A NARRATIVE REVIEW OF MORPHOLOGY OF CANCELLOUS BONE AT DIFFERENT HUMAN ANATOMY-METHODS AND PARAMETERS

Morphology of cancellous bone has been studied for years, with researchers always seeking accurate methods to assess the parameters. They also study the importance of cancellous morphology in itself. Despite the amount of previous research, there are currently no reviews on the morphology at different anatomy. This paper evaluate the methods and parameters of cancellous bone morphology at different human anatomy.
• Bone consists of two main components, which is cortical and cancellous bone.
• Cortical is an outer dense layer of the bone, and the spongy internal part is known as cancellous or trabecular bone.
• Since the early 1970’s, morphology of cancellous bone has been studied with researchers always looking for accurate methods to assess the parameters or indices.
• They had also studied the importance of cancellous morphology.

(Trabecular Bone)
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The morphology parameters, also known as structural indices, that have been widely used in studies.

Throughout the years many studies have been conducted investigating the morphology of human cancellous bone.

Several methods of assessing the cancellous morphology have been proposed and used by researchers.

In addition, numerous papers published on the morphology parameters have attempted to correlate the morphological data with the mechanical properties of cancellous bone.

It is known that cancellous bone has different morphology properties at different anatomy [1-4] which will be mentioned in this paper.
There are many techniques used to obtain the morphological data, such as imaging technique, manual calculation, ultrasound, machining, etc.

Several imaging techniques have been performed to calculate the cancellous bone parameters in construction of cancellous bone in three dimensional (3D) images.

The most popular is an imaging technique widely used by researchers in order to study the cancellous morphology, known as micro-computed tomography (μCT) [5-14].

Other imaging techniques used to determine the morphology parameters are Magnetic Resonance Imaging (MRI) and flat-panel volume computed-tomography (fp-VCT).

Whilst many use computational methods in identifying the morphology parameters, there are several researchers using manual calculation such as algorithms and the Archimedes' principle.

The new methods proposed in the study of morphology parameters are ultrasound and computer numerical controlled (CNC) milling machine.
• μCT scan imaging is non-destructive, fast and a very accurate procedure for determining the morphology parameters [15].

• In addition, that there are spatial drawbacks for applying the μCT based analysis to large specimens because it would require large scanning and reconstruction of voxel size [8].

• Also, the values from the μCT scan were overestimated for high density specimens and underestimated for lower density specimens [10].

• Thus, the value needs to be corrected to true values obtained from Archimedes’ principle, since many researchers used Archimedes’ principle to calculate bone volume fraction [16-18].
• It is point out that μCT scans are much more accurate compared to MRI [19].
• Nevertheless, it is suggest that the MRI would be suitable for in vivo bone measurements in humans [1].
• Another interesting imaging technique introduced is using the fp-VCT to analyse cancellous bone structure [20].
• The fp-VCT is an acceptable technique to assess the cancellous structure with low inter-scan, intra-reader and inter-reader variability.
• Unlike the μCT scan, the fp-VCT can conduct in vivo imaging and visualise the cancellous structure directly.
Further, ultrasound is also one of the methods used by researchers to evaluate the cancellous bone parameters.

The direction of ultrasound measurement depends on the ability of ultrasound to reflect the cancellous independently of density [21].

Moreover, the apparent density was the major determinant of ultrasonic properties in the transverse axes.

Another method used by researchers to measure the morphology of cancellous bone is by using the computer numerical controlled (CNC) milling machine [23, 24].

CNC milling technique is an accurate method for analysing the cancellous bone architecture [23].

In this technique, the bone specimen will serially being removed layer by layer using the CNC milling machine, and the image of the exposed cross section will be captured by low magnification digital camera.

From Table 1, it can be seen that many researchers are interested in studying the cancellous bone morphology at different anatomies. The results show that the morphology parameters between anatomies varies.
### Table 1: Cancellous Parameters for Human from Various Research Study

<table>
<thead>
<tr>
<th>Authors</th>
<th>Anatomical Site</th>
<th>BV/TV [%]</th>
<th>Thickness</th>
<th>Bone Density [g/cm³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Majumdar et al. [1]</td>
<td>Calcaneus</td>
<td>app 0.26 (0.13)</td>
<td>app 0.17 (0.05)</td>
<td>app 1.46 (0.34)</td>
</tr>
<tr>
<td></td>
<td>Distal femur</td>
<td>app 0.27 (0.15)</td>
<td>app 0.20 (0.07)</td>
<td>app 1.47 (0.37)</td>
</tr>
<tr>
<td></td>
<td>Proximal femur</td>
<td>app 0.27 (0.15)</td>
<td>app 0.19 (0.04)</td>
<td>app 1.29 (0.39)</td>
</tr>
<tr>
<td></td>
<td>Vertebral</td>
<td>app 0.17 (0.08)</td>
<td>app 0.17 (0.02)</td>
<td>app 0.95 (0.37)</td>
</tr>
<tr>
<td>Elise F. Morgan [4]</td>
<td>Greater Trochanter</td>
<td>-</td>
<td>1.137 (0.013)'</td>
<td>1.022 (0.165)'</td>
</tr>
<tr>
<td></td>
<td>Proximal Tibia</td>
<td>-</td>
<td>0.135 (0.006)</td>
<td>1.184 (0.15)</td>
</tr>
<tr>
<td></td>
<td>Femoral Neck</td>
<td>-</td>
<td>0.196 (0.03)</td>
<td>1.598 (0.186)</td>
</tr>
<tr>
<td>P. H. F. Nicholson et al. [21]</td>
<td>Lumbar Vertebral</td>
<td>0.0817 (0.0251)</td>
<td>0.0639 (0.0114)</td>
<td>1.266 (0.233)</td>
</tr>
<tr>
<td>N. Portero-Muzy et al. [25]</td>
<td>Right Calcaneus</td>
<td>11.4 (3.5)</td>
<td>0.118 (0.0211)</td>
<td>0.96 (0.18)</td>
</tr>
<tr>
<td>T. Hildebrand et al. [26]</td>
<td>Iliac Crest (ICF),</td>
<td>0.156 (0.054)</td>
<td>0.151 (0.027)</td>
<td>1.402 (0.265)</td>
</tr>
<tr>
<td></td>
<td>Second Lumbar Spine (LS2B)</td>
<td>0.083 (0.024)</td>
<td>0.122 (0.019)</td>
<td>1.278 (0.201)</td>
</tr>
<tr>
<td></td>
<td>Fourth Lumbar Spine (LS4A)</td>
<td>0.087 (0.033)</td>
<td>0.139 (0.028)</td>
<td>1.161 (0.181)</td>
</tr>
<tr>
<td></td>
<td>Femoral Head (FRA),</td>
<td>0.261 (0.078)</td>
<td>0.194 (0.033)</td>
<td>1.595 (0.292)</td>
</tr>
<tr>
<td></td>
<td>Calcaneal Core (CAB)</td>
<td>0.172 (0.035)</td>
<td>0.129 (0.018)</td>
<td>1.462 (0.202)</td>
</tr>
<tr>
<td>J. Y. Rho et al. [27]</td>
<td>Human Femoral</td>
<td>0.26 (0.07)</td>
<td>0.12 (0.03)</td>
<td>2.11 (0.26)</td>
</tr>
<tr>
<td></td>
<td>Human Lumbar</td>
<td>0.08 (0.03)</td>
<td>0.06 (0.02)</td>
<td>1.30 (0.23)</td>
</tr>
<tr>
<td></td>
<td>Lumbar 1</td>
<td>0.1477 (0.0439)</td>
<td>0.2333 (0.0217)</td>
<td>0.6272 (0.1509)</td>
</tr>
</tbody>
</table>
• The morphology is important in analysing the bone quality characterisation in order to accurately predict bone quality.
• It has been commonly accepted that morphology studies can contribute to the mechanical properties of the cancellous bone.
• This review shows that morphology parameters vary at different anatomy sites. There are many methods proposed by researchers which have both advantages and disadvantages.
• With availability of methodologies and technology, the researchers are able to identify which methods are best suited to their application.
• Furthermore, the application of morphology studies can be applied to forensic studies.
• In the future, this imaging technology could provide accurate predictions of morphology at affordable prices.
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