ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Acta Orthop Traumatol Turc 2010;44(5):361-364
doi:10.3944/AOTT.2010.2291

Is the rabbit knee a suitable model for the human interphalangeal and metacarphophalangeal joints of the hand?

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Objectives: The purpose of this study was to assess the suitability of the rabbit knee as a small joint model for the human interphalangeal and metacarphophalangeal joints of the hand.

Methods: The proximal joint surface areas of 47 middle phalanges, the proximal and distal joint surface areas of 90 proximal phalanges, and the distal joint surface areas of 42 metacarpals of various human cadavers were calculated and compared with the distal femoral and proximal tibial joint surface areas of 20 knee of 10 New Zealand white rabbits by a photogrammetric method.

Results: The mean joint surface area of the rabbit proximal tibia was larger than the proximal joint surface area of the middle phalanx, the distal joint surface area of the proximal phalanx, the proximal joint surface area of the proximal phalanx, and the distal joint surface area of the metacarpal. The mean joint surface area of the rabbit distal femur was larger than that of the middle phalanx, but similar to the proximal joint surface area of the proximal phalanx, and that of the distal metacarpal and distal proximal phalanx.

Conclusion: The rabbit knee is not suitable model for the human interphalangeal and metacarphophalangeal joints of the hand. There is still a lack of an appropriate animal model for the small joints of the hand.

Key words: Animal model; hand; interphalangeal joint; metacarpophalangeal joint; rabbit knee.

Uncorrected deformity or stiffness resulting from a fracture or other intra-articular pathologies of the finger joints in the hand can produce a significant functional or cosmetic deficit. Arthrodesis and arthroplasty of these joints are the most commonly performed reconstructive procedures for these problems. Numerous fixation techniques have been described for finger joint arthrodesis[1-6] and many kinds of materials are used for finger joint arthroplasty.[7-11] Research is still ongoing to find better techniques and materials, but the major problem is that there is not an acceptable animal model. As an in vivo model for arthrodesis of the interphalangeal (IP) and metacarpophalangeal (MP) joint, the rabbit humeroulnar joint has been used.[2] For finger implants, the in vivo rabbit knee model was first described by Minamikawa et al.[12] in 1994. Although the rabbit knee is a hinge joint and has a meniscus in addition to anterior and posterior cruciate ligament, its bony morphologic shape approaches that of the human proximal IP joint, and thus has been suggested by many to be a good model for arthrodesis arthroplasty across the IP joint.[7]

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Submitted: July 3, 2009 **Accepted:** June 28, 2010

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In terms of joint morphology there are differences between the MP joint, IP joint, and the rabbit knee joint that they are elipsoid, uniaxial hinge, and ginglymus type joints, respectively.

The purpose of this study was to compare the rabbit knee with the MP and proximal IP joints of the human hand to determine if there are similarities in joint surface area.

Materials and methods

This study was performed at Selçuk University Experimental Medicine Research and Application Center (SUEMRAC) after approval by SUEMRAC Ethics Committee (Decision date and number: 10/02/2006, 2006/03). The experimental animals used in this study were 6-month old female New Zealand rabbits, which were provided by SUEMRAC. Anesthetic overdose was used as euthanasia method.

The proximal joint surface areas of 47 middle phalanges, the proximal and distal joint surface areas of 90 proximal phalanges and the distal joint surface areas of 42 metacarpals of various cadavers were evaluated together with the distal femoral and proximal tibial joint surface areas of 20 knees of 10 New Zealand white rabbits.

In order to calculate the areas of the articular surfaces of these joints by a photogrammetric method, the checkpoints were marked at certain intervals on the articular surfaces (Fig. 1). The distance between the two most appropriate reference points was taken as the base measurement for each articular surface, and this base measurement was then used to transform the model into its actual dimensions on computer. The camera calibration process was performed with PhotoModeler 4.0 software to eliminate the lenticular errors of the Sony DSC-W5 digital camera with 5.1 mega pixel resolution, with which the photographs had been taken. Later, the three-dimensional model of the articular surfaces was constituted using the PhotoModeler 4.0 software by measuring the checkpoints previously marked on the articular faces after transferring the photographs onto the computer with at least 60% superposition (Fig. 2). The model was brought to its actual size by entering the basic values measured for each articular surface. This computer model was converted into a Data Exchange Format (DXF) file format and the area of each articulation surface was calculated by

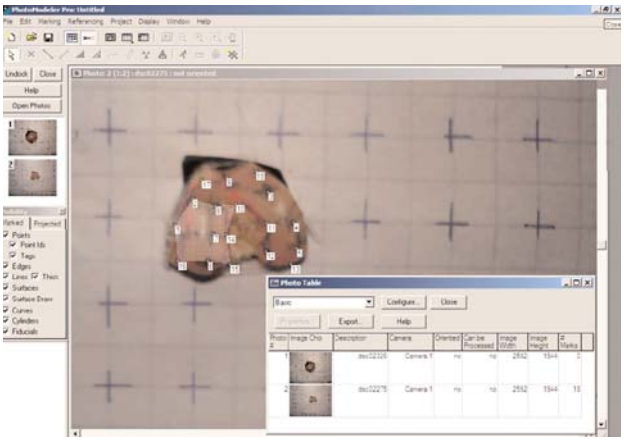

Fig. 1. Marking articulation surfaces in PhotoModeler software.

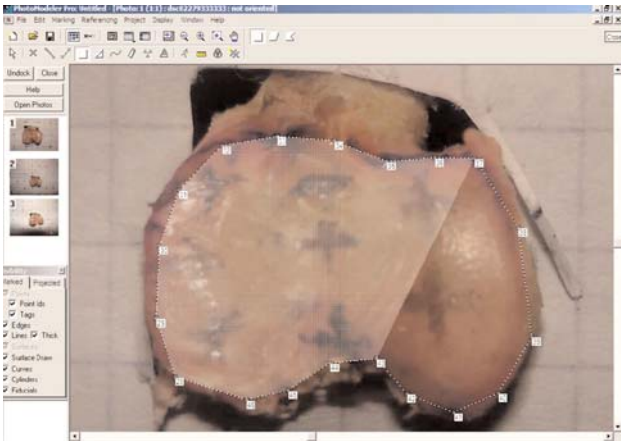

Fig. 2. Obtaining the three-dimensional model of the articulation surfaces in PhotoModeler software.

opening the DXF extended file in Netcad 5.0 software.

Statistical comparison of the groups was performed with the parametric independent t-test. Significance was set at $p<0.001$.

Results

The MP and IP joint surface areas of human hands (proximal joint surface area of the middle phalanx, distal joint surface of the proximal phalanx, proximal joint surface of the proximal phalanx, distal joint surface of the metacarpal) and the joint surface areas of rabbit knees (distal joint surface of the femur was and proximal joint surface of the tibia) are given in Table 1. The joint which has the smallest surface area in human hands was proximal joint of the middle pha-

lanx (55.0±11.2 mm^2) and the joint which has the largest surface area in human hands was the proximal joint of the proximal phalanx (117.2±21.63 mm^2).

The mean joint surface area of the rabbit proximal tibia was larger than that of the proximal middle phalanx ($p<0.001$), the distal joint surface area of the proximal phalanx ($p<0.001$), the proximal joint surface area of the proximal phalanx ($p<0.001$), and the distal joint surface area of the metacarpal ($p<0.001$).

The mean joint surface area of the rabbit distal femur was larger than that of the proximal joint surface of the middle phalanx ($p<0.001$), but similar to the proximal joint surface area of the proximal phalanx ($p>0.001$), and the distal joint surface area of the metacarpal ($p>0.001$) and the distal joint surface area of the proximal phalanx ($p<0.001$).

Discussion

MP joints are usually considered ellipsoid. However, the metacarpal heads are adapted to shallow concavities on the phalangeal bases; they are not regularly convex, but partially divided on their palmar aspects and thus almost bicondylar. Each joint has a volar plate and two collateral ligaments. The IP articulations are uniaxial hinge joints; each has a palmar ligament (also known as the volar plate) and two collateral ligaments. The arrangement of these ligaments is similar to those in the MP articulations. The extensor tendons substitute for the posterior ligaments.[13] The rabbit knee is a ginglymus type joint like the human knee with cruciate ligament and menisci. Neither the IP nor the MP articulations of the hand have cruciate ligaments and menisci.

Flexion, extension, adduction, abduction, circumduction, and limited rotation all take place at the MP. Rotation cannot occur in isolation, but may accompany flexion-extension. Flexion is almost 90°, whereas extension is only a few degrees—both movements are limited mostly by antagonistic muscles. The MP of the thumb has a flexion-extension range of 60°, which is almost entirely flexion. Other movements are adduction-abduction (maximal range 25°), which invariably accompanies the corresponding carpometacarpal movements and increases their combined range, and slight conjunct rotation, but greater adjunct rotation, which accompany flexion-extension.[13] Movements at the IP are flexion and extension, and are greater in range at the proximal joints. Flexion and extension are accompanied by slight conjunct rotation. The amount of flexion is quite considerable, but extension is limited by the volar and collateral ligaments.[13] On the other hand, the movements which occur in the rabbit knee joint are flexion, extension, adduction, abduction, and circumduction; but abduction and adduction are very limited.

Although, the morphology and direction of movements as well as the average range of motion of the rabbit knee is similar to the human finger joints, there are some questions regarding the use of the rabbit knee as a model for finger joints. The force distributed through the rabbit knee is reported to be higher than finger joints. In addition, the extension force in relation to the flexion force is higher in the rabbit knee.[14] There are also some differences in the anatomical structure in that there are no cruciate ligaments or menisci in finger joints.

Table 1
Areas of the joint surfaces

Joints	Mean (mm^2)	Range (mm^2)
Proximal of middle phalanx	55.0±11.2	31.2-87.1
Proximal of proximal phalanx	117.2±21.63	80.0-166.8
Distal of proximal phalanx	92.4±16.17	56.0-142.4
Distal of metacarpal	112.4±31.27	63.2-185.7
Distal of rabbit femur	105.8±4.16	96.1-111.4
Proximal of rabbit tibia	146.7±9.77	132.6-165.4

Based on relevant publications, the rabbit knee is a more suitable model for studies of articular cartilage repair,[15] anterior cruciate ligament or medial collateral ligament reconstruction,[16] osteoarthritis,[17,18] osteoporozis[19] or hand surgery,[2,7] etc. The authors chose to use the rabbit knee since it has been widely used and well studied, is of an appropriate size for surgical procedures to be performed and specimen handling, and is relatively economical compared to that of dogs. One shortcoming of using rabbits is that they seem to be more fragile than rats and dogs.

To the best of our knowledge, there is not a morphometric study comparing the rabbit knee with human MP and IP joints. In this study, the distal joint surface area of the rabbit femur was found to be similar to the proximal joint surface of the proximal phalanx, the distal joint surface area of the proximal phalanx, and the distal joint surface of the metacarpal; but the proximal joint surface of the rabbit tibia was larger than all the studied joints. Therefore, we could not find a correlation between MP and IP joint surface areas and the rabbit knee surface area. In addition, we found that the distal surface area was extremely larger than proximal surface area of rabbit knee, which was different from human MP and IP joint surface areas.

In conclusion, the rabbit knee is not suitable model for the human interphalangeal and metacarphophalangeal joints of the hand. There is still a lack of an appropriate animal model for the small joints of the hand.

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