

Panoramic Radiograph Analysis of Trabeculae, Cortical, and Radius of Condyle Head in Post Menopausal Women

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Abstract

The case of osteoporosis in Indonesia increases from time to time. One of three post menopausal women stricken with osteoporosis. Osteoporosis decreases bone density causing bone fracture. Method: Research subjects meeting inclusion criteria sign ethically-approved informed consent. Scanning by using Dual Energy X-Ray absorpsimetri (DEXA) and panoramic radiograph are conducted in Rumah Sakit Gigi dan Mulut (RSGM) Universitas Padjadjaran. Preprocessing using background-offset compensation is conducted to improve image quality with average value of the lowest variant. Feature extraction is conducted in micro structure of the trabeculae by using 3 methods (GLCM, histogram, and fraction analysis). Macro analysis is conducted by using 2 methods which are cortical width and resorption of head condyle analysis.

Relationship of T-score = $-7,046 + 10,227$, mean fraction + $0,235$ right cortical (Tka3) + $0,027$ right radius (R3). This model provides determination coefficient value of 32.1%.

Panoramic radiograph could be used in order to determine bone quality based on micro and macro analysis of the condyle structures.

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Introduction

The case of osteoporosis in Indonesia increases from time to time. One of three post menopausal women experienced osteoporosis. Osteoporosis decreased bone density causing bone fracture in post menopausal women due to the low level of estrogen that stimulated proinflammation cytokine IL 1, IL 6, TGF β and RANKL. Osteoblast activity then decreases, while osteoclast activity increases. 17 β -estradiol is the most dominant form of estrogen in women. This estrogen has biological effect by binding estrogen receptor alpha (ER α) and beta (ER β) in the bone and TMJ synovial fluid. Endogenous estrogen affected remodeling process in TMJ by transforming extracellular

matrix within the joint that is formed by collagen and noncollagen protein. Estrogen is one important hormone regulating calcification process that caused systemic bone resorption in trabeculae and cortical. This change causes distortion in internal structure of TMJ and changes bone volume.^{1,3}

The very first change occurred in the spine, the lumbal vertebrae, is correlated with femur trochanter and radius. This change also occurred in peripheral bones such as the maxillae and the mandible.^{5,6} Intraorally, periodontal disease, missing teeth, alveolar ridge resorption, and mandibular cortical thinning may occurred.⁷

Condyle is the largest part of the mandible that actively move and received the largest force in stomatognathic system. Condyle is mandibular part containing many trabeculae and small part of the cortical is hidden and hindered from local effect as if in mandibular body.⁸ Decrease in estrogen level has been proven to cause internal resorption of head condyle trabeculae and affected trabeculae, cortical, and volume of the head condyle.^{9,11} Panoramic radiograph showed

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2D image with density gradation of certain density range and plenty of noise that less represent the real density. Further process is necessary in order to represent actual density range using filter called *preprocessing*.¹²⁻¹⁵ White et al (2011) describes that systemic decrease of bone density occurred at the trabeculae in incivies apical región.¹⁶ Amer et al (2011) shows that fractal anaylis of trabeculae ROI at mandibular mental, angulus and ramus are corellated.¹⁷ Erchang et al (2016) mentioned that ROI of mental, angulus, ramus and condylar cérvix could be used as site of trabeculae análisis.¹⁸ This study is aimed at determining the relationship of bone quality T score with trabeculae density, cortical width, and radius of head condyle using panoramic radiographs.

Materials and methods

Subjects who met the inclusion criteria signed informed consent that had previously approved by ethical committee. Scanning using Dual Energy X-Ray absorpsimetri (DEXA) (Lunar Corporation Madison, Wisconsin, USA) are conducted. Bone quality classification is obtained from T-score. T-score ≥ -1 is normal; $\leq -2,5$ is osteoporosis; and between -1 and $-2,5$ is osteopenia. Afterwards, digital panoramic radiograph is conducted in Rumah Sakit Gigi dan Mulut (RSGM) Universitas Padjadjaran (Picasso Trio, EPX Implra, Korea). Radiograph analysis is conducted by using Intel Pentium Dual Core 2 Ghz, Ram 4GB with Samsung monitor using *tool box freeware scientific image processing dip image* program for image processing.

Preprocessing

Image quality improvement conducted in this study is using background offset compensation, which compensated the whole image with average value of the image with the lowest varians. This is due to the presence of offset on background, which intensity is not equal to zero, as shown in figure 1, 2 (A, B, C, D). However, this image intensity improvement method is not suitable for determining the normal, osteopenia, or osteoporosis objects. Separation of the trabeculae and cortical of the head condyle are separated manually using software and extracted and further processed by treshoulding background into zero and the trabeculae is left in grayscale.

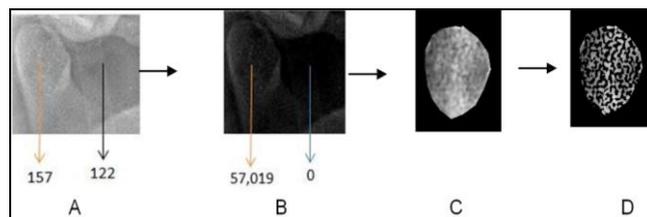


Figure 1,2. A. Original image, B. Gradated after compensation, C. Extraction fitur, D. Gradated trabeculae and zero background.

Feature Extracting

Trabeculae is extracted based on both its micro and macro structure. Micro structure consists of fraction analysis, gray level co-occurrence matrix (GLCM), and histogram.

1. Fraction Analysis

Fraction is the comparison of trabecular intensity value and trabecular area in predetermined ROI

2. Gray Level Co-occurrence Matrix (GLCM) Analysis

Gray Level Co-occurrence Matrix (GLCM) is a texture analysis using statistical approach. This method used gray degree of neighboring relationship in an image.¹¹ Four features of GLCM Contrast showed moment inersia of image matrix element. Contrast measured the number of local variation in an image. Energy, also known as uniformity or angular second moment counted texture uniformity in coupled pixel repetition. The maximum value of energy is one. High energy value occurred when gray degree distribution is in constant or periodic form. Correlation is a linear dependence value of the gray degree in an image. Homogeneity, also known as inverse difference moment, showed homogeneity of an image, which the maximum value when all element in the image is the same. Homogeneity is inversely proportional with contrast. Homogeneity decreased as contrast increased while energy remained constant.

3. Histogram

Histogram is the simplest method. Probability Density Function (PDF) described comparisons of gray value in images. Histogram could be normalized by dividing image value in histogram into its maximum value so that the histogram height is within range of 0-1 without modifying the image maximum intensity value and its histogram range.

Meanwhile, macro structure consists of cortical width and resorption of head condyle analysis.

1. Resorption of Head Condile Analysis

The amount of head condyle resorption in the anterior and posterior is quantified by drawing radius in the head condyle.¹³ The anterior point is established as the most convex part in the anterior not contacted with articular eminentia. A horizontal line is then drawn from the anterior point to the posterior surface until intersecting with posterior cortical, assigned as the posterior point. Line drawn from the anterior point to the posterior point is the midline of the head condyle. The median of the midline is the center of head condyle. A perpendicular line is drawn from the centre to the superior direction, forming 90° until intersected with the cortical, known as the superior point. Afterwards, radial line is drawn by creating 30° angle passing the centre, forming 7 radius of right and left condyles. Measurement is obtained in three groups: normal, osteopenia, and osteoporosis. R is the right head condyle with R1 and R7 representing diameter of head condyles, R2 and R3 posterior surface, R4 superior surface, and R5 and R6 anterior surface.

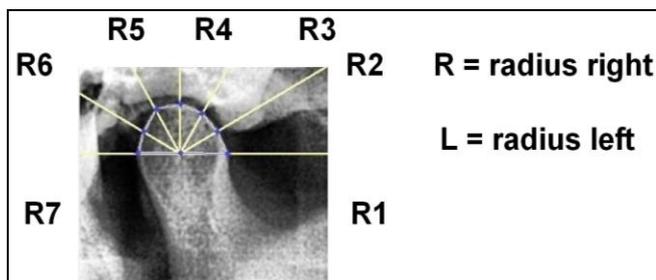


Figure 3. Head Condyle Radius.

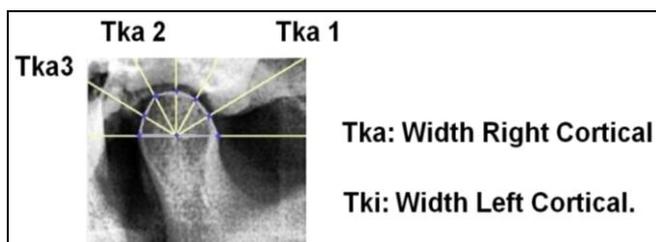


Figure 4. Head condyle cortical width.

2. Cortical Width

Condyle radius lines are used as guidance to find cortical surface location. The most superior line is the superior surface of the head condyle. Line forming 60° is a vertical line in posterior used as posterior surface. The one forming 60° in anterior is the anterior surface. Width measurement starts from endosteal cortical until outer surface of the head condyle on

the anterior, superior, and right anterior (Tka1, Tka2, Tka3), or left anterior (Tki1, Tki2, Tki 3).

Results

Subject characteristics noted in this study are age, height, weight, and body mass index of patients.

No	Description	Group	
		Normal (n=39)	Osteopeni/ Osteoporosis
1	Age (SD)	59,1(5,6)	66,0(8,7)
2	Hight (SD)	157,1(4,1)	152,35(5,1)
3	Weight (SD)	61,8(9,6)	53,75(6,8)
4	Bone Mass Index (SD)	25,0(4,0)	23,16 (2,5)

Table 1. Subject Characteristic.

From the table above, it can be seen that the age of postmenopausal women with osteoporosis is higher than those with normal bone density or osteopenia.

Trabeculae Structure of Two Study Groups

Examination is conducted by using used three methods: GLCM with 4 features (contrast, correlation, energy, homogeneity), histogram with 2 features (maximum histogram, range histogram), and fraction method 1 feature. The comparison of the three group can be seen in Table 2.

Correlation T-score	Coefficien correlation	P value
- Contras	0,233	0,040
- Correlation	0,342	0,020
- Energy	-0,147	0,198
- Homogenitas	-0,107	0,353
- Fraction	0,377	0,014
- max. Histogram	0,253	0,025
- Rank Histogram	-0,060	0,603

Table 2. Correlation of T-score and 7 Features of Trabeculae Structure Analysis. $r_s =$ Correlation Coefficient rank Spearman.

Variable	Coef B	SE(B)	t value	p value
I. Initial mode:	-0,471	322	0,356	0,723
- Contras	18,060	28,091	0,643	0,522
- Correlation	10,252	20,580	0,498	0,620
- Energy	-32,525	53,850	0,604	0,548
- Homogenitas	13,578	13,466	1,007	0,317
- Fraction	-0,114	3,084	0,037	0,971
- Max. Histogram	-5,332	3,627	1,470	0,446
- Rank Histogram				
II. End mode:	15,559	5,505	2,826	0,005
- Fraction	0,382	2,520	2,037	0,045
- Rank histogram				
- Constanta				

Table 3. T-score Relationship with 7 feature of Structure Analysis of head condyle trabeculae according to Multiple Regression Analysis. r (multiple) = 0,544; $p < 0,001$.

According to the correlation counts above, T-score is related to contrasts, correlation, fraction, and histogram. However, the relationship is weak according to Guilford criteria ($r_s < 0,40$). Further analysis using multiple regression relationship between various microstructure and age showed that fraction is positively related to T-score.

Condyle Cortical Width Measurement

Condyle cortical width measurement is conducted on posterior surface (Tka 1), superior surface (Tka 2), anterior surface of right condyle (Tka 3), anterior surface (Tki 1), superior surface (Tki 2) and anterior surface (Tki 3) of left condyle for all three groups. Result of varians test of two groups shows no cortical alteration in condyle surface. Multiple regression analysis showed relationship between condyle cortical width and T-score, with significant result in right cortical (Tka 3).

Variable	Coef B	SE (B)	t value	p value
I. Initial mode				
:	0,073	0,079	0,929	0,356
- Right cortical (Tka1)	0,023	0,016	1,450	0,152
- Right cortical (Tka2)	0,257	0,075	3,445	0,001
- Right cortical (Tka3)	0,040	0,071	0,571	0,570
- Left cortical (Tki1)	-0,035	0,054	0,651	0,517
- Left cortical (Tki2)	-0,045	0,062	0,731	0,467
- Left cortical (Tki2)	0,300	0,629	6,714	<0,001
II. End mode:				
- Right cortical (Tka3)	-4,226			
- Constanta				

Table 4. Relationship between Condyle Cortical Width and T-score According to Multiple Regression Analysis. r^2 multiple (%) = 20,2.

Head Condyle Radius Measurement in Panoramic Radiograph

The measurement shows that head condyle radius is altered if occurred on both right and left condyle. In order to prove which surface plays role on the process, R2 and R3 point are picked to represent the posterior surface of right condyle, R4 represented superior surface, and R5 and R6 represented anterior surface.

T-score relationship with Right Head Condyle Radius According to Multiple Regression Analysis

Multiple regression analysis with multivariable is conducted to obtain which condyle radius related to T-score. The result is positive and significant for R3, while R1 shows negative relationship.

Meanwhile, left head condyle radius showed that L2 had significant relationship with T-score according to multiple regression analysis

($p < 0,05$) but it showed negative relationship. Furthermore, the result of the T-score related regression model: Fraction, right cortical condyle (Tka 3), and radius R3 is shown in table 5.

Variable	Coef B	SE (B)	t value	p value
I. Initial Mode :				
Radius R1	-0,117	0,033	3,583	0,001
Radius R2	0,065	0,032	2,027	0,047
Radius R3	0,021	0,021	1,009	0,317
Radius R4	0,024	0,023	1,023	0,310
Radius R5	-0,006	0,028	-0,219	0,827
Radius R6	-0,019	0,030	-0,633	0,529
Radius R7	0,038	0,022	1,710	0,092
II. End Mode:				
Radius R3	0,052	0,011	4,546	<0,001
Constant	-3,466			

Table 5. Relationship of Radius and T-score according to Multiple Regression Analysis.

r^2 multiple (%) = 25,7 %

Table 6 shows multivariable relationship between fraction, right condyle radius, right condyle cortical (Tka 3) and the T-score with the regression equation model is as follow: T-score = -7,046 + 10,227 mean fraction + 0,235 right cortical (Tka3)+ 0,027 right radius (R3). This model shows determination coefficient of 32.1%.

Variable	Coef B	SE (B)	t value	p value
Fraction	10,227	4,729	2,163	0,034
Radius R3	0,027	0,009	2,862	0,005
Cortical Tka3	0,235	0,067	3,521	0,001
Coonstanta	-7,046	-		

Table 6. Relationship of T-score and trabeculae Fraction, Cortical (Tka-Tki) and Radius (R3) according to Multiple Regression Analysis.

r multiple = 0,566; atau r^2 multiple (%) = 32,1 %.

Discussion

Bone quality analysis with panoramic radiograph is still a controversy. Various methods are developed. However it has not yet given satisfactory analysis. This study proposed an alternative method to analyse bone structure radiograph by using head condyle as Region of Interest (ROI). Head condyle is picked as ROI with the consideration of its anatomy, physiology, and radiograph aspects. Anatomically, head condyle possessed 98.4% of trabeculae and relatively homogenous.¹⁹

Condyle received the largest load in stomatognathi system. Endochondral mechanism of condyle formation makes it sensitive to estrogen decrease compared to mandibular body that is formed via intramembranouse.²⁰⁻²²

Trabecular study using micro-CT in primates mandibles received ovariectomy (OVX) as osteoporosis model showed larger difference of trabeculae in condyle rather than in mandibular body.²³ Alteration of trabeculae occurred in subchondral of head condyle. Trabeculae interconnectivity occurred forming larger marrow space compared to the central part.²⁴ Other factor played role in successful analysis is establishing ROI that followed condyle shape to avoid missing trabeculae.²⁵

The T-score obtained (lumbar spine) is correlated with 7 features (trabecular head of the condyle). It shows that in general the correlation is weak according to Guilford ($r < 0.4$). The best correlation is with the contrast, correlation, and fraction. Fraction feature is independent from ROI so that ROI that follow the condyle shape, alteration on the peripheral of head condyle can be detected. Fraction gives better result than GLCM and Histogram. Fraction method basic count is also conducted in bone density measurement DEXA system as Gold standard.

Bone used as ROI in DEXA is similar to condyle head, containing trabeculae and formed through enchondral method. Lumbar bone received the largest load in human body, while condyle received the largest load in stomatognathic system. A study conducted by White et al (2007) showed correlation between BMD lumbar spine and trabeculae ROI in lower incisor apical and upper right molar apical. Meanwhile, Watanabe et al (2007) shows that radiograph trabeculae is different between female and male.

Sutthard et al. (2011) finds correlation between lumbar DEXA and mandibular DEXA. Density alteration due to estrogen level decrease occurred not only simultaneously on trabeculae but also occurred simultaneously on cortical bone.⁵ The result from three surface of head condyle showed that the best surface is the right anterior surface (Tka3) with $p = 0.001$ (Tabel 7), followed by superior surface (Tka2) with $p = 0.002$. While the left posterior (Tki) showed p value of 0.09.

Cortical bone quality reduction Tka3 in menopausal women occurred due to estrogen level reduction and masticatory load on the right side is generally higher due to patients comfort which stimulated proinflammation cytokine to provoke resorption in cortical endosteal surface as occurred in mental region. This resorption

occurred twice as much the premenopausal, while the bone formation decreased 50% in postmenopausal patients.

A study in rat showed a slower reaction towards cortical bone in those receiving ovariectomy (model osteoporosis), which is 16 weeks post ovariectomy (OVX), while reaction in the trabeculae is observed on the second week following OVX. Taguchi et al (2007) shows that cortical bone in mental region had sensitivity of 89.5% and specificity of 33.9%. Bone density reduction on trabeculae and cortical caused resorption on the head condyle followed by shape alteration. Head condyle shape analysis is used with various analysis, one of them is using radius size.

Loads received by the head condyle surface affects dimensional development especially in the lateral and medial direction.¹² The ability to resist deformation depends on the quality of cortical and trabecular bone, one load factor. Patients with low occlusal force tend to have smaller condyles heads, stimulation of osteoblast function is shown with shorter radius, especially on the lateral side of the corona and posterior in sagittal slices.¹² In radius analysis R3, the posterior surface formed 60° with the horizontal line and correlated with T-score. The posterior surface received the largest load in centric occlusion. Load factor is a factor stimulating cytokine. Right jaw showed a consistent effect towards estrogen reduction in cortical and head condyle radius. Occlusion is a factor played role in condyle growth and development, as written by Aya Kusuru et al (2009). A study conducted to rat receiving ovariectomy also showed general volume reduction.¹¹

Head condyle shape alteration is related to gender hormonal imbalance, face type, age, genetic, malocclusion, and function. A general volume reduction in rats receiving ovariectomy is due to a difference masticatory system from human.^{17,18}

Head condyle shape is correlated to occlusion load in human masticatory system. Direction and occlusal load affected the head condyle development.^{19,20}

The three analysis methods showed multivariable relationship between fraction, right condyle radius, right condyle cortical (Tka 3) and the T-score with the regression equation model

is T-score = $-7,046 + 10,227 \text{ mean fraction} + 0,235 \text{ right cortical (Tka3)} + 0,027 \text{ right radius (R3)}$. This model showed determination coefficient of 32.1%. These analysis methods showed that fraction trabeculae analysis, anterior cortical width, and posterior radius affected the T-score with the largest contribution found in trabeculae analysis followed by right anterior surface cortical width, and radial analysis. It is in line with a study conducted by White et al (2007) that showed larger contribution from the trabeculae compared to the cortical.¹⁵

Conclusions

Trabeculae structure analysis, cortical width, and head condyle radius in panoramic radiograph of postmenopausal women can be used for early osteoporosis detection.

Declaration of Interest

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