Effect of Cotton Roll Biting on Auditory Evoked Magnetic Fields

Yoshimasa Kobayashi

*Department of Epidemiology and Public Health, Tokyo Dental College,
2-9-18 Misaki-cho, Chiyoda-ku, Tokyo 101-0061, Japan*

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Abstract

The effects of change in occlusal pressure on the cortical mechanisms responsible for hearing were investigated. Changes in the magnetic field in response to auditory stimulation when subjects (5 healthy, right-handed, male volunteers aged between 22 and 30 years) bit a cotton roll were analyzed by using magnetoencephalography. All equivalent current dipoles estimated from the fields obtained under 3 different bite force conditions were closely localized within 1 mm of those obtained in the non-bite control group. No significant difference was observed between the bite and non-bite conditions in the latency of the 100-ms component (N100 m) of the magnetic fields. The amplitude of the N100 m component decreased with increase in bite pressure in both the right and left hemispheres ($p < 0.05$). These results suggest that an increase in bite pressure influences auditory function.

Key words: Auditory evoked field — Magnetoencephalography — Bite — Mastication

Introduction

Several clinical studies have reported a relationship between occlusal conditions and hearing^{3,4,17,23}. One large community-based epidemiological study investigated the longitudinal association between tooth loss and age-associated hearing loss¹¹. The present team has also reported cases where unilateral chewing appeared to have a negative impact on hearing¹⁶. The same study also noted that

dental treatment and instruction on how to correct improper chewing reversed this effect¹⁶. Taken together, these findings suggest a relationship between hearing ability and the occlusal conditions that drive oral function²². However, the effects of change in occlusal pressure on the cortical mechanisms responsible for hearing remain to be clarified. The aim of this study was to investigate the effect of occlusion and chewing on changes in the magnetic field in response to

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auditory stimulation (hereafter, auditory evoked fields, AEFs) by using magnetoencephalography (MEG). Auditory evoked fields were compared in healthy subjects under bite and non-bite conditions.

Materials and Methods

1. Subjects

The subjects comprised 5 healthy, right-handed¹⁹⁾, male volunteers aged between 22 and 30 years with no disorder in oral function. Written informed consent for participation in the study was obtained from all subjects, and the study protocol was approved by the Ethics Committee (HRC3A10) of Tokyo Dental College in accordance with the Declaration of Helsinki.

2. Biting a cotton roll task: equipment to measure occlusal pressure without generating magnetic field

Magnetoencephalographic signals were measured in the presence or absence of auditory stimuli while each subject bit a cotton roll with varying degrees of pressure (hereafter, bite task). The subjects were instructed to bite the cotton roll with the right first molar. A button-sheet sensor (FlexiForceTM, Tekscan, South Boston, MA, USA) with a diameter of 9.5 mm was wrapped in the cotton roll, which was then placed between the upper and lower teeth (Nichiei Co., Sakai-shi, Osaka-fu, Japan). The sensor used was capable of monitoring occlusal pressure of up to 50 kg/cm². A very thin layer of ink designed to sense pressure prevented the sensor itself from generating a magnetic field. A total of 3 experimental conditions were set, with the subjects being instructed to maintain occlusal pressure at less than 20%, 20–40%, or 40–60% of maximum occlusal pressure (MOP). Occlusal pressure during the task was projected onto a screen to aid the subject in maintaining the required amount of pressure. The occlusal pressure displayed was also checked by the experimenter. Most of the subjects appeared to have no difficulty in maintaining less than

40% of MOP.

3. MEG recordings and auditory stimulation

A helmet-shaped, 306-channel, superconducting quantum interference device (SQUID) magnetometer (Neuromag Vectorview, Elekta Oy, Helsinki, Finland) was used to record magnetic fields. Signals were obtained from 204 planar gradiometers placed at 102 positions encompassing the entire scalp. These signals allowed measurement of the two orthogonal derivatives of the radial magnetic field. To align the coordinate systems of the MEG and head magnetic resonance (MR) imaging, the locations of 3 anatomical landmarks (the nasion and bilateral preauricular points) and the positions of 4 head position indicator coils were determined with a 3-dimensional digitizer (Isotrak, Polhemus Inc., Colchester, VT, USA). Structural MR images were obtained in each subject with a 1.5-T scanner (Symphony, Siemens, Erlangen, Germany). An electromyogram (EMG) of the temporalis and masseter muscles was also obtained during the recording of the AEFs. The subjects were required to rest comfortably on chairs in a magnetically shielded room during the MEG and AEF recordings.

All signals were digitized at 999 Hz and band-pass-filtered (0.1–330 Hz). Each subject was electroencephalographically monitored to check awareness. When an epoch contained an MEG signal exceeding 1,500 fT/cm, or when a subject became drowsy, the measurement was excluded from the analysis and the procedure repeated. Magnetic signals were averaged for each session of 100 trials. Each trial lasted 900 ms, comprising a 100-ms baseline period and 800 ms following auditory stimulation. An average of 100 AEF responses was recorded under each condition.

Tone bursts of 1,000 Hz with a sound pressure of 80 dB were generated using software (Gentask, Compumedics Neuroscan, Charlotte, NC, USA) and were presented for a duration of 40 ms with a rise/fall time of 10 ms. A total of 100 tone stimuli were delivered unilaterally to the ear with an insert connected to a tone generator *via* a plastic tube.

The inter-stimulus intervals were randomized from 1–2 seconds.

4. Offline analysis of AEFs

Muscle activity can contaminate magnetic waveforms; therefore, frequency-constitution analysis was used to remove muscle activity artifacts from the AEF signals. There may have been differences in the wavelengths of the evoked magnetic field bands due to masseter and/or temporal muscle activity arising from the bite task and sound stimuli (AEF responses). Therefore, 18 planar gradiometers were situated near each auditory cortex (36 channels in total) to further analyze the AEF waveforms obtained. To minimize muscle artifact contamination in the AEF analysis, high-frequency muscle artifact components in the magnetic fields obtained from total AEFs were removed by using a low-pass digital

filter. These filtered AEF responses were then subjected to fast Fourier transform (FFT) analysis. The peak values of the FFT-AEF waveforms were plotted against frequencies in 1.8-Hz steps. Equivalent current dipoles (ECDs)²⁰⁾ were then calculated from the magnetic waveforms obtained by the 36 bilateral planar gradiometers.

5. Statistical analysis

A mixed repeated measures ANOVA was used to compare the latencies of the AEF waveforms. The mean amplitudes of the AEF responses were analyzed using a paired *t*-test. All statistical analyses were performed with SAS software (Ver.8.02; SAS Institute, Cary, NC, USA).

Fig. 1 Representative traces of amplitudes of auditory-evoked magnetic responses (AEFs) were obtained from 36 gradiometers located on both left and right auditory cortices. Here, they are plotted against frequency distribution by task type and stimulus side; in controls (A), where no cotton roll biting was performed, magnetic responses to sound stimuli were observed in low frequency band (circles). When subject bit strongly (0–20% (B), 20–40% (C), or 40–60% (D) of MOP), magnetic noise caused by myogenic potential (squares) contaminated AEF signals. Under 20–40% or 40–60% MOP conditions, influence of myogenic artifacts was too large to obtain satisfactory results (squares in C and D).

A: Right hemisphere **B: Left hemisphere**

Fig. 2 Averaged values of AEF responses (mean $\pm$ standard deviation) by FFT analysis obtained from each set of 18 gradiometers for right auditory cortex (A) and left auditory cortex (B) were plotted against frequencies. With increase in bite pressure from 0 to 40% of MOP, amplitudes of low-frequency AEF responses (less than 17 Hz) for each hemisphere following each side sound stimulus changed, while magnetic responses in high-frequency bands caused by myogenic potential increased. Therefore, AEF frequency components lower than 17 Hz were further analyzed in this experiment. Data points represent mean $\pm$ standard deviation.

Results

The AEFs from the 36 bilateral gradiometers situated near the auditory cortices were analyzed by FFT and superimposed on the baseline (Fig. 1A). In the control task (no bite), a comparison of the FFT waveforms without sound stimuli to those with sound stimuli showed that components under 17 Hz corresponded with the responses to sound stimuli (Fig. 1A, circles). With each lateral sound stimulation, responses showed a high-frequency component corresponding to myogenic potential when the subject bit with 20–40% (Fig. 1C) or 40–60% (Fig. 1D) of MOP.

The peak values of AEF responses and their frequency distributions in the right (Fig. 2A) and left (Fig. 2B) hemispheres under control and bite task conditions (0–20% or 20–40% of MOP) following left- or right-side auditory stimulation were also analyzed. A change in AEF response was observed at frequencies of

less than 17 Hz or greater than 26 Hz (Fig. 2) with increase in bite pressure. At frequencies of below 17 Hz, the amplitudes of the AEF components forming the peak at frequencies below 8 Hz showed a decrease; however, the new component could be found at frequencies of over 8 Hz during the bite task.

Individual MR images of the ECDs for the AEF responses at latencies of approximately 100 ms (the N100 m component) following sound stimuli (Fig. 3) were localized using AEF components with frequencies of less than 17 Hz. The averaged latencies of the N100 m component (from 5 subjects) were calculated for each hemisphere, task, and auditory stimulation side. No significant difference was observed among them (Fig. 3A). The localization of ECDs for the N100 m in the MR images during the bite task at 0–20% MOP (blue) or 20–40% of MOP (yellow), or with no bite (red) is shown in Fig. 3B. These ECDs from the right hemisphere were obtained during left-side auditory stimulation

Fig. 3 (A) Summary of each averaged latency of N100 m component of AEF in 5 subjects calculated for each hemisphere, task and side applied sound stimulation; No significant difference was observed among them. (B) Localization of ECDs for N100 m in MR images without biting (red) and with 0–20% (blue) or 20–40% of MOP (yellow). These ECDs were obtained in right hemisphere by left-side auditory stimulus presentation in Subject A. No significant difference was observed in ECD location between each condition. ECDs obtained during all tasks were located in transverse temporal gyrus. Data were low-pass filtered at 17 Hz.

Fig. 4 (A) Plots show AEF amplitudes of N100 m in each subject (5 subjects) during each task (control, no bite; with 0–20% of MOP; or with 20–40% of MOP) in left and right hemispheres following auditory stimulus presentation to each side. (B) Summary bar graphs show averaged peak amplitudes of N100 m during each task (control, no bite; with 0–20% of MOP; or with 20–40% of MOP) in left and right hemispheres following auditory stimulus presentation to each side. Significant differences were observed in amplitudes among tasks in right hemisphere (*: $p=0.025$, **: $p=0.0067$, ***: $p=0.0018$, ****: $p=0.0029$, *****: $p=0.0322$).

in Subject A. No significant difference was observed in the ECD locations between each condition. The ECDs obtained under all conditions were located in the transverse temporal gyrus. The ECDs of the N100 m at 40–60% of MOP could not be estimated, however, due to high amounts of EMG artifacts.

The peak amplitude of the N100 m component in the AEF responses in each hemisphere under control or bite task conditions (0–20% or 20–40% of MOP) during auditory stimulus presentation on each side was compared (Fig. 4). The individual (Fig. 4A) and averaged (Fig. 4B) values of the amplitudes of the N100 m in both hemispheres showed a decrease as the subject bit down with increased strength. The AEF responses showed a significant decrease in the auditory area in the right hemisphere with increase in MOP.

Discussion

The results showed that biting a cotton roll affected AEF response depending on the strength of the occlusal force applied. Biting significantly lowered the AEF responses of the N100 m components in the right hemisphere auditory areas^{5,9,20,21}.

The equipment used to measure occlusal pressure in the present study did not affect MEG measurement. In addition, occlusal pressure could be well controlled using this system. All ECDs estimated on the MR images for the N100 m, with or without biting, were localized in the auditory cortex after removal of myogenic artifacts.

There are several possibilities for the mechanisms affecting AEF responses during biting. Change in the peripheral anatomical structures during biting may modulate AEF responses²². In this way, chewing may influence anatomical and functional structures of the sound conduction system in the middle and inner ear^{1,2,6,8,14,24}. Furthermore, cortico-cortical networks between the auditory and other cortices may influence AEF responses during biting. Some studies have shown a strong relationship between somatosensory

or visual stimulation and cognitive function^{7,10,15}. It has also been shown that auditory stimuli affect somatosensory-evoked magnetic fields^{12,13,18}. However, one cognitive study in which auditory and visual information were presented simultaneously revealed that AEF responses were not influenced by visual stimuli¹⁵. Although the results of the present study showed no change in the localization of ECDs (subjects observed their own occlusal pressure projected onto a screen during MEG recording), they are in line with those of previous reports.

In summary, change in occlusal pressure significantly affected neural responses in the auditory cortex. Although further study is needed to clarify the detailed mechanism underlying the relationship between cortical response and occlusal pressure, structural changes in the sound conduction system in the middle and inner ear, as well as the temporomandibular joint during biting, may influence neural activity in the auditory cortex. In addition, somatosensation elicited by biting, such as sensation from the periodontal membrane, may also play a role in the modulation of cortical auditory function.

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Correspondence:

Dr. Yoshimasa Kobayashi
 Kobayashi Dental Clinic,
 1-43-3, Wada, Suginami-ku,
 Tokyo 166-0012, Japan
 E-mail: y.kobayashi@koba-dc.jp