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## EVALUATION OF THE CORTICAL BONE THICKNESS IN LUMBAR VERTEBRA USING CT AND RP EXPERIMENTAL TECHNIQUES

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### ABSTRACT

The main objective of this paper was to assess the cortical bone thickness of human lumbar vertebra, through Computed Tomography (CT) images by using radiology reading software (iQ-VIEW), image processing software (ScanIP) and the rapid prototyping (RP) experimental methodology. The study here presented focus sixteen postmenopausal patients from the North of Portugal, with age between 50 and 85 years, collected from May to June 2011. All clinical data were obtained in a Medical Centre of Radiology and Imaging, in Porto. Results regarding the cortical bone thickness and the biomechanical resistance of human lumbar vertebra are presented in this work. The acquirement of accurate values, concerning cortical bone thickness, could improve the prediction of fracture risk.

**Keywords:** bone, rapid prototyping, lumbar vertebrae

### INTRODUCTION

Bone Mass Density (BMD) is a good predictor of fractures, particularly at the spine (Beaupied, 2007). Nonetheless, fracture risk assessment based only on trabecular BMD, disregards other features of bone's biomechanical competence. Spinal BMD is commonly assessed by dual energy X-ray densitometry (DEXA), however this result on reflects the total bone mass of individual vertebrae expressed as an areal density  $g/cm^2$  (Flynn, 1993). Age-related physical changes include decreased cortical thickness, one of several structural changes that translate to alterations in bone's strength and risk for fracture (Epstein S, 2006). Thus, consideration of cortical bone thickness clearly improves the prediction of fracture risk. CT is the most common technique used for examination in medicine, because it permits the visualization of soft tissues and bone structures (Cavalcanti, 2001). Actually, CT images can be processed using specific software that allows analysing the bone geometry and creating 3D templates of anatomical specimens. RP is the automatic construction of physical 3D objects using solid freeform fabrication (Tukuru et al, 2008). This method was originally introduced in industry to improve design and reduce product development time, now being applied to medicine, allowing an immediate and intuitive understanding of the most complex 3D geometry (McGurk, 1997). There are currently a number of RP technologies, based on special sintering, layering or deposition methods, (Tukuru et al, 2008). The technique of 3D printing creates models by spraying liquid through ink-jet printer on to a layer of metallic or ceramic powder, thus creating a solid thin slice and subsequent slices generating the final model, (Tukuru et al, 2008). These types of techniques are non-invasive and/or non-destructive and can provide structural information about bone. The spatial arrangement of bone at the macroscopic and microscopic levels is thought to provide additional, independent in

formation to help to better predict fracture risk and assess response to any intervention (Genant et al, 2008).

## METHODOLOGY AND MATERIALS

The current study was based on spine CT images and previous results from BMD exams. Women were previous classified according to BMD score, as a normal, osteopenic and osteoporotic. The distribution of participants according to the age range and BMD score is presented in Table 1, with the identification of the pathology in lumbar vertebra L4.

Table 1 – BMD score in lumbar vertebra L4.

	Women's age (years) n (%)		
	50-59	60-69	>70
Normal	2 (40.0)	1 (11.0)	1 (50.0)
Osteopenic	2 (40.0)	5 (56.0)	0 (0.0)
Osteoporotic	1 (20.0)	3 (33.0)	1 (50.0)

The mean and standard deviations (SD) age of the patients was 62.3 (8.2) years old with a body mass index (BMI) of 28.3 (4.3) kg/m<sup>2</sup>. The mean value of BMD for lumbar vertebra L4 in all patients is equal to 0.98g/cm<sup>2</sup>, as represented in Fig. 1.

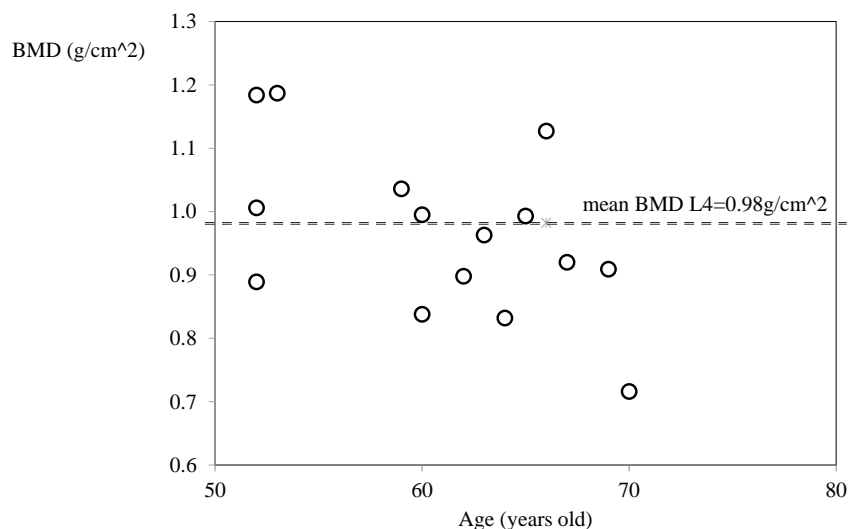


Fig. 1 BMD versus age of the patients.

The cortical thickness in the body of the lumbar vertebra was evaluated using two methodologies, digital and experimental.

## DIGITAL METHODOLOGY

With digital methodology, the cortical thickness was measured in different layers, through 5 anatomical positions, using radiology reading software (iQ-VIEW). The 3D visualization of the medical images was obtained using InVesalius 3.0 (FREE Beta2 Software, C.T.I. Renato Archer).

Fig. 2 represents a CT and all different anatomical positions considered for measure the cortical thickness in this study.

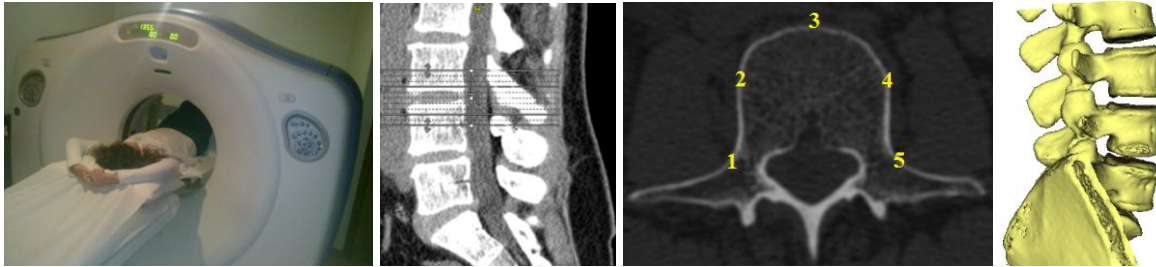


Fig. 2 CT obtained in medical clinical to measure the cortical lumbar vertebra (L2-L5).

## EXPERIMENTAL METHODOLOGY

The second methodology used is an experimental technique (RP) for measure the cortical thickness in different body of lumbar vertebra. RP methodology could be applied to medicine using CT images. These images are available in DICOM format (Digital Imaging and Communications in Medicine), a typical format used in medical clinical to evaluate the type of patient pathologies. Using a computerized system, DICOM images could be combined to give a 3D model through a Computer Aided Design (CAD) format. CAD model is exported in a native format, as Stereolithography (STL) data. This format is supported by many programs used in RP and Computer Aided Manufacturing (CAM).

Figure 3 represents a flowchart with the main tasks to convert DICOM in STL format.

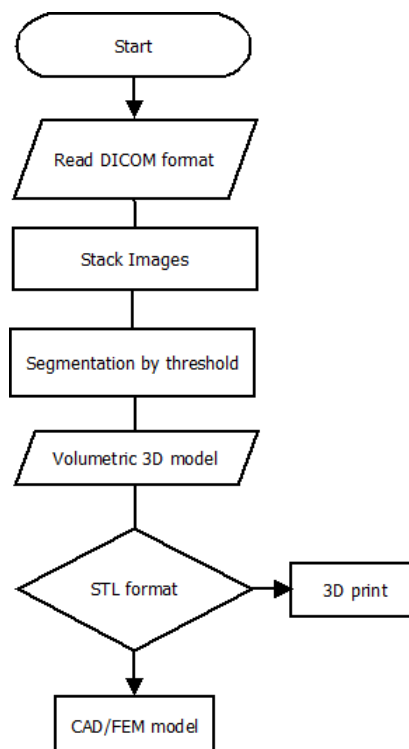


Fig. 3 Flowchart with steps to convert DICOM in STL format.

These techniques enable the construction of the 3D model useful in experimental analysis. In this work the ScanIp image processing software was used, as represented in Fig. 4. This software provides an extensive selection of image processing and regions of interest from any volumetric 3D data.

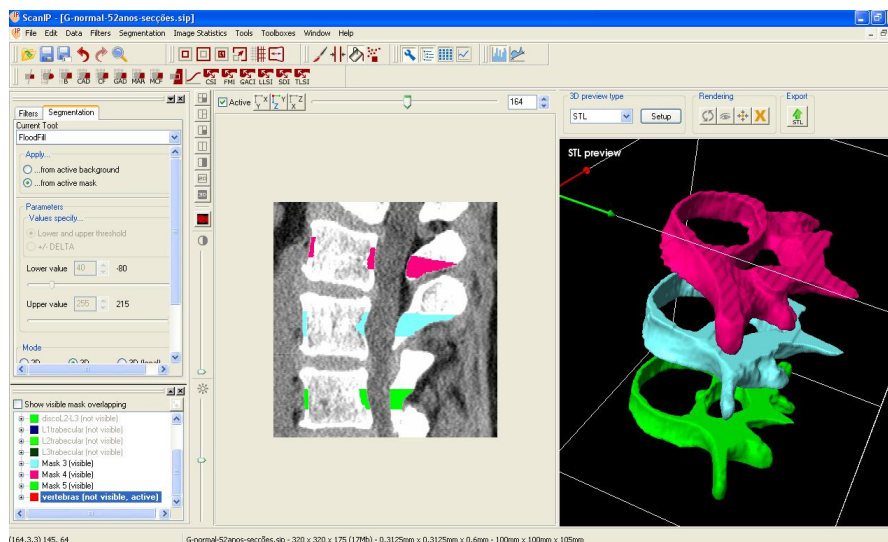


Fig. 4 CAD model of the lumbar vertebra segments L4-L2 (F52).

In this work, each segment of lumbar vertebra was produced with a monochromatic 3D ZPrinter from digital data using RP technology. Using this technique, the cortical bone thickness will be measured and compared with the values previous obtained. Only six lumbar vertebrae L4 from all patients were selected. The collected data cover two patients, from each different pathology.

Fig. 5 shows the experimental RP procedure used for measuring some different lumbar vertebra slices of a female patient with 52 years (F52).

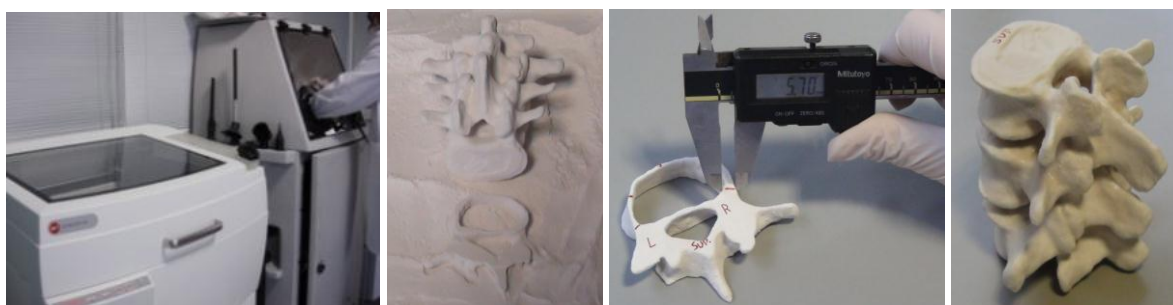


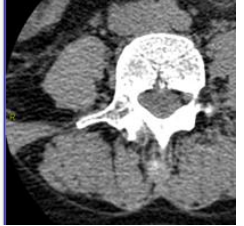

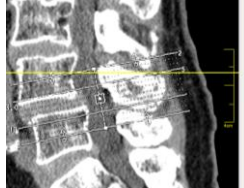





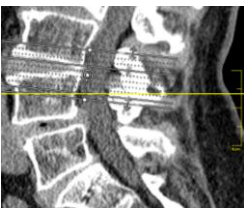


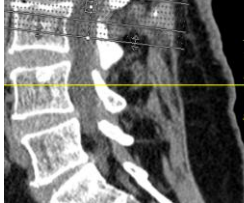


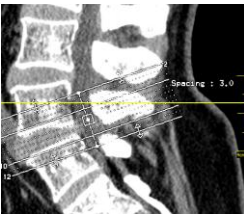



Fig. 5 ZPrinter and RP experimental methodology used for measure lumbar vertebra segments L4 (F52).

## RESULTS AND CONCLUSIONS

Values of cortical thickness in L4 for six different patients are shown in Table 2 using RP procedure and iQ-VIEW digital measuring. All values were obtained from a mean calculation in the neighbour slices. Simultaneously, the mean of BMD for each patient was presented.

Table 2 – Cortical thickness measuring with two different techniques.

Cortical thickness measuring in L4, [mm]						RP	iQ-VIEW	
F52n (normal)								
Position	1	2	3	4	5			
RP	3.93	2.15	1.88	2.30	4.25			
iQ	3.92	2.21	1.90	2.25	4.19	Mean of BMD=1.18g/cm <sup>2</sup>		
F83n (normal)								
Position	1	2	3	4	5			
RP	2.85	1.85	1.70	2.35	3.15			
iQ	2.80	1.80	1.60	2.40	3.10	Mean of BMD=1.23g/cm <sup>2</sup>		
F64p (osteopenic)								
Position	1	2	3	4	5			
RP	3.55	1.65	1.25	2.00	5.35			
iQ	3.49	1.56	1.25	2.00	5.46	Mean of BMD=0.83g/cm <sup>2</sup>		
F66p (osteopenic)								
Position	1	2	3	4	5			
RP	3.30	2.10	1.75	2.20	3.60			
iQ	3.26	2.00	1.80	2.25	3.64	Mean of BMD=1.13g/cm <sup>2</sup>		
F70o (osteoporosis)								
Position	1	2	3	4	5			
RP	3.25	1.70	1.30	2.00	5.20			
iQ	3.26	1.77	1.25	2.00	5.05	Mean of BMD=0.72g/cm <sup>2</sup>		
F62o (osteoporosis)								
Position	1	2	3	4	5			
RP	3.55	2.15	1.70	2.45	3.65			
iQ	3.60	2.10	1.60	2.40	3.70	Mean of BMD=0.89g/cm <sup>2</sup>		

The use of CT and RP experimental methodologies gave results quite similar regarding the measured cortical thickness, as represented in table 2 or in the Fig. 6. The cortical thickness decreases in the vertebra L4 with osteoporosis. And the normal vertebra presents higher values of cortical thickness. The BMD values decrease with patient age. Smaller values of thickness were found in the position 3 and higher values were measured in the position 5. Also, according iQ-VIEW, the images from osteoporotic patients present a higher lumbar curvature and a thinly cortical bone.

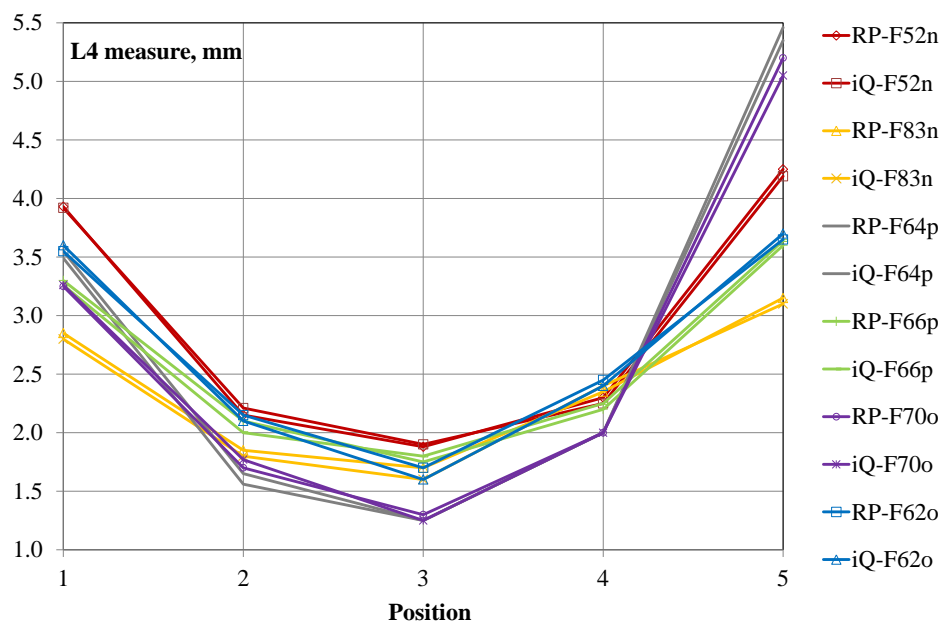


Fig. 6 L4 measure for all lumbar vertebrae.

Further analysis will provide this information for all sixteen patients, according the previous DEXA diagnosis of osteopenia or osteoporosis. The use of this information could be useful for complementary diagnostic and clinical treatment planning.

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