

**PhD Thesis Title:** Segmentation and Quantitative Evaluation of Tibio-Femoral Cartilage Using MR Parameters

**Name:** Rafeek T, **Entry Number:** 2016BMZ8336

**Center for Biomedical Engineering (CBME)**

**Supervisors Name:** Dr. Anup Singh & Dr. Amit Mehndiratta, Associate Professors, CBME

---

## **ABSTRACT**

Osteoarthritis (OA) is one of the leading chronic disability mainly affects elder population. The degeneration of weight-bearing articular cartilage present in the hip and knee is the prime reason for OA condition. Presently, medical imaging-based screening methods are widely used for the diagnosis of OA because of its non-invasive nature. MR-imaging is considered as an important imaging technique due to its soft tissue contrast and 3D visualisation property. The recently developed advanced MRI techniques shows promising potential in OA diagnosis and grading. Both structural and molecular changes can be evaluated using MRI techniques. Despite applications of quantitative MRI in OA diagnosis, its potential use in the routine clinical practice is limited. There are some challenges in the quantitative evaluation of these advanced MRI techniques including cartilage segmentation, which should be addressed for its potential clinical applications. There is need of robust computer-aided-diagnosis (CAD) systems for automated or semi-automated evaluation of quantitative changes in knee joints cartilage and for evaluating clinical potential of quantitative MRI in OA diagnosis and grading.

In this dissertation, research studies have been carried out for addressing some of the challenges of quantitative evaluation of knee joint MRI along with evaluating its clinical potential in diagnosis and grading of OA. The main objectives of the study were to develop weight-bearing articular cartilage segmentation algorithms especially in OA patients having subchondral bone abnormality (SBA) and to develop a framework to automatize the quantitative evaluation methods of cartilage degeneration followed by grading of OA disease. Another objective of the study was to quantitatively evaluate the biochemical and morphological characteristics of cartilage corresponding to the biomechanical loading.

Subchondral bone abnormality (SBA) is considered as one of the advanced characteristics of OA. Therefore, the evaluation of characteristic changes of weight bearing

cartilage area, superficial to SBA, is important in OA diagnosis. In the current study, a modified radial search approach using thresholding, connected component labelling, convex-hull operation and spline-based curve fitting was introduced for the improved segmentation of tibiofemoral cartilage especially in patients with SBA condition. Modified radial-search approach successfully performed on different MRI sequence images. Proposed approach has great potential in the quantitative evaluation of cartilage degradation studies.

Presently, the clinicians qualitatively analyse the MR-images for detecting the abnormality. The quantitative evaluation of cartilage degeneration using advanced MRI is promising; however, in general clinicians draw line segments and select different ROIs manually from slices of interest. This approach is time consuming and prone to inter-intra reader variability. To overcome this difficulty, we have developed a framework (CAD) for quantitative evaluation of cartilage degeneration followed by OA diagnosis. In the current study, the proposed framework showed promising results in differentiating healthy volunteers' group from OA patients group as well as Early-OA group from Advanced-OA group. Proposed tool and research findings can be used for screening and disease diagnosis.

MR studies with and without loads on knee joint is important for analysing the stress distribution during loading. In the current study, the changes present in the biochemical and morphological characteristics of articular cartilage corresponding to the applied load was examined with the help of an in-house developed MRI compatible loading device. The T2 relaxation time changes corresponding to the biomechanical load are quite small; therefore initially, the inter-intra day variability of MRI parameters is evaluated. For the quantitative analysis, we have evaluated the changes present in the T2 relaxation time and thickness values of cartilage in load and unload condition. In the current study, the changes due to loading effect were more on medial compartment than lateral compartment. Also, during loading, the T2 mean values were increased in deep layer and decreased in superficial layer in medial compartment.

In brief, the thesis work is a comprehensive study of weight-bearing cartilage segmentation methods, development of a framework for quantitative evaluation of cartilage degeneration, optimisation of MR-parameters for OA classification, loading response of articular cartilage and some clinical applications of the proposed methodologies. The current research work presented in this thesis would be beneficial to clinicians for improved diagnosis and treatment planning of OA patients.