ANALYSIS OF THE RELATIONSHIP OF MANDIBULAR MOVEMENT WITH THE CONDITION OF THE MASSETER MUSCLES AND THE TEMPOROMANDIBULAR JOINT USING MULTI-SECTION DYNAMIC MRI AND DTI AND A T1, T2 MAP

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Introduction: The number of patients with temporomandibular joint disease has tended to increase in recent years. This increase is a major challenge in dental and oral surgery because treatment for temporomandibular joint disorder has not been established, partly because the condition is caused by multiple factors such as dysarthrosis and muscle tone. In conventional measurements, movement of the temporomandibular joints is indirectly determined with respect to a location on the skull surface. This method can be used to measure trajectories of incisor teeth, but cannot measure movement of mandibular condyles or observe internal changes in tissues such as the articular disks during movement. To address this issue, we optimized a rapid imaging sequence and developed a multi-section dynamic imaging technique that can simultaneously image four sections, including the sagittal sections of the right- and left-sided temporomandibular joints, the transverse section containing the right- and left-sided mandibular condyles, and the mandibular median sagittal section that is evaluated in normal measurement of mandibular movement. In this study, we analyzed trajectories of the mandibular condyles and articular disks during mouth opening and shutting movements using multi-section dynamic imaging [1]. The conditions of masseter muscles were examined based on high-resolution 3D images, the DTI technique, and T1 and T2 values; and the relationships among mandibular movement, articular disks, and the conditions of the masseter muscles were determined [2].

Methods: The subjects were 10 adult volunteers who gave informed consent after receiving an explanation of the study. All MRI experiments were performed on a 1.5T whole body MRI scanner (Magnetom Sonata, Siemens AG, Erlangen, Germany) and a CP head array coil. Mandibular movement was evaluated by multi-section dynamic imaging performed with the True FISP sequence (TR:5.43ms, TE:2.72ms, pixel size:0.684×0.684mm, flip angle:70deg., thickness:3mm). The planned imaging sections were the right- and left-sided mandibular condylar surfaces for obtaining trajectories of the articular disks and mandibular condyles; the median sagittal section for the trajectory of the mandibular central incisor, which is the most general measurement point when evaluating mandibular movement; and the transverse section for transverse movements of the temporomandibular joints, including the right and left mandibular condyles, during mouth opening and shutting. Trajectories of mandibular movement were measured from the images using in-house software. Dislocation states of the articular disks during movement were also analyzed in each image. The volumes of masseter muscles were measured by MRI using the 3D-MPRAGE sequence (TR:2200ms, TE:3.54ms, TI:1100ms, pixel size:0.58×0.58mm, flip angle:15deg., thickness:1.1mm). ROIs of the right and left masseter muscles were extracted in each slice using image analysis software. For DTI, MR images were taken in the axial plane using a twice refocused spin echo EPI diffusion sequence (TR:2700ms, TE:70ms, pixel size:1.56×1.56mm, flip angle:90deg., thickness:5mm, b value:600, 6axis). Using DTI techniques, FA (fractional anisotropy) maps and MD (mean diffusivity) maps were made from the images obtained. By setting a ROI of the masseter muscle in each slice of the FA map and MD map, the means for MD and FA were determined. The T1 value of the masseter muscles was determined using a spin echo sequence (TR:100, 500, 2000ms, TE:152ms, pixel size:1.56×1.56mm, flip angle:90deg., thickness:5mm) and T2 was determined with a turbo spin echo sequence (TR:3000ms, TE:13.1, 26.2, ... ,419.2ms, pixel size:1.56×1.56mm, flip angle:90deg., thickness:5mm). The T1 and T2 values of the masseter muscles were measured from images using our in-house data-processing and measurement software. Finally, the relationships among mandibular movement, the temporomandibular joint, and the masseter muscle were analyzed using data from the trajectories of mandibular movement, measured values (T1, T2, FA, MD), and the conditions of the articular disks and masseter muscles.

Results: An image of skull model which input the movement data that we measured in dynamic imaging is shown in Fig. 1. The measurements of mandibular movement suggested that disorder in the articular disk was related to displacement in the LR direction. An image displaying extracted masseteric three-dimensional data superimposed on a skull is shown in Fig. 2. The volume measurements for the right and left masseter muscles are shown in Fig. 3. The mean volume of the right and left muscles was 23.3 cm^3. These results show that subjects with large dislocation of the articular disk also had a large difference in the masseter muscle between the right and left sides. The mean values of FA and MD were 0.347 and 1.44×10^{-3} mm^2/s, respectively, the mean T1 was 1290 ms, and the mean T2 was 82.0 ms. Displacement in the LR direction between trajectories of the mandibular condyles were related to the differences in each parameter on the right and left side (Fig. 4).

Discussion: In the present study, the masseter muscle was evaluated utilizing properties of MRI, in a manner that cannot be achieved with other techniques. The results indicated a tendency for larger displacement of mandibular movements in the LR direction in subjects with a dislocated articular disk. This suggests that under these conditions the articular disk restricts smooth movement of the temporomandibular joint and that the variation becomes large enough to be detected in imaging. The differences in volume of the masseter muscles on the right and left side showed the strongest relationship with displacement in the LR direction. This finding is consistent with the idea that the amount of muscle has the most direct effect on joint movement. The difference in volume of the right and left muscles may also cause unbalanced movements. These findings suggest that if the condition of the articular disk worsens, displacement in the LR direction in mouth opening and shutting becomes larger. The volume and condition of muscles change in response to the worsened articular disk and an equilibrium state in mouth opening and shutting is achieved. These factors are intertwined with each other, which may make it difficult to develop therapy for this condition. And the differences in each values (T1, T2, FA, MD) on the right and left side showed the relationship with displacement in the LR direction. These result s suggest that the quality of muscle is related with the movement. In the present investigation of mandibular movement, articular disks, and masseter muscles, MRI revealed relationships among mandibular trajectories, disorder in articular disks, and the condition of the masticatory muscles. In this context, the study shows the importance of the MRI technique for identifying the causes of temporomandibular joint disease.

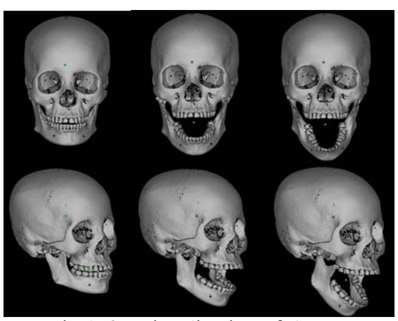

Fig.1. 3D visualization of the mandible movement.

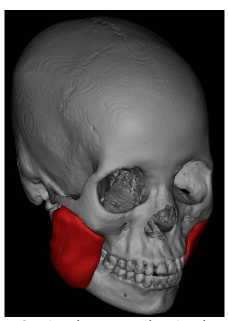

Fig.2. An image displaying extracted masseteric 3D data superimposed on a skull.

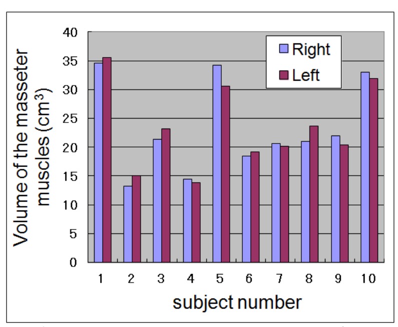

Fig.3. The volume measurements for the right and left masseter muscles.

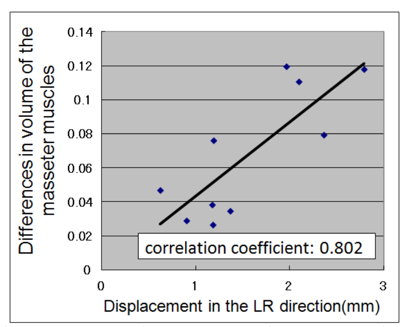

Fig.4. A correlation between displacement in the LR direction and differences in volume of the masseter muscles on the right and left side

References: [1] Azuma, T., Magn. Reson. Imaging, 2009; 27(3): 423-33. [2] Nakai, R., J. Appl. Physiol., 2008; 105(3): 958-63.