Original article

Dentures wearing reduce motion artifacts related to tongue movement in magnetic resonance imaging

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Purpose: Tongue movement with unstable swallowing cause artifacts on magnetic resonance imaging (MRI). This may be associated with loss of occlusal support. This study aimed to clarify whether motion artifacts can be mitigated by denture wearing during MRI examination in patients without occlusal support, and whether denture wearing affect tongue stability, form, and position were also evaluated.
Methods: Ten subjects without occlusal support (6 male, 4 female; mean age 73.20 ± 10.12 years) participated in the study. MRI was performed with dentures worn (DW), followed with removal of dentures (NDW). Luminance standard deviation (LSD) was measured in regions of interest in the axial and sagittal planes. The position of the base of the tongue (TB), tip of the tongue apex (TA), and tongue's long diameter (TLD) were compared between DW and NDW.
Results: NDW evoked ambiguous MR images in the axial and sagittal planes compared with DW. There were significant differences in LSD between DW and NDW in both the axial ($p = 0.047$) and sagittal planes ($p = 0.02$). No significant difference in the position of TB were observed ($p = 0.78$). The position of TA was significantly more protruded with DW ($p = 0.007$). Also, TLD was significantly longer with DW ($p = 0.001$).
Conclusions: Results of this study suggest that wearing the dentures during MRI examination reduces motion artifacts in edentulous patients without occlusal support, and maintained the normal form of the tongue during imaging.

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1. Introduction

Japan has become a globally unprecedented super-aged society, and this trend is expected to continue into the future [1,2]. Morbidity rates of malignant neoplasms, heart disease, and cerebrovascular disease are among the leading causes of death in this country [1]. Tongue cancer, salivary gland disease, and temporomandibular joint disease are also expected to increase according to this demographic trend. Magnetic resonance imaging (MRI) is an efficient method of detecting and diagnosing lymph node metastasis and distant metastasis in malignant neoplasms [3–5]. Unambiguous MRI aids diagnosis [6]; thus, ambiguous or distorted MR images (i.e., artifacts) should be avoided. Although artifacts can generally be caused by chemical shift(s), non-uniform radio frequency fields and magnetic fields, it can be prevented by using certain methods [7]. Motion artifact(s) caused by patient movement is, however, more difficult to control [7,8].

The majority of patients requiring MRI for oral-related disease are elderly and, in general, have fewer remaining teeth; thus, the prevalence of edentulous individuals with or without occlusal support tend to be high. Frequent dental interventions in these individuals include fabrication and delivery of removable prostheses to recover masticatory function and esthetics. When individuals wearing denture prostheses require MRI of the head and neck region, the examiner asks for their removal because the dental alloy used in removable appliances cause metallic artifacts, and may generate harmful heat and, possibly, dislodgement of the prostheses during imaging. The patient, therefore, is instructed to remain as still as possible [9]. However, this is largely patient dependent, and inhibition of movement varies with each patient; thus, removing the denture evokes an unstable mandible and tongue position during swallowing compared with dentate subjects, especially in edentulous individuals without occlusal

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support, which in turn causes artifact(s) [10–13]. These tongue motion artifact(s) can limit the acquisition of clear margins between tongue squamous cell carcinoma and extrinsic muscles. Thus, diagnosis of the stage classification of the malignant tumor will be limited and affect treatment decisions and operative methods.

In contrast, by wearing a removable prosthesis during MRI, the position of the lower jaw and the tongue is expected to be stabilized when compared with non-denture wear [10,13]. This is achieved by mandibular stability, occlusal support, fulfilling denture space by adequate denture, and achieving "tongue–palate contact" during swallowing [11–13]. The reduction in mandible and tongue movement is expected to decrease artifacts and improve diagnosis of malignant tumor staging. However, the relationship between this stability and the reduction of artifact remains unclear. If the relationship between mandibular position and artifact is clarified, it would be worthwhile to establish guidelines and effective device(s) to stabilize mandibular position during MRI examination.

The purpose of this study, therefore, was to investigate the effect of denture wearing on the reduction of motion artifacts of the tongue in edentulous individuals and/or those without occlusal support, and to evaluate positional stability of the tongue with the denture.

2. Material and methods

2.1. Subjects

Subjects included 10 patients (6 men, 4 women; mean age 73.20 ± 10.12 years; mean number of remaining teeth: 2.60 ± 3.86) who received treatment at the Kita Kashiwa Rehabilitation General Hospital (Kashiwa-Shi, Chiba, Japan). Inclusion criteria were as follows: subjects in Eichner Index group C; subjects wearing dentures; and no soft tissue disease in the oral cavity. Exclusion criteria included subjects with: involuntary movement during MRI in the oral and maxillofacial regions, or any other part of the body; absolute and/or principle contraindications to MRI, such as pacemaker, cochlear implant, or claustrophobia; individuals with non-removable ferromagnetic metal in the oral cavity; swallowing disorder caused by a 10 mm increase or decrease in the occlusal vertical dimension compared with normal position.

Informed written consent was obtained from all participants after they received a written form explaining the purpose and methods of the study and explained by the examiner. The study protocol was approved by the Institutional Review Board (Ethical Committee of Nihon University School of Dentistry at Matsudo; approval no. EC 16-15-019-1). The protocol was also registered to a clinical trial registry database (ClinicalTrials.gov [NCT03018158]).

In the Eichner classification, each posterior contact area, including both the premolar and molar regions, are counted as one zone, yielding a total of four supporting zones [14]. In this study, group C, who have no occlusal contact were included. Group C1 has at least one tooth in both the mandible and maxilla without any occlusal contact, group C2 has at least one tooth in either the mandible or maxilla, and group C3 is fully edentulous in both arches.

2.2. MRI

MRI was performed using a 1.5 Tesla scanner (Vantage Titan, Toshiba Medical Systems, Otawara, Japan) equipped with a head coil. All images were obtained in both the axial and sagittal planes. The measurement of MR images were performed on T2-weighted images with fat saturation (T2WI + FS) due to its satisfactory depiction of tumors [15,16].

Axial imaging was performed using the following parameters: repetition time (TR) = 6500 ms; echo time (TE) = 100 ms; number of excitations (NEX) = 1; slice thickness = 4.0 mm; gap = 0.8. Sagittal imaging was performed with the following parameters: TR = 6500 ms; TE = 100 ms; NEX = 1; slice thickness = 5.0 mm; gap = 0.1.

2.3. MRI conditions

Subjects underwent imaging while wearing their denture, followed by removal of the denture.

Denture wearing (DW): Subjects were imaged in occlusion with their dentures worn. The denture was determined according to the occlusal vertical dimension determined by maxillomandibular registration in the physiological rest position. In cases of partial dentures that contained ferromagnetic metal, for which the development of the metal artifact was predicted, a non-metal copy denture was fabricated beforehand and worn during the MRI examination. A dentist confirmed occlusal stability and reproducibility of the denture worn for imaging before MRI and made adjustments as needed. The patient was instructed to maintain mandibular position and the tongue stationary during imaging.

Denture non-wearing (NDW): After imaging with the denture worn was completed, the denture was removed with the head in a fixed position, and MRI was performed with the mandible in the rest position. A dentist confirmed the rest position of the mandible in subjects before imaging, and the subjects practiced reproducing the position spontaneously. Patients were instructed to maintain the practiced mandibular position and to keep the tongue stationary during imaging.

2.4. Image analysis

All images were analyzed using software version 2.31 included in the console of the MRI device.

Luminance standard deviation (LSD): A circular region of interest (ROI) 20 mm in diameter was placed on each image (Fig. 1). The ROIs were confirmed by consensus among the three examiners, i.e., a radiological technologist and two dentists. LSD was measured within the ROIs of the axial and sagittal planes on the T2WI + FS under the two oral conditions, i.e., DW and NDW.

Tongue form and position: The position of the base of tongue (TB) was measured according to the methods described by Fujiki et al. [17] and Gokce et al. [18] in the sagittal plane (Fig. 2). The position of the tip of the tongue apex (TA) and the tongue's long diameter (TLD) were measured according to methods described by Fujiki et al. [17] in the sagittal plane (Fig. 2). Each form and position evaluation was performed by measurement of the distance that was parallel to a palatal plane [17,19]. The palatal plane is an anatomical standard plane in the midsagittal slice, and can be drawn based on a line from the anterior nasal spine to the posterior nasal spine (PNS) [20]. Measurements were confirmed by consensus among three examiners, i.e., the radiological technologists, and two dentists.

2.5. Statistical analysis

We examined the normality of the data using the Kolmogorov–Smirnov test and normality was confirmed. Thus, decided to use parametric test for the following analysis. The paired t test was performed to analyze the influence of denture wearing on motion artifacts caused by the tongue, and LSDs of denture wearing and non-wearing were compared. Additionally, the paired t test was used to analyze the position of TB and TA, and TLD in the sagittal plane, as influenced by denture wearing on the stability of tongue position. SPSS version 21 (IBM Corp., Armonk, NY, USA) was used for analysis at a significance level of 5 %.