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Three-Dimensional Measurements of Glenohumeral Joint Surfaces in Sheep, Cat and Rabbit by Photogrammetry

Hakan Karabork
Department of Geodesy and Photogrammetry Engineering,
Faculty of Engineering and Architecture, University of Selcuk, 42079, Konya, Turkey

Abstract: The aim of this study, was the 3-dimensional analysis of the glenohumeral joints of the sheep, cat and rabbit. Twelve glenohumeral joints of animals were examined as materials. The surface areas of the glenoid cavity and the caput of the humeral head, the maximum cranio-caudal and medio-lateral depths of the glenoid cavity, the maximum cranio-caudal and medio-lateral heights of the humeral head, the cranio-caudal and medio-lateral curvature distances of the glenoid cavity and the cranio-caudal and medio-lateral curvature distances of the humeral head were measured by photogrammetric technique in the animals. Ratios amongst surface area of glenoid cavity and caput of humeral head, maximum cranio-caudal depth of glenoid cavity and height of humeral head, maximum medio-lateral depth of glenoid cavity and height of humeral head, cranio-caudal curvature distance of glenoid cavity and humeral head and medio-lateral curvature distance of glenoid cavity and humeral head were determined. The sheep had the largest values for the glenohumeral joint, except for some ratios. Cats had the smallest ratios for all measured values. As a result, this photogrammetric technique may be useful for veterinary anatomy and surgery.

Key words: Glenohumeral joint, photogrammetry, sheep, cat, rabbit, 3-dimensional analysis

INTRODUCTION

Medical imaging techniques have facilitated the production of 3-Dimensional (3D) surface measurements and are a very important source of data for anatomical and clinical research, diagnosis and treatment. In modern healthcare practice, many medical imaging modalities are used to classify anatomical (digital radiography imaging, magnetic resonance imaging, Computed Tomography (CT) etc.) and functional data (positron emission tomography functional magnetic resonance imaging, etc.).

However, there are great differences among these techniques, including the types of measurements possible and their resolution, acquisition time and accuracy. For instance, CT gives excellent images of bone and dense structures, whereas, Magnetic Resonance (MR) imaging gives excellent images of soft tissue but not of bone. However, photogrammetry accommodates both radiometric and geometric constraints and can reconstruct 3D objects and so can supply highly accurate measurements. The 3D measurement and mapping of irregular surfaces is a well-developed discipline in photogrammetry (Elad and Einav, 1990; Patias, 2002). It was stated that photogrammetry is an effective medical measurement tool and has many advantages over alternative methods (Malian *et al*., 2004; Pateraki *et al*., 2006). It was also reported that photogrammetric technique is a reliable and versatile method for determining areas of joints (Ateshian *et al*., 1994).

The glenohumeral joint (shoulder joint, articulatio humeri) is formed by the glenoid cavity of the scapula and the head of the humerus. It can move in any direction, but its main movements are extension and flexion (Evans, 1993). Although, photogrammetric analysis is used in human anatomy (Mitchell, 1995), there have been few photogrammetric studies until now. To the best of our knowledge, no investigation has examined the glenohumeral joints of animals using photogrammetric analysis.

The aim of this study, was to use a photogrammetric technique to describe the morphology of the glenohumeral joint.

MATERIALS AND METHODS

Twelve joints of 3 adult animal species, the Akkaraman sheep, stray cats and New Zealand White rabbits, were examined. The bones were supplied by the Anatomy Department of the Veterinary Faculty, Selcuk University, Konya, Turkey. The bones are preserved specimens used for the education of students and for this reason, no ethics approval was necessary.

The points that best formed the boundaries of the joint surfaces and the most appropriate points to represent the surfaces were synthetically marked at intervals of 3 mm (Fig. 1). To establish the 3D coordinates of the marks representing the joint surfaces using the photogrammetric method, a framework with fixed coordinates, with which to determine the shooting positions of the camera based on the object, was manufactured at the laboratories of Selcuk University, School of Technical Sciences (Fig. 2). It was manufactured from 24 metal bars with diameters of 1 cm, in varying positions and heights on a platform 30×20×3 cm in size.

The X, Y and Z coordinates of the 24 points on this framework were measured with a Ferranti brand 3D coordinate measuring device (Maxi-Check 750 FC, Ferranti, UK), which has a precision of ±4.9 µm, at Konya Tumosan A.S. Engine Factory (Konya, Turkey). Each bone to be prepared for measurement was placed in the framework in such a manner that the whole joint surface could be seen. The images of the joint surfaces were taken from different angles so that all the points representing the surface would appear on at least 2 digital images (Fig. 2). For each material, 6-11 digital images were taken with a calibrated Nikon Coolpix 950 digital camera (image size 1600×1200 pixels, pixel size 4 µm; Nikon Corporation, Tokyo, Japan). The digital images and the coordinates of the 24 points on the framework were transferred onto a computer. The image processing was evaluated using the Pictran photogrammetric evaluation software package (Technet GmBH, Berlin Technical University, Germany). In other words, the coordinates of the 24 points were matched with the same points on the framework in the images taken. Thus, the shooting (filming) positions of the camera, from which each image was taken, were determined. Using these shooting positions of the cameras, each of the marks on the object was recorded on at least 2 images and the 3D coordinates of the marks were determined. Then, triangles were drawn among the points, using their coordinates to calculate the surface area. The Cranio-Caudal (CC) and Medio-Lateral (ML) curvature distances of the glenoid cavity and the humeral head were also determined.

Fig. 1: Markers of the glenohumeral joint surfaces in the sheep

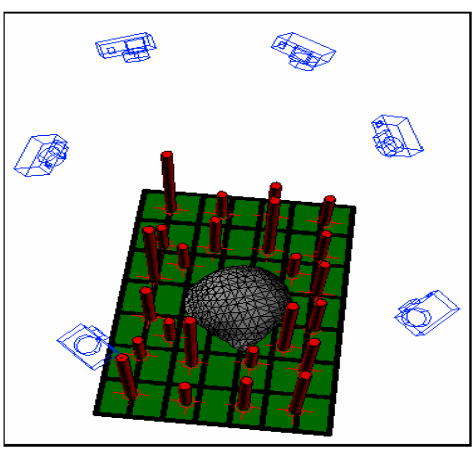

Fig. 2: A framework with fixed coordinates and camera positions for images taken from different angles

The parameters of the glenohumeral joints examined were evaluated with Tukey's test. The data are expressed as means±SE. Significance was accepted at $p<0.05$.

RESULTS

The values for the glenohumeral joints are shown in Table 1. The sheep had the largest values for the glenohumeral joint compared with those of the cats and rabbits, except for some ratios. The greatest ratios of the surface area of the glenoid cavity/surface area of the caput of the humeral head, the maximum CC depth of the glenoid cavity/maximum CC height of the humeral head and the CC curvature distance of the glenoid cavity/CC curvature distance of the humeral head were observed in the sheep. The smallest ratios for the surface area of the glenoid cavity/surface area of the caput of the humeral head, the maximum CC depth of the glenoid cavity/maximum CC height of the humeral head, the maximum ML depth of the glenoid cavity/maximum ML height of the humeral head, the CC curvature distance of the glenoid cavity/CC curvature distance of the humeral head and the ML curvature distance of the glenoid cavity/ML curvature distance of the humeral head were observed in cats. Rabbits had the greatest ratios for the maximum ML depth of the glenoid cavity/maximum ML height of the humeral head and the ML curvature distance of the glenoid cavity/ML curvature distance of the humeral head.

Table 1: Photogrammetric analysis of the glenohumeral joints in the sheep, cat and rabbit (mean±SE)

Photogrammetric analysis	Sheep	Cat	Rabbit
Surface area of glenoid cavity (mm^2)	600±10.6^a	78.2±1.83^b	64.7±0.96^b
Surface area of caput of humeral head (mm^2)	1255±19.3^a	227±6.93^b	161±2.61^c
Surface area of glenoid cavity/surface area of caput of humeral head	0.478±0.010^a	0.345±0.001^c	0.402±0.002^b
Maximum CC depth of glenoid cavity (mm)	6.167±0.115^a	2.48±0.122^b	1.905±0.145^c
Maximum CC height of humeral head (mm)	11.55±0.358^a	7.342±0.120^b	6.340±0.262^b
Maximum CC depth of glenoid cavity/maximum CC height of humeral head	0.532±0.008^a	0.337±0.012^b	0.300±0.023^b
Maximum ML depth of glenoid cavity (mm)	3.215±0.194^a	0.997±0.059^c	1.787±0.126^b
Maximum ML height of humeral head (mm)	8.770±0.273^a	4.022±0.195^b	2.567±0.292^c
Maximum ML depth of glenoid cavity/maximum ML height of humeral head	0.367±0.029^b	0.263±0.013^b	0.730±0.118^a
CC curvature distance of glenoid cavity (mm)	31.32±1.22^a	12.40±0.066^b	10.80±0.303^b
CC curvature distance of humeral head (mm)	43.67±1.119^a	23.08±0.299^b	19.87±0.363^c
CC curvature distance of glenoid cavity/CC curvature distance of humeral head	0.712±0.006^a	0.535±0.008^b	0.545±0.010^b
ML curvature distance of glenoid cavity (mm)	24.24±0.323^a	8.177±0.337^c	10.15±0.097^b
ML curvature distance of humeral head (mm)	38.54±0.721^a	16.12±0.348^b	12.80±0.404^c
ML curvature distance of glenoid cavity/ML curvature distance of humeral head	0.632±0.019^b	0.510±0.029^c	0.798±0.034^a

CC: Cranio-Caudal; ML: Medio-Lateral. $^{a, b, c}$Different letters on a line indicate that the values are statistically different from one another ($p<0.05$)

DISCUSSION

Although, many digital analytical techniques are used for medical purposes, photogrammetry in particular meets all the criteria for clinical measurements. Photogrammetry can rapidly present accurate and essential data (Mitchell, 1995). In this study, it was demonstrated that the sheep has the largest surface areas of the glenoid cavity and humeral head and the greatest CC and ML measurements (curvature distances, depths and heights) of the glenoid cavity and humeral head compared to those of the cat and rabbit (Table 1). These differences primarily reflect the anatomical differences of the animals. In this investigation, the ratios of the various measured values were calculated for each animal to justify the anatomical differences amongst animal species. When the ratios were evaluated, the ratios for the surface area of the glenoid cavity/surface area of the caput of the humeral head, the maximum CC depth of the glenoid cavity/maximum CC height of the humeral head and the CC curvature distance of the glenoid cavity/CC curvature distance of the humeral head were greatest in the sheep. The rabbit had the greatest ratios for the maximum ML depth of the glenoid cavity/maximum ML height of the humeral head and the ML curvature distance of the glenoid cavity/ML curvature distance of the humeral head. It has been reported that in the horse, the glenoid surface is about half as large as that of the humeral head (Sisson, 1975). This may indicate that the humeral surface in herbivores is about twice that of the glenoid cavity. Cats had the smallest ratios for the all parameters analyzed. These differences may reflect their athletic anatomy as carnivores. These results may also indicate that each animal should be evaluated according to their characteristic anatomy and diet.

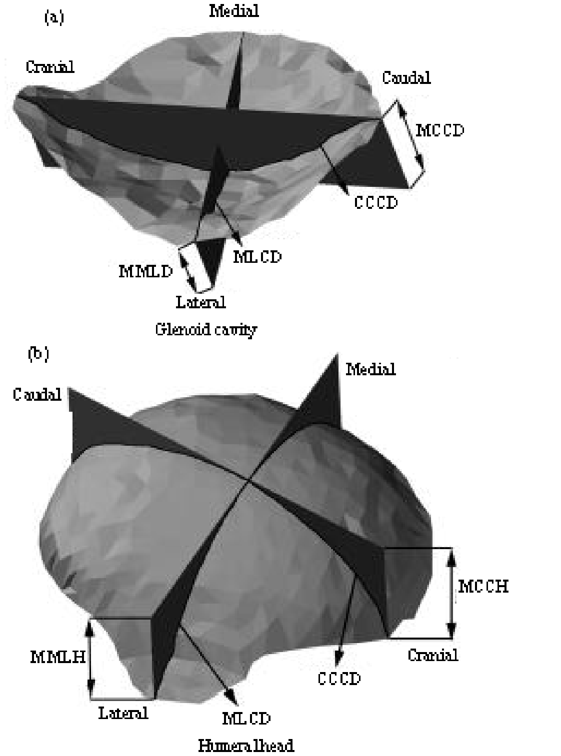

Fig. 3: a) 3D model of the glenoid cavity, b) the humeral head (right glenohumeral joint surfaces in the sheep). Maximum Medio-Lateral Depth (MMLD), Maximum Cranio-Caudal Depth (MCCD), Cranio-Caudal Curvature Distance (CCCD), Medio-Lateral Curvature Distance (MLCD), Maximum Medio-Lateral Height (MMLH), Maximum Cranio-Caudal Height (MCCH)

In this study, the glenohumeral joints of three different animal species were analyzed with a photogrammetric technique (Fig. 1-3). Photogrammetric analysis (Jordan *et al*., 2001) and the AutoCAD program (Eslaminejad *et al*., 2006) have been used to evaluate the deformation of hoof horn capsules in the horse and in the reconstruction of the cartilage canals of the right tibia in chicks. Examination of the glenohumeral joints in animals using photogrammetric techniques is especially, important in orthopedic surgery. Because the glenohumeral joint has the largest range of motion of any major diarthrodial joint in the body, the morphological details of the articular surfaces are important in the surgical reconstruction of traumatized joints and the design of arthroplastic devices (Ege *et al.*, 2004). The morphometric analysis of the glenoid fossa of the scapula is important in understanding the kinematics of the glenohumeral joint and in joint replacement surgery (Monk *et al.*, 2001). Hence, specific measurement should be made in evaluating the glenohumeral joint before and after prosthesis is implanted (Rozing and Obermann, 1999).

CONCLUSION

Photogrammetry may be useful in the study of veterinary anatomy. The information obtained with this technique may be important in the orthopedic clinic.

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