Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology 2022;8(1):27–34

Content available at: https://www.ipinnovative.com/open-access-journals

Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology

Journal homepage: www.joooo.org

Original Research Article

Radiomorphometric indices as indicator in osteoporosis-A digital panaromic study

Sangeetha J[1], Balaji Pachipulusu[1,*], Poornima Govindraju[1], Syeda Muskan Jan[1]

[1] *Dept. of Oral Medicine and Radiology, Rajarajeswari Dental College and Hospital, Bengaluru, Karnataka, India*

ARTICLE INFO

Article history:
Received 10-01-2022
Accepted 17-01-2022
Available online 25-03-2022

Keywords:
Mandible
Bone mineral density
Osteoporosis
Panoramic radiography

ABSTRACT

Background & Objectives: Osteopenia/ osteoporosis affect many elderly people and might not be detected until symptoms of fractures occur. Early detection of osteopenia/ osteoporosis is important and would allow preventive measures and treatment. Access to screening of osteoporosis is often limited, whereas panoramic radiography is widely used in dentistry. This highlights the role of the dentist in the early diagnosis of this disease. With this background the present study is intended to analyse the radiomorphometric indices of mandible using digital panoramic radiographs.

Materials and Methods: The study subject consisted of 300 panoramic radiographs of which 150 were males and 150 were females, in the age group of 21-70 years. The obtained data were statistically analysed.

Results: GI and AI showed a downward trend with age. MI showed a decline in mean values from the age of 61 years only in females. PMI showed a sudden drop after the age of 40 years. C2 and C3 categories increased with age. Male patients demonstrated significantly higher measured values for GI, AI and MI than female patients. C3 cortical appearance was predominantly seen in females. GI, AI, MI and MCI were strongly influenced by dental status.

Conclusion: The mandibular cortical thickness was reduced in older females. Dentition had a significant effect on all indices, except PMI. This study showed that GI, AI, MI PMI and MCI are useful for identifying patients with low skeletal bone mineral densities or osteoporosis. Hence, it is advocated that oral physicians play an unique role in screening of patients for the evaluation of osteopenia.

1. Introduction

Osteoporosis is a growing health problem recognized in both developed and developing countries. It is associated with substantial morbidity and socio-economic burden worldwide.[1] Osteoporosis is considered to be a silent disease that entails significant social and economic burdens. So, there has been a growing interest in the diagnosis and oral signs of osteoporosis recently[2]

Bone loss occurring with age is a commonly observed phenomenon in humans. It affects both females and males, but it is increased in postmenopausal females. Women suffer from rapid decline of bone mass during the first 5–10 years after menopause, while later the decrease stabilises at a lower rate. In men, bone loss starts later and progresses more slowly than in women.[3] This loss of bone in both men and women lead to a more porous bone leading to a condition called osteoporosis. In 30 % to 50 % of women and 15%–30% of men, osteoporosis-related fractures can occur in their lifetime.[1]

Many bone-mass measuring techniques have been advocated to assess the changes which include dual X-ray energy absorptiometry (DXA), quantitative computed tomography (QCT) and neutron activation analysis with DXA being considered as gold standard. However, they are increased treatment cost and involve expensive equipment.

* *Corresponding author*.
E-mail address: drbalaji_24@rediffmail.com (B. Pachipulusu).

https://doi.org/10.18231/j.jooo.2022.006

As osteoporosis is related to considerable mortality and increasingly higher costs of health care, screening for osteoporosis particularly in high-risk populations is required. With the above background the present study is intended to analyse the radiomorphometric indices of mandible using digital panoramic radiographs.[4,5]

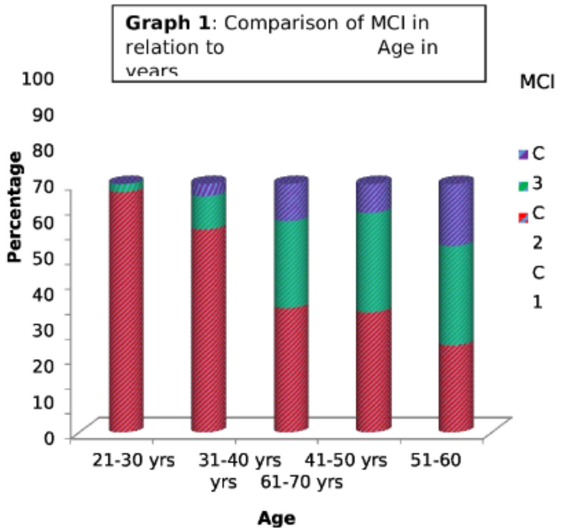
2. Materials and Methods

Three hundred patients were randomly taken for study aged between 21-70 years the patients were equally divided into males & females & each of this group were further subdivided into 5 age groups with a 10-year interval, these patients were subjected to panaromic radiograph using Sirona Orthophos XG 5 DS/ Ceph digital OPG machine with standard exposure parameters after obtaining the institutional ethical clearance, the patients were equally divided into males & females & each of this group were further subdivided into 5 age groups with a 10-year interval. The measurements were made using the SIDEXIS software considering the magnification factor of the equipment. All the indices and mean were measured and calculated respectively for right and left sides of the mandible after considering the inclusion and exclusion criteria. The observer were blinded for the age and gender of the patient while performing the measurements. Following radiomorphometric indices were measured on right and left sides:

1. Gonial index (GI)–A line drawn parallel to posterior border of ramus. Another line drawn tangent to lower border of mandible. A third line drawn which bisect the angle formed between the first two lines. Gonial Index will be thickness of cortex along this third line.[5]
2. Antegonial index (AI)–A line drawn parallel to ascending ramus extending down to cross the lower border. At this intersection, another line was drawn tangent to lower border of mandible. A third line was drawn perpendicular to this tangent. Measurement of the cortical thickness is made along this third line.[6]
3. Mental index (MI) -It wass the cortical thickness at mental foramen. The mental foramen was identified and a line was traced which passes perpendicular to the tangent to the lower border of the mandible and through the center of the mental foramen. The cortical width was measured at this point.[7]
4. Panoramic mandibular index (PMI) –The panoramic mandibular index (PMI), first introduced by Benson in 1991. The mental foramen is located and a perpendicular line was drawn on the tangent at the lower margin of the mandible which passes through the mental foramen. Along this perpendicular, superior and inferior PMI are calculated.[8]
   PMI is the mean of superior and inferior PMI.
5. Mandibular cortical index (MCI) –MCI was assessed according to criteria described by Klemetti et al. (1994). It is the appearance of the inferior mandibular cortex.[8]

C1 — Endosteal margin of the cortex is even and sharp on both sides.
C2 — Endosteal margin shows semilunar defects (lacunar resorption) and /or seems to form endosteal cortical residues on one or both sides.
C3 –The cortical layer forms endosteal cortical residues and is clearly porous.

The measurements were repeated after 1 month by the same observer. Also, the measurements were made by a second observer. At least 20 % of the radiographs were assessed for inter & intra observer reliability.



Graph 1: Comparison of MCI in Relation to age in years

3. Results

The relevant demographic data including name, age, gender and patient identification number were recorded for each selected image in a specially designed proforma. The subject's informed consent was obtained after explaining of the general nature of the study. The radiomorphometric indices were recorded as described in the methodology. The maxillary and mandibular dentition was recorded using a simple classification system (third molars not included): full dentition, partial dentition (missing any teeth) and edentulous as described by A Gulsahi et al. 15 All measurements were made separately on the right and left mandibular sides and their means were calculated considering the magnification factor of the equipment which was 19%. The obtained data was then subjected to statistical analysis 20% of the radiographs were assessed for inter and intraobserver reliability after a month and was found to be

Table 1: Dentition status of patients studied

Dentition Status	No. of patients	%
Dentulous	148	49.3
Partially Edentulous	143	47.7
Completely Edentulous	9	3.0
Total	300	100.0

Table 2: Comparison of GI, AI, MI and PMI in relation to age in years

Variables	Age in years					Total	P value
	21-30 yrs	31-40 yrs	41-50 yrs	51-60 yrs	61-70 yrs		
GI	1.00±0.35	0.90±0.32	0.95±0.41	0.80±0.41	0.83±0.36	0.90±0.38	0.018*
AI	3.39±0.74	3.26±0.63	3.39±0.64	3.22±0.84	3.04±0.76	3.26±0.73	0.050+
MI	3.85±0.98	4.23±3.69	3.75±0.92	3.82±1.00	3.84±1.12	3.9±1.88	0.646
PMI	0.19±0.11	0.28±0.36	0.17±0.12	0.16±0.11	0.17±0.13	0.19±0.20	0.003**

Table 3: GI/ AI/ MI/ PMI/ MCI distribution of patients studied with gender

Variables	Gender		Total (n=300)	P value
	Female (n=150)	Male (n=150)		
GI				
<1	106(70.7%)	78(52%)	184(61.3%)	
1-1.5	42(28%)	58(38.7%)	100(33.3%)	<0.001**
>1.5	2(1.3%)	14(9.3%)	16(5.3%)	
AI				
<2.5	28(18.7%)	13(8.7%)	41(13.7%)	
2.5-5	119(79.3%)	134(89.3%)	253(84.3%)	0.041*
>5	3 (2%)	3(2%)	6(2%)	
MI				
<3	24(16%)	12(8%)	36(12%)	
3-6	124(82.7%)	135(90%)	259(86.3%)	0.097+
>6	2(1.3%)	3(2%)	5(1.7%)	
PMI				
<0.2	79(52.7%)	85(56.7%)	164(54.7%)	
0.2-0.8	66(44%)	64(42.7%)	130(43.3%)	0.436
>0.8	5(3.3%)	1(0.7%)	6(2%)	
MCI				
C1	86(57.3%)	101(67.3%)	187(62.3%)	
C2	39(26%)	40(26.7%)	79(26.3%)	0.013*
C3	25(16.7%)	9(6%)	34(11.3%)	

statistically insignificant with p value < 0.8. Dentition status of patients studied the study population consisted of 49.3% of dentate individuals, 47.7% were partially edentulous and 3% were completely edentulous. (Table 1).

3.1. Comparison of GI, AI, MI and PMI in relation to age in years

GI, AI, PMI which is statistically significant whereas MI showed contrast result comparing to other index. (Table 2)

3.2. Comparison of MCI among different age groups showed

21-30 years: A relatively large proportion had C1 category, but only a small proportion had C2 category.

31–40 years: A majority in this age group had C1 category, patients had C2 category, but only a small minority had C3 category.

41-50 years: There was a dip in the level of C1 compared to the previous age group. The categories of C2 and C3 were moderately increasing. 51-60 years: C1 and C2 categories were almost similar compared to C3.

61-70 years: The levels of C3 sharply increased compared to the former age group. The comparison of MCI among the different age groups was strongly significant. (p value < 0.436). PMI is not associated with gender. As age advanced, the category of C1 was gradually decreasing, whereas C2 and C3 were steadily increasing. (Graph 1)

Table 4: Comparison of age, GI, AI, MI and PMI in relation to gender in different age groups

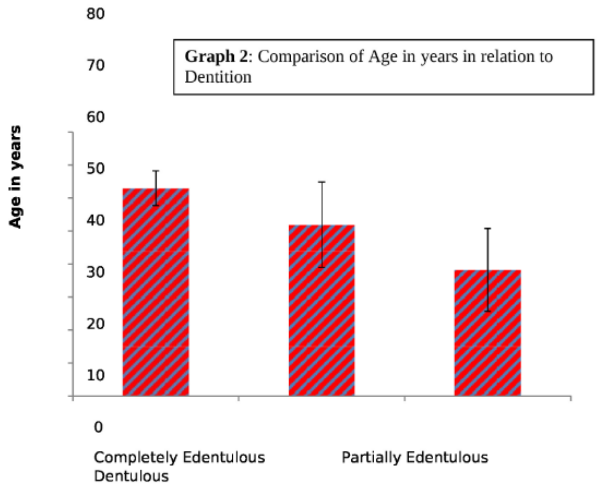
Age in years	Gender		Total	P value
	Male	Female		
21-30 yrs				
GI	1.01±0.39	0.78±0.33	0.90±0.38	<0.001**
AI	3.37±0.68	3.15±0.77	3.26±0.73	0.010**
MI	4.03±0.94	3.77±2.48	3.90±1.88	0.237
PMI	0.18±0.12	0.21±0.25	0.19±0.20	0.185
31-40 yrs				
GI	0.93±0.31	0.87±0.34	0.90±0.32	0.452
AI	3.24±0.55	3.27±0.72	3.26±0.63	0.857
MI	4.01±0.56	4.46±5.23	4.23±3.69	0.639
PMI	0.22±0.18	0.34±0.48	0.28±0.36	0.201
41-50 yrs				
GI	1.14±0.41	0.77±0.34	0.95±0.41	<0.001**
AI	3.52±0.62	3.25±0.65	3.39±0.64	0.109
MI	3.85±1.00	3.64±0.84	3.75±0.92	0.376
PMI	0.15±0.08	0.18±0.15	0.17±0.12	0.348
51-60 yrs				
GI	0.97±0.46	0.63±0.27	0.80±0.41	0.001**
AI	3.51±0.68	2.93±0.88	3.22±0.84	0.006**
MI	4.02±0.98	3.61±1.00	3.82±1.00	0.114
PMI	0.16±0.09	0.16±0.14	0.16±0.11	0.798
61-70 yrs				
GI	0.94±0.39	0.71±0.30	0.83±0.36	0.013*
AI	3.20±0.73	2.87±0.76	3.04±0.76	0.092+
MI	4.22±0.99	3.46±1.14	3.84±1.12	0.007**
PMI	0.16±0.10	0.18±0.16	0.17±0.13	0.541

Table 5: GI/ AI/ MI/ PMI/ MCI distribution of patients studied with dentition status

Variables	Dentition Status			Total (n=300)	P value
	CE(n=9)	PE (n=143)	D (n=148)		
GI					
<1	8(88.9%)	97(67.8%)	82(55.4%)	184(61.3%)	
1-1.5	1(11.1%)	42(29.4%)	57(38.5%)	100(33.3%)	0.179
>1.5	0 (0%)	7(4.9%)	9(6.1%)	16(5.3%)	
AI					
<2.5	4(44.4%)	27(18.9%)	10(6.8%)	41(13.7%)	
2.5-5	5(55.6%)	115(80.4%)	133(89.9%)	253(84.3%)	0.001**
>5	0(0%)	1(0.7%)	5(3.4%)	6(2%)	
MI					
<3	1(11.1%)	24(16.8%)	11(7.4%)	36(12%)	
3-6	8(88.9%)	118(82.5%)	133(89.9%)	259(86.3%)	0.104
>6	0(0%)	1(0.7%)	4(2.7%)	5(1.7%)	
PMI					
<0.2	6(66.7%)	77(53.8%)	81(54.7%)	164(54.7%)	
0.2-0.8	3(33.3%)	62(43.4%)	65(43.9%)	130(43.3%)	0.820
>0.8	0(0%)	4(2.8%)	2(1.4%)	6(2%)	
MCI					
C1	2(22.2%)	69(48.3%)	116(78.4%)	187(62.3%)	
C2	5(55.6%)	45(31.5%)	29(19.6%)	79(26.3%)	<0.001**
C3	2(22.2%)	29(20.3%)	3(2%)	34(11.3%)	

Table 6: Comparison of age, GI, AI, MI and PMI in relation to dentition indifferent agegroups

Age in years	Dentition CE	PE	D	Total	P value
21-30 yrs					
GI	0.00±0.00	1.08±0.32	0.99±0.36	1.00±0.35	0.460
AI	0.00±0.00	3.16±0.74	3.44±0.74	3.39±0.74	0.302
MI	0.00±0.00	3.45±0.66	3.92±1.02	3.85±0.98	0.186
PMI	0.00±0.00	0.18±0.08	0.19±0.12	0.19±0.11	0.790
31-40 yrs					
GI	0.00±0.00	0.92±0.30	0.89±0.34	0.90±0.32	0.717
AI	0.00±0.00	3.18±0.65	3.30±0.63	3.26±0.63	0.477
MI	0.00±0.00	3.94±0.69	4.38±4.51	4.23±3.69	0.668
PMI	0.00±0.00	0.36±0.53	0.25±0.24	0.28±0.36	0.281
41-50 yrs					
GI	0.00±0.00	0.87±0.44	1.05±0.37	0.95±0.41	0.103
AI	0.00±0.00	3.29±0.62	3.50±0.67	3.39±0.64	0.220
MI	0.00±0.00	3.71±1.12	3.80±0.61	3.75±0.92	0.710
PMI	0.00±0.00	0.19±0.15	0.14±0.06	0.17±0.12	0.116
51-60yrs					
GI	0.48±0.28	0.87±0.47	0.76±0.31	0.80±0.41	0.162
AI	2.05±0.91	3.17±0.83	3.5±0.64	3.22±0.84	0.004**
MI	2.88±1.55	3.76±0.97	4.07±0.87	3.82±1.00	0.078+
PMI	0.12±0.08	0.17±0.14	0.15±0.06	0.16±0.11	0.613
61-70yrs					
GI	0.72±0.35	0.82±0.34	0.90±0.52	0.83±0.36	0.690
AI	3.26±0.97	3.02±0.74	3.03±0.81	3.04±0.76	0.798
MI	3.98±0.77	3.72±1.19	4.46±0.64	3.84±1.12	0.219
PMI	0.19±0.10	0.17±0.14	0.18±0.10	0.17±0.13	0.963



Graph 2: Comparison of age in years in relation to dentition

3.3. GI/ AI/ MI/ PMI/ MCI distribution of patients studied with gender

There was a significant association between GI, AI, MI and gender. PMI was not associated with gender. There was a significant difference in the categories of MCI between males and females. C1 appearance was seen relatively greater in males and C3 appearance was predominantly seen in females. (Table 3)

3.4. Comparison of GI, AI, MI and PMI in relation to gender in difference age groups

GI, AI is influenced by gender in the age group of 21-30 years and was statistically significant whereas MI, PMI was not statistically significant.

GI, AI, MI, PMI didn't show statistically significant results in age group of 31-40 years.

There is a drastic drop in the mean values of PMI commencing from the age of 41 years among the females.

Under the age group of 51-60 years — GI, AI was strongly significant whereas MI, PMI did not show statistically significant result.

GI, AI, MI was influenced by gender in the age group of 61-70 years whereas PMI was not statistically significant.(Table 4)

3.5. GI/ AI/ MI/ PMI/ MCI distribution of patients studied with dentition status

GI, MI, PMI did not exert a significant effect on the dentition. Whereas AI showed a significant effect among the 3 groups of dentition. Hence, C1 cortical appearance was predominantly seen in dentulous patients whereas in partially and completely edentulous patients, C2 and C3 was the most common cortical appearance. (Table 5)

3.6. Comparison of age, GI, AI, MI and PMI in relation to dentition status

GI, AI is strongly influenced by the dental status whereas MI, PMI was contrast with other index (Graph 2)

3.7. Comparison of age, GI, AI and MI in relation to dentition in different age groups

Among the age groups of 21-30 years, 31-40 years, 41-50 years and 61-70 years, the mean values of GI, AI, MI and PMI are not statistically significant. In the age group of 51 – 60 years, AI was significantly higher among dentulous patients, followed by partially edentulous and completely edentulous which is strongly significant. Hence, dentition has a significant effect on the AI and MI only in the age group of 51 – 60 years (Table 6).

4. Discussion

In humans, bone is constantly resorbed and formed by the process known as remodelling. Bone loss occurring with age is a commonly observed phenomenon. From 3rd to 5th decade, the amount of bone formed approximately equals the amount resorbed irrespective of the gender. With aging, the amount of bone resorbed by osteoclasts is not fully restored with bone deposited by osteoclasts and this imbalance leads to loss of bone mass and strength.[9] Estrogen plays a pivotal role in maintaining positive balance in bone remodelling by supporting osteoblasts and preventing bone resorption by suppressing osteoclast formation, stimulating osteoclast apoptosis, and counteracting oxidative stress.[10]

Peak bone mass is achieved during early adulthood but varies between men and women. Both men and women start losing bone in their 40s. Women experience a rapid phase of loss during the first 5–10 years after menopause, due to loss of estrogen. In men, this phase is obscure, since there is only a slow and progressive decline in sex steroid production. Hence, the loss of bone in men is linear and slower.[11] This loss of bone in both men and women lead to a more porous bone leading to a condition called osteoporosis.[4]

Various studies have demonstrated that osteoporotic individuals have altered morphology of mandible and also there exists a good correlation between the mandibular and skeletal bone mineral densities. Dental radiographs, especially panoramic images have been used to predict patients with low BMD. Hence, by using various qualitative and quantitative radiomorphometric indices, it is possible to measure the bone mineral density of mandible on panoramic radiographs. These radiographs are relatively inexpensive, and they are already being made regularly as an aid in the diagnosis of oral and dental diseases. They may also provide information on a patient's osteoporotic status and thus display enormous potential in being used as a screening tool for osteoporosis.[12] Therefore we as oral physicians can identify low BMD using the panoramic radiographs and create awareness of osteoporosis. Although many studies have been conducted on radiomorphometric indices of mandible, very few correlative studies have been conducted on younger populations. Therefore, in our study we also included younger individuals to determine whether osteoporotic bone changes occurred earlier than they were actually detected, by using mandibular indices. In addition, not many studies have conducted to study the effect of dentition on the indices. Hence, our study was conducted to go one step closer by also assessing the effect of dentition on the mandibular indices together with age and gender. In terms of age, GI (Table 2)showed a negative correlation with age which was statistically significant.AI also (Table 2) showed a downward trend with age which was of statistical significance. (p value <0.050) These findings are in accordance with a study conducted by Ledgerton et al.,[6] Bras et al.[13] and Kribss et al.[14] This could be attributed to the age related bone loss.

A sharp decline in mean values of MI starting from the age of 61 years only in females was noted in our study (Table 4) which was of statistical significant. It is in accordance with a studies conducted by Knezovic Zlataric et al.[15] and Govindraju et al.[4] This could be due to post-menopausal bone loss. PMI had a significant influence on age. There was a drastic dip in the mean PMI values starting from the age of 41 years (Table 2) which was of statistical significance. These findings were in accordance with previous studies conducted by Raghdaa et al.[16] Nemati, et al.[17] and Bathla et al.[18] It can be explained by the age changes in cortex.

Among the 3 categories of MCI, C1 was the most detected category followed by C2 and C3 being the least. This finding is consistent with the previous studies conducted by A Gulsahi et al.[19] and Govindraju et al.[4] C1 was seen in younger males and females, but as age advanced, the number of individuals who had C2 and C3 categories increased (Table 3) which was found to be statistically significant. This is correlating with the results of previous studies which were conducted by Knezovic-Zlataric et al.[15] Gulsahi et al.[19] and Haster et al.[20] This is because the prevalence of porosity in the mandibular cortex increases with age. Several radiographic studies have shown reductions in mandibular cortical thickness in older females. Although both men and women are affected, women lose bone mass at a rate which is three times that of men, especially after menopause.

As discussed above, the mean GI values were considerably lower in females compared to males (Table 3) which was statistically significant. This finding is in accordance with a study conducted by Alonso MBCC et al.[21] It can be explained by the constitutional differences between sexes. Our study reported a notable decrease in antegonial bone thickness (AI) among elderly females and that resorption was lower among elderly males (Table 3) which was of statistical significance. This is consistent with the studies conducted by Dutra et al.[22] and Ivona Musa et al.[23] The reason being that osteoporosis was more often seen in older females. The mean values of MI were lower in females compared to males (Table 3) which was statistically significant. This finding is in accordance with the previous studies conducted by Dagistan and Bilge[24] and Alonso MBCC et al.[21] The females of older age group demonstrated lower MI values (Table 4)which was of statistical significance. This is in accordance with the studies conducted by Benson et al., Dutra et al.[25], Raghdaa et al.[16] and Ivona Musa et al.[23] It could be attributed to the fact that osteoporosis was more often seen in older females.

There was no significant difference in the mean values of PMI between both sexes except in the age group of 31 to 40 years, where females had lower values (Table 4) which was found to be statistically insignificant. This finding is in accordance with a previous studies conducted by Raghdaa et al.[16] This could be because of a lower distance between the mental foramen and the inferior cortex of the mandible owing to skeletal variations between sexes. However, this was in contrast to the study conducted by Hastar et al.[20] It could be attributable to difference in race.

There was a statistically significant difference amongst the categories of MCI between males and females. C1 appearance was predominantly seen in males, C2 was equally seen among the either gender whereas C3 appearance was predominantly seen in females (Table 3). This finding is in agreement with the studies conducted by Knezovic-Zlataric et al.[15] Gulsahi et al.[19] Haster et al.[20] and Govindraju et al.[4] This might be explained by the hormonal differences between males and females resulting in more pronounced and faster bone mass loss in females. Some investigators have revealed the effect of dental status on radiomorphometric indices which was correlating in the present study as well. The mean GI values were lowest in completely edentulous patients followed by partially edentulous and then dentulous patients (Graph 2 Graph 2) which was statistically significant. These findings are in accordance with the studies conducted by Bras et al.[13], Ledgerton et al.[16] and Dutra et al.[22] This could be attributed to the masticatory muscle atrophy with age in edentulous individuals. Similarly, the mean AI values were lowest among completely edentulous patients followed by partially edentulous and then dentulous patients (Graph 2) which was of statistical significance which is in concurrence to the previous studies conducted by Ledgerton et al.[6] and Khayam et al.[26] This could be due to the change in structure and function of masticatory muscles with age in edentulous individuals.

The mean MI values were highest among dentulous patients, followed by partially edentulous and then least in edentulous patients (Table 6), which was statistically significant. This is in concurrence with the previous study conducted by Ledgerton et al.[6] This could be due to remodelling of edentulous mandible and masticatory muscles change in structure and function with age. However, it is in contrast with the study conducted by Dutra et al.[22] which can be attributable to the difference in race, the age group selected and the span of edentulousness.

There was no significant difference in the mean values of PMI among different dental groups. (Graph 2). The findings of our study is in accordance with the studies conducted by Dutra et al.[22], Ledgerton et al.[6] and Raghdaa et al.[16] The reason may be though there is alveolar bone resorption above the foramen, distance from foramen to inferior border remains constant throughout life. Amongst the three categories of MCI, we found C2 and C3 cortical appearances predominantly among partially and completely edentulous patients, whereas C1 in dentulous patients (Table 5) which was of statistical significance. Our study findings were in accordance with the findings of studies conducted by Gulsahi et al.[19] and Nemati et al.[17] This could be due to increase in the prevalence of porosity with the loss of teeth. Although radiomorphometric indices are regarded as an ancillary method for the diagnosis of osteoporosis on panoramic radiographs, they should be a routine procedure in dental examination and dentists may be able to refer postmenopausal women younger than 65 years for bone densitometry on the basis of incidental findings on dental panoramic radiographs. Hence, it is advocated that oral physicians play an unique role in screening of patients for the evaluation of osteopenia /osteoporosis.

5. Source of Funding

None.

6. Conflict of Interest

None.

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Author biography

Sangeetha J, Consultant, Maxillofacial Radiologist

Balaji Pachipulusu, Professor and Head

Poornima Govindraju, Professor

Syeda Muskan Jan, P G Student

Cite this article: Sangeetha J, Pachipulusu B, Govindraju P, Muskan Jan S. Radiomorphometric indices as indicator in osteoporosis-A digital panaromic study. *J Oral Med, Oral Surg, Oral Pathol, Oral Radiol* 2022;8(1):27-34.