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# Analysis of the Thickness and Curvature of Articular Cartilage of the Femoral Condyle

(Running title: Anatomy for Cartilage Graft)

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# Analysis of the Thickness and Curvature of Articular Cartilage of the Femoral Condyle

ABSTRACT

**Purpose:** In order to develop an optimal autologous osteochondral transplantation technique, we have analyzed the thickness and curvature of the femoral condyle. **Type of study:** Basic research for surgical technique, anatomic study.

**Materials and Methods:** Eight cadaveric femoral condyles were sectioned sagittally into seven slices. Photographs of each slice were digitized, and the thickness and curvature of the overlaying cartilage were analyzed using an NIH image program.

**Results:** The average thickness of the cartilage was 1.69 mm . The minimum and maximum values were measured at 0.22 mm and 3.65 mm respectively with the thinnest part observed in the sulcus terminalis (the groove for meniscus). The average curvature of the cartilage was 4.4 $m^{-1}$. The minimum and maximum values were measured at –20.0 $m^{-1}$ and 27.2 $m^{-1}$ respectively. **Conclusions:** When the chondral lesion is assumed at the weight bearing area of the medial or lateral femoral condyle, the anterior portion to the sulcus terminalis (the groove for meniscus) in the middle section of the lateral condyle is considered to be the optimal donor site.

**Key words:** anatomy, cartilage thickness, cartilage curvature, autologous osteochondral graft

## INTRODUCTION

Localized articular cartilaginous lesions such as traumatic chondral injury and osteochondritis dissecans present a challenging clinical problem. Many surgical techniques, including subchondral drilling, abrasion arthroplasty, osteochondral grafts, periosteal or perichondrial grafts, and chondrocyte transplantation with collagen gel have been developed and reported.[1-6] Among those procedures, autologous osteochondral transplantation has several advantages including the graft of matured hyaline cartilage containing active chondrocyte, the initial stabilization of the osteochondral graft followed by a bony union at the subchondral area and the elimination of the risk of disease transmission.[4] It has been reported that multiple autologous osteochondral transplantation from the trochlea leads to good clinical results with fewer complications at the donor site.[4] It has also been shown that the thickness of cartilage is area specific and proportional to the amount of the local joint load.[7,14] Joint congruity, which is determined by the surface shape, is another influential factor in achieving a desirable mechanical environment.[8] To ensure the good function of joint with osteochondral transplantation, it is important to match the grafted cartilage to the adjacent articular cartilage morphologically. However, there are few reports regarding the selection of the donor site in autologous osteochondral transplantation. Therefore, we have measured the cartilage thickness and the surface curvature of the femoral condyle taken from cadavers to suggest a method for selection of the optimal donor site in autologous osteochondral transplantation of the knee.

## MATERIALS AND METHODS

Specimens were obtained from cadavers donated for the Clinical Anatomical Course at the Department of Anatomy in Kobe University Graduate School of Medicine. The cause of death and medical history of the donors had no bearing on the musculoskeletal systems. The cadaveric tissue was perfusion-fixed in

embalming fluid containing 10 % formaldehyde, 10% phenol, and 40% ethanol. Eight femoral condyles were taken from the knee joint, which appeared to be structurally normal upon visual inspection. The age of death ranged from 69 to 84 years, with an average age of 79 years. A specially designed jig was used to take sagittally sections of the femoral condyles (Fig. 1 A). Both medial and lateral epicondyles were identified and clamped with prows attached to the section device. The femoral condyle was sectioned sagittally vertical to the transepicondylar axis.[9] First, the femoral condyle was sectioned sagittally into the medial and lateral halves through the highest point of the intercondylar notch. Then, each of the condyles was divided into four parts in a plane parallel to the cut surface. Thus, eight sections containing articular cartilage of equal widths were obtained from each knee and used for the subsequent examination.

To analyze the thickness and surface curvature of the cartilage, photographs of the sliced condyles were taken using a 35 mm single lens reflex camera loaded with 100 ASA color film at a right angle to the cut surface. That film was digitized using a film scanner at 2700 dpi resolution and a morphological analysis was performed using an NIH image program on a personal computer (Fig. 1 B). As a unit of analysis, the cartilage layer of the sliced condyle was divided into 1 cm long compartments on both sides of the sulcus terminalis (the groove for meniscus). The thickness was measured at the center of each compartment three times and the average of the measured values was taken to correspond to the thickness of the cartilage. The curvature of the surface of each compartment was calculated as the reciprocal of the curvature radius. The curvature radius of the cartilage surface was measured as the radius of a circle passing three points that divided each compartment equally. The thickness and curvature radii of all compartments of the sliced sections obtained from the eight cadaveric femoral condyles were measured. Thereafter, the average of thickness and curvature of each compartment were calculated and schematically mapped on the femoral condyle. The standard deviation was calculated to validate the results between the

cadavers.

## RESULTS

*Thickness of cartilage*

The distribution pattern of the thickness of each compartment was similar in the eight knees. The average thickness obtained from the eight femoral condyles is shown as a contour line and the average thickness of each compartment is indicated on the schematic right femoral condyle as a representative pattern (Fig. 2, 3). The average thickness of the cartilage was 1.69 mm. The standard deviation of the compartment of each femoral condyle was 0.1 to 1.2 mm. The minimum and maximum values were measured at 0.22 mm and 3.65 mm respectively with the thinnest part observed in the sulcus terminalis (the groove for meniscus). The cartilage at the center of the trochlea was thickest in the femoral condyle.

*Curvature of cartilage*

The distribution pattern of the curvature of each compartment was similar in the eight knees. The average curvature of each compartment obtained from the eight femoral condyles is indicated on the schematic right femoral condyle as a representative pattern (Fig. 4). The average curvature of the cartilage was 4.4 $m^{-1}$. The minimum and maximum values were measured at –20.0 $m^{-1}$ and 27.2 $m^{-1}$ respectively. The standard deviation of the compartment of each femoral condyle was 0.51 to 9.7 $m^{-1}$. Concave curve observed in the sulcus terminalis (the groove of meniscus) was recorded as a negative value.

## DISCUSSION

We have analyzed the thickness and curvature of the cartilage of the femoral condyle in order to attempt to determine an optimal donor site for the chondral lesions of the femoral condyle and to develop an osteochondral graft technique. As for both the thickness and the curvature of the cartilage, the anterior portion of the lateral trochlea matches the weight bearing area of both the medial and the

lateral femoral condyles.

It has been shown that the thickness of cartilage is area specific and proportional to the amount of the local joint load.[7] Joint congruity, which is determined by the surface shape, is another influential factor in achieving a desirable mechanical environment.[8] We have reported that cell morphology of the grafted articular cartilage changes after osteochondral transplantation in the animal model.[10] These cell morphological changes of the grafted cartilage may be influenced by the mechanical property of cartilage. Therefore, it is considered to be important to match both the thickness and surface topography of the grafted cartilage to those of the injured cartilage in autologous osteochondral transplantation.[11]

In practical osteochondral transplantation, the transplanted osteochondral plug should be harvested perpendicular to the surface of the femoral condyle and the graft should be inserted to the level flush with the surrounding cartilage in order to achieve good congruity with the joint surface.[12] To match the surface of the grafted cartilage congruent with the surrounding articular cartilage, the curvature and the thickness of the grafted cartilage should be equal to that of the injured cartilage, threfore it is necessary to have the data of the curvature and the thickness of the femoral condyle.

Through the analysis of cartilage thickness of the femoral condyle using magnetic resonance imaging (MRI) or stereophotogrammetry, it has been reported that the thickest area is located at the center of the trochlea, and the thinnest part is in the sulcus terminalis (the groove for meniscus).[13,14] The distribution pattern of the cartilage thickness analyzed in our study confirmed those findings.

According to the results of thickness and curvature analyses of the femoral condyle conducted through stereophotogrammetric examination, the distal medial trochlea and intercondylar notch are the superior donor sites for transplant to a cartilage defect on the medial or lateral femoral condyles because of the low donor site involvement in native load bearing.[17] However, curvature analysis of the

femoral condyle using a laser-based coordinate measuringmachine suggests the medial and lateral aspect of the trochlea provide a significantly better topographic match to the weight bearing portions of the femoral condyles.[15] Our results could make a suggestion in the selection of the optimal donor site to chondral lesion in the practical osteochondral transplantation. Anterior portion of the lateral trochlea matches to the weight bearing area of the femoral condyle, which is often injured as for cartilage thickness and articular courvature. And that portion has been recommended for the donor of autologous osteochondral graft. [4] Now our result confirmed that.

The weak points of this study were the measuring technique and the age of the cadavers. We directly measured thickness and curvatures of the cadaveric femoral condyle. This direct measuring is very simple, but it is accurate and analogous to harvesting the graft in practical surgery. However, it is difficult to cut the femoral condyle perpendicularly as well as to take an osteochondral plug perpendicularly in practical osteochondral transplantation. Although the knee joint of all the cadavers appeared to be structurally normal upon visual inspection, the average age of the cadavers was 79 years, which is higher than the average age of the patients who need the osteochondral transplantation. In future, a schematic map of the thickness and curvature of articular should be made by coordinating various data, such as stereophotogrammetric examination, MRI, and direct measuring.

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## LEGENDS

Figure 1: Caudal view of the cadervaric femoral condyle divided into seven slices sagittally (A). Surface of articular cartilage was further divided into 1-cm-long compartments on sagittal section, and thickness was measured at the center of this compartment, while curvature radius was measured using three points dotted in each compartment (B).

Figure 2: Contour of the average cartilage thickness of each compartment of the eight specimens was schematically mapped on right femoral condyle.

Figure 3: The average cartilage thickness of each compartment of the eight specimens was mapped on the schematic right femoral condyle with a color scale.

Figure 4: The average cartilage curvature of each compartment of the eight specimens was mapped on the schematic right femoral condyle with a color scale.

figure 4

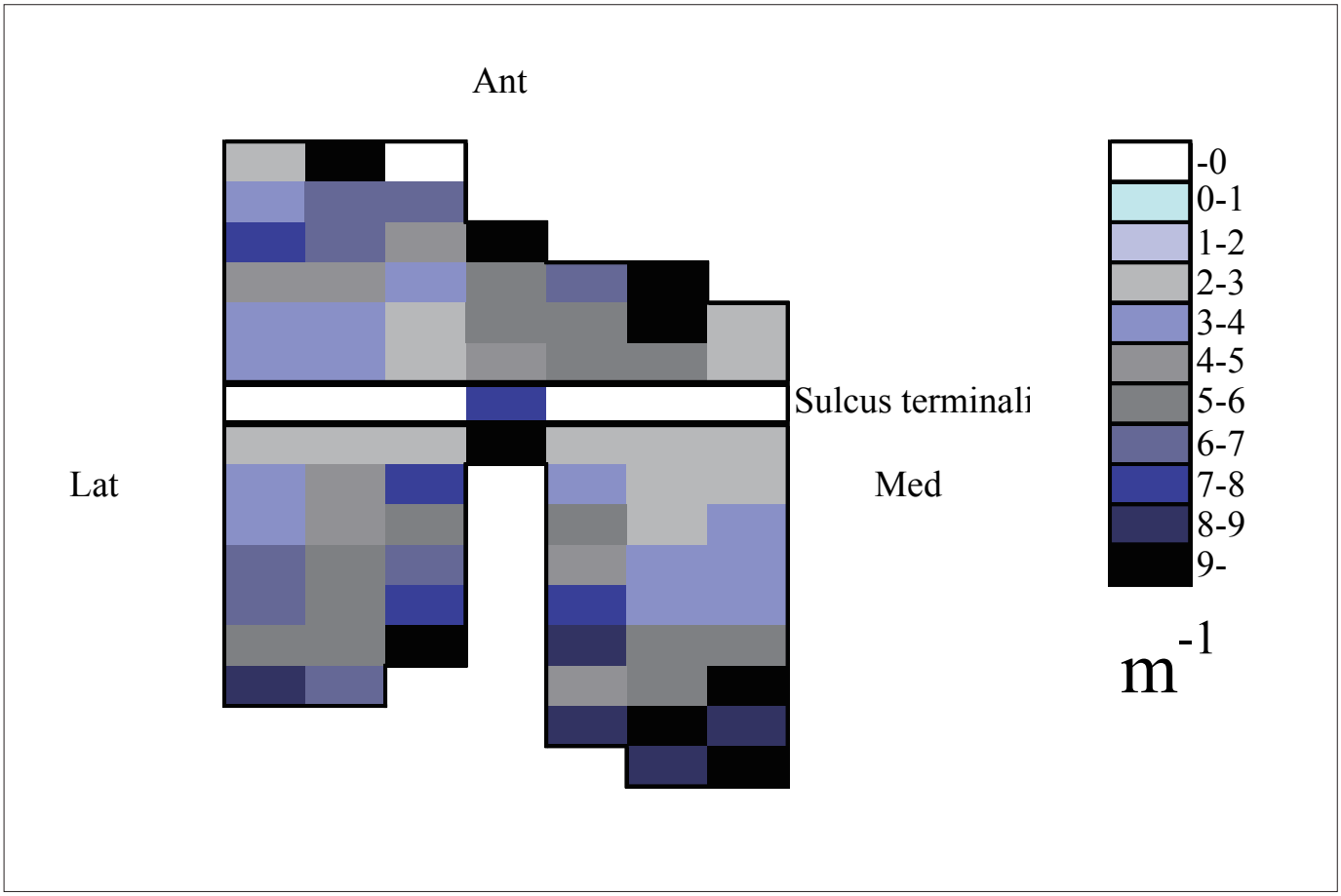


figure 1

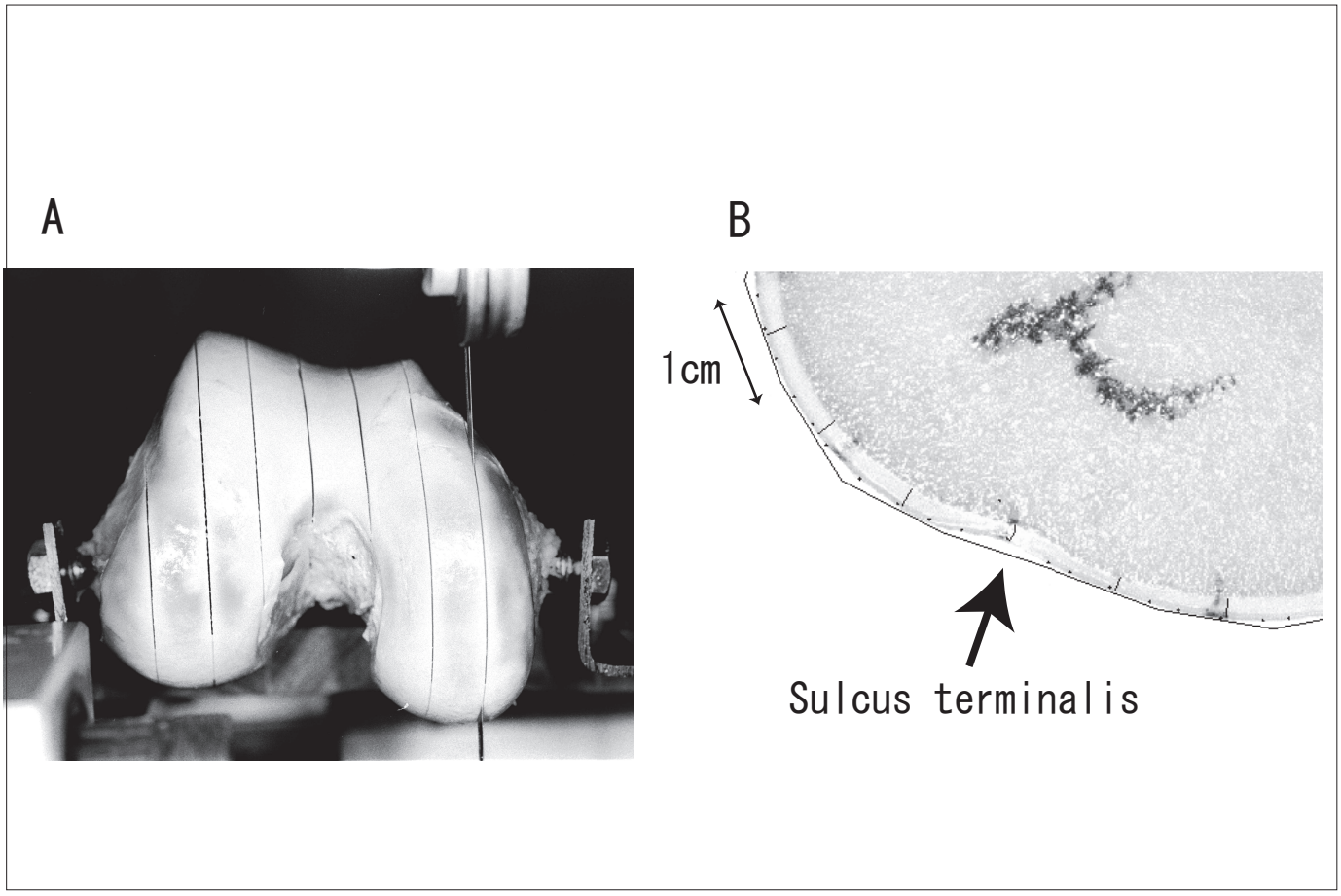

figure 2

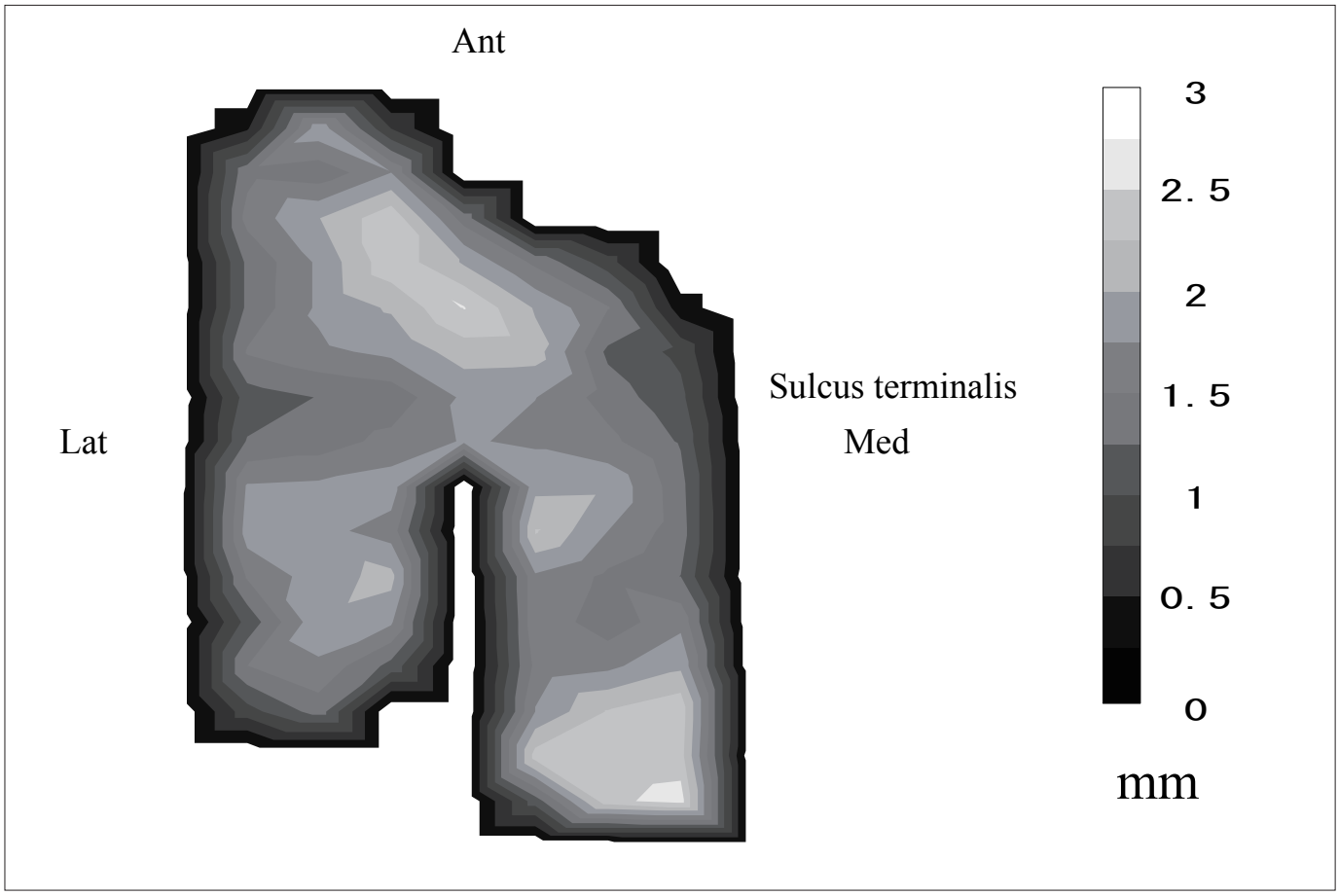


figure 3