# A Mandibular Bone Density Index for Prediction of Jaw Bone Osteoporosis in Men

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**Abstract**

Reduction in mandibular bone mineral density can be measure using panoramic radiography; however, this method has limited applicability in remote areas in Indonesia. Therefore, an urgent need exists for the development of a simple screening tool for predicting mandibular bone density. The objective of this study was to develop an index, consisting of osteoporosis risk factors, for predicting mandibular bone density in men. This study employed a case-control design, and included 89 elderly men (age>60 years) with mandibular bone osteoporosis as cases and 87 elderly men with normal mandibular bone as controls. Several risk factors for osteoporosis were analyzed. In this study, we used panoramic radiography to measure the decrease in mandibular density. The primary risk factors for decreased mandibular bone density in men were testosterone level(p=0.00),calcium intake (p=0.00),age(p=0.01), physical activity (p=0.0),and multivitamin intake (p=0.01). The index for predicting mandibular bone osteoporosis comprised these significant risk factors as well as some risk factors that were important ($p < 0.25$) but not statistically significant (p>0.05), such as history of fractured bones and food texture. In this study, we developed an index for predicting mandibular bone density in elderly men that can be used as a simple and easy screening tool for predicting osteoporosis.

***Clinical article (J Int Dent Med Res 2017; 10(Special Issue: pp. 612-618)***

**Keywords:** Mandible, bone density, osteoporosis, elderly, men.

**Received date:** 15 August 2017 **Accept date:** 17 September 2017

## Introduction

Bone is a living tissue consisting of collagen and calcium phosphate. The combination of calcium and phosphate results in flexible yet strong bone that can adapt to pressure. The process of bone resorption and formation occurs throughout human life. Bone resorption, a natural process that occurs in women as well as men, increases with age. An imbalance between bone resorption and bone formation results in osteoporosis.[1,2]

Osteoporosis is characterized by generalized low bone mass and fragility, with an increase in fracture risk, particularly of the vertebrae, hip, and wrist. It is a sex- and age-related condition caused by a decrease in bone mineral density, as well as structural changes.[3] The global population of individuals aged ≥65 years is expected to rise from 323 million to more than 1.5 billion by the year 2050.This demographic change is expected to result in an increase in the worldwide prevalence of osteoporosis, and consequently, the treatment cost of osteoporosis and fracture.[3] A recent study showed that 83% of hip fractures occurred in people aged ≥70 years, and approximately half of these cases were attributable to osteoporosis: 264,000 in men and 1.10 million in women.[4]

Because of the increase in the aging population, the prevalence of osteoporosis in men is increasing. As men age, bone mineral density decreases at a rate of approximately 1% per year, and one in five men over the age of 50

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years will experience an osteoporotic fracture during their lifetime. Of all osteoporotic fractures, hip fractures are associated with the greatest morbidity and mortality, and almost 30% of all hip fractures occur in men.[5] Old age is a risk factor for osteoporosis, and several studies have revealed that the mortality rate in men is twice that in women during the first year after the fracture. Men also have a higher risk of postoperative complications such as chest infections and heart failure.[6] Approximately 60% of elderly men with hip fractures are hypogonadal;[7] therefore, early diagnosis of osteoporosis in men is critical.

Bone health depends on many factors such as genes, hormones, amenorrhea and menopause in women, and low testosterone levels in men. Risk factors for osteoporosis are as follows: genes, ethnicity, age, sex, body mass index, level of physical activity, immobilization, exposure to sunlight, smoking, drinking alcohol and sodas, coffee consumption, calcium and vitamin D intake, long-term glucocorticoid use, anti-convulsant medications, and anorexia nervosa. Food texture, the duration of missing teeth, and wearing dentures also play a role as local predisposing factors for the resorption of alveolar bones and decreased mandibular bone density.[2,8,9,10]

A study by Indrasari et al. revealed an association between alveolar bone resorption level and bone density: postmenopausal women with decreased bone density (osteopenia or osteoporosis) experienced a higher level of alveolar bone resorption.[11] Other researchers have found that osteoporosis is related to changes in the iliaca, femur, and jaw trabecular bone. Several studies have shown decreases in bone density in other bones followed by decreased jaw bone density. [9,7,12,13,14]

Densitometry is the gold standard for the diagnosis of osteoporosis. However, its use is limited because it is expensive and not easily available in remote areas in Indonesia. Therefore, there is an urgent need for a cheap and easy-to-use index for predicting jaw bone density. Kusdhany et al. (2005) developed a mandibular bone density index for predicting osteoporosis in postmenopausal women.[9] The objective of the present study was to develop an index to predict jaw bone density in elderly men. This study was also conducted to identify various risk factors for the decrease in mandibular bone density that causes osteoporosis in elderly men. This study was conducted in Indonesia in elderly Indonesian men, who differ from elderly men in other countries in terms of genetics, lifestyle, physical activities, sunlight exposure, and eating habits.

## Materials and Methods

This was a case-control study in men aged >60 years. Cases were 89 elderly men with mandibular bone osteoporosis, and controls were 87 elderly men with healthy mandibular bones. This study was conducted in Bekasi and Depok City, West Java, Indonesia. Informed consent was obtained from the participants before the study was initiated. A case-control design was chosen because it enabled us to establish a causal relation between risk factors and the decrease in mandibular bone density, and to simultaneously examine several risk factors that contributed to the decrease in mandibular bone density. Study variables were body height, body weight, and testosterone level.

Questionnaires were used to collect data on other variables such as age, education, job, economic status, multivitamin intake, lifestyle, exercise and daily activities, sunlight exposure, food texture, history of bone fracture, history of denture use, type and location of denture, and duration of denture use. Four questionnaires were used: a questionnaire on intake of food containing calcium, a questionnaire on physical and daily activities, a questionnaire on sunlight exposure, and a questionnaire on lifestyle. Because these questionnaires were new, we tested their validity and reliability before using them. The face validity of the questionnaires was measured by a panel of four experts in related topics. After they were approved by the experts, the questionnaires were subjected to statistical analysis in order to measure their construct validity.

The results showed that the correlations between items in each component were weak to very strong with rates of 0.001–0.988, whereas the correlations of items to total components were also weak to very strong with rates of 0.0018–0.936. A reliability test showed that the internal construct was weak to strong with a Cronbach's alpha of 0.034–0.858.

Testosterone level was measured using a validated testosterone level questionnaire developed by Harman et al.[10] The diet profile of

calcium- and protein-containing food intake was obtained with questionnaires by using the food frequency method. Mandibular bone density data were obtained through panoramic radiography, using the mandibular cortical index (MCI) method.[15] MCI measurement results were correlated with several risk factors that were analyzed through questionnaires.

The panoramic radiography MCI method was used to measure the decrease in mandibular bone density.[15] MCI was measured on the basis of mandibular cortical shapes on dental panoramic radiographs, by observing the mandibles distally from the mental foramina bilaterally and by categorizing them into one of the three groups according to the method of Klemetti et al.:

*C1*: Normal cortex - The endosteal margin of the cortex was even and sharp on both sides.

*C2*: Mild to moderately eroded cortex -The endosteal margin showed semilunar defects (lacunar resorption) or it appeared to form endosteal cortical residues.

*C3*: severely eroded cortex- The cortical layer formed heavy endosteal cortical residues and was clearly porous.[15]

The chi-square test was used to statistically analyze the relation between risk factors and mandibular bone density. Multivariate analysis using logistic regression was performed to identify risk factors for decreased mandibular bone density in elderly men. The statistical significance threshold was set at $p<0.05$. The results of the multivariate analysis were used to design the mandibular bone density index in the form of a scoring model.

**Results**

This study was approved by the ethical commission of the Faculty of Dentistry Universitas Indonesia and the Faculty of Medicine Universitas Indonesia. The panoramic radiographs were normal in 67subjects (CI) and abnormal in 89 participants (C2, C3). The results of bivariate analysis of risk factors of low mandibular bone density (osteoporosis) are shown in Table 1.

The analyses revealed that testosterone levels, physical activities (sports and daily activities), intake of food containing calcium, and multivitamin intake were significantly correlated with mandibular bone density ($p < 0.05$).

In contrast, age, education, food texture, lifestyle, intake of food containing protein, sun exposure, and history of fractured bones were not significantly correlated with decreased mandibular bone density; however, these factors($p <0.25$) were considered to play a role in the decrease of mandibular bone density, and were therefore, included in the multivariate analysis.

The final multivariate analysis revealed that testosterone level and intake of food containing calcium had the most significant influence on osteoporosis in men, whereas age, physical activity, history of fractured bones, multivitamin intake, and food texture also played a role in the decrease in mandibular bone density (Tabel 2).

The mandibular bone density index for predicting jaw bone osteoporosis was based on the results of the multivariate analysis. The scoring model was obtained by dividing the coefficient of the observed variable by the standard error. The variable with the smallest value was chosen as the standard. Other variables were divided by the standard (Table 3).

The scoring model comprised risk factors that could be measured by health workers, dentists, or doctors. In regions with no osteoporosis examination facilities, the scoring model could be used for early detection of osteoporosis so that preventive measures could be implemented and early treatment could be administered.

A cutoff of 7 was used to categorize mandibular bone density (sensitivity 68.5%, specificity 70.1%): a score of 0–7 indicated normal mandibular bone density and a score of 7–14 indicated osteoporosis.

**Table 1.** Risk Factors of Low Mandibular Bone Density (Osteoporosis) in Men

| Risk Factors | | Controls | | Osteoporosis Cases | | P-Value | OR | 95% CI |
|---|---|---|---|---|---|---|---|---|
| | | N (87) | % | N (89) | % | | | |
| Testosterone level | Good | 55 | 64.0 | 31 | 36.0 | 0.000 * | 3.216 | 1.736–5.957 |
| | Decreasing | 32 | 35.6 | 58 | 64.4 | | | |
| Age (years) | ≤70 | 58 | 54.7 | 48 | 45.3 | 0.084 * | 1.708 | 0.928–3.145 |
| | >70 | 29 | 41.4 | 41 | 58.6 | | | |
| Education | High | 74 | 52.1 | 68 | 47.9 | 0.146 * | 1.758 | 0.817–3.782 |
| | Low | 13 | 38.2 | 21 | 61.8 | | | |
| Jobs | Office | 74 | 51.0 | 71 | 49.0 | 0.358 | 1.443 | 0.659–3.161 |
| | Non–Office | 13 | 41.9 | 18 | 58.1 | | | |
| Multivitamin Intake | Yes | 26 | 38.8 | 41 | 61.2 | 0.027 * | 0.499 | 0.268–0.928 |
| | No | 61 | 56.0 | 48 | 44.0 | | | |
| Food Texture | Hard | 73 | 52.5 | 66 | 47.5 | 0.112 * | 1.817 | 0.864–3.820 |
| | Soft | 14 | 37.8 | 23 | 62.2 | | | |
| Life Style | Good | 78 | 48.1 | 84 | 51.9 | 0.247 * | 0.516 | 0.166–1.606 |
| | Not Good | 9 | 64.3 | 5 | 35.7 | | | |
| Calcium Intake | Sufficient | 52 | 60.5 | 34 | 39.5 | 0.004 * | 2.403 | 1.312–4.403 |
| | Insufficient | 35 | 38.9 | 55 | 61,1 | | | |
| Protein Intake | Sufficient | 52 | 54.7 | 43 | 45.3 | 0.127 * | 1.589 | 0.875–2.888 |
| | Insufficient | 35 | 43.2 | 46 | 56.8 | | | |
| Sun Exposure | Sufficient | 47 | 54.0 | 40 | 46.0 | 0.228 * | 1.439 | 0.795–2.606 |
| | Insufficient | 40 | 44.9 | 49 | 55.1 | | | |
| Physical Activity | Sufficient | 51 | 58.6 | 36 | 41.4 | 0.016 * | 2.086 | 1.143–3.804 |
| | Insufficient | 36 | 40.4 | 53 | 59,6 | | | |
| Fracture History | No. | 83 | 50.9 | 80 | 49.1 | 0.162 * | 2.334 | 0.691–7.885 |
| | Yes | 4 | 30.8 | 9 | 69.2 | | | |
| Expenses | >1.5 million | 34 | 54.0 | 29 | 46.0 | 0.369 | 1.327 | 0.715–2.462 |
| | ≤1.5 million | 53 | 46.9 | 60 | 53.1 | | | |
| Body Mass Index | Normal | 48 | 51.6 | 45 | 48.4 | 0.540 | 1.203 | 0.665–2.177 |
| | underweight | 39 | 47.0 | 44 | 53.0 | | | |

*P<0.25 to be included in multivariate analysis. CI, confidence Interval; OR, Odds Ratio.

**Table 2**. Final Multivariate Analysis of Risk Factors of Low Mandibular Bone Density (Osteoporosis) in Men

| Variable | Coefficient | Se | P-value | OR | 95% CI | |
|---|---|---|---|---|---|---|
| Testosterone | 1.35 | 13.99 | 0.00 | 3.89 | 1.91 | 7.93 |
| Age | 0.91 | 5.87 | 0.01 | 2.49 | 1.19 | 5.21 |
| Multivitamin intake | -0.90 | 6.06 | 0.01 | 0.40 | 0.19 | 0.83 |
| Food Texture | -0.60 | 1.83 | 0.17 | 0.54 | 0.22 | 1.31 |
| Calcium | 1.43 | 13.85 | 0.00 | 4.18 | 1.96 | 8.88 |
| Physical activity | 0.88 | 6.15 | 0.01 | 2.41 | 1.20 | 4.85 |
| Fracture History | 0.89 | 1.48 | 0.22 | 2.45 | 0.58 | 10.35 |
| Constant | -1.21 | 4.57 | 0.03 | 0.29 | | |

CI, confidence Interval; OR, Odds Ratio.

**Table 3.** Mandibular Bone Density Index for Predicting Osteoporosis in Men.

| Variables | Weight | Score |
|---|---|---|
| Testosterone | | |
| ≤300 mg/dl | 3 | … |
| >300 mg/dl | 0 | |
| Age | | |
| > 70 years | 2 | … |
| ≤70 years | 0 | |
| Multivitamin Intake | | |
| No | 2 | ... |
| Yes | 0 | |
| Food Texture | | |
| Soft | 1 | … |
| Hard | 0 | |
| Calcium Intake | | |
| ≤587.95 mg/day | 3 | … |
| >587.95 mg/day | 0 | |
| Physical activity | | |
| ≤60 minutes/day | 2 | … |
| >60 minutes/day | 0 | |
| History of fracture | | |
| Yes | 1 | .... |
| No. | 0 | |
| Total = | | |

## Discussion

It has long been postulated that mandibular bone density may be indicative of systemic bone mineral density. Many studies have shown that mandibular bone mass is not affected by age, but is significantly associated with skeletal bone mass in the spine and wrist.[16,9] A study by Govindraju et al. showed that MCI, mental index, and panoramic mandibular index were useful for identifying patients with low skeletal bone mineral densities or osteoporosis, and that digital panoramic radiographs were better than analog radiographs for determining these indices.[15] Diagnosis of osteoporosis in the jaw bone is crucial for dentists in order to prevent dental treatment failure due to insufficient alveolar bone density.

Jonasson et al. found that the mandibular trabecular pattern was a significant predictor of future fracture risk, with its effectiveness as a fracture predictor increasing with age.[13] Dentists can use regular dental radiographs as a rough tool for identifying women at high risk for future fractures.[13]

A study conducted in Gujarat, India with 180 elderly men and women aged >60 years revealed the following risk factors for decreased bone density: age, sex, calcium intake, protein intake, joint inflammation, lack of stamina, and body mass index.[1] A systematic review by Drake et al. identified statistically significant associations that may help stratify and screen men for bone density testing. Statistically significant associations were found between decreased bone density and age, low body mass index, current smoking, excessive alcohol use, chronic corticosteroid use, and a history of prior fractures, falls, hypogonadism, stroke, and diabetes.[17] In the present study, we found that testosterone level, age, and low calcium and multivitamin intake were risk factors for osteoporosis in men.

A previous study showed that estrogen and testosterone play a dominant role in regulating bone density, bone resorption, and bone loss in elderly men. Testosterone and estradiol levels decline significantly with age. Although serum testosterone was not correlated with lumbar spine or femoral bone mineral density, a lower testosterone level was a strong predictor of fractures. These findings suggested that the effect of testosterone on fracture risk in elderly men may be mediated via non-skeletal

factors such as muscle strength and fall risk.[5] The present study showed that participants with a testosterone level ≤300 mg/dl had a 3.9-fold higher risk of decreased mandibular bone density than participants with a testosterone level >300 mg/dl did ( p=0.00).

In 2008, the World Health Organization introduced the fracture risk assessment tool (FRAX) for evaluation of patients' absolute risk of osteoporotic fracture. To predict an individual's 10-year probability of major osteoporotic fractures or hip fracture alone, FRAX takes into account the interaction of multiple risk factors such as age, sex, and personal and family history. The risk factors may be analyzed with or without the inclusion of bone mineral density data. Compared to bone mineral density, the FRAX score had the best predictive value for vertebral fracture, with an area under the curve of 0.738 (cutoff =2.9%), and sensitivity and specificity of 82% and 62%, respectively. [18]

In the present study, we developed a mandibular bone density index on the basis of multivariate analysis of risk factors for osteoporosis in men. This index for predicting jaw bone osteoporosis comprised significant risk factors along with risk factors that were important ($p < 0.25$) but not statistically significant($p > 0.05$) i.e. history of fractured bones and food texture. This index can be used as a screening tool for patients with a high risk of mandibular bone osteoporosis. After determining that a patient has osteoporosis/osteopenia, clinicians need to conduct further diagnostic tests using bone densitometry.

Calcium is a key component of bone, and therefore, calcium deficiency is strongly associated with osteoporosis. In the present study, participants with a calcium intake of <587.95 mg per day had a 4.2-fold higher risk of decreased mandibular bone density compared to participants with a calcium intake of >587.95 mg per day (p=0.004). Many people fail to meet the recommended daily intake of calcium (800–1000 mg per day) because of an inadequate diet, impaired absorption, or food intolerance.

However, calcium supplementation has proven unsuccessful in preventing or halting the progression of osteoporosis. Moreover, ingestion of calcium citrate leads to the rapid absorption of a bolus of calcium, resulting in a sharp increase in blood calcium and giving rise to the term "calcium supplement syndrome."[2]

Fluctuation in calcium homeostasis results in an increased risk of developing kidney stones and cardiovascular disease, but has no positive effect on bone formation. Therefore, calcium supplements are no longer recommended for either children or adults by many health organizations worldwide.[2] However, increasing dietary calcium, in conjunction with an adequate vitamin D supply, remains a key strategy for preventing osteoporosis. Dietary calcium in milk is absorbed differently than ionized calcium; therefore, highly fortified calcium-containing milk remains safe for delivering calcium without perturbing calcium homeostasis.[2]

In the present study, a mandibular bone density index for predicting jaw bone osteoporosis in elderly men was developed on the basis of multivariate analysis results. This index can be used to screen patients with a high risk for mandibular bone osteoporosis. If mandibular bone osteoporosis or osteopenia is detected, the patient should be referred to a general practitioner for further diagnostic tests and treatment, and dental treatment should be administered simultaneously.

Kusdhany et al. developed a similar index for postmenopausal women. Postmenopausal women could use this index to estimate the condition of their mandibular bone, and consequently, the condition of their other bones. Depending on the results, they could implement preventive measures and seek medical treatment from their general practitioner, obstetrician, or gynecologist. This model included a digitized radiographic examination. In remote areas that do not have any osteoporosis examination facilities but have dental radiology facilities, dentists can use this index for early detection of osteoporosis and then refer the patient to a general practitioner, obstetrician, or gynecologist for further treatment.[9]

Osteoporosis is a silent disease without any noticeable symptoms, and therefore, a majority of patients are unaware that they have osteoporosis. In Indonesia, both indexes can be useful for screening postmenopausal women and elderly men with osteoporosis risk, which will enable implementation of measures for early prevention of fractures. In a previous study in Korea, Oh et al. developed an osteoporosis risk-assessment model for Korean men that included bone mineral density measurements and other

risk factors for osteoporosis. This model has the same benefits as the mandibular bone density index developed in the present study for elderly Indonesian men. Oh et al. suggested that their model was a useful pre-screening tool for osteoporosis in Korean men. Since it is easy to implement, it can be used either in a primary care setting or for general use as a self-screening tool.[19]

## Conclusion

To predict mandibular bone density in elderly men, we developed a mandibular bone density index based on multivariate analysis of several risk factors for osteoporosis in men. This index can be used as screening tool for osteoporosis in elderly men. Risk factors for decreased mandibular bone density in elderly men are low calcium intake, advanced age, low physical activity, history of fracture, low multivitamin intake, and soft food texture.

## Acknowledgements

This research is supported by the Directorate of Research and Community Service (DRPM) of the University of Indonesia and the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia. The publication of this manuscript is supported by Universitas Indonesia

## Declaration of Interest

The authors report no conflict of interest.

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