21] However, Sameshima and Asgarifar[16] observed the smallest magnification in the anterior and the greatest in the posterior region. The smaller magnification towards the posterior region found in the present study can be justified by the position of the mandible in relation to the image layer of the machine. Although the image layer has the same configuration as that of the mandible, with sufficient width to accommodate it,[22] the central portion of the image layer, where vertical and horizontal magnifications are equal, is narrow. Thus, the posterior region of the mandible in all evaluated groups remained positioned in the outer portion of the image layer, resulting in the smallest magnification.[2,23,24]

In the analyses of horizontal measurements, all mandibular groups showed magnification in different regions, greater in the anterior region and smaller in the posterior region, similar to results reported by Catic et al.[21] Schropp et al[11] observed results to the contrary with greater magnification in the posterior region. These different results can be explained by the panoramic radiographic technique, which has a high propensity for horizontal magnification because the geometry of exposure, caused by variation in the distance between X-ray source, anatomical structures and film, is changed in different regions during rotation of the machine, as mentioned by some authors.[11,25–27]

When the mandibular groups were compared, a greater variation in horizontal measurements was observed in comparison with vertical measurements. Puricelli[13] mentioned that horizontal measurements are less accurate. Schropp et al[11] and Catic et al[21] mentioned that vertical measurements are more reliable when the patient is properly positioned. However, in the present study both measurements showed variations. In all three groups a greater magnification in the incisor regions was shown in the horizontal than in vertical measurements, while in the molar and mandibular angle and ramus regions the vertical measurements showed greater magnification.

In the incisor regions, the greater magnification in horizontal measurements indicated that there was image distortion. This distortion was induced because the central portion of the image layer in the anterior region was very thin, with insufficient width to accommodate it,[20] thus the mandible was in a position closer to the film or to the X-ray source depending on its anatomical shape. In a previous study[21] it was observed that when the horizontal measurements were made on the midline to assess bilateral structures of the anterior region, a greater magnification of measurements occurred. Hayakawa et al[24] reported the greatest distortions in the midline region. In the present study, the results were similar to those mentioned above[20,24] because the horizontal measurements in the incisor regions were also taken on both sides of midline in the radiographs.

However, greater magnification occurred in the horizontal measurement of the posterior and mandibular angle and ramus regions in all groups, owing to the mandibular anatomy that caused the mandible to be positioned outside the central portion of the image layer, as was also reported by Sameshima and Asgarifar.[16] The mandibular shape of the group G2 caused the image distortion in the molar regions. These facts can be justified by the position of the rotation centre of the X-ray beam because the anatomical regions that showed greater magnification are situated closer to these centres.

Therefore, any measurement on panoramic radiographs should be avoided because the panoramic radiographic image shows magnification and distortion.[2,13,27] The measurements obtained in the present study showed variation between different regions within the same group, with different magnifications between horizontal and vertical measurements. However, in the comparison between the three different groups, the magnification was constant.

Furthermore, it must be emphasized that the results of study using macerated mandibles with very similar

Table 4 Mean (standard deviation) of linear measurements of triangles for group G2

	Measurements	
Region	*Vertical*	*Horizontal*
Incisors	1.263 (0.053)B	1.855 (0.141)A
Canines/premolars	1.285 (0.038)A	1.328 (0.053)A
Molars	1.258 (0.044)A	1.190 (0.054)B
Mandibular angle	1.180 (0.042)A	1.058 (0.047)B
Mandibular ramus	1.148 (0.073)A	1.033 (0.041)B

Letters represent horizontal differences using Tukey's test ($p \leq 0.05$).

shapes are not directly applicable to clinical practice owing to anatomical variability of the general population. The variation in mandibular shape, considering different dental arches, could change its position in the image layer and consequently the resulting image. Therefore, future studies should address the mandibles with different shapes but maintain the same intergonial distance.

In conclusion, intergonial distance had no influence on image formation in panoramic radiographs.

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