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ORIGINAL ARTICLE

Comparative study of axial and femoral bone mineral density and parameters of mandibular bone quality in patients receiving dental implants

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Abstract *Introduction:* In view of the increase in the life expectancy of humans and in edentulism of the population above 50 years of age, in which the prevalence of osteoporosis is also higher, it is fundamental to better understand the effects of systemic bone mass loss on the healing process of dental implants and to determine the quality of the bone that surrounds them. The objective of the present study was to compare systemic osteoporosis (axial and femoral) and parameters of mandibular bone quality, and to evaluate osseointegration in postmenopausal women receiving dental implants. *Methods:* The sample consisted of 39 women aged 48–70 years, 19 with a densitometric diagnosis of osteoporosis in the lumbar spine and femoral neck and 20 controls with a normal densitometric diagnosis. Bone mineral density was measured in the patients and controls by dual-energy X-ray absorptiometry. Eighty-two osseointegrated dental implants were placed in the mandible, 39 of them in the osteoporosis group and 43 in the control group. Mandibular bone quality was evaluated by classifying mandibular inferior cortical and trabecular bone on panoramic radiographs and by histomorphometric analysis of a mandibular bone biopsy. Osseointegration was analyzed after 9 months. *Results:* No significant difference was observed between patients with osteoporosis and controls when comparing individuals with a normal cortex and those with a severely or moderately eroded cortex determined on panoramic radiographs. Histomorphometric analysis also revealed no difference in the parameters of bone formation or resorption between the two groups. Implant failure was observed in only one case. *Conclusion:* We conclude that there is no association between systemic osteoporosis (axial and femur) and parameters of poor mandibular bone quality. The loss of one implant (1.2%) is compatible with the literature and cannot be attributed to systemic osteoporosis.

Keywords Bone histomorphometry · Bone mineral density · Dental implant · Osseointegration · Osteoporosis

Introduction

In view of the increase in the life expectancy of humans and because edentulism mainly affects the population above 50 years of age, there is a growing need for the treatment of elderly patients with dental implants. Since the prevalence of osteoporosis is also higher in this population, it is fundamental to better understand the effects of systemic osteoporosis on the healing process around dental implants and to determine the quantity and quality of the bone that surrounds them.

The changes in bone metabolism that occur in the jaw region seem to be the same as those observed in long bones [1]. The effect of a decrease in bone density on dental-implant healing has been little investigated [2], and so far it is not known whether bone density and quality influence the favorable prognosis of dental implants. Jaffin and Berman [3] reported a higher failure rate for implants placed in bone with low bone mineral density (BMD) and an increase in the time of osseointegration, whereas Mori et al. [4] observed inadequate bone formation adjacent to the implant. Von Wower et al. [5] demonstrated that BMD is significantly lower in the oral cavity of patients with systemic osteoporosis than in normal subjects. In contrast, Wakley et al. [6] believe that the existence of osteoporosis in the axial or appendicular skeleton does not indicate the

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presence of the disease in the region of the maxilla or mandible, and if the disease is present, it does not predict an unfavorable outcome of dental implants [7, 8].

In view of the scarcity of studies and the controversial findings in the literature in which some authors report a relationship between osteoporosis and dental implant failure and others do not, the objective of the present study was to determine the correlation between axial and femoral osteoporosis and parameters of mandibular bone quality and to evaluate osseointegration.

Subjects and methods

Thirty-nine female patients, 19 with a densitometric diagnosis of osteoporosis in the lumbar spine and femoral neck and 20 normal controls (no densitometric diagnosis of osteoporosis and/or osteopenia) matched for age and race, were studied. The subjects were classified as osteoporotic or normal according to criteria established by the World Health Organization based on T-scores: osteoporosis, T-score ≤−2.5 standard deviations; normal, T-score ≥−1 standard deviation [9].

BMD was measured in patients and controls by dual-energy X-ray absorptiometry (DXA) using a Hologic QDR 2000 densitometer, and is reported as g/cm^2. The regions analyzed were the lumbar spine (L1–L4) and femoral neck.

The patients and controls were selected from the Metabolic Bone Diseases outpatient clinic of the Rheumatology Service, University Hospital, School of Medicine, University of São Paulo. The study was approved by the Ethics Committee of the institution, and all subjects signed a free informed consent form to participate.

The general exclusion criteria were chronic diseases, current smoker, chronic alcoholism, use of glucocorticosteroids or other immunosuppressive drugs at the time of the study, and use of bisphosphonates at the time of the study or within 6 months prior to the study. Dental exclusion criteria included inability of the patients to follow instructions and perform proper oral hygiene, presence of residual roots, presence of local inflammation, diseases of the oral mucosa, a history of radiotherapy in the head and neck region, insufficient bone quantity in the region of the mandible (height <13 mm and thickness <4 mm), and tooth extraction within the 4 months prior to the study [10].

Dental implant

All subjects had an indication for a dental implant and prosthetic rehabilitation in the region of the mandible. Eighty-two osseointegrated dental implants (model Conus, INP), 4 mm thick and 13 mm long, were placed as follows: 39 implants in the osteoporosis groups and 43 in the control group.

Evaluation of bone quality

Radiologic assessment of mandibular inferior cortical and trabecular bone

The extraoral panoramic radiographs used for surgical-prosthetic planning were analyzed to evaluate the level of mandibular inferior cortical bone resorption. Radiographic reports were elaborated by three dental surgeons with experience in radiography, who were unaware to which group (osteoporosis or control) the patient belonged. The final report was made based on agreement between at least two observers.

Mandibular cortical shape on dental panoramic radiographs was determined by bilateral observation of the mandible distally from the mental foramen and was classified into three groups according the criteria of Klemetti et al. [11] and Klemetti and Kolmakow [12] as follows: (1) normal cortex: the endosteal margin of the cortex is even and sharp on both sides, (2) mildly to moderately eroded cortex: the endosteal margin shows semilunar defects (lacunar resorption) or appears to form endosteal cortical residues, (3) severely eroded cortex: the cortical layer forms heavy endosteal cortical residues and is clearly porous.

The same panoramic radiographs were also analyzed to evaluate the level of mandibular trabecular bone resorption, which was classified into two groups: dense and rarefied trabecular bone.

Bone histomorphometry

During the surgical procedure, a bone fragment was obtained from 18 subjects (9 with osteoporosis and 10 controls) and analyzed histomorphometrically to determine bone characteristics.

All histomorphometric indices are reported according to the nomenclature recommended by the American Society for Bone and Mineral Research [13]. The following histomorphometric parameters were obtained: (1) tissue area (mm): total area occupied by bone and medullary tissue, (2) bone area (mm): area occupied by cortical and trabecular bone, (3) cortical thickness (μm): thickness of cortical bone, (4) fibrosis volume: percentage of bone marrow occupied by fibrosis, (5) osteoid surface: percentage of trabecular bone surface covered with osteoblasts, (6) eroded surface: percentage of total cancellous bone surface showing resorption cavities with or without osteoclasts, (7) trabecular number: density of the trabeculae.

Evaluation of osseointegration

Osseointegration of the dental implants was evaluated after 9 months by clinical examination based on the criterion recommended by Smith and Zarb [14]. Periapical radiographs were analyzed according to the criteria of

Spiekermann et al. [15], and the stage of peri-implantitis was evaluated as proposed by Jovanovic [16].

Statistical analysis

The distribution of each continuous variable was examined graphically and statistically for normality. Numerical data are summarized as the mean and standard deviation (SD) and percentage. Data not normally distributed were compared using the Wilcoxon nonparametric test for differences. Data normally distributed were compared using Student's *t*-test. Categorical data among groups were compared by the Fisher's exact test. Statistical significance was accepted at the $P<0.05$ level.

Results

Characteristics of the sample

The anthropometric and dental characteristics of the 39 subjects studied, including 19 with osteoporosis and 20 normals subjects, are shown in Table 1. A significantly lower weight and body mass index were observed in patients with osteoporosis compared to control. Among the 39 patients examined who received a total of 82 dental implants, 13 were totally edentulous and 26 were partially edentulous. The time between tooth loss and implant placement ranged from 2–30 years, with this period being longer in patients with osteoporosis than in controls ($P=0.05$). The mean number of mandibular teeth lost was 11.47 in patients with osteoporosis and 8.45 in control subjects.

Panoramic radiography

Analysis of the morphology of the mandibular cortex on panoramic radiographs according to the classification of Klemetti and Kolmakow [12] showed a normal cortex in 5 patients with osteoporosis and in 11 control subjects, and a moderately or severely eroded cortex in 14 patients with osteoporosis and in 9 controls. There was no significant difference between the osteoporosis and control groups when comparing subjects with a normal cortex to those with severe or moderate erosion of the cortex (χ^2; $P=0.1053$) (Table 2).

Analysis of mandibular trabecular bone on panoramic radiographs also showed no significant difference between the two groups when comparing subjects with dense and rarefied trabecular bone (χ^2; $P=0.3406$) (Table 2).

Bone histomorphometry

Regarding bone histomorphometry, a smaller osteoid surface and greater resorption surface were observed in patients with osteoporosis, but this difference was not significant (Table 3).

Comparison of panoramic radiographs showing a moderately and/or severely eroded mandibular cortex and normal cortex with histomorphometric parameters (osteoid and resorption surface) revealed no significant difference (Table 4). Similarly, no significant difference was observed between panoramic mandibular cortical indices (severely eroded cortex vs. normal cortex) and spinal and femoral neck BMD (Table 5).

Evaluation of osseointegration

With respect to osseointegration, only one patient lost the implant 5 months after placement. The characteristics of this patient were as follows: age=67 years, body mass index=18.19 kg/m^2, L1–L4 T-score=−3.6, femoral neck T-score=−2.95, time since tooth loss=20 years, classification of mandibular cortical morphology on panoramic radiographs=moderately eroded cortex and rarefied trabecular bone.

Evaluation of osseointegration in the other subjects by clinical examination according to Smith and Zarb [14] showed no difference between patients with osteoporosis and controls, with all parameters being normal.

Assessment of osseointegration based on periapical radiographic findings 9 months after implant placement

Table 1 Anthropometric and dental characteristics of patients with osteoporosis (OP) and control subjects

	OP (*n*=19)	Control (*n*=20)	*P*
Age (years)	59.6±6.34	56.9±5.25	>0.05
Weight (kg)	55±8.66	68±8.74	0.0001*
Height (m)	1.54±0.07	1.55±0.05	>0.05
Body mass index (kg/m^2)	23.19±3.81	28.46±3.94	0.0001*
Race (white/nonwhite)	17/02	19/01	>0.05
Time since tooth loss (years)	13.6±8.02	9.16±3.72	0.05*
Mandibular teeth lost (*n*)	11.47±5.62	8.45±4.55	>0.05
Totally edentulous (*n*)	9	4	>0.05
Partially edentulous (*n*)	10	16	>0.05
Implants (*n*)	39	43	>0.05

*Statistically significant

Table 2 Evaluation of mandibular inferior cortical and trabecular bone on panoramic radiographs in patients with osteoporosis (OP) and controls

Region	OP (n=19)	Control (n=20)	P
Cortical			
NC	5	11	>0.05
MEC/SEC	14	9	>0.05
Trabecular			
Dense	9	13	>0.05
Rarefied	10	7	>0.05

NC Normal cortex, *MEC* mildly to moderately eroded cortex, *SEC* severely eroded cortex

(5 months after loading) only demonstrated images suggestive of a reduction in the bone crest for 14 implants in seven patients with osteoporosis (35.9%) and for 25 implants in nine control subjects (59.5%). No peri-implant radiolucent area was observed in the other regions analyzed.

Discussion

In the present study, no significant difference was observed in the panoramic radiographic findings of cortical and trabecular bone or bone histomorphometry between patients with densitometric osteoporosis and subjects with normal densitometry, demonstrating the lack of an association between axial and femoral osteoporosis and mandibular osteoporosis.

Bone assessment by panoramic radiography of the mandibular inferior cortex showed no significant differences between patients with osteoporosis and controls, but moderately or severely eroded cortex was observed in 73.7% of the former compared to only 45% of controls. These data suggest involvement of mandibular cortical bone in most patients with systemic osteoporosis.

Although panoramic radiography has been used as a reference method in different studies, various investigations agree with the present results showing the lack of an association between low axial and/or peripheral BMD and mandibular bone rarefaction [11, 12, 17–26].

Mohajery and Brooks [19] conducted a study to determine whether radiographic changes could be detected in the mandible of patients with and without osteoporosis and also observed no significant difference between these two groups, concluding that it is not possible to predict systemic osteoporosis based on panoramic radiographs. On the other hand, Klemetti and Kolmakow [12] evaluated bone quality by classifying the mandibular cortex, and observed a positive relationship between low BMD and radiographically demonstrated eroded mandibular cortical bone.

Taguchi et al. [26] found a significant association between mandibular cortical erosion on panoramic radiographs and an increase in biochemical markers of bone resorption (N-terminal telopeptide of collagen), and between cortical width and spine BMD, suggesting that mandibular inferior cortical morphology might be an indicator of bone turnover and spinal BMD in postmenopausal women.

Horner and Devlin [21], studying 40 edentulous women, observed that the mandibular cortical index and subjective bone quality index were significantly correlated with mandibular cortical bone density measured by DXA [21]. However, agreement between repeated measurements of these indices was moderate to poor, particularly for the mandibular cortical index, and the authors questioned the use of these indices in clinical practice.

Other studies have demonstrated that signs of alveolar bone resorption and mandibular inferior cortical width and morphology on panoramic radiographs are associated with systemic osteoporosis [5, 27].

Similar to the findings of cortical bone assessment, in the present series analysis of mandibular trabecular bone showed no significant correlation when comparing osteoporotic patients and controls.

The assessment of mandibular trabecular bone by panoramic radiography is controversial since bone quality might be underestimated when based on radiographic density. Overlapping soft tissue, exposure time and different image receptor types are some factors that might interfere with the radiographic result [28].

In view of the controversies regarding panoramic mandibular findings, in the present study we also used histomorphometric analysis of a bone biopsy to better assess the quality and quantity of bone tissue in the mandibular region. It should be emphasized that there is no report in the Brazilian or international literature that evaluates mandibular bone quality based on histological parameters.

The studies performed by Frost [29] formed the basis for bone histomorphometry and for the understanding of the mechanisms involved in normal bone remodeling and metabolic bone diseases.

Thomsen et al. [30] developed a new and rapid method for conducting static histomorphometry on large histologic sections, and applied this method to iliac crest and lumbar vertebral bone in order to compare age-related changes at these two skeletal sites and to investigate the correlation

Table 3 Characterization of bone histomorphometric findings in 8 patients with osteoporosis (OP) and 11 controls

	OP (n=8)	Control (n=10)	P
Total area/bone area (mm/mm)	1.46±0.40	1.74±0.59	0.2691
Cortical thickness (µm)	77.1 ±44.08	55.67±30.44	0.2401
Medullary fibrosis (%)	4.99±9.39	3.54±4.30	0.8968
Osteoid surface (%)	7.55±7.37	14.93±13.96	0.1967
Resorption surface (%)	8.12 ±10.05	3.23±4.89	0.3599
Number of trabeculae (n)	2.02±0.61	1.92±0.58	0.7270

Table 4 Comparison between cortical indices on panoramic mandibular radiographs (MEC/SEC vs. NC) and histomorphometric parameters

	MEC/SEC (*n*=13)	NC (*n*=5)	*P*
Osteoid surface (%)	13.80±11.83	6.05±10.95	>0.05
Resorption surface (%)	6.97±8.56	1.34±3.00	>0.05

MEC Mildly to moderately eroded cortex, *SEC* severely eroded cortex, *NC* normal cortex

between histomorphometric measures in these two regions. The authors concluded that static histomorphometry performed on one skeletal site does not automatically predict these measures at another site. Therefore, it is recommended that static histomorphometry be performed at the skeletal site of interest, if possible.

Based on the concepts outlined above, in the present study histomorphometric examination was performed at the site of interest. Statistical analysis of these measures also demonstrated no difference between patients with osteoporosis and controls. We also observed no association of eroded and normal cortical bone on panoramic radiographs with the histomorphometric findings despite a tendency toward a greater osteoid surface and resorption area in patients with moderate or severe cortical erosion. Thus, further studies possibly involving a larger sample size are necessary to confirm these findings.

Clinical anamnesis demonstrated a longer mean time since tooth loss in patients with osteoporosis compared to controls. These data agree with the literature showing a positive association between osteoporosis, tooth loss and edentulism [31]. In this respect, evidence indicates that treatments designed to increase BMD such as hormone replacement and bisphosphonate therapy may be associated with less tooth loss [32].

Taguchi et al. [33], evaluating the relationship among L1–L4 vertebral bone mass, tooth loss and mandibular bone mass in Japanese women, suggested that bone loss in the region of the posterior teeth is associated not only with a reduction in alveolar bone height but also in BMD. These authors concluded that alveolar bone height might be related to a decrease in lumbar spine BMD.

With respect to osseointegration, in the present study 81 of the 82 dental implants were clinically immobile after load placement. The patients did not complain of pain or neuropathy, and there were no signs of inflammation or infection in the peri-implant region.

Periapical radiographic assessment of osseointegration revealed no peri-implant radiolucent evidence suggestive of implant loss, although a reduction in the bone crest was observed that was more frequent in control subjects than in patients with osteoporosis (59.5 vs, 35.9%). These contradictory findings possibly have no meaning since isolated assessment of the bone crest does not seem to be important for the outcome of osseointegration [15]. In addition, a crestal bone loss of 1.5–2.0 mm is expected in the first year of an implant [34]. Adell et al. [35] reported that changes in marginal bone height predominantly occur during the healing and remodeling phases from the installation of the implant to the end of the first year after prosthesis placement, with a mean bone loss of approximately 1.2 mm during these phases and subsequent annual losses of 0.1 mm.

No radiolucent images were observed in the other implant areas analyzed radiographically in the present study, in agreement with Adell et al. [35], Branemark et al. [36], and Strid [37], who stated that a clinically stable implant is radiologically characterized by a normal bone image in intimate contact with the metal surface at the level of radiographic resolution, whereas the presence of a peri-implant radiolucent image is indicative of the presence of soft tissue and consequent implant mobility.

In the present series, one implant was lost 9 months after surgery, with an osseointegration success rate of 98.8%, a value compatible with studies conducted on the general population. For example, the survey by Jemt et al. [38] showed a success rate for dental implants of 99%. Adell et al. [39] reviewed the survival rates of prostheses and fixtures in 759 jaws among a total of 4,636 implants and observed rates of 91–99% 5 years after loading.

Although we were unable to demonstrate a significant association between systemic osteoporosis and poor bone quality evaluated by panoramic radiography and bone histomorphometry, it is interesting to note that with respect to osseointegration the only implant lost belonged to a patient with important systemic osteoporosis, and we therefore question the importance of bone health as an indicator of dental implant outcome.

Baxter and Fattore [40] reported that osteoporosis is a systemic condition with can potentially interfere with implant treatment and suggested that the maxilla and mandible are affected by this process. According to these authors, the prognosis of osseointegration in patients with osteoporosis might be improved if they receive medical treatment. However, there is no scientific evidence to contraindicate the use of dental implants in these patients since the bone healing process seems to be similar to that of healthy subjects.

The literature regarding this subject is highly controversial. Dao et al. [41] reported that the success of osseointegration mainly depends on the site where the implant will be installed and they do not consider systemic osteoporosis an important indicator of dental implant outcome. According to these authors, a decrease in bone mass and the presence of fracture at a site other than the mandible does not contraindicate implant placement, with the evaluation of bone quality at the surgical site being more important [41, 42].

Table 5 Comparison between spinal and femoral neck BMD and cortical indices on panoramic mandibular radiographs (SEC vs. NC)

	SEC (*n*=6)	NC (*n*=16)	*P*
Spinal BMD (g/cm^2)	0.848±0.237	0.969±0.182	>0.05
Femoral neck BMD (g/cm^2)	0.631±0.14	0.814±0.144	>0.05

BMD Bone mineral density, *SEC* severely eroded cortex, *NC* normal cortex

Similarly, Zarb and Schmitt [43], who determined whether a decrease in systemic bone mass might affect the maxilla and mandible impairing the process of oral rehabilitation, concluded that, although osteoporosis results in a decrease in bone mass, especially in long bones, adequate repair and healing seem to occur. The authors suggested that advanced age and osteoporosis are not contraindications for osseointegrated implant therapy.

In summary, the present findings and some reported in the literature show that systemic osteoporosis is not associated with mandibular osteoporosis and this disease is not a contraindication for dental implants. In this respect, further epidemiological studies including a larger sample and a longer follow-up period of patients receiving dental implants are necessary to reach more precise conclusions.

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