WEAR OF KNEE CARTILAGE VOLUME EVALUATED BY COMPUTER TOMOGRAPHY AND AUTOCAD

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ABSTRACT

Osteoarthritis, also called degenerative joint disease, is the most common type of arthritis. Osteoarthritis causes the cartilage in a joint to become stiff and lose its elasticity, making it more susceptible to damage. Over time, the cartilage may wear away in some areas, greatly decreasing its ability to act as a shock absorber. As the cartilage wears away, tendons and ligaments stretch, causing pain. The objective of this study is to develop an improved automated method that will segment and measure the volume and the wear area of articular cartilage in the human tibiofemoral joint (knee) from CT scan. This new method should be faster and more reliable than the currently used methods. It should allow clinicians to accurately measure articular cartilage and mark the severity of osteoarthritis in the patient knee.

KEYWORDS: knee, joint, cartilage, wear, computer tomography.

1. INTRODUCTION

The arthrosis is a wear of the joints and arises naturally more strongly with older humans. The joints pulled in are thereby knees, shoulder and hips in addition, the finger joints and spine. The pain results from the cartilage wear. Osteoarthritis is characterized by degeneration of the articular cartilage surfaces of a joint. The development of osteoarthritis is strongly correlated with age.

Joint cartilage is a tissue that is exposed to a variety of physical forces that modulate cartilage matrix remodeling (breakdown and repair), primarily through the activities of cells called chondrocytes. Although physical wear can affect the function of cartilage, the mechanism for maintenance of the tissue involves the biosynthetic and degradative activities of the chondrocytes. Mechanical load across joints is critically important for the maintenance of cartilage, and abnormal mechanical loading of joints can lead to pathological conditions. A through understanding of the joint wear is necessary to analyze initial joint derangement and progressive degeneration of the joint. Previous studies of the knee have, however, been limited due to the invasive nature of anatomic studies and inaccuracies of external measurement. [1].

2. PATHOLOGY

The characteristic structural changes that typify the arthrosis are disorganization and loss of articular surfaces and proliferation of tissues in and adjacent to these surfaces [1].

In primary arthrosis it is not known whether synovial membrane changes precede articular cartilage changes. With advancing age a considerable number of chemical, biologic, and mechanical alterations occur in normal articular cartilage (fig. 1). The classic morphologic changes of osteoarthritic articular cartilage begin with fibrillation a local surface disorganization involving a splitting of the superficial layers of the cartilage. The early splitting is tangential with the cartilage surface, following the axes of the predominant collagen bundles. Horizontal flaking of cartilage occurs along with the development of shallow pits or clefts perpendicular to the cartilage surface. Eventually, the splitting extends deeper, altering the normal arrangement of the collagen bundles. As the disease progresses, the clefts extend entirely through the cartilage to its junction with subchondral bone. With disease progression, fibrillation continues and is accompanied by synovial hyperplasia and adjacent osteophyte formation (fig. 1). Continued deterioration of articular cartilage leads to exposure of subchondral bone and a more generalized synovial change. Another bony change that often accompanies arthrosis is that of growth at the margins of the articular surface. [1, 4]

Marginal osteophytes occur at the junction or interface between the articular cartilage and synovial membrane. They may appear as protuberances into the joint space or develop within capsular or ligamentous attachments at the joint margins.
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Osteophyte formation begins as a deposition of mineral outside the existing bony cortex. Further deposition of new bone, resorption, and remodeling ultimately produce a mature osteophyte. Capped by a hyaline or fibrocartilage surface, mature osteophytes communicate freely with the marrow spaces of the bone from which they arose. A last significant bony change of arthrosis is the development of sclerosis in the subchondral area. The bone in this area becomes denser with increasing loss of the articular cartilage above. This sclerosis has been described as being the result of increased loads placed on the bone because of the articular cartilage loss [5].

3. COMPUTER TOMOGRAPHY OF THE KNEE CARTILAGE

CT (computed tomography), sometimes called CAT scan, uses special x-ray equipment to obtain image data from different angles around the body and then uses computer processing of the information to show a cross-section of body tissues and organs.

CT imaging is particularly useful because it can show several types of tissue like bone, soft tissue like cartilage with great clarity. The CT scan makes it possible to establish an inventory of the lesions osseous, ligament, capsular or cartilaginous and measure the cartilage volumes.

CT uses an X-ray-sensing unit, which rotates around your body, and a large computer to create cross-sectional images (like slices) of the inside of your body.

During a CT scan, you lie on a table inside a doughnut-shaped machine called a gantry. An X-ray tube inside the machine rotates around your body and sends small doses of radiation through it at various angles. As X-rays pass through your body, different tissues absorb different amounts. Detectors inside the gantry measure the radiation leaving your body and convert the radiation into electrical signals. This CT scanner directs a series of X-ray pulses through the body. Each X-ray pulse lasts only a fraction of a second and represents a “slice” of the organ or area being studied. The slices or pictures are recorded on a computer and can be saved for further study or printed out as photographs. CT scanning can be used to obtain information about almost any body organ (such as the liver, pancreas, intestines, kidneys, adrenal glands, lungs, and heart), blood vessels, the abdominal cavity, bones, and the spinal cord [6].

A dye that contains iodine (contrast material) is often injected into the blood (intravenously) during a CT scan.
The dye makes blood vessels and other structures or organs more visible on the CT scan pictures. The dye may be used to evaluate blood flow, detect tumours, and locate areas of inflammation. A computer gathers these signals and assigns them a colour ranging from black to white depending on signal intensity. The computer then assembles the images and displays them on a computer monitor [2].

4. MATERIALS AND METHODS

The objective of this study is to develop an improved automated method that will segment and measure the volume and the wear area of articular cartilage in the arthrosis human tibiofemoral joint (knee) from CT scan.

In this study the authors use just one patient, with a relevant pathology, who underwent CT arthrography of the knee charged and uncearged. The patients' age is 28 years and was a female whiteout patella.

Before CT scanning, the anterolateral aspect of the knee was punctured with an 18G needle, and 20 ml of contrast material containing 370 mg of iodine per milliliter was injected. If the patient had joint effusion, the fluid was drained just before injecting the contrast medium. Patients were required to 'soft walk' or perform flexion-extension movements of the knee joint for 15 minutes before the CT scan. Suprapatella bandages with an elastic band were applied to reduce the volume of the joint cavity, so as to allow sufficient contrast medium to be administered between the articular cartilage and the meniscus. Patients were scanned in the pronatory position and with a chare by 60 kg of the affected knee joint, so as to provide the contact area between the cartilages [4].

4.1. CT Scanning and the Acquiring Axial Images

CT scans were performed with a 4-channel multislice CT scanner. The parameters used were 0.5 mm collimation and 150-mA. The images were reconstructed with a slice thickness of 0.5 mm with 0.2 mm increments (fig.2). The scan range was from the upper border of the patella to just below the fibular head. About 400-600 axial images were obtained from the patient [2].

4.2. Multiplan Reformation

Sagittal, coronal, and transverse images were reformatted using a PC-based 3D reconstruction program (AutoCAD) with a thickness of 1mm. For this arthrosis joint the charged and uncharged volumes are calculated. Articular cartilage volume was calculated from 3D reformations of the CT images by using a semiautomated program AutoCAD (fig. 2).

The authors use a 3 step method. First, the bone/cartilage interfaces (tibial and femoral) are delineated using a sub-pixel accuracy active contour method.

Second, the cartilage/tissues interfaces are delineated in a similar way.

Last, when all the segmentations are done for all images the authors build a 3D model of each structure and automatically compute the cartilage volumes for all regions.

5. RESULTS

For calculate the contact area we take the tibial and femoral charged volume and make the intersection and the result is the wear contact area (table: 1).

In uncharged situation between femoral and tibia plan a contact doesn’t exist, two volumes are separated by a thin layer of synovial fluid.
### Table 1. The cartilage volume results by AutoCAD.

<table>
<thead>
<tr>
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<th>Femoral wear volume ($V_f$)</th>
<th>Tibia wear volume($V_t$)</th>
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<tr>
<td><strong>In frontal plan</strong></td>
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<tr>
<td>Femoral volumes</td>
<td>$\Delta V_f$ charged = 13.6 mm³</td>
<td>$\Delta V_f$ uncharged = 22.2 mm³</td>
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<td></td>
<td>$\Delta V_f$ compressed = 8.6 mm³</td>
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<tr>
<td>Tibia volumes</td>
<td>$\Delta V_t$ charged = 10.2 mm³</td>
<td>$\Delta V_t$ uncharged = 11.9 mm³</td>
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<td>$\Delta V_t$ compressed = 1.7 mm³</td>
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<td><strong>In sagittal plane</strong></td>
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<td>Femoral volumes</td>
<td>$\Delta V_f$ charged = 27.7 mm³</td>
<td>$\Delta V_f$ uncharged = 25.7 mm³</td>
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<td>$\Delta V_f$ compressed = 22 mm³</td>
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<tr>
<td>Tibia volumes (superior [s] &amp; inferior [i])</td>
<td>$\Delta V_{sf}$ charged = 7.3 mm³</td>
<td>$\Delta V_{sf}$ charged = 7.7 mm³</td>
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<tr>
<td></td>
<td>$\Delta V_{sf}$ uncharged = 8.1 mm³</td>
<td>$\Delta V_{sf}$ uncharged = 9.1 mm³</td>
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<td>$\Delta V_{sf}$ compressed = 1.2 mm³</td>
<td>$\Delta V_{sf}$ compressed = 1.4 mm³</td>
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6. **CONCLUSIONS**

The results are promising because they indicate that cartilage volume losses are detectable. Further analyses are needed, however, to establish the correlation of the cartilage losses with clinical parameters. These results are useful to evaluate the progression of knee osteoarthritis and the therapeutic efficacy of “condroprotective” agents in clinical trials.

**REFERENCES**