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RESEARCH

Does low bone mineral density have an association with head and neck soft tissue calcifications?

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Abstract

Objectives To evaluate whether low bone mineral density (BMD) has an association with the presence of head and neck soft tissue calcifications (STC), aging, and impaired mandibular canal cortices visibility.

Materials and methods Panoramic radiographs of 1000 women aged between 50 and 75 years old were evaluated by two examiners to classify BMD using mandibular cortical index (C1- normal, C2-moderately eroded and C3-severely eroded), the presence of STC, and also the mandibular canal cortices visibility at the ramus region. Chi-square test evaluated the association between the variables ($\alpha = 5\%$).

Results There was no association between bone loss and the presence of head and neck soft tissue calcifications, except for calcified thyroid cartilage, which was less visualized at C3 group than others ($p < 0.05$). Women aged 61 to 70 years old presented higher bone loss than those between 50 and 60 ($p < 0.05$). The mandibular canal was more poorly visualized at C3 group than C1 and C2 ($p < 0.05$).

Conclusions In general, no association between BMD and the presence of STC was found. However, greater bone loss had a positive correlation with aging and impaired mandibular canal cortices visibility.

Clinical relevance No relationship between bone mineral density and the existence of soft tissue calcifications was found. Nevertheless, increased bone loss was positively associated with aging and a reduced mandibular canal cortices visibility. This finding highlights the clinical importance of considering bone density factors when planning treatment strategies for patients with related disorders.

Keywords Bone density · Mandibular canal · Panoramic radiography · Physiologic calcification

Introduction

Osteoporosis is a disease characterized especially by low bone mineral density (BMD) and bone tissue microarchitecture deterioration, leading to bone fragility and susceptibility to fractures [1]. Usually, women in advanced age are more affected than men, due to the estrogen deficiency-related bone loss. The diagnosis of osteopenia and osteoporosis is through the Dual-energy X-ray absorptiometry (DXA) exam, which is a validate technique to measure bone mineral density (BMD) [2]. However, studies suggest that bone mineral density can be evaluated in panoramic radiography [3].

Klemetti and collaborators suggested in 1994 that osteoporosis may erode the mandibular cortex, and created an index that is known as mandibular cortical index (MCI) [4]. Since then, several researchers found a positive correlation between MCI and bone loss caused by osteoporosis, concluding that this index can be used for screening osteoporotic patients, using panoramic radiography and cone-beam computed tomography [5].

The fast bone loss caused by osteoporosis along with calcium and vitamin D intake, which is generally used as treatment, probably increases the calcium blood level. That can induce ectopic calcifications by the deposition of this ion throughout vascular walls, fatty plaques, and fibers. A correlation between the presence of sialolith and elongated styloid process and osteoporosis, and also an increase in vascular calcifications among osteoporotic patients was found [6–8].

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It is very common to find soft tissue calcifications as incidental finding in panoramic radiographs, as elongated styloid process, sialoliths, calcified triticeous cartilage, and atheroma [9]. When dentists visualize an image that suggest atheroma in panoramic radiographs, they must refer the patient to confirm with other exams and then to medical care for further evaluation due to the possibility of inducing cardiovascular events and stroke [10, 11]. In that matter, considering that osteoporosis can have a correlation with soft tissue calcification, the aim of this study was to evaluate if there was an association between the stage of bone loss with the presence of head and neck soft tissue calcification, aging and also with the mandibular canal cortices visibility. The null hypothesis was that no correlation would be found between them.

Materials and methods

This study was approved by the local institutional review board by the following protocol number 46110821.4.0000.5418. When it comes to the informed consent, all patients undergoing dental treatment in all departments of the university necessarily agreed with the use of their medical records to be used for scientific research.

Sample selection and preparation

In this observational retrospective study, the sample consisted in 1000 panoramic radiographs collected randomly from the image database of a university. All images were acquired with OP300 Maxio unit (Instrumentarium Dental, Tuusula, Finland) with exposure parameters according to each patient, and ranged from 66 to 70 kVp, from 8 to 12.5 mA. Those images were obtained between 2018 and 2020 for reasons unrelated to this study. We selected only images of women above 50 years old to restrict the sample between patients that probably were going through menopause, being the age average of 58.53, and standard deviation of 5.71 years. Radiographies of women who had undergone orthognathic surgeries, those with fractures or bone lesions and those acquired with an inappropriate technic, were excluded.

Image assessment

All images were exported in TIFF (Tag Image File Format) format and assessed in consensus by two evaluators with 3 years of experience in evaluation of panoramic radiographs using an LCD display of 15.6 inches and spatial resolution of 1920 × 1080 pixels (NP300E5K; Samsung). Before that, a calibration session was done based on the evaluation of 100 images with a clear explanation regarding all the evaluation process, and those images were not included in the study. The images were assessed in a quiet and dimmed light room, using the Image J software (NIH Image, Bethesda, MD). The evaluators were allowed to adjust brightness and contrast, and also could use the zoom tool. They were blinded regarding patient's age, and they had to search for soft tissue calcifications, analyze the integrity of the mandibular cortex using the mandibular cortical index and also to evaluate the mandibular canal cortices visibility as follows.

Presence of soft tissue calcification

The evaluators should state if soft tissue calcification was absent or present in each image, and also clarify which soft tissue was calcified. They were asked to look for the presence of: atheroma; calcified triticeous cartilage; calcified thyroid cartilage; tonsilolith; elongated styloid process (Fig. 1). If more than one type of calcification was present, all should be registered.

Mandibular cortical index

The mandibular cortical index was used to subjectively quantify the bone loss, according to that proposed by Klemetti and collaborators in 1994 [4]. In which C1 was characterized as a sharp and even cortex; C2 as a cortex with some endosteal cortical residues and some semilunar defects; C3 as a clearly porous cortex, with heavy endosteal cortical residues (Fig. 2). That evaluation happened in both sides, right and left, of the mandible, and the worst index between the sides was considered for each patient.

Mandibular canal cortices visibility

The evaluation of the mandibular canal cortices visibility was performed at the ramus in both sides (right and left); the mandibular body was not used to avoid the interference of a possible bone trabeculae alteration around the dentate area due to inflammatory processes. That assessment was performed in a 3-point scale: 1, when both superior and inferior mandibular canal cortices showed good visibility; 2, when only one mandibular canal cortex (superior or inferior) was visualized; and 3, when no mandibular canal cortices (superior and inferior) was visualized (Fig. 3). Again, the worst score between the sides was considered for each patient.

Thirty days after the evaluation, 20% of the sample was randomly selected and re-evaluated under the same conditions to verify intra-examiner agreement.

Statistical analysis

The statistical analyses were performed using the SPSS software 23.0 (IMG, Armonk, USA) with a significance

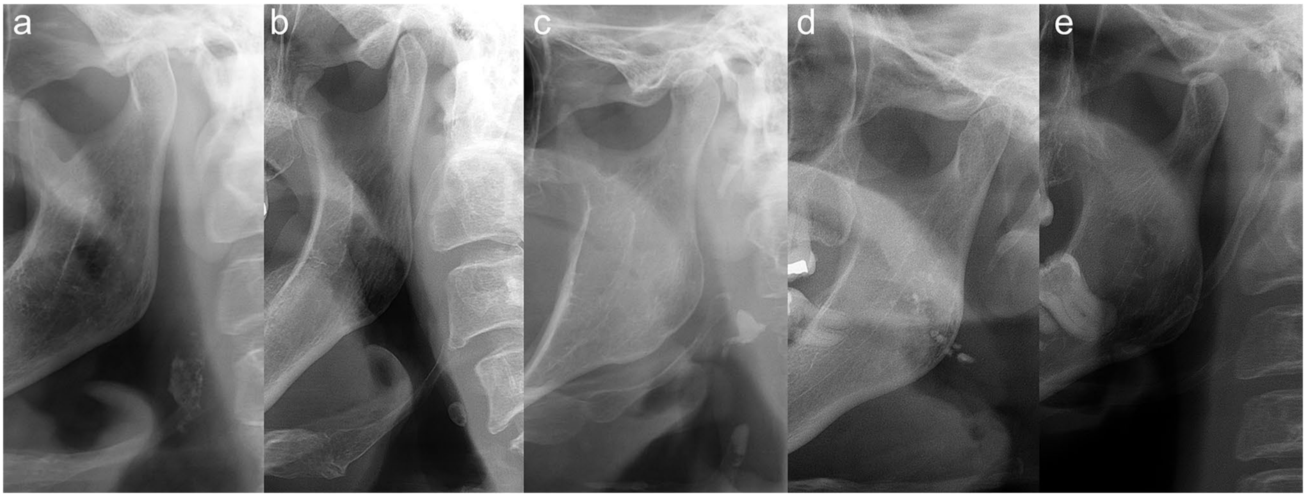


Fig. 1 Representation of the soft tissue calcifications evaluated in the study. **a** atheroma; **b** atheroma or calcified triticeous cartilage; **c** atheroma and calcified thyroid cartilage; **d** tonsilolith; and **e** elongated styloid process

Fig. 2 Figure representing the mandibular cortical index evaluation. **a** C1 — mandibular cortex even and sharp; **b** C2 — cortex with some semilunar defects and some endosteal cortical residues; **c** C3 — clearly porous cortex with heavy endosteal cortical residues

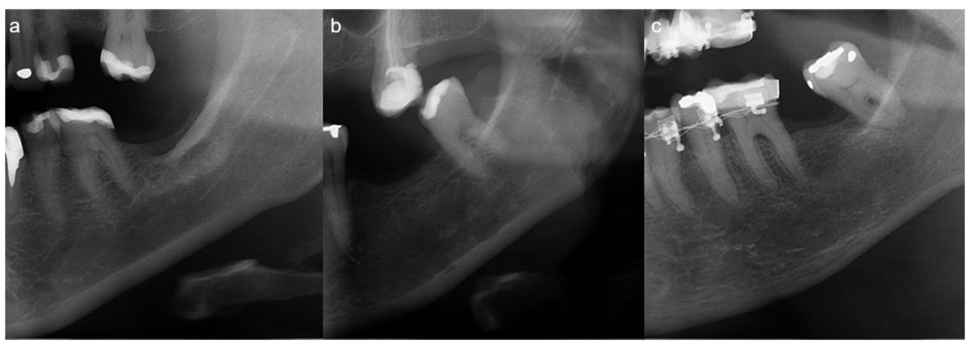
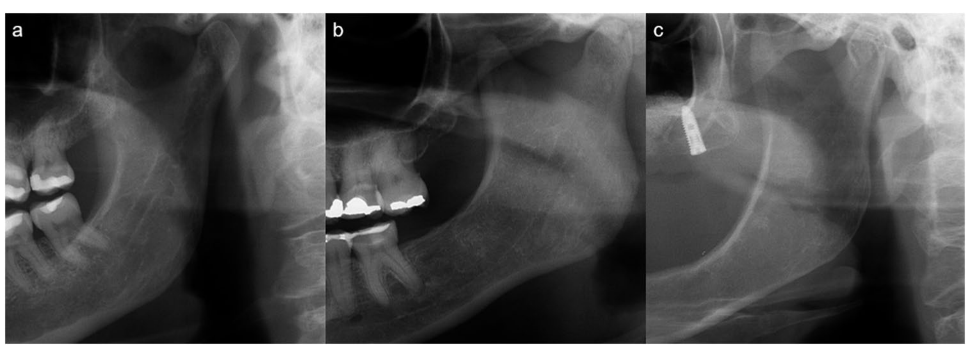


Fig. 3 Representation of the evaluation of the mandibular canal cortices visibility. **a** 1 — good visibility of both mandibular canal cortices; **b** 2 — only superior or inferior mandibular canal cortex was visualized; and **c** 3 — superior and inferior mandibular canal cortices were not visualized



level of 5%. The association between the presence of soft tissue calcification, age, and mandibular canal cortices visibility with MCI was analyzed using chi-square test. In the analysis, the atheroma and the calcified triticeous cartilage were grouped because of the difficulty in differentiating them on panoramic radiography. Considering chi-square value, freedom of liberty, and the number of radiographs evaluated, the power of analysis was 95%, except for elongated styloid process, which was 80%. The intra-examiner agreement was calculated using weighted Kappa analysis for MCI and mandibular canal cortices visibility and with Kappa analysis for soft tissue calcifications and interpreted as previews Landis and Koch [12], classification: < 0.20 poor; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 substantial; and 0.81–1.00 almost perfect.

Results

The Kappa values for intra-examiner agreement ranged from substantial to almost perfect (0.73 for mandibular canal cortices visibility; 0.75 for MCI, atheroma and tonsilolith; 0.79 for calcified triticeous cartilage, 0.85 for calcified thyroid cartilage, and 1 for elongated styloid ligament) [12].

Table 1 shows the distribution of soft tissue calcifications according to MCI. In general, no association was found between stage of bone loss and presence of soft tissue calcification ($p > 0.05$), except for the calcified thyroid cartilage ($p < 0.05$). In this case, only 40.78% of the patients classified as C3 for MCI had this calcification, which was unexpected according to the distribution of cases for MCI scores C1 and C2.

When it comes to the mandibular canal cortices visibility, there was a significant association between the more eroded cortex with an impaired mandibular canal cortices visibility. For patients classified as C3 for MCI, more patients were rated as 3 for mandibular canal cortices visibility (no visibility) (67.00%), and fewer patients were rated as 1 (good visibility) (20.70%) than expected ($p < 0.05$). In contrast, for patients classified as C1 for MCI, more were rated as 1 for mandibular canal cortices visibility (37.00%) and fewer as 3 (7.30%) than expected ($p < 0.05$) (Table 2).

Regarding age range, there was a significant association between the greatest stage of bone loss and advanced age ($p < 0.05$). Patients between 66 and 70 years old presented MCI classified as C3 more than expected and scores C1 and C2 less than expected (69.23%, 6.92%, and 23.85%, respectively). A similar condition was observed in patients between 61 and 65 years old, who presented more score C3 and less score C1 than expected (58.45% and 9.59%, respectively). In contrast, patients aged from 50 to 55 years old presented more score C1 and C2 and less score C3 than expected (34.99%, 44.90%, and 20.11%, respectively) (Table 3).

Table 2 Absolute number and relative frequency (%) of the mandibular canal cortices visibility according to mandibular cortical index

MCI	Mandibular canal cortices visibility		
	1	2	3
C1 ($n=204$)	**91 (37.00%)**	97 (18.10%)	**16 (7.30%)**
C2 ($n=384$)	104 (42.30%)	224 (41.80%)	**56 (25.70%)**
C3 ($n=412$)	**51 (20.70%)**	215 (40.10%)	**146 (67.00%)**
Total	246 (100.00%)	536 (100.00%)	218 (100.00%)

*Values in bold represent those that showed distribution different from that expected ($p < 0.0001$)

MCI: mandibular cortical index; 1, good mandibular canal cortices visibility (superior and inferior); 2, one mandibular canal cortex visualized (superior or inferior); 3, no mandibular canal cortices (superior and inferior) visualized

Percentage in the columns

Discussion

Osteoporosis treatment usually involves high calcium and vitamin D intake, and drugs that increases the calcium blood levels, which may lead to ectopic calcifications throughout the body [7, 13, 14]. Therefore, the authors questioned if there was a correlation between the stage of bone loss and the presence of head and neck soft tissue calcifications, considering that increased calcium blood level could favor its deposition in soft tissue. If a positive association had been found, the results could alert professionals to pay more attention in the search for soft tissue calcifications in head and neck region if bone loss was noticed in mandibular cortices, and vice versa. However, in general, no association between stage of bone loss and soft tissue calcifications was found.

The authors also hypothesized that the changes caused by bone loss in the mandibular cortices could also be seen in

Table 1 Absolute number and relative frequency (%) of the presence of soft tissue calcifications according to mandibular cortical index

MCI	Atheroma/calcified triticeous cartilage		Calcified thyroid cartilage		Elongated styloid ligament		Tonsillolith	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present
C1 ($n=204$)	131 (64.22%)	73 (35.78%)	100 (49.02%)	104 (50.98%)	160 (78.43%)	44 (21.57%)	194 (95.10%)	10 (4.90%)
C2 ($n=384$)	232 (60.42%)	152 (39.58%)	191 (49.74%)	193 (50.26%)	310 (80.73%)	74 (19.27%)	345 (89.84%)	39 (10.16%)
C3 ($n=412$)	248 (60.19%)	164 (39.81%)	**244 (59.22%)**	**168 (40.78%)**	327 (79.37%)	85 (20.63%)	368 (89.32%)	44 (10.68%)
Total	611 (61.10%)	389 (38.90%)	535 (53.50%)	465 (46.50%)	797 (79.70%)	203 (20.30%)	907 (90.70%)	93 (9.30%)
p value	0.591		0.010		0.786		0.051	

*Values in bold represent those that showed distribution different from that expected ($p < 0.05$)

Percentage in the rows within each soft tissue calcification

MCI: mandibular cortical index

Table 3 Absolute number and relative frequency of mandibular cortical index according to age range

MCI	Age range				
	50–55	56–60	61–65	66–70	71–75
C1 (n=204)	**127 (34.99%)**	46 (16.37%)	**21 (9.59%)**	**9 (6.92%)**	1 (14.29%)
C2 (n=384)	**163 (44.90%)**	119 (42.35%)	70 (31.96%)	**31 (23.85%)**	1 (14.29%)
C3 (n=412)	**73 (20.11%)**	116 (41.28%)	**128 (58.45%)**	**90 (69.23%)**	5 (71.42%)
Total	363 (100.00%)	281 (100.00%)	219 (100.00%)	130 (100.00%)	7 (100.00%)

*Values in bold represent those that showed distribution different from that expected ($p < 0.0001$)

Percentage in the columns

MCI Mandibular cortical index

the mandibular canal cortices, compromising their visibility. The significant association between the greater stage of bone loss and the impaired mandibular canal cortices visibility shows that probably the cortices can also be affected by osteoporosis, interfering in the bone microarchitecture and decreasing its density, and for that reason its visibility got prejudiced in the panoramic radiograph. Until the present moment, there is no study evaluating the correlation between the mandibular canal cortices visibility and osteoporosis. Further studies should be conducted in that regard.

To test the hypotheses, panoramic radiographs were used because studies suggest it may be able to determine the bone mineral density and also is an image modality that provides the visibility of head and neck soft tissue calcifications [3, 5, 9].

Regarding soft tissue calcifications, some studies found a positive correlation between the presence of elongated styloid process and sialoliths with osteoporosis, which is the opposite of the current results [6, 8]. This distinction with the previews studies is probably due to different methodology used, such as a reduced number of patients in the sample in the previous studies, and different calcifications evaluated, for example. It is relevant to highlight that elongated styloid process and sialoliths are not as harmful as vascular calcifications, since the last has a potential to cause a stroke.

A preview study used computed tomography angiographic (CTA) and panoramic radiographs to observe the association between calcified carotid artery and stroke. They found that 100% of patients at the stroke group presented calcified carotid artery at the CTA [11]. Depending on how much an atherosclerotic plaque is calcified, it is possible to observe it in a panoramic radiograph image close to the vertebrae C2 and C5, around the bifurcation region of the carotid artery [11]. However, occasionally a calcified triticeous cartilage can be misinterpreted as atheroma, due to the fact that they can be positioned around the same region and look very alike, therefore their differentiation can be complicated. For that reason, as we had no confirmation regarding the identification of atheroma (CT, computed tomography angiographic or Doppler ultrasonography), this calcification and calcified triticeous cartilage were grouped for statistical analysis. And as a result, no association was found between the presence of atheroma/calcified triticeous cartilage with any stage of bone loss. That result is in accordance with a preview study that assessed the relationship between the presence of atheroma with osteopenia/osteoporosis in 50 female patients using panoramic radiographs; although they did not evaluate triticeous cartilage, no significant association was found between this metabolic disease with this type of vascular calcification [15].

A soft tissue calcifications prevalence study found that carotid artery calcification was the second most prevalent type in the sample, and it was more identified in individuals over 80 years old [16], which was not included in the present study. It is believed that the prevalence of comorbidities among older patients may predispose them to show soft tissue calcifications. For example, in a postmenopausal sample with patients of 50 years or older, women with hypertension and hypercholesterolemia showed significant association with the presence of carotid artery calcification [17]. Although in present study we had no information regarding patients' health conditions, older patients were more classified as C3 for MCI and no significant association was found between C3 patients (older women) and the presence of coronary artery calcification. That difference with the first cited study is probably due to the different methodology used, as the present study had no intention to approach soft tissue calcifications prevalence: additionally, their sample was composed of men and women with no age limit.

Controversially, in the present study, the calcified thyroid cartilage was significantly absent in patients classified as C3 for MCI. That was unexpected, due to the fact that those patients that presented greater bone loss had 61 to 70 years old, and studies suggests that soft tissue calcifications increase with aging [18]. Besides, in a soft tissue calcifications prevalence study in older adults, using panoramic radiographs, the calcified thyroid cartilage was the most prevalent among all others [16]. We believe that this may have happened due to different patient positioning in the panoramic unit; since the thyroid cartilage is located inferiorly on the radiograph, some of them may not have been included in the image, which made it difficult to see its calcification.

The radiographic image of the mandibular canal is characterized as a dark ribbon between two radiopaque lines, which represent the cortical walls (borders) [19]. The mandibular canal cortices visibility in panoramic radiographs is very important to conduct treatments as teeth extraction and rehabilitation with implants, avoiding nerve injuries, and also because each patients has its own mandibular canal course [20]. In this study, the mandibular canal cortices visibility was evaluated at the ramus, to avoid the interference of a possible bone trabeculae alteration around the dentate area due to inflammatory processes, as that could cause bias. We found that the mandibular canal visibility impairment showed a significant association with advanced bone loss. In that matter, as the majority of patients classified as C3 were older than 60 years old, we can suggest that the mandibular canal cortices visibility can be impaired with aging, and that is very important to conduct a safe treatment for those patients that usually requires a more invasive and surgical rehabilitation.

For this study, we chose to select panoramic radiographs of women above 50 years old to restrict the sample with patients that are probably in menopause. In the present research, women older than 60 years old were more frequently classified as C3 for MCI (advanced stage of bone loss), than women aged from 50 to 60 years old. That is in agreement with preview study that monitored the mandibular cortex and the trabeculation patterns using panoramic radiographs of 1000 patients for 24 years [21]. They noticed that the mandibular cortex can get very porous with aging, and they also observed an association between a sparse trabecular pattern and eroded cortex in older women.

The limitation of this study is the lack of clinical information about the patients' overall health status, including metabolic diseases and the use of medication. The age and the sex of the patients were the unique confirmed information. Although we did not have the clinical information or confirmation of osteoporosis through a DXA examination, our results regarding MCI classification showed that the sample was characterized by gradual bone loss caused by age, and that the methods used in this study were trustworthy. Future studies should be conducted to correlate the presence of soft tissue calcifications and the mandibular canal cortices visibility in postmenopausal embracing their health condition.

Conclusions

No association between bone loss and the presence of head and neck soft tissue calcifications was found overall. However, greater bone loss had a positive correlation with aging and impaired mandibular canal cortices visibility. Based on the findings of this study, the mandibular canal cortices visibility may be an aid to monitoring bone loss, particularly in older individuals. Professionals should also be aware that the mandibular canal cortices visibility may be compromised in these individuals when a surgical planning is required.

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Author contribution M.F.S.A.B., D.Q.F., conceived the ideas; M.F.S.A.B., M.B.C., and D.Q.F. collected and analyzed the data; M.F.S.A.B. and M.B.C. imaging analysis; D.Q.F. the statistical analysis; M.F.S.A.B and D.Q.F. led the writing – original draft; M.F.S.A.B., M.B.C., I.C.D., and D.Q.F writing — review and editing.

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Declarations

Ethics approval All procedures performed in this study were conducted in accordance with the ethical standards of the Human Research Ethics Committee of Piracicaba Dental School, University of Campinas, Brazil (protocol number #46110821.4.0000.5418) and with the Helsinki Declaration.

Informed consent An informed consent was obtained from all patients receiving dental treatment across various departments of the university, ensuring their medical records could be utilized for scientific research purposes.

Conflict of interest The authors declare no competing interests.

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