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Alteration of masticatory muscle EMG activities during chewing after a reversible bite-raising in guinea pigs☆

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ABSTRACT

Previous studies have investigated the effects of increasing the occlusal vertical dimension (OVD) with an oral appliance on masticatory muscle EMG activity during oral behaviours in humans and animals. The present study investigated whether a short-term and reversible increase in OVD, followed by a reduction in OVD to the normal level, resulted in a time-correlated change in the EMG activities of the masseter and digastric muscles during chewing. To do this, a guinea pig model in which an increased OVD was established with natural tooth contacts was used. In the control group, in which no bite-raising treatment was applied, OVD gradually increased with a natural growth during the experimental period whilst the masseter and digastric EMG activities, burst duration, and chewing rhythm were unchanged. When the increase in OVD was established in the bite-raised group, the EMG activities of the masseter and digastric muscles were significantly increased by 88.6 and 55.2% from those before bite-raising treatment, respectively. However, during the following 11 days, the increased EMG activities of both muscles did not show changes associated with the subsequent decrease in the OVD to a normal level. The burst durations of both muscles and chewing rhythm were not significantly affected by the change in OVD during the experimental period. Within the limited recording period of the study, the return of OVD from increased to normal levels did not reverse the increased chewing-related masticatory muscle EMG activity that was induced by the bite-raising treatment.

1. Introduction

Previous studies have investigated the effects of increasing the occlusal vertical dimension (OVD) on masticatory muscle EMG activity during chewing or various oral behaviours in humans[1,2] and animals.[3–6] As an acute response to an increased OVD produced by an oral appliance, the EMG activity of the masseter muscle during chewing was decreased

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whilst that of the digastric muscle was increased.[2–4] When an oral appliance was fixed in place for a few weeks, the duration of muscle activation was increased in both the masseter and digastric muscles although the oral behaviours involved were not specified.[3,5,6] These studies suggested that the neuromuscular activities of jaw muscles during oral behaviours are able to respond to an experimentally increased OVD depending on the time frame after the oral appliance has been fixed to the teeth.

When using guinea pigs to investigate the effects of changes in OVD, although their neuromuscular functions can adapt to experimental bite-raising, the OVD should be strictly controlled and maintained at a level appropriate for guinea pigs.[7,8] In an animal model in which animals were subjected to a reversible increase in OVD with natural molar tooth contact using an oral appliance, the increased OVD had returned to the same level as that of age-matched naïve controls within 4–5 days after the oral appliance had been removed.[7–9] This model allows the bite-raised animals to contact their opposing natural teeth after the removal of appliance. The changes in chewing movements induced by an increase in OVD were found to be exclusively associated with the reduced gape and no alterations in chewing rhythm or pattern were seen.[9] However, these changes in chewing jaw movements disappeared as the OVD returned to the normal level. These findings suggest that chewing movements can be modified by a temporal change in OVD although the intrinsic programme for chewing is maintained.

Since jaw movements reflect the neuromuscular activities of masticatory muscles, we hypothesized that EMG activities in jaw-closing and opening muscles during chewing may be associated with the changes in OVD as the increased OVD decreases to a normal physiological level. Therefore, the purpose of the present study is to evaluate masseter and digastric EMG activity during chewing according to the OVD before and after reversible bite-raising was applied to guinea pigs.

2. Materials and methods

All experimental procedures were approved by the Committee on Animal Research of the Matsumoto Dental University. Eighteen male Hartley guinea pigs (4–5 post-natal weeks old) were used.

2.1. Surgical preparation

Prior to the experiments, the animals were prepared for the chronic recording of electromyogram (EMG) activity of the jaw-opening and jaw-closing muscles. They were anesthetized with pentobarbital sodium (50 mg/kg, i.p.) prior to the surgery. Urethane-coated stainless steel wires (diameter: 0.05 mm) were inserted into the bilateral anterior bellies of the digastric (Dig) and masseter (Mass) muscles for EMG recording. These wires were soldered to a multiple pin socket, which was fixed to the parietal skull with dental acrylic resin. Antibiotic ointment (gentamycin sulphate) was applied around the wound, and an antibiotic (oxytetracycline, 10 mg/kg, i.p.) was injected for 3 postoperative days. After surgery, the animals were allowed 7–10 days to recover before the bite-raising treatment (−10th day).

2.2. Bite-raising treatment

In 10 animals (bite-raised group), a bite-raising appliance was attached to the lower incisors with bonding resin, as has been described in previous studies[7–9] (−10th day). The appliance was removed 10 days after being fixed in place (0th day). The fixation and removal of the appliance were performed under sodium pentobarbital anaesthesia (30 mg/kg; i.p.). Another 8 animals that were used as controls (control group) were anesthetized according to the same schedule as was used for the bite-raised animals.

2.3. Measurement of OVD

Micro-computed tomography (micro-CT) was used to estimate the change in the OVD, before the attachment of the appliance (the −10th day) and on the 0th, 1st, 4th, 7th, and 11th days after the appliance had been removed (R_mCT, Rigaku Inc., Tokyo, Japan). As has been described in our previous study,[9] during the scanning, each animal's head was fixed to a custom-made acrylic stereotaxic apparatus under pentobarbital anaesthesia (30 mg/kg, i.p.). Small images ($51.2 \times 51.2 \times 38.4$ mm) with a fine voxel size ($100 \times 100 \times 100$ μm) were taken using the micro-CT system. Using the image management software (i-View, Morita Inc., Kyoto, Japan), the micro-CT volume data were re-sliced so that the palate plane was horizontal on 1 mm thick sagittal micro-CT images taken from three directions. On the micro-CT images, the foramen mentale and the incisive foramen were used as anatomical landmarks to measure the OVD.[10] The distance between the incisive foramen in the upper jaw and the point on the sagittal plane that the left-right foramen mentale projected to was defined as the OVD. Micro-CT analysis confirmed that the inter-molar space was filled by the erupted teeth on the 0th day in the bite-raised group.

2.4. Recording jaw muscle EMG activity

The jaw muscle EMG recordings were performed at the baseline (the −10th day) before fixation of the bite-raised appliance, and on the 1st, 4th, 7th, and 11th days after the appliance had been removed (Fig. 1). Before every recording, we fasted the animals for 5 h. When EMG recordings were made for 1 h (14:00–15:00), an animal was placed in the recording chamber and allowed to move and ingest standard pellets for guinea pig (diameter: 3.2 mm; length: 10 mm) freely. The EMG recordings were amplified (AB-621G, NIHON-KODEN, Japan) using a low-cut filtre with a time constant of 0.03 ms. Data acquisition (sampling rate: 2 kHz) was performed using waveform management software (Spike2®, Cambridge Electronic Design Limited, Cambridge, UK).

2.5. Analysis of EMG activity

Successful EMG recordings were made for at least 28 days after surgery in twelve animals (six in the bite-raised group and six in the control group). Four bite-raising and two control animals could not complete the experimental protocol