Comparison of morphometric indices obtained from dental panoramic radiography for identifying individuals with osteoporosis/osteopenia*

Comparação de índices morfométricos obtidos na radiografia odontológica panorâmica na identificação de indivíduos com osteoporose/osteopenia

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Abstract   **OBJECTIVE:** The present study was aimed at comparing indices obtained from dental panoramic radiographs with bone densitometry results in the identification of individuals affected by osteoporosis/osteopenia. **MATERIALS AND METHODS:** Panoramic mandibular, mental, antegonial, gonial and mandibular cortical indices calculated with basis on dental panoramic radiographs of postmenopausal women were compared with bone densitometry results, twice by one observer and once by a second observer. **RESULTS:** Significant differences were not found between the two measurements performed by the same observer, except for the antegonial index on the left side. Interobserver agreement for both sides was good. The variance analysis demonstrated statistically significant differences among groups (normal, osteopenia and osteoporosis) for all the indices evaluated. Differences were significant among all mean panoramic mandibular and mental indices. On the other hand, for the antegonial and gonial indices, only the normal group presented higher means as compared with the other groups (osteopenia and osteoporosis) which did not differ between themselves. **CONCLUSION:** The indices evaluated were reproducible; panoramic mandibular and mental indices presented the highest sensitivity in the detection of osteopenia/osteoporosis, however the panoramic mandibular index specificity was low. Although all the indices evaluated could identify low bone density, only the panoramic mandibular and mental indices could differentiate patients affected by osteopenia/osteoporosis.
Keywords: Osteoporosis; Panoramic radiography; Risk factors.

Resumo   **OBJETIVO:** Comparar índices obtidos de radiografias panorâmicas odontológicas com a densitometria óssea na identificação de indivíduos com osteopenia/osteoporose. **MATERIAIS E MÉTODOS:** Os índices panorâmico mandibular, mentoniano, antegoníaco, goníaco e cortical mandibular foram obtidos de radiografias panorâmicas de mulheres na pós-menopausa e comparados aos resultados da densitometria óssea, por um observador duas vezes, e por outro observador uma vez. **RESULTADOS:** Não foram observadas diferenças significativas entre as duas medições realizadas pelo mesmo observador, exceto para o índice antegoníaco no lado esquerdo. Houve boa concordância entre os diagnósticos utilizando o lado esquerdo e o lado direito e entre os diagnósticos dos dois observadores. A análise de variância demonstrou diferenças significativas entre os grupos (normal, osteopenia e osteoporose) para todos os índices. Para os índices panorâmico mandibular e mentoniano todas as médias diferiram entre si. Já para os índices antegoníaco e goníaco, somente o grupo normal apresentou média superior aos demais (osteopenia e osteoporose), as quais não diferiram entre si. **CONCLUSÃO:** Os índices avaliados foram reprodutíveis; os índices panorâmico mandibular e mentoniano foram os que apresentaram maiores valores de sensibilidade para detectar osteopenia/osteoporose, porém a especificidade do índice panorâmico mandibular foi baixa; todos os índices avaliados foram capazes de identificar baixa massa óssea, contudo, apenas os índices panorâmico mandibular e mentoniano permitiram diferenciar pacientes com osteopenia/osteoporose.
Unitermos: Osteoporose; Radiografia panorâmica; Fatores de risco.

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INTRODUCTION

Osteoporosis is a progressive, systemic disease characterized by decreased bone mass resulting in deterioration of the bone

microarchitecture, causing bones fragility and consequently increasing the risk for fractures[1]. According to the World Health Organization (WHO)[2], 33% of women above the age of 65 years are affected by osteoporosis. In Brazil[3], it is estimated that about one million women may become disabled and at least 200 thousand will die

from subsequent fracture-related complications in the next years, if this disease is not managed. So, osteoporosis starts being considered as a public health problem responsible for a considerable yearly expenditure[4,5].

Considering that biopsy would be the most accurate method for detecting osteoporosis, bone densitometry has been consensually accepted as the golden standard in the diagnosis of osteoporosis[2]; however, a systematic assessment of the population by this method has not been recommended. Patients are referred for examination on the basis of a clinical history positive for risk, postmenopausal fracture, familial history or use of pharmaceuticals[6]. Several questionnaires have been developed and tested as tools for identifying patients with low bone density, with approximately 80% sensitivity and 50% specificity[7].

Considering that odontological patients are frequently referred for being submitted to panoramic radiography — a widely available, low-cost method capable of demonstrating aging-related morphological alterations of the mandible —, several indices, techniques for analysis and images processing have been researched in order to evaluate the applicability of this type of radiography for detecting bone mass loss[8]. However, the results of these studies have been contradictory.

The present study was aimed at comparing mandibular cortical measurements based on panoramic radiographs with bone densitometry data of postmenopausal women to evaluate the effectiveness of these measurements in the identification of cases of osteopenia/osteoporosis.

MATERIALS AND METHODS

This observational and transversal study was approved by the Committee for Ethics in Research of the Institution (register No. 2005-236H). The sample included women > 40 years of age referred for evaluation by panoramic radiography for dental treatment purposes in 2006, who agreed in participating in the present study and met the following inclusion criteria: postmenopausal women with bone densitometry study performed for at last three months before, not undergoing hormone replacement or calcium therapy, who had not been submitted to hysterectomy or oophorectomy and free form osteoporosis-related metabolic diseases. Presence of bone lesion, fracture, deformity or previous mandibular surgery has also constituted exclusion criteria.

The radiographic images were acquired in an Orthophos equipment (Siemens; Frankfurt, Germany) with kilovolt in the range between 65 kV and 80 kV and 16 mA, utilizing Kodak T-Mat (Kodak; São Paulo, Brazil) films processed in a DENT X 9000 (Dent X Co.; Elmsford, USA). Films with poor image quality were excluded from the sample with basis on previously defined criteria as follows: patient positioning errors, faults in density, contrast and detail[9].

Each radiographic image was given an identification number in order to allow a blind review by two observers specialized in odontological radiology, with respectively 17- and two-year experience. The structures of interest were traced on transparencies placed on the radiographs and mounted in cardboard frames, over a negatoscope, with 0.25 mm Pigma Micron 1 (Sakura Corporation; Osaka, Japan). Measurements were bilaterally performed with an electronic, digital, 0.01 mm resolution pachimeter (Starrett; Jedburg, Scotland), on the transparency by the same observer (odontological radiologist). This procedure was repeated for all of the cases in the sample, with a two-week interval between readings. A second observer performed the same measurements in only one side of the images and in a single moment. Measurements (Figure 1) were aimed at obtaining the following radiomorphometric indices:

• Panoramic mandibular index (PMI)[10] – the ratio of the mandibular cortical thickness measured on the line perpendicular to the bottom of the mandible, at the middle of the mental foramen, by the distance between the inferior mandibular cortex and the bottom of the mandible (normal value: ≥ 0.3);

• mental index (MI)[11] – mandibular cortical thickness measured on the line perpendicular to the bottom of the mandible at the middle of the mental foramen (normal value: ≥ 3.1 mm);
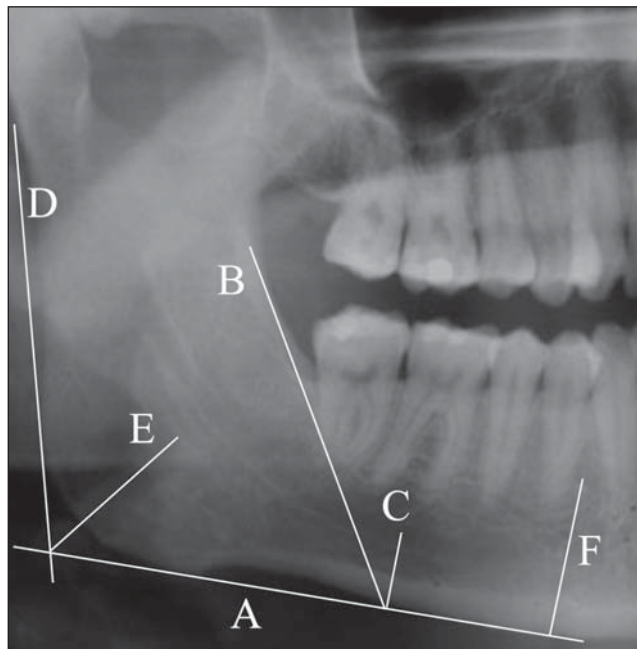
Figure 1. Morphometric mandibular indices based on related original articles[10–13]. A, tangent line to the bottom of the mandible; B, tangent line to the anterior border of the branch; C, perpendicular to A, at the intersection of B with the bottom of the mandible; D, tangent line to the posterior border of the branch; E, bisectrix of the angle between A and D; F, perpendicular to A, at the middle of the mental foramen. The indices, in mm, result from: AI – mandibular cortical thickness over the line C; GI – mandibular cortical thickness over the line E; MI – mandibular cortical thickness over the line F; IPM – ratio of the measurement of mandibular cortical thickness over the line C by the distance between the inferior border of the mandible and the inferior border of the mandibular canal over the same line.

• antegonial index (AI)[12] – mandibular cortical thickness measured on the line perpendicular to the mandibular cortical at the intersection with the tangent line to the anterior border of the branch (normal value: ≥ 3.2 mm);

• gonial index (GI)[13] – mandibular cortical thickness measured on the bisectrix of the angle between the tangent lines to the posterior border of the branch and the bottom of the mandible (normal value: ≥ 1.2 mm).

The radiographs were classified according to the mandibular cortical index (MCI)[14], qualitatively considering the endosteal margin of the mandibular cortex, as follows: C1 – normal (even and sharp endosteal margin); C2 – osteopenia (with semilunar defects); and C3 – osteoporosis (presence of porosity and reduced cortical thickness). The data were organized on a worksheet and the patients were classified according to the indices[10–13] for later comparison with the bone densitometry results, based on the WHO criteria[2], the t-score for osteopenia corresponding to a range between –1 and –2.5 standard deviation, and for osteoporosis, –2.5 standard deviation below the bone mass peak. In the cases where discrepancies were found in the bone densitometry study (spine and femur), the worst result was adopted.

The intra- and interobserver reproducibility were evaluated by the Wilcoxon and t-Student (α = 1%) tests, the first one for the scores resulting from the MCI, and the second for the other indices. The same tests were utilized for evaluating the agreement between results for the right and left sides.

Calculation of sensitivity, specificity, positive predictive and negative predictive values of the indices utilized for detection of bone mass loss, was based on the classification of the patients into normal or with bone mass loss, according to the bone densitometry results. Finally, the comparison among indices at the golden standard level, considering the three patients groups (normal, osteopenia and osteoporosis), the variance analysis (α = 1%) supplemented by the Tukey's test was utilized.

RESULTS

Based on the bone densitometry results, the 49 patients included in the sample of the present study were classified as follows: 19 normal and 30 with bone mass loss (24 with osteopenia and six with osteoporosis) in the age range between 41 and 59 years (mean, 49.9 years), weighting between 59 kg and 75 kg (mean, 65.7 kg), and height in the range between 1.57 m and 1.74 m (mean, 1.63 m).

The indices resulting from the two measurements by a same observer at different moments were compared by means of the t-Student test for paired samples, with no significant difference found between the two measurements, except for AI on the left side ($p = 0.01$). This difference may be considered as clinically irrelevant (0.09 mm). The non-parametric Wilcoxon test demonstrated no significant difference between the two classifications based on the MCI.

The same statistical tests did not evidence any significant difference between measurements and scores attributed by both observers.

The highest agreement between diagnoses utilizing the panoramic radiograph right and left sides was found for the GI, and the lowest for the MI (Table 1). The t-Student test for paired samples demonstrates that there is no significant difference

Table 1 Agreement between diagnoses utilizing right and left sides of panoramic radiographs for each index.

Index	Agreement		Disagreement	
	n	%	n	%
GI	48	98.0%	1	2.0%
PMI	46	93.9%	3	6.1%
MCI	45	91.8%	4	8.2%
AI	44	89.8%	5	10.2%
MI	43	87.8%	6	12.2%

GI, gonial index; PMI, panoramic mandibular index; MCI, mandibular cortical index; AI, antegonial index; MI, mental index.

(α = 1%) between measurements for both sides. The non-parametric Wilcoxon test did not demonstrate any significant difference between classifications based on the MCI for both sides.

Based on the mean between the two evaluations performed by the first observer adopting the worst diagnosis (left or right side) of each index, the patients were classified into normal or with bone mass loss (osteopenia and osteoporosis). Then, these diagnoses were compared with the bone densitometry results, and the sensitivity, specificity, positive predictive and negative predictive values of the indices utilized for detection of bone mass loss were calculated (Table 2).

Considering three groups (normal, osteopenia and osteoporosis) the variance analysis (Table 3) supplemented by the Tukey's test demonstrated that significant differences occurred among the three groups. For the PMI and MI, all the means were different among each other. On the other hand, for AI and GI, the normal group presented a higher mean than the other groups (osteopenia and osteoporosis) with no difference each other.

DISCUSSION

There are evidences that the shape and mandibular cortical index at panoramic radiographs can be utilized as tools in the detection of low mineral bone density not for diagnosis purposes, but to identify the risk for bone mass loss and appropriately refer the patient for assessment by bone densitometry[15], allowing to prevent the development of the disease[16]. Additionally, the role of clinical dentists in the identification of mandibular cortical erosion detected at panoramic radiographs of postmenopausal women results in 73% of cor-

Table 2 Sensitivity, specificity, positive predictive, and negative predictive values for the indices utilized.

Index	Sensitivity	Specificity	Positive predictive value	Negative predictive value
PMI	100%	47%	75%	100%
MI	87%	95%	96%	82%
AI	80%	89%	92%	74%
GI	80%	74%	83%	70%
CMI	77%	53%	72%	59%

PMI, panoramic mandibular index; MI, mental index; AI, antegonial index; GI, gonial index; MCI, mandibular cortical index.

Table 3 Comparison of mean indices among golden standard groups.

Index	n	Mean*	Standard deviation	CI 95%	p
PMI					
Normal	19	0.32[a]	0.03	[0.30 to 0.34]	≤ 0.01
Osteopenia	24	0.25[b]	0.03	[0.24 to 0.26]	
Osteoporosis	6	0.21[c]	0.03	[0.17 to 0.24]	
MI					
Normal	19	4.84[a]	0.46	[4.61 to 5.06]	≤ 0.01
Osteopenia	24	3.53[b]	0.47	[3.33 to 3.73]	
Osteoporosis	6	3.01[c]	0.39	[2.61 to 3.42]	
AI					
Normal	19	3.88[a]	0.51	[3.63 to 4.12]	≤ 0.01
Osteopenia	24	3.18[b]	0.37	[3.02 to 3.33]	
Osteoporosis	6	3.04[b]	0.15	[2.88 to 3.20]	
GI					
Normal	19	1.55[a]	0.41	[1.35 to 1.74]	≤ 0.01
Osteopenia	24	1.22[b]	0.25	[1.11 to 1.32]	
Osteoporosis	6	1.10[b]	0.03	[1.07 to 1.13]	

* Means marked with a same letter do not differ one from each other (variance analysis: α = 1%, supplemented by the Tukey's test). *n*, number of patients; CI 95%, confidence interval 95%; PMI, panoramic mandibular index; MI, mental index; AI, antegonial index; GI, gonial index.

rectness in the identification of low mineral bone density[17].

In this sense, the results of the present study are promising. The analysis of repeated measurements reproducibility resulted in statistical difference only for the left side AI, but this difference is lower than 0.1 mm and may be associated with the manual method of measurement. Also the scores applied to the MCI were reproducible, notwithstanding being based on visual inspection and therefore theoretically subject to error. Both measurements and scores were also reproducible in relation to the sides and the observer.

It is possible that also the surgeon dentist can identify patients at risk for bone mass loss when they seek odontological treatment[18]. Besides the reproducibility, the validity of these indices, however, depends on their sensitivity and specificity as compared with the bone densitometry results[19].

In the present study, the PMI presented the highest sensitivity, but its specificity was the lowest in the whole range of indices evaluated, almost 50% of the most specific index (MI). The MCI presented the worst results, in agreement with the findings of Knezović-Zlatarić et al.[20] and Devlin et al.[21]. Upon analysis of Table 3, it is recommended that these indices are utilized as a whole, considering their simple application.

As regards limitations of the present study, it is important to note that the bone densitometry studies were not performed in the same equipment, and that the dental condition of the patients was not taken into consideration as a variable. Also, it is important to note that even the patients under the age of 50 were classified by the *t-score*; the *z*-score was not utilized because the whole sample included postmenopausal women. The utilization of the new classification based on the *z*-score, according to Sampaio Netto et al.[22], leads to the lack of preoccupation with those patients considered as presenting with low mineral bone density according to the WHO criteria.

Studies comparing all these indices in a single sample have not been frequently found in the literature. Comparing PMI, MI, AI, GI and MCI, bilaterally measured on panoramic radiographs of 94 women divided into three groups (normal, osteopenia and osteoporosis), Kim et al.[23] have concluded that the thickness and shape of the cortical mandible reliably reflect the systemic condition associated with bone mass loss. These results are similar to the ones of the present study. All of these indices could be utilized for differentiating between patients with normal and low bone mass density. Only two of these indices (PMI and MI) could differentiate between osteopenia and osteoporosis, likewise the

conclusions reported by Devlin & Horner[24].

Recently, Devlin et al.[21] recommended the utilization of MI values < 3 mm as a criterion for referral of patients for a bone densitometry study. In the present study, however, patients with osteoporosis have met this criterion. However, patients with osteopenia presented with higher MI values (mean, 3.53 mm). The indication of a specialized study for patients in this category would allow an early approach of this systemic condition that can b precociously prevented and treated.

Therefore, it is important that the surgeon dentist is focused on the possibility of obtaining these indices and can evaluate their results to interact with other health professionals in the assessment of the risk for osteoporosis.

CONCLUSIONS

The following conclusions can be drawn from the findings of the present study:

– The indices evaluated were reproducible (< 0.1 mm variation) and did not varied as a function of the observer or the side where the measurement was performed;

– the PMI and MI presented the highest sensitivity for detecting bone mass loss, but the MPI specificity was low;

– all the indices evaluated in the present study could identify a low bone mass density, but only the PMI and MI could differentiate between patients with osteopenia and osteoporosis.

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