Original Article

3D SCANNER AND CAD SOFTWARE APPLICATION IN ANIMAL OSTEOMETRY

APLICAÇÃO DO SCANNER 3D E SOFTWARE CAD EM OSTEOMETRIA ANIMAL

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ABSTRACT: The research of the structure of wild animal anatomy is important and can be used to help with species conservation. The objective of this study was to describe the methodology used to digitally scan bone structure of these animals. Thus, all the steps used to perform the scapula scan of an adult specimen of *Cerdocyon thous* was thoroughly described as a way to illustrate the process that is being developed for the study of skeletons. A scapula was chosen to be digitalized because it is a plane bone of the forelimb and is fundamental to unite the limb to the animal's trunk. Advanced morphometric analysis of osteometry was depicted by creating three-dimensional physical models of bone structures utilizing the 3D Model Uniscan, a computational engineering tool that enables accurate results of the bone structure in the model. The equipment works by reading the points of the piece through the reflection of the laser in the lenses and sensors. These points are computed and positioned by VXelements software which is responsible for the capture of the targets, which in turn, generates a triangular surface mesh in real time which reproduces the 3D surface of the bone instantaneously. Finally, these sets of acquired data can be converted into various file formats compatible with CAD software, such as Solidworks which allows the dimensions to be extracted at different points of the object. This way of characterization and modeling allows the analysis of the structures' dimensions to be more informative and real. The obtained results of such analyzes have application in the studies of ecomorphology and evolution.

KEYWORDS: Wild carnivores. *Cerdocyon thous*. Morphometric analysis.

INTRODUCTION

The Carnivora order is at the top of the nature food chain and plays a key role in balancing ecosystems (EWER, 1973). In Brazil, there are 29 species of wild carnivores and, despite great ecological importance, the majority of them are being threatened (CHEIDA et al., 2011). This anthropic pressure is caused by sport hunting, animal trafficking, ill-treamen by farmers and especially the destruction of their natural habitat due to agricultural activity (MIRANDA, 2003).

A detailed animal anatomy provides knowledge that allows us to understand how they interact in the wild or in captivity and can also be used for species preservation (MOURA et al., 2007). 3D technology is beginning to be introduced by researchers as a tool used to obtain accurate information about the anatomy of current and extinct species (MARTÍN et al., 2015).

Details provided by scans can be observed on the software evolution and its computer models, added to continuous challenges posed by biological science are providing an outstanding opportunity for the development and improvement of analysis and study techniques of animal morphology. New

and sophisticated techniques applied to three-dimensional analysis and the models helps provide more information to the knowledge base. The equipment scans the object and collects data from its surface building three-dimensional models. Generated files can be saved in many different formats. These formats are compatible to CAD software which imports and processes data into a digital image. This technology has a significant variety of details which includes several magnitudes of object scale according to Bindean and Stoian (2013) and Straub and Kerlin (2014). In order to facilitate the acquisition of this technology for economically challenged users, many authors are working on projects with the purpose of developing inexpensive 3D scanner applications using different methodologies and technologies (REYES et al., 2013).

The operating principle of the equipment is based on two mechanisms: laser scanning and reflective target recognition system that allows the instrument to position itself in relation to the object that is being researched Achille et al. (2007). The *3D scanner* operates by reading points on a targeted piece by laser reflection in lenses and sensors. These points are computed and positioned by

software responsible for points abstraction, forming a three-dimensional model for analysis (JATOBA; BUENO, 2011)[1]. According to Cooper (2009), physical analysis of biological systems when performed manually and in large numbers, is time consuming and exhausting. This study aimed to report the use of three-dimensional technology for the analysis of the scapula bone structure in an adult male species *Cerdocyon thous* (crab-eating fox)*. S*capula analysis, as well as analyses of other bones of the forelimb provides important information on the movements performed during hunting (MARTÍN et al., 2015). The same methodology will be applied to other bones to characterize their skeletal proportions to help the understand movement and hunting motion performed by wild carnivores.

MATERIAL AND METHODS

3D laser scanning of the scapula was performed on an adult male *Cerdocyon thous,* collected dead on RS-287 highway near São Vicente do Sul-RS, authorized by IBAMA / SISBIO No 33667. The scapula was selected to the scan due to bone design and its importance of structural shape in the specimen torso. This digitized prototype serves as a model for others that are being scanned. The purpose is to develop measurements of various bone points of functional interest and conformity assessment in the three-dimensional model. Once the scan is completed, a digital database is available. The piece was prepared as follows: First, the left scapula was dismantled from the body and then adjacent soft tissue was scraped. Afterwards, the scapula was boiled for 30 minutes. Finally, another scraping was performed to remove all remaining fibrous tissues.

For the study, it was necessary to connect the 3D scanner equipment to a computer where the 3D *scanner software* was previously installed. The piece to be scanned was placed inside a black painted box (this surface color would not reflect the laser beam back), see Figure 1A and check "Detail 1" in Figure 1B. The object was held up by a cast iron clamp as illustrated in "Detail 2" in Figure 1B. The clamp was used to support the bone without any to the various angles of faces of the object during the scanning process. The bone was also cleaned with a dry cloth to avoid the presence of dust and any other particles that could cause problems to the scanned material. "Detail "4" in Figure 1B shows the scapula positioned on the clamp and ready to be scanned. To facilitate the operation of the equipment a laser s*canner* Model 3D laptop UNISCAN with reflective targets with small circles of 6mm in diameter was used along the sides of the box's dark surfaces, as shown in "Detail 3" in Figure 1B. These targets reflectors serve to position the points during the scanning process to calculate its position in the coordinate system (X, Y, Z). Figure 1C shows how the scanning process is performed by the 3D scanner machine. Figure 1 shows images of the process before and during the scanning process.

[1]JATOBÁ, Silva e BUENO, Fernando. Planejamento do processo de medição utilizando um scanner 3D. 2011. 79 f. Projeto de graduação (Relatório submetido como requisito parcial para obtenção do grau de Engenheiro Mecânico) - Faculdade de Tecnologia, Departamento de Engenharia Mecânica, Universidade de Brasília, Brasília, 2011.
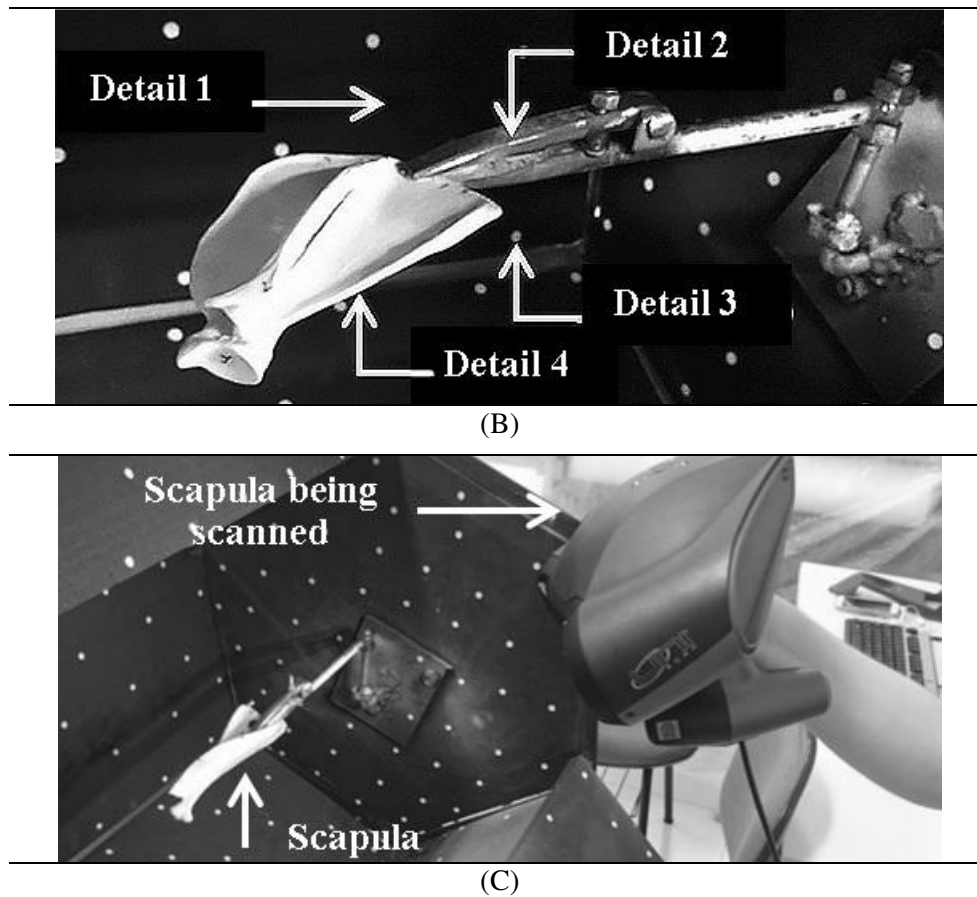

(A)

(B)

(C)
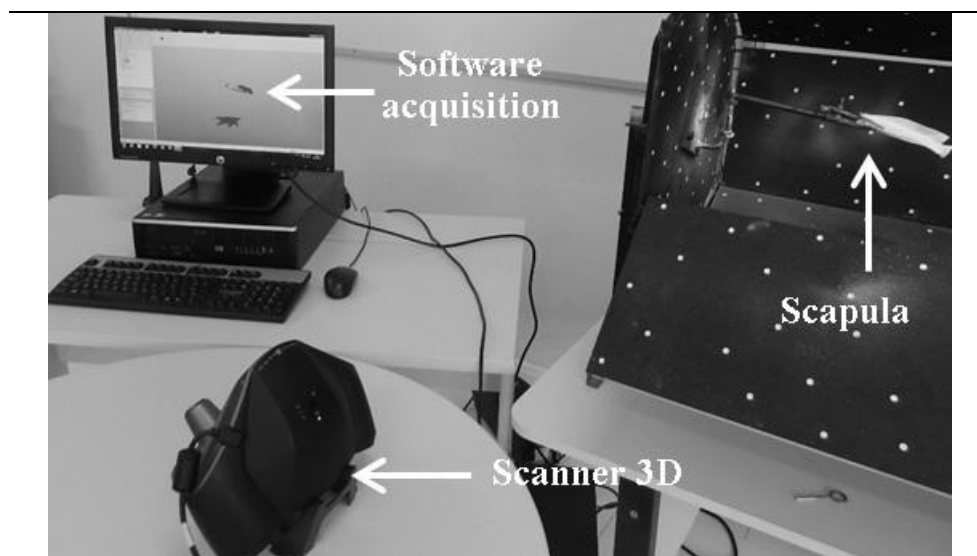
Figure 1. Scapula preparation for image scanning process.

The next step shows the scanning process of the object. The tool is able to recognize the target's patterns acquire points of the cloud shape. The, 3D *scanner software* connected to the VXelements machine generates a triangular surface mesh in real time which produces a 3D surface instantaneously. This makes it possible to check for the validity of the results during use, preventing errors during scanning. The sets of acquired data can be converted into various file formats compatible with most CAD data / CAM modeling and manipulation *software* such as Geomagic, Polyworks, Rapidform and Solidworks (ACHILLE et al., 2007).

Because it is a small object, the bone was scanned using 0.5 mm resolution as shown in Figure 2. The data was converted to a file with 281 target points recognized through the equipment's lens and an estimated 86,891 faces was obtained. The generated file format "Point cloud", was saved with a cloud point size of 34,558. This started the process of the images in the CAD software, Solidworks, a design tool that allows 3D data to be utilized as points and mesh clouds to be imported, analyzed, manipulated, modified, and finally, converted into solid or 3D surfaces.

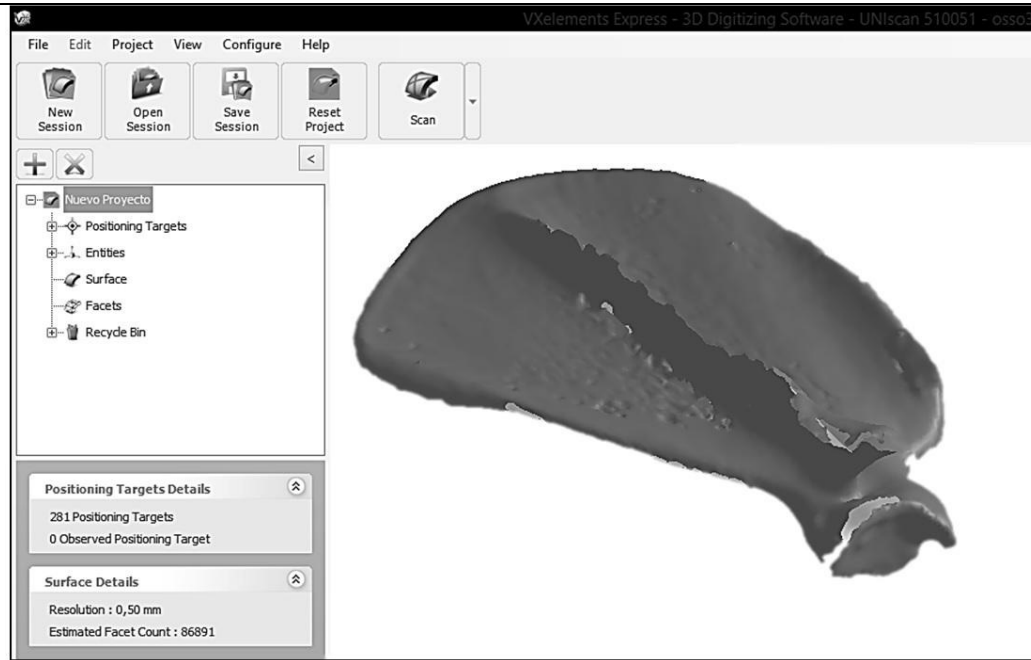However, it was not required to convert the files into solids for this study.

Figure 2. Image of the bone structure in the digital imaging VXelements *software*

By importing the scapula bone image through the solidworks software, an image of the object was obtained, as shown in Figure 3.
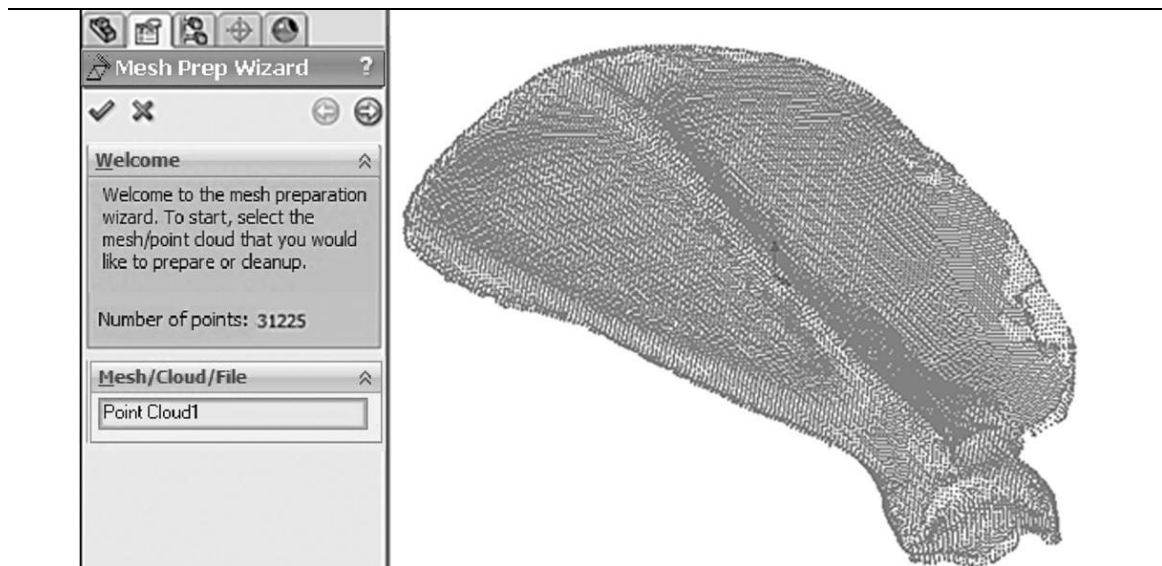

Figure 3. The scapula image as a cloud of points in solidworks software.

Utilizing the software, one can fix the object's mesh with noise correction. The noises are points distributed outside the boundaries of the object which end up generating a sequence of random errors. Removing the noise helps improve image quality. It is also possible to measure the cloud point. However, the goal for this study was to measure the object that was scanned using the solidworks software, by creating a coordinate axis and defining the zero point thereof. The definition of the Y-axis coordinate starts at the axis defined by a continuous straight line as illustrated in Figure 4A. The datum represented in Figure 4A coordinates the fixed axis to the end point of the straight line X, as shown in Figure 4A, 4B, and 4C. It is noted that the X axis is defined by a straight line that goes from *midpoint* Y to a point on the edge of the scapula and dotted in Figure 4B called the zero point. With the determination of the two axes, X and Y, a Z axis can be set that forms a 90 degree angle with the remaining X and Y lines, as shown in the image in Figure 4C. From the point of

origin generated by the axes meeting, points of interest in anatomical detail can be analyzed.

Such points, which stand out in bone relief represent local exchanges fastening tendons of the muscles.
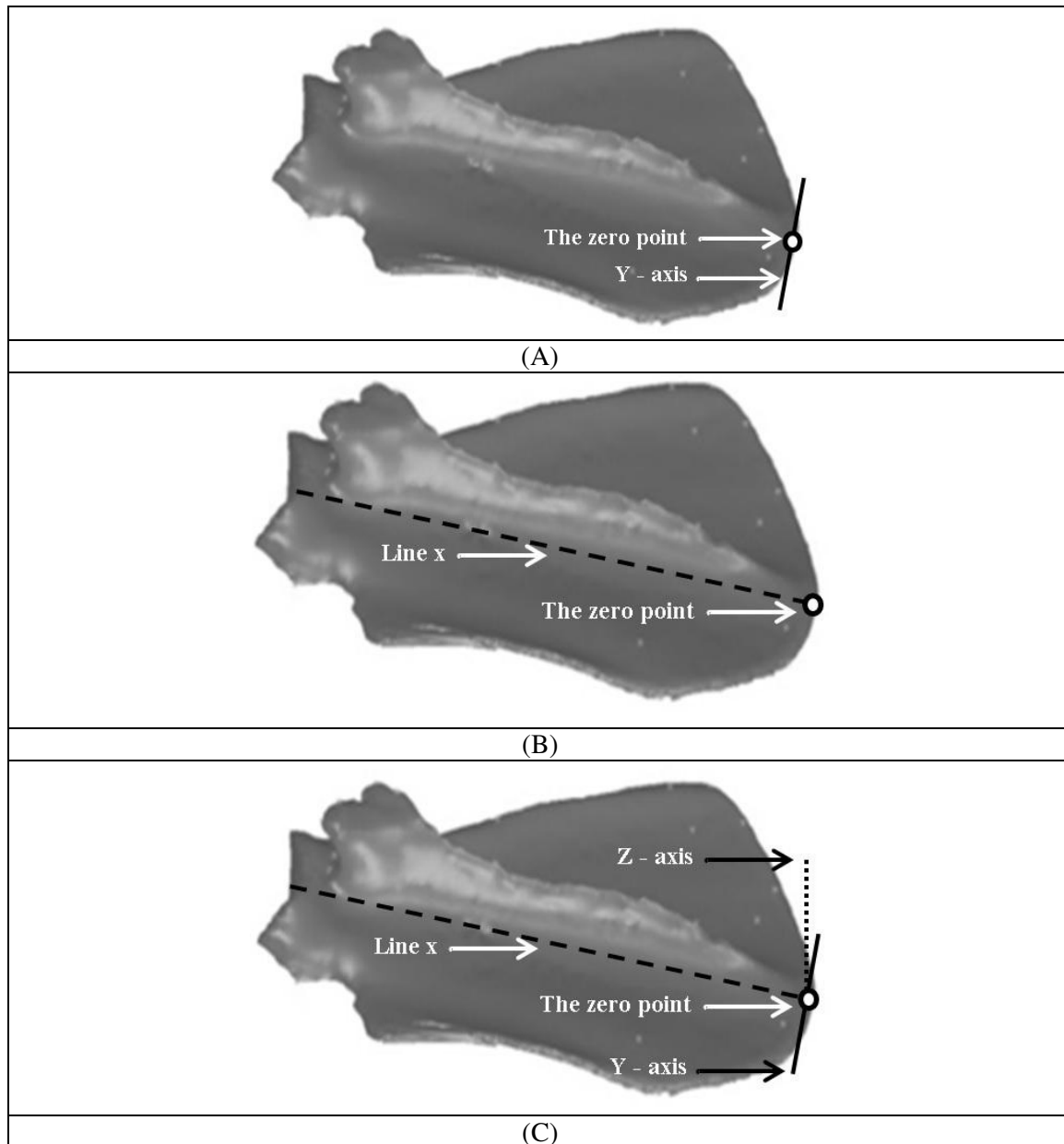

(A)

(B)

(C)

Figure 4. The object measurement steps.

RESULTS AND DISCUSSION

The research analyzed two kinds of important information in order to give anatomical details of the bone studied. First was the accurate characterization of the distance between points of attachment of the tendons in general protrusions which stand out in the shape of the bone surface. These values provided a three-dimensional proportion that tends to repeat itself in average individuals of the same species. It is expected that the scapula of a regular-sized adult *Cerdocyon*

thous in a given population have similar proportions regardless of the absolute distance between protrusions. Thus, it can be assumed that the data set obtained characterizes the proportional dimensions of that bone for that particular species in a given population. By creating a database, it is possible to settle doubts on bone fragments found on archaeological sites or even to document the presence of certain species in a locality. The use of a computerized method can eliminate the effect of subjectivity to clarify to which species the bone belongs to. Alternatively, Shahar and Milgrim

(2005) used an electronic coordinating measurement device to determine the coordinate points of muscle attachments and bony landmarks in the thoracic limb of domestic dogs.
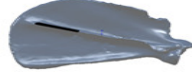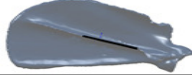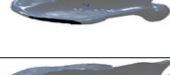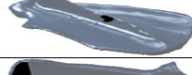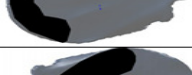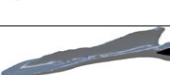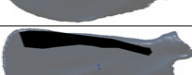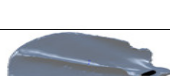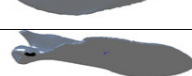
The second type of analysis in regards to the determination of the area occupied by muscle on the bone surface examined, if performed by manual methods, would show to be inaccurate. Table 1 shows the images of the points "1" to "17", the attached regions of the scapula's muscles in the *Cerdocyon thous*. For example, the area of point 1 fixates on the supraspinatus muscle, while point 2 represents the infraspinatus muscle. Note that the areas occupied by both types of muscles on the bone are similar, although the supraspinatus muscle occupies a slightly larger area. This is explained by the fact that the first muscle to promote the extension of the shoulder joint and the second flexion, whic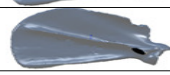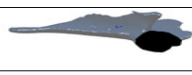h are antagonistic movements. The two movements tend to be balanced amplitude because they act in as terrestrial locomotion. In other species that use forelimbs to climb trees (not in the case of *Cerdocyon thous*), shoulder flexion becomes a much more important movement and therefore the muscle attachment area on the scapula, tends to be greater. This is subjectively analyzed to visually compare the bones of various species (EWER, 1973), but the scan methodology quantifies this difference precisely.

Anatomical associations between muscle characteristics in animals have been made on the basis of qualitative observations (EWER, 1973), muscle mass measurements (DAY and JANE, 2007; GYAMBIBI and LEMELIN, 2013) and equations that provides an estimate of muscle isometric forces (WILLIAMS et al., 2008). The precise quantification of the muscle attachment area proposed in this study may aggregate a novel source of data for analysis in comparative myology.

The image, point 18 in Table 1 represents the area of the articular surface of the scapula (glenoid cavity) for the articulation of another bone, the humerus head. The wider the area, the higher the rotational movements are. However, the more narrow it is, the more limited the rotational movement is.

The case reported in this paper illustrates the methodology used to obtain data for the anatomical study of scapula bone. The same methodology used for other bones in the forelimb (humerus, radius, ulna, etc.,) will allow for the development of various models with vectors that can be drawn from the points of attachment to the tendons in the bones facilitating an understanding of the levers movement and providing an interpretion to the different habits in the wild.

Table 1. Shows the results found in all areas calculated by this method proposed scapulae for this bone structure.

Points	Area (mm^2)	Image	Points	Area (mm^2)	Image
1	1188.46		10	38.61	
2	1095.11		11	58.57	
3	56.78		12	11.11	
4	45.86		13	536.58	
5	65.59		14	592.77	
6	67.6		15	845.95	
7	25.41		16	328.77	
8	14.89		17	9.53	
9	28.14		18	194.31	

CONCLUSION

The use of the 3D scanner in osteology is a promising tool that is capable of providing real data. From the information obtained from this method, it is possible to accurately characterize the normal bone proportions of a determined species and to expand the variables for analyses of the movements performed in the wild. The results of these analyzes may have application in ecomorphology and evolution studies.

RESUMO: O detalhamento da anatomia de animais silvestres é importante, uma vez que pode ser usado a favor da conservação. Objetivou-se, com este trabalho, descrever a metodologia para realizar a digitalização da estrutura óssea desses animais. Assim, foram descritas todas as etapas utilizadas para efetuar a digitalização da escápula de um espécime adulto de *Cerdocyon thous* como uma forma de exemplificar o processo que está sendo desenvolvido para o estudo de esqueletos. Além disso, escolheu-se digitalizar a escápula, pois se trata de um osso plano do membro torácico, fundamental para unir o membro ao tronco do animal. As análises morfométricas avançadas de osteometria foram realizadas por meio da criação de modelos tridimensionais de estruturas ósseas, através de modelos físicos reais, com o uso do equipamento SCANNER 3D Modelo Uniscan, uma ferramenta de engenharia computacional que possibilita obter resultados precisos da estrutura óssea do modelo. O equipamento funciona por meio da leitura dos pontos da peça pela reflexão do laser nas lentes e sensores. Estes pontos são computados e posicionados pelo software VXelements que é responsável pela captação de alvos que, por sua vez, geram uma malha de superfície triangular em tempo real, o qual reproduz a superfície 3D instantânea do osso. Ao final, estes conjuntos de dados adquiridos podem ser convertidos em diversos formatos de arquivo compatíveis com softwares CAD como, por exemplo, o Solidworks que permite que as dimensões sejam extraídas em diferentes pontos do objeto. Sendo assim, esta forma de caracterização e modelagem permite tornar a análise da dimensão mais elucidativa e real. Os resultados obtidos nessas análises têm aplicação em estudos de ecomorfologia e evolução.

PALAVRAS-CHAVE: Carnívoros silvestres. *Cerdocyon thous.* Análise morfométrica.

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