Development of Dedicated dGEMRIC Protocol for Biochemical Imaging of the Temporomandibular Joint Disc at 3 Tesla: A Feasibility Study

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Abstract. *The temporomandibular joint (TMJ) is one of the most complex joints in the human body. TMJ degenerative changes are studied by means of MRI morphological techniques. So far, to our best knowledge, there was no attempt to show the biochemical ultrastructure of cartilage in the TMJ in humans in-vivo. Our feasibility study show that the tracer accumulation occurs within 30 minutes and an inversion recovery technique in combination with application of delayed-Gadolinium Enhanced Magnetic Resonance Imaging of Cartilage can reveal biochemical composition of TMJ in terms of GAG content.*

Keywords: MRI, Temporomandibular joint, MRI biochemistry, MR contrast agents

1. Introduction

Temporomandibular joint and muscle disorders refer to a complex set of conditions that can cause pain in the area of the jaw joint and associated muscles and/or problems using the jaw. Both or just one of the TMJ may be affected. This can affect a person's ability to speak, eat, chew, swallow, make facial expressions, breathe, cause head and neck pain, a jaw that is locked or difficulty to open, and popping/clicking noises. The TMJ is a hinge and gliding joint that is the most often used joint in the body. TMJ and muscle disorder has been reported of occuring in 5% to 44% of persons examined in epidemiologic and clinical studies [1-3].

MR diagnostic techniques extensively tested, optimized and clinically applied for articular cartilage of the human body are now further optimized for TMJ. MR protocols has to be adapted due to a complicated anatomy and small size. Higher nominal in-plane resolution and thin slice are required in order to prevent partial-volume effects during subsequent image evaluation. Promising methodology for TMJ enhancement in MR imaging is application of gadolinium based contrast agents and its dynamics during uptake and washout period. The aim of the present feasibility-study is to develop delayed Gadolinium enhanced MR imaging techniques for the cartilage tissues in the TMJ. Furthermore, certain pathologies (internal derangements, osteoarthritis) of the TMJ or reactions of the soft tissues after splint use or with functional orthodontic appliances could be assessed.

2. Subject and Methods

The TMJ is one of the most complex joints in humans. It is a synovial articulation between the processus condylaris of the mandibular condyle and the fossa articularis of the temporal bone. The TMJ is classified as a ginglymoarthrodial (hinge-gliding) joint. The upper joint space is separated from the lower joint space by an ovoid mixed-fibrous and fibrocartilagenous disc or meniscus [4]. Figure 1 shows detail of the TMJ anatomy [1]. The disc is thin in the center (1mm) and thick peripherally (2,8mm posteriorly and 2mm anteriorly), thus being “erythrocyte-shaped”. The disc is attached to the circumference of the

joint by a tough, fibrous joint capsule. Posterior to the joint, there is the bilaminar zone, formed superiorly by the elastic ligamentous insertion of the disc into the tympanic bone and inferiorly by the fibrous ligamentous insertion into the subcondylar region [5]. TMJ disorders are very common. Approximately 70% of the general population exhibit signs of TMJ disorder, but only about 5% seek medical or dental treatment [6].

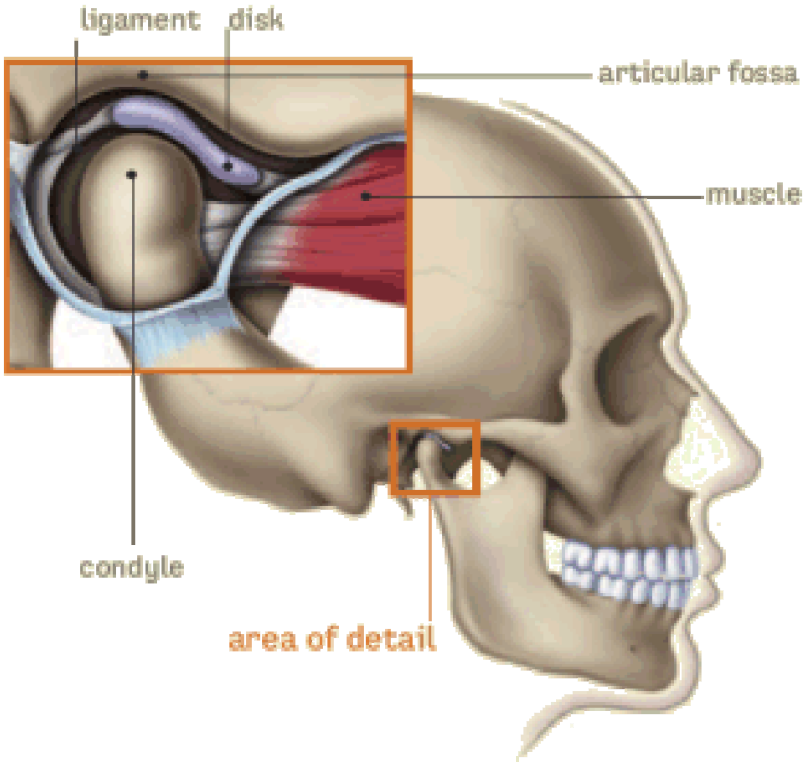

Fig. 1. TMJ anatomy

MRI technique has proven its ability to follow differences in T_1 relaxation time constant before and after CA administration in case of articular cartilage. T_1 relaxation time constant dropped down after CA administration followed by the intense excercise to approximately 50% of native T_1 values in case of articular cartilage. This technique of contrast agent application known as a delayed-Gadolinium Enhanced Magnetic Resonance Imaging of Cartilage (dGEMRIC) has proven good correlation with glycosaminoglycan (GAG) amount, which is one of the principal components of the articular cartilage in human body. Main objective of presented feasibility study is therefore to optimize MR protocols in combination with dGEMRIC for the TMJ in-vivo study.

Figure 2 shows example MR image of the TMJ. Measurements were performed using Inversion Recovery (IR) technique. This technique is known for robustness and insensitivity to the B_1 RF field inhomogeneity. Disadvantage of the inversion recovery technique is long measurement time and consequently low time resolution. Furthermore, the probability of the movement artifacts is high if measurement takes long time. The total measurement time limited to 30 minutes allowed to perform 9 inversion time measurements. Subsequently ROIs were evaluated on 9 images by an experienced dentist (E.P.) and mean values and standard deviations were recorded. Measurements were performed on the 3T Siemens Trio (Siemens Medical, Erlangen, Germany) MR system using flexible eight-channel coil, consisting of two separate components with 4 channels on each side (Noras MRI products, Höchberg, Germany).

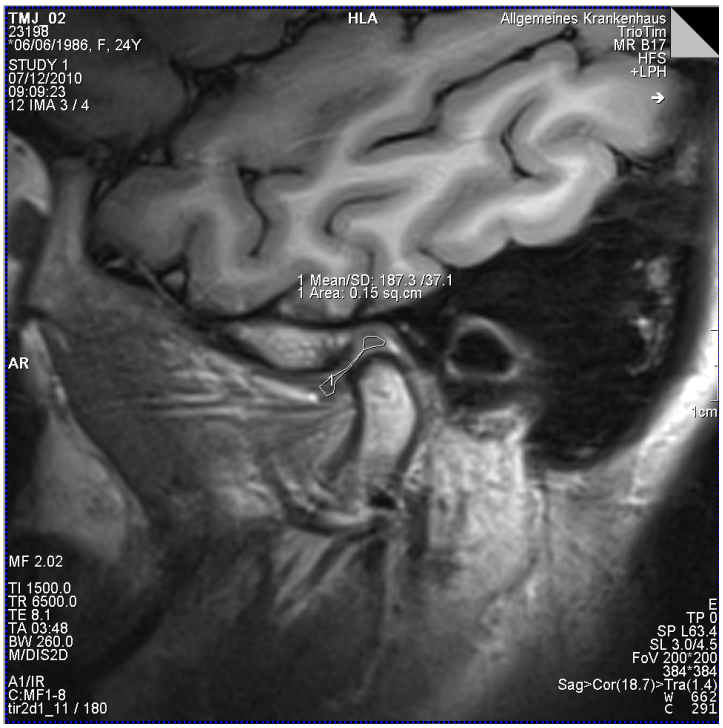

Fig. 2. MRI of the volunteer: left TMJ with ROI drawn. T_1 mean value and standard deviation (SD) are displayed above ROI. Sequence parameters are depicted on the Figure as well.

3. Results

Figure 3 shows the T_1 relaxation time behavior of the TMJ cartilage. Contrast agent uptake was quick and caused significant drop of T_1 from the starting value of 678ms before contrast agent administration to the 332ms 30 minutes after contrast agent administration, 325ms 60 minutes after CA, 367ms 120 minutes after CA and 358ms 180 minutes after CA.

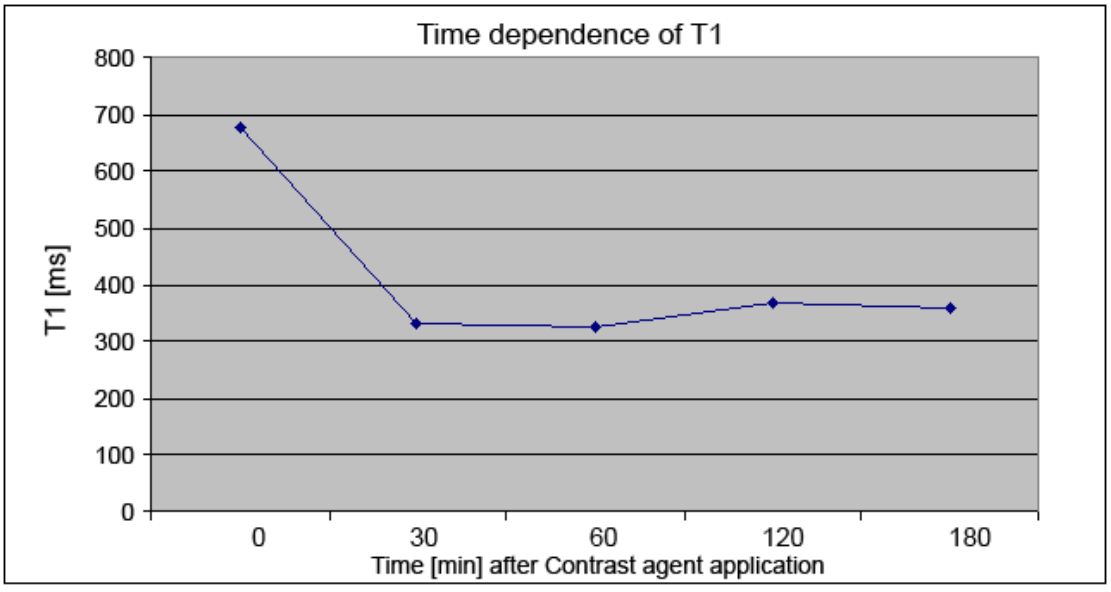

Fig. 3. Native T_1 relaxation time constant (time 0) and T_1 values in different post-contrast times.

Levenberg-Marquardt least-squares fit was performed using IDL (RSI, Builder, Colorado) routine. Asterisk on a figure 4 represent measured values. Line represents fitting curve. R^2 equal to 0.970713 represents quality of fit.

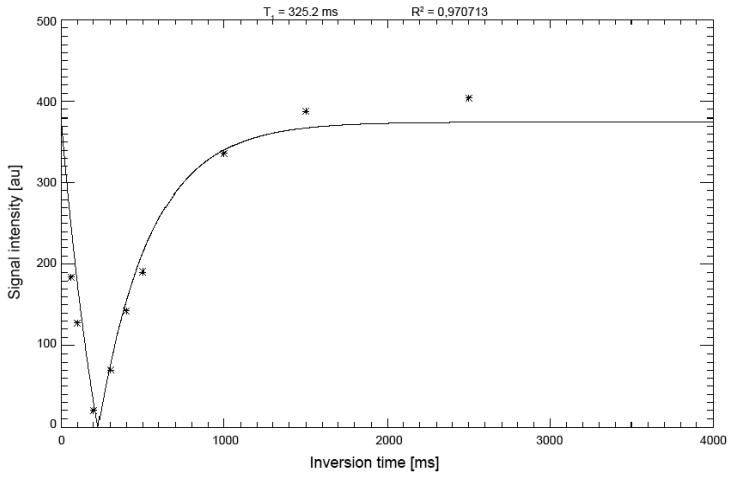

Fig.4. An example of curve fitting using non-linear least squared method

4. Discussion

As apparent from the figure 3, dramatic drop of the T_1 relaxation time constant after a contrast agent administration can be resolved only in steps of 30 minutes, due to slow Inversion Recovery measurement. Alternative to this technique could be dual-flip angle 3D-spoiled GRE technique (VIBE), which is much faster but at the same time also less precise, due to its high sensitivity to the B_1 imperfections.

5. Conclusions

Presented study show that biochemical properties of the TMJ can be evaluated by the dGEMRIC MR techniques. It is known that amount of gadolinium based contrast agent is inversely proportional to the GAG content. By measuring T_1 relaxation time constant of the TMJ we found that after 30 minutes contrast agent penetration has reached stable level. The first successful volunteer experiments encourage us to further optimize biochemical sequences for the TMJ of healthy volunteers.

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