The Correlation between Mandible Trabecular Texture Parameter on Panoramic Radiograph with Bone Mass Density

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Abstract
Osteoporosis is a common metabolic disease characterized by low bone mass density. It affects both trabecular and cortical bone. Bone density is an important determinant which plays a vital role in the success of dental implant and denture treatment. A study to determine correlation between mandible trabecular bone texture parameter with bone mass density value has been done. Samples of this study were panoramic radiographs and bone mass density values collected from 70 post-menopausal women. A digital panoramic radiograph and scanning using Dual X-ray Absorptiometry (DEXA) for each site of right femoral neck and lumbar spine were taken from subjects. The aim of this study is to determine the correlation between texture parameter values of mandible trabecular bone with bone mass density values. Texture parameter extraction on region of interest (ROI) of panoramic radiographs has been done using run length method, i.e. short run emphasis (SRE) and long run emphasis (LRE). SRE and LRE was correlated with each subject’s bone mass density (BMD) and T score. Spearman correlation test show significant negative correlation between SRE of right posterior ROI with lumbar spine T-score (p<0.05; -0.280<r<-0.257) and significant positive correlation between LRE of anterior ROI with femoral neck BMD (p<0.05; 0.106<r<0.114). Pearson correlation test show significant negative correlation between LRE of left posterior ROI with femoral neck BMD (r<0.05; -0.276<r<-0.249). Most of trabecular texture parameters in this study show no significant correlation with bone mass density value, therefore several trabecular feature extraction methods need to be developed in order to get best fit mandible density predictor using digital panoramic radiograph.

Keywords: panoramic radiograph, bone mass density, run length, trabecular bone, texture

Introduction
Bone Mass Density
Osteoporosis is a systemic skeletal disease characterized by decrease of bone mass density and alteration of bone architecture, so that bone become fragile and more susceptible to fracture caused by slight or even without trauma. Osteoporotic fracture usually occurs in bone that mostly constructed by trabecular bone, i.e. wrist, spine, and hip [1]. One of the Ministry of Health programs to overcome osteoporosis in Indonesia is case discovery and early detection of osteoporosis on high risk population, which is elderly and postmenopause women. The implementation of this program aims at decrease the morbidity and mortality due to osteoporotic fracture [2]. Early detection of osteoporosis is implemented by examining the bone mass density (BMD). BMD examination in postmenopausal women is an important effort aimed to reduce the prevalence of osteoporosis in Indonesia [3].
Examination of BMD can be done by various methods, such as by using dual energy X-ray absorptiometry (DEXA), ultrasound bone densitometry, and quantitative ultrasound (QCT). DEXA is the gold standard of BMD examination approved by WHO [4]. The results of DEXA examination shows calcium density analysis, but can not show the bone architecture. Whereas bone architecture is an important parameter in bone quality assessment [5]. Alteration on cortical and trabecular bone also can not be observed using DEXA examination. In addition, the cost of DEXA examination is relatively expensive, and the availability of this facility is limited on major hospitals in urban area. Concerning these situation, the use of DEXA examination is insufficient to implement, especially in developing countries [6].

Adult and elderly population often visit dentist to get caries, prosthodontic, and periodontal disease treatment. Their opportunity to visit dentist is greater than opportunity of them to visit hospital in order to get osteoporosis screening [7]. Dental radiography is the most widely used examination in dental practise, that needed to stated diagnosis and treatment planning [8,9]. Previous study has shown that postmenopausal women who experience changes in mandibular bone condition based on dental radiographic examination proved to have risk of osteoporosis, as indicated by their low vertebral BMD [8]. Correlation between trabecular bone texture on dental radiographs with BMD values of DEXA examinations allow dentists to play a vital role in early detection for osteoporosis screening [10,11]. This study was conducted to assess the potentiality of SRE and LRE texture parameters on panoramic radiographs as indicator and predictor of mandible density level by correlate these parameters with bone mass density value assessed by DEXA examinations as gold standards.

Bone is dynamic organ which experience continues remodeling throughout life. Bone remodeling process is modulated by hormonal system and local factors such as gravity, physical activity, and loading. Cells involving in bone remodeling process are group of osteoblasts as bone-forming cells and group of osteoclasts as bone reabsorption cells [12]. Macroscopically, bone is divided into 2 types, i.e. cortical bone (compact bone) and trabecular bone (cancellous bone). Human skeleton consists of 80% cortical bone and 20% trabecular bone. The composition of cortical and trabecular bone are varies depend on their different sites. Cortical bone is dense and solid surrounding the bone marrow, whereas trabecular bone is a honeycomb-like network spread in the bone marrow [13,14].

Bone quality is a manifestation of bone architecture (bone geometry, micro architecture, cortical thickness, and trabecular connectivity) combine with matrix and bone mineralization. It determines bone mineral content of bone density known as bone mineral density (BMD). BMD has a high correlation with fracture risk and allows clinician to determine pharmacological intervention for patients [15].

Low bone quality in osteoporosis patients affect dental treatment planning. In the case of prosthodontic treatment, osteoporosis patients tend to experience alveolar bone resorption caused by inability of jaw bone in weight-bearing, so that they often feel their dental prosthesis unstable and slack. Osteoporosis patients require denture replacement 3 times more often than patients who had normal bone quality [2,16]. In addition, low bone quality in osteoporosis patients leads failure on osseointegration of dental implants [17].

Dental Radiograph
Radiography is an imaging technique to produce a radiographic image. This technique applies X-rays as sources for imaging an objects. In medical field, this technique is commonly used to assist diagnosis, in particular to obtain information about condition of part of the body that can not be observed directly on clinical examination. The results of the radiographic technique
is an visual image on film or monitor known as radiograph with different levels of radiopacity. Level of radiopacity on radiograph is influenced by difference attenuation coefficient ($\mu$) of an object being imaged. When X-rays pass through a material, the amount of X-rays are weakened that depends on X-ray scattering and absorption. Lambert law states the relationship between material thickness and X-ray attenuation coefficient, as expressed in equation (1).

$$\ln \frac{I}{I_0} = -\mu x$$

with $I$ is X-rays intensity passing through certain material (object), $I_0$ is initial intensity of X-rays before passing object, $\mu$ is the linear attenuation coefficient, and $x$ is the thickness of the material. The existence of such interactions leads to various X-ray beam intensity after passing through a material, so that these form difference image radiopacity in radiographs [18].

A perfectly white image (totally radio-opaque) of an object on radiograph represents objects that have high density, so that no X-rays pass through these materials. A totaly radiolucent image on radiograph represents that X-rays transmitted entirely through the object. Gray image on radiograph represent that X-rays passing through the object attenuated on various degrees of impairment based on Lambert’s law as shown by equation (1). The higher X-ray attenuation coefficient, the brighter radiographic image obtained from certain material [19,20].

Material capability on X-ray absorption is depend on the quality of X-ray beam, the character of atoms making up the material, material density, and material thickness. The amount of calcium in bones affect X-rays absorption. Decline on bone mineralization result in decreased of bone calcium following lower X-rays absorption on radiographic procedure, so that changes in bone structure can be observed on radiograph. A radiograph can reflect density, histology, and morphology of the skeletal parts being examined. The principle of detection of osteoporosis on radiograph is increase of radiolucency, changes in bone microstructure description that includes bone perforation, trabecular and cortical bone thinning, which in turn result in changes of bone morphology, leading in changes of bone shape and osteoporotic fractures [21].

DEXA is a radiographic technique which is used as gold standard of BMD measurement for detecting osteoporosis. DEXA scan produce a radiographic images and numerical scan data of bone density (BMD and T score values). It uses X-rays beam on two different level of energy, which is 38 keV and 70 keV [22]. DEXA scans analysis for osteoporosis diagnosis is generally performed on lumbar spine and femoral neck.

Panoramic radiograph also known as orthopantomography (OPG), displays orofacial structures including maxillary and mandibular teeth, and temporomandibular joints. These overall anatomical structures are shown on single image [23]. Panoramic radiograph is widely used for screening jaw bone on prosthodontic treatment to ascertain whether any dental roots, cysts, foreign bodies and neoplasm [24]. In addition to imaging the teeth, panoramic radiograph also portray maxilla and mandible bone, so that observation of jaw bone condition though panoramic radiograph can be used for screening and early detection of osteoporosis as well as a number of other systemic diseases such as diabetes mellitus, hyperparathyroidism, tuberculosis, malignant tumors and metastases [25].
Texture Parameters of Mandible Trabecular Bone
Texture is a function of gray level spatial variation, whereabauts repetition of basic texture elements (Texel). Terms of texture formation is presence of Texel patterns consisting of one or more pixels that appear repeatedly at specified distance and direction intervals that can be predicted or found as characteristic repetition. Texture analysis can be applied as image features extraction method. One example of statistical approach of texture analysis is Grey Level Run Length (GLRL) method [26,27].

Gray level run is a set of points that set in successive (consecutive) and relative (collinear) images that have same gray level value. Length of run is the number of points on the run. Gray level run length matrix (GLRL) can be computed for a run with direction determined from an image. GLRL matrix (i,j) states how many times an image appears with a long run j, the direction of which is determined, composed of points with gray level i. The run length parameters in image analysis include short run emphasis (SRE) and long run emphasis (LRE) [28,29]. Short run emphasis (SRE) is a run length parameter used to emphasize short run, given by equation (2),

\[
SRE = \sum_{i=1}^{M} \sum_{j=1}^{N} p(i,j) j^2
\]

while long run emphasis (LRE) is confirm the long run, given by equation (3),

\[
LRE = \sum_{i=1}^{M} \sum_{j=1}^{N} j^2 p(i,j)
\]

Materials dan Methods
This study was conducted after obtaining ethical clearance from ethics committee of Faculty of Dentistry, Universitas Gadjah Mada. Sample of this study was obtained from previous studies [30], panoramic radiographs and DEXA scan results data of 70 subjects. Subject of this study was Javanese postmenopausal woman who has no metabolic diseases as well as not taking medications that could affect bone metabolism. DEXA scan results data and digital panoramic radiographs obtained from each subject. Panoramic radiograph performed using Panora deluxe dental X-ray unit with the voltage setting, currents strong, and successive exposure time were 70-80 kVp, 12mA, and 12 s. Panoramic radiography processing was done digitally using DBSWin 4.5, Durr Dental. DEXA scans performed using GE Lunar Prodigy Primo DEXA scan system with voltage setting, currents strong, and successive exposure time were 76 kVp; 1.5 mA, and 74 s for femoral neck scanning and 87 s for lumbar spine scanning. DEXA scan results data stated in bone mineral density (BMD) value and T-score value.

Image feature extraction using SRE and LRE texture parameter method performed on region of interest (ROI). ROI in this study were mandible trabecular bone visible on panoramic radiographs. If possible, there were 3 ROI taken from each radiograph: anterior ROI, right posterior ROI, left posterior ROI. ROI were taken using Corel Photopaint X5 software. The anterior ROI size were 128 pixels x 64 pixels while posterior ROI size were 64 pixels x 64 pixels.
Gray level matrix of ROI were transformed into gray level run length matrix (GLRL). Texture parameter extraction done on Matlab 2010a software using SRE and LRE extraction algorithm that has been built on previous study [31].

Result of The Study

After a thorough quality assurance assessment, 55 anterior ROI data obtained in this study, 64 ROI collected from right posterior region, and 63 ROI collected from left posterior region. Texture parameter extraction at 0°, 45°, 90°, and 135° direction were done on each of ROI image. SRE and LRE parameter data in this study being correlated with BMD and T-score data from each subject.

<table>
<thead>
<tr>
<th>BMD Value</th>
<th>Anterior ROI</th>
<th>Right Posterior ROI</th>
<th>Left Posterior ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0°</td>
<td>45°</td>
<td>90°</td>
</tr>
<tr>
<td>Femoral neck BMD r</td>
<td>-0.131</td>
<td>-0.097</td>
<td>-0.107</td>
</tr>
<tr>
<td>p</td>
<td>0.339</td>
<td>0.483</td>
<td>0.435</td>
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<tr>
<td>n</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Femoral neck T-Score r</td>
<td>-0.088</td>
<td>-0.059</td>
<td>-0.071</td>
</tr>
<tr>
<td>p</td>
<td>0.521</td>
<td>0.669</td>
<td>0.604</td>
</tr>
<tr>
<td>n</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Lumbar spine BMD r</td>
<td>-0.083</td>
<td>-0.073</td>
<td>-0.083</td>
</tr>
<tr>
<td>p</td>
<td>0.546</td>
<td>0.599</td>
<td>0.548</td>
</tr>
<tr>
<td>n</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Lumbar spine T-Score r</td>
<td>-0.025</td>
<td>-0.013</td>
<td>-0.021</td>
</tr>
<tr>
<td>p</td>
<td>0.857</td>
<td>0.927</td>
<td>0.879</td>
</tr>
<tr>
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</table>

* significant Spearman correlation test (p<0.05)
TABLE II. CORRELATION TEST RESULT BETWEEN LRE TEXTURE PARAMETER WITH BONE MASS DENSITY VALUE

<table>
<thead>
<tr>
<th>BMD Value</th>
<th>Anterior ROI</th>
<th>Right Posterior ROI</th>
<th>Left Posterior ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral neck BMD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.106*</td>
<td>0.111*</td>
<td>0.114*</td>
</tr>
<tr>
<td>p</td>
<td>0.442</td>
<td>0.420</td>
<td>0.418</td>
</tr>
<tr>
<td>n</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Femoral neck T-Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.115*</td>
<td>0.116*</td>
<td>0.117*</td>
</tr>
<tr>
<td>p</td>
<td>0.405</td>
<td>0.400</td>
<td>0.394</td>
</tr>
<tr>
<td>n</td>
<td>55</td>
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<tr>
<td>Lumbar spine BMD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.058</td>
<td>0.065</td>
<td>0.069</td>
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<tr>
<td>p</td>
<td>0.671</td>
<td>0.637</td>
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<td>55</td>
</tr>
<tr>
<td>Lumbar spine T-Score</td>
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<td></td>
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<tr>
<td>r</td>
<td>0.012</td>
<td>0.019</td>
<td>0.013</td>
</tr>
<tr>
<td>p</td>
<td>0.931</td>
<td>0.893</td>
<td>0.922</td>
</tr>
<tr>
<td>n</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
</tbody>
</table>

* significant Spearman correlation test (p<0.05)
# significant Pearson correlation (p<0.05)

Result of correlation tests in this study (Table I) mostly show no significant correlation between SRE parameters with BMD level, except results of Spearman correlation test between SRE of right posterior ROI with lumbar spine T-score that show significant negative correlation (p<0.05) on weak correlation strength (-0.280<r<-0.257). Increase on SRE parameter of right posterior ROI indicate lower levels of lumbar spine T-score. This condition is characterized by presence of perforation and trabecular network disconnection of mandible, so that a decrease in bone mass density will be accompanied by an increase in trabecular perforation [32]. Result of this study showed conformity with previous studies [33,34].

Table II shows that LRE parameter has no significant correlation with BMD, except with femoral neck BMD. Pearson correlation test also show that femoral neck BMD significantly correlated (p<0.05) with LRE parameters of left posterior ROI on negative weak correlation strength (-0.276<r<-0.249). On the contrary, LRE of anterior ROI show significant (p<0.05) very weak positive correlation with femoral neck BMD (0.106<r<0.114).

Discussion

Osteoporosis conditions is indicated by low trabecular bone connectivity. Decrease of bone density leads thinning of bone cortex accompanied by decrease in number and size of trabecular bone. In addition, osteoporosis patients experience perforation and decreased in trabecular bone connectivity. These indicated by histo-morphometry analysis [12]. Trabecular connectivity is an important parameter that determines bone strength. Trabecular bones are more susceptible to osteoporotic fracture due to its porous structure [35].

The principles of osteoporosis detection on radiograph are increase of radiolucent, changes in bone microstructure description includes formation of trabecular bone perforation, thinning of trabecular and cortical bone, which in turn result in changes in bone morphology, following changes of bone shape and fractures [21]. Changes in texture parameters of trabecular bone on panoramic radiographs may correlate with changes in trabecular connectivity. High or low trabecular connectivity may be indicated by SRE and LRE parameters. In case of properly connected trabeculae, the texture run that occur on its image of certain ROI is long runs pattern, so that LRE parameter value will be higher. Conversely, in case of much unconnected trabeculae, the formed patterns are short runs that shown by high SRE parameter value [33].
Results in this study showed difference correlation between right and left posterior ROI with subject’s BMD, whereas SRE parameters of right posterior ROI significantly correlated on negative direction with T-score of femoral neck, meanwhile LRE of left posterior ROI is correlated significantly on negative direction with BMD of lumbar spine. The results showed that there were different texture pattern in different regions, i.e right posterior ROI texture pattern is different to left posterior ROI texture pattern, and relationship between right and left posterior ROI trabecular texture with BMD levels also widely vary. These results also can be influenced by prior image preprocessing on panoramic radiograph using digital radiography facilities before taking the ROI. Whether similar studies using ROI taken from original image (panoramic radiograph which has not experienced any digital radiographic processing) will provide the same results is not yet known. The use of digital radiographic processing in this study considers that each radiograph used by dentists must have been through the radiographic processing.

There are several methods of texture analysis that can be applied to image as well as run length methods. Application of several parallel texture analysis methods on panoramic radiograph may provide more comprehensive information. Several methods of texture analysis is better to be carried out parallely to quantify the trabecular bone texture, because certain method can provide better results for ROI of particular bone, but the same method may provide different results when applied to ROI derived from other types of bone [34]. Possibility to use original image input (image from panoramic radiograph which has not experienced any radiographic processing) can be considered to be applied in next studies.

**Conclusion**

It can be concluded from result of this study that most of mandible trabecular texture parameters for both SRE and LRE at 0°, 45°, 90°, and 135° on anterior ROI and posterior ROI showed no significant relationship with bone mass density level. A significant correlation obtained in this study for the correlation between SRE parameter of right posterior ROI with T-score lumbar spine and between LRE parameter of left posterior ROI with BMD of femoral neck. These study show that image characteristics extraction using run length method has various results, which may be affected by variations of trabecular pattern based on the location of trabecular bone image taken as ROI, and also may be affected by image preprocessing which is done to the radiograph. Thus, further study is required to obtain the appropriate method to be applied as predictor of mandible density using dental radiographs.

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**References**


