# Collagene order of articular cartilage by clinical magnetic resonance images and its age dependency

**Peter Seidel, Wilfried Gründer**
Institute of Medical Physics and Biophysics, University of Leipzig, Germany

## Abstract

*The present papers describes a novel method to obtain information on the degree of order of the collagen network of the knee meniscal cartilage by means of a single clinical MRI. Images were obtained from 34 healthy volunteers aged between 6 and 76 years as well as from one patient with clinically-diagnosed arthrosis at the age of 32 and 37 years. A Siemens Vision (1.5 T) MRT with TR = 750 ms, TE = 50 ms, FoV = 160 mm, and Matrix 512×512 was used for this purpose.*
*The MR signal intensities of the cartilage were read out along slices with constant height above the subchondral bone and plotted versus the actual angle to the external magnetic field. The obtained intensity curves were fitted by a model distribution, and the degree of order of the collagen fibers was calculated. For the knee meniscal cartilage, there was an age-dependency of the degree of order and a significant deviation of the volunteer with arthrosis from the normal curve.*
*The results are discussed in view of the arcade model and of a possible use of non-invasive clinical MRT for the detection of early arthrotic changes of cartilage.*

**Keywords:** Cartilage, knee, MRI, collagen network, arthrosis

## Bestimmung der Altersabhängigkeit der Ordnung des Kollagenfasernetzwerkes anhand klinischer MRT-Aufnahmen

## Zusammenfassung

*Es wird ein neues Verfahren zur Bestimmung des Ordnungsgrades der Kollagenfasern des Vorderhornknorpels aus klinischen MRT-Aufnahmen vorgestellt. Die MRT-Aufnahmen wurden mit einem Siemens Vision (1,5 T)-Gerät bei TR = 750 ms, TE = 50 ms, FoV = 160 mm, MATRIX = 512×512 von 34 gesunden Freiwilligen im Alter von 6 bis 76 Jahren gewonnen sowie an einer Person mit klinisch diagnostizierter Arthrose im Alter von 32 bzw. 37 Jahren.*
*Dazu wird die MR-Signalintensität des Knorpels entlang von Schichten konstanter Höhe über dem subchondralen Knorpel ausgelesen und über dem jeweiligen Winkel zum äußeren Magnetfeld aufgetragen. Die so erhaltenen Kurven werden durch Modelle angepasst und der Ordnungsgrad der Kollagenfasern aus der Winkelabhängigkeit der MR-Signalintensität des Knorpels bestimmt. Für das menschliche Vorderhorn wurden eine Altersabhängigkeit des Ordnungsgrades sowie die signifikante Abweichung einer Person mit klinisch bekannter Arthrose von der Normalkurve festgestellt.*
*Diese Ergebnisse werden in Hinblick auf das bekannte Arkadenmodell diskutiert und könnten für die nicht-invasive Diagnose früher arthrotischer Veränderungen des Knorpelgewebes von Nutzen sein.*

**Schlüsselwörter:** Knorpel, Knie, MRT, Kollagennetzwerk, Arthrose

## Introduction

The motivation to determine the degree of order of the collagen fibres of articular cartilage by MR-images is the non-invasively early recognition of arthrotic changes [5, 7, 9, 12, 14]. Methods for the determination of the degree of order of the collagen fibres by evaluating $T_2$-weighted MR-images are known [1, 2, 16, 17, 15]. Due to the dependency of the dipole-dipole-interaction on the orientation to the external magnetic field, and the assignment of the information of anisotropy of

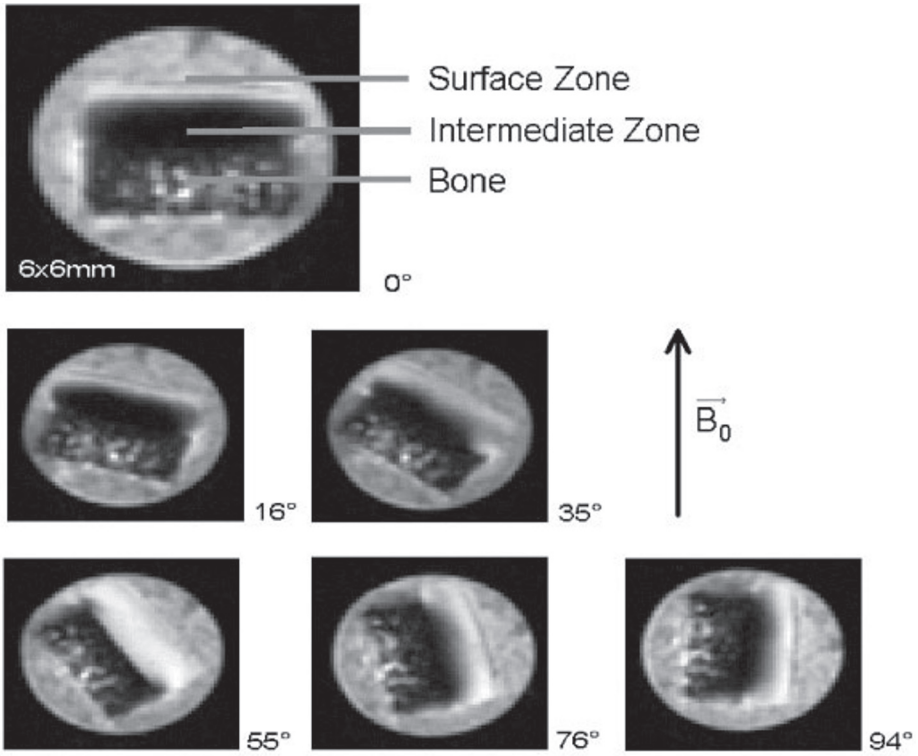


*Figure 1 MR-Images of an ovine femoral in-vitro sample and angle-dependency of the intensity on its orientation to the magnetic field (2 years old sheep, MR-parameters: 128×128 Matrix, FoV = 6 mm, TE = 20 ms, TR = 750 ms).*

the collagen fibers, there is a magic angle effect at articular cartilage at $T_2$ weighted MR-images [10, 15, 17] (Fig. 1). The intensity of the cartilage at a MRI depends on the degree of order of its collagen fibres and the angle between the main fibre direction and the external magnetic field. The determination of the degree of order of the collagen fibres from the measured intensities (Fig. 2) by rotating the sample is done by fitting certain models to the obtained curves [10].

The rotation of the sample is in most cases not possible under clinical conditions. Due to the spatial limitations of the MRT, it is impossible to rotate the patient or parts of the body in an sufficient angle interval to the external magnetic field.

Provided, the cartilage possesses due its anatomical situation a sufficient interval of its actual angle to the static magnetic field, the following method is applicable: The MR signal intensities of the cartilage are read out along slices with constant height above the subchondral bone and plotted versus the actual angle to the magnetic field. The obtained curves are fitted by a model distribution, from that the degree of order is calculated.

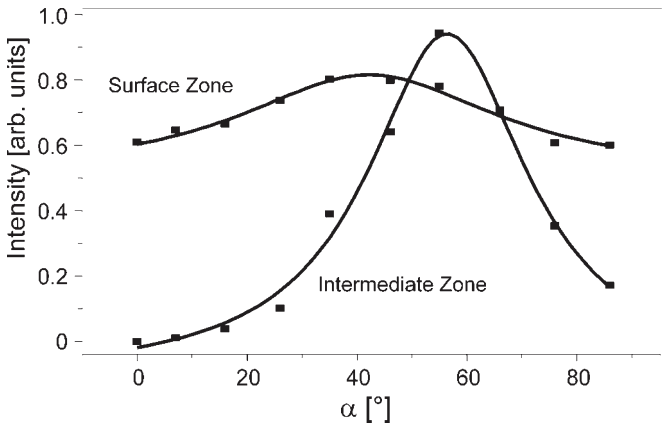


*Figure 2 Angle-dependent intensity and fitted model functions for the two cartilage zones shown in the MR-images of Fig. 1.*

## Method

For the in-vitro investigations at ovine cartilage, freshly prepared cylindrical cartilage-bone plugs were used from healthy juvenile animals immediately after slaughtering. The plugs were 18 mm in diameter and came from femoral condyles. The measurements were performed at room temperature on a Bruker AMX 300 spectrometer (7.1 T) equipped with a microimaging unit. Spin echo sequences were used, typically with echo times (TE) of 20 ms and a repetition time (TR) of 500 ms. These echo times were chosen to optimise the observation of the dipolar $T_2$-effects. Pixel resolution was 78 µm, slice thickness was 500 µm. Typically two or four scans were acquired.

For a study at human subjects MR-images of the knee of N = 34 persons in the age of 6 to 76 years were evaluated. A Siemens Vision 1.5 T clinical system was used. The images