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Original research

Effects of temporomandibular joint sensory deprivation on cerebral activity during clenching

Machi Hamada*, Yuri Muroi, Kenji Kakudo

Second Department of Oral and Maxillofacial Surgery, Osaka Dental University, 1-5-17 Otemae, Chuo-ku, Osaka, 540-0008, Japan

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ABSTRACT

Objective: The objective of this study was to investigate the effect of sensory deprivation of the temporomandibular joint on cerebral activity during clenching.
Materials and methods: The subjects comprised 4 healthy volunteers without temporomandibular joint disorder. First, functional magnetic resonance images (fMRI) were obtained during clenching without anesthesia using a 1.5-T clinical scanner. Next, Lidocaine (2 ml) was injected into the left superior temporomandibular joint cavity for sensory deprivation, and images during clenching were obtained. Additionally, sensory deprivation of the right temporomandibular joint was performed and images were obtained in the same manner. Statistical parametric mapping software was used for image processing and statistical analysis of the fMRI data.
Results: Analysis results on clenching without local anesthesia revealed cerebral activation in bilateral sensory, motor, and premotor areas, the sensory association and prefrontal cortex, limbic system, and left parietal association cortex. Bilateral parietal association cortices were activated on sensory deprivation of the bilateral temporomandibular joint. There was no activation of the bilateral limbic system with sensory deprivation of the left or bilateral temporomandibular joint during clenching.
Conclusion: These results suggest that sensory input from the temporomandibular joint cavity during clenching is closely related to the activated state of the brain.

1. Introduction

Bruxism is a well-known factor in jaw dysfunction [1–3]. Many dentists believe that bruxism is caused by psychological stress. However, the mechanism by which bruxism influences neurological activity has yet to be elucidated. Several reports have been published on brain activation during a variety of jaw movements, including clenching, which is a kind of bruxism [4–6]. In past studies, positron emission tomography (PET) showed human motion tasks, including jaw movement [7,8], but it was difficult to record actual brain activation during jaw movement because of low spatial and temporal resolution.

In recent years, the real-time brain activation has become observable noninvasively using functional magnetic resonance imaging (fMRI). fMRI involves a series of processes in which brain function is analyzed and mapped on imaging using MR devices. This modality offers the advantages of excellent spatial resolution, minimally invasive imaging, and the ability to measure the entire brain. As a result, fMRI is frequently used in research and clinical diagnosis of human brain function. The principle underlying the detection of brain activation sites by MR devices is based on the blood oxygenation level-dependent (BOLD) effect (Fig. 1) [9]. The BOLD effect is due firstly to increased neuronal activation, with a resulting increase in oxygen consumption. When this happens, oxyhemoglobin (oxy-Hb) is converted to deoxyhemoglobin (deoxy-Hb). In the neuron periphery, because oxygen concentration transiently decreases, cerebral blood flow rapidly increases, and levels of oxy-Hb, incompletely consumed by neurons, rapidly increase. Oxy-Hb is diamagnetic, while deoxy-Hb is paramagnetic, so these molecules display differing magnetic properties. The increase in oxy-Hb results in a series of events leading to MR signal enhancement. With MRI, changes in blood flow in the microcirculation are observed. Therefore, with fMRI, to exclude information other than that associated with brain activation, images are taken both when the brain is stimulated and when the brain is not stimulated. By analyzing significant differences in signal changes, only the areas showing significant differences in MR signals due to stimulus changes are identified. The fMRI analysis results compare task

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* Corresponding author. Tel.: +81 6 6910 1510; fax: +81 6 6910 1030.
E-mail addresses: machii0621@yahoo.co.jp (M. Hamada), yuri7925@yahoo.co.jp (Y. Muroi), kakudo@cc.osaka-dent.ac.jp (K. Kakudo).

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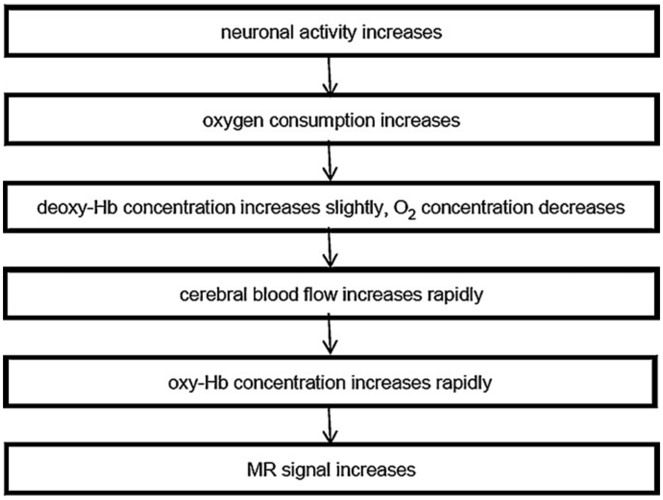

Fig. 1. Flowchart of BOLD effect.

performance with resting periods, and significant activation sites are displayed in varying shades of red to reflect the brain activation [10].

Previous reports using fMRI revealed that brain activation was observed in the sensory and motor areas during opening and closing, lateral movements and clenching of the mandible [11–14]. It is thought that information regarding the occlusal force is provided from sensory receptors in the oral mucosa, periodontal ligament, masticatory muscles, and temporomandibular joint (TMJ) during clenching. Although receptors of the periodontal membrane [15], masticatory muscles [16], and TMJ [17] are believed to play an important role in conveying information on orientation toward the nerve center, and in sensorimotor regulation of jaw movements, the details are unknown. Although there are several reports on the relationship between receptors of the periodontal membrane and brain activation [15,18–20], no reports are available on the relationship between receptors in the TMJ cavity and brain activation. In the present study, the TMJ sensory input was blocked by local anesthesia, and the change of cerebral activation during clenching was analyzed using fMRI and compared with that during normal clenching to investigate the influence of sensory receptors in the TMJ on cerebral activation.

2. Materials and methods

2.1. Subjects

Four healthy volunteers (two male and two female, aged 25–29, mean age 26.7) were enrolled in this study, which was approved by the Ethics Committee of Osaka Dental University, Japan. Inclusion criteria were healthy dentition without large restorations or large interdental spaces. Exclusion criteria were: a history of psychiatric or neurological illness, arthritides, and gross asymmetry in craniomandibular anatomy. Informed consent was obtained from each subject after explanation of the methodology of this study.

2.2. fMRI measurement

For fMRI, a 1.5-T clinical scanner (EXCELART^{TM}) was used with a head coil. Prior to the fMRI examination, high-resolution, sagittal T1-weighted magnetic resonance (MR) images were obtained to determine the imaging plane parallel to the anterior commissure (AC)–posterior commissure (PC) line. Functional MR imaging data were acquired by the gradient echo-planar imaging (EPI) sequence [21]. An EPI pulse sequence was used with conditions of TR 2000, TE40, flip angle 90°, slice thickness 6 mm, NEX = 1, number of slices 10, FOV = 25, and matrix size 128 × 128 (pixel size 2 mm).

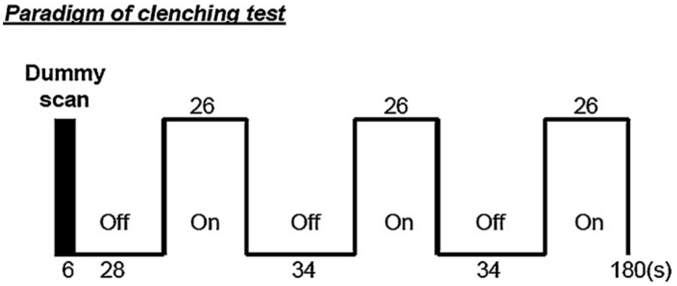

Fig. 2. Paradigm of clenching test. For the series, subjects alternated between 34 s of mandibular rest position (off) and 26 s of clenching task with maximum occlusal force (on) for 180 s. As the MR signal is very large and unstable immediately after the start of imaging, a 6-s dummy scan was made.

In the fMRI environment, the subjects were laid supine on the scanner bed, and then the head was positioned in the head-coil and fixed with cushions. All subjects were instructed to minimize head movements and keep their eyes closed. Each subject performed 3 cycles of 26 s maximum voluntary clenching (MVC) tasks. For the measurements, subjects alternated between 34 s rest (off) and 26 s of clenching (on) task (Fig. 2), for a total fMRI scanning time of 3 min. Each measurement series consisted of 900 scans with a total duration of 180 s.

2.3. Temporomandibular joint sensory deprivation

The experimental design is shown in Fig. 3. After analysis of normal clenching, 2 ml of 2% lidocaine was injected into the left superior temporomandibular joint cavity by a dentist trained in pumping manipulation. The location of the needle tip in the superior joint cavity was confirmed by back-flow of lidocaine. The effect of anesthesia was confirmed after 10 min by the disappearance of extension in the TMJ. After confirming the effect of the left TMJ sensory deprivation by local anesthesia, fMRI analysis of the clenching task was obtained. Right TMJ sensory deprivation was performed in the same manner, and fMRI images during bilateral TMJ sensory deprivation were obtained.

2.4. Data analysis

Image processing and statistical analysis of the fMRI data were conducted using statistical parametric mapping software version 5 (SPM5, http://www.fil.ion.ucl.ac.uk/spm/). SPM5 is representative of internationally standardized software created for the analysis of brain function imaging. SPM5 runs in the MATLAB operating environment (The Math Works, Natick, MA, USA; version 6.51 and higher). Using linear transformation, magnitudes in the *x*, *y*, and *z* directions are precisely aligned; then nonlinear transformation using warping is undertaken to achieve more detailed anatomical alignment to match the brain of the individual patient to a standard brain map. For anatomical alignment under nonlinear

(1) Normal (without anesthesia as a control)

(2) Left temporomandibular joint
sensory deprivation

(3) Bilateral temporomandibular joint
sensory deprivation

Fig. 3. Experimental design.