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Temporal alteration of chewing jaw movements after a reversible bite-raising in guinea pigs☆

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ABSTRACT

Previous studies analysed the temporal changes of occlusal vertical dimension (OVD) with natural molar tooth contacts in bite-raised guinea pigs and found that the OVD is strictly maintained in the growing guinea pigs. Since the OVD is considered to be the influencing factor for performing mastication, we hypothesised that a control of the OVD is integrated with maintenance of an appropriate chewing behavior. In young adult guinea pigs with or without bite-raised treatment, the OVD was measured by micro-CT and stable chewing movements were recorded during 11 days after the removal of the bite-raising appliance. In control animals, the OVD increased developmentally up to $10.5 \pm 6.0\%$ for 11 days. In the bite-raised animals, the increased OVD was increased by $19.1 \pm 6.7\%$ with the bite-raising appliance, and the OVD rapidly decreased to the same level as that of controls within 4 days after the removal of the appliance. During chewing on the first day after the removal of the appliance, the most closed position of the jaw was lower in bite-raised animals than in controls while the most opened position did not differ between the two groups, i.e., the jaw gape was decreased. These changes disappeared when OVD returned to the same level as that of controls. Any other variables for movements (e.g., rhythm) did not differ between the both groups throughout the experimental period. These results suggest that there is a robust association between an innate OVD and a centrally-programmed pattern of chewing movements for functional integrity.

1. Introduction

Recent studies demonstrated that the OVD is strictly controlled and maintained at a level appropriate in guinea pigs.[1,2] In this model, the increased occlusal vertical dimension (OVD) can be experimentally established with the appliance.[3] Molar teeth in the upper and the lower jaws occluded each other at an increased level of the OVD within a week after the appliance was attached on the lower incisors. The increased OVD returned to the same level as that of age-corresponding naïve controls within 5 days after the removal of the appliance. After that, both groups showed the same increase

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of the OVD due to normal developmental growth.[1] Sensory inputs from the trigeminal mesencephalic nucleus (MesV) contribute to this strict control of the OVD because a lesion of MesV caused a disturbance in the maintenance of the OVD.[2]

The OVD can provide an important reference position of the jaw during oral functions such as chewing. Several studies have suggested that the physiological significance of OVD for the chewing functions because the increased OVD by an insertion of the oral appliances can affect the chewing movements in humans and animals.[4–8] Nonetheless, during a natural growth with which the OVD continues to increase, chewing movement does not change very much in rabbits.[9] Thus, there might be a functional integrity between an innate OVD and an intrinsic pattern of chewing movements for appropriately performing chewing.[9–11]

In this study, we hypothesised that a strict control of the OVD is integrated with maintenance of chewing behavior. To test the hypothesis, we analysed the jaw movement trajectories of chewing while the experimentally increased OVD returned to a normal level in guinea pigs.[1,2] This model allows us to investigate the physiological correlation between the OVD and chewing movements, because animals can chew food with the increased OVD without the oral appliance.

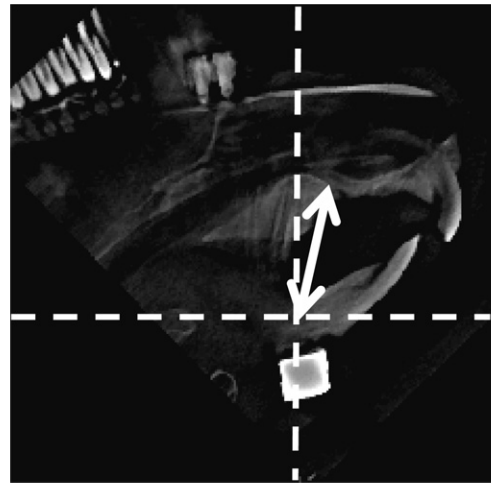

Fig. 1 – Measurement of the OVD on the micro-CT image. The micro-CT image on sagittal plane is indicated. Double arrow indicates the OVD measured in this study. The vertical and horizontal dotted lines indicate frontal and horizontal planes, respectively (see text for details).

2. Materials and methods

2.1. *Animal preparation*

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

Prior to experiments, a following surgical preparation was done for chronic recording of jaw movements.[12,13] They were anesthetised with pentobarbital sodium (50 mg/kg, i.p.) during the surgery. To mount the animal's head on the metallic stereotaxic apparatus for recording jaw movements, we attached a nut on the frontal skull and a sylindrical aluminum tube on the parietal skull by dental acrylic resin and by five small metal screws implanted to the skull. The nut was used to attach to the metal plate of the streotaxic apparatus and the aluminum tube was fitted into the special bars. This method allows atraumatic fixation of the animal's head at the same position during subsequent recording sessions in the different days. In addition, to use a detachable phototransistor array for tracing jaw movements, the following preparation was made.[10,11] The female part of the acrylic attachment was mounted with dental acrylic resin on the small stainless steel screws, which were implanted to the mandibular mentum. The male part was attached to the back of the phototransistor array for tracing jaw movements. The attachments allowed us to temporarily fix the phototransistor array to the mandible while recording the jaw movements.

2.2. *Bite-raising treatment*

For seven animals (bite-raised group), a bite-raising appliance was set on the lower incisors with bonding resin as has been described in the previous papers.[1,2] The appliance was removed 10 days after being fixed. Fixation and removal of appliance were performed under sodium pentobarbital anesthesia (30 mg/kg, i.p.). Other seven animals, used as controls, were anesthetised at the same time as the bite-raised group.

2.3. *Measurement of the OVD*

The micro-computed tomography (micro-CT) (R_mCT®, Rigaku Inc., Tokyo, Japan) was used to determine the change of the OVD, before attachment of appliance (−10th days) and 0, 1st, 4th, 7th and 11th days after the appliance was removed.[12] The scanning was done under general anesthesia (pentobarbital sodium, 30 mg/kg, i.p.). Each animal's head was fixed to a custom-made acrylic stereotaxic apparatus (different apparatus from that used for jaw movement recording) and upper and lower dentitions were occluded in midline. Images were taken with the small image size (51.2 mm × 51.2 mm × 38.4 mm) and the fine voxel size (100 μm × 100 μm × 100 μm) by the micro-CT system.[12] Using the image management software (i-View®, Morita Inc., Kyoto, Japan), the micro-CT volume data were resliced so that the palate plane became horizontal on a sagittal micro-CT image with 1 mm thick slice images from 3 directions (Fig. 1). From a micro-CT image the foramen mentale and the incisive foramen were used as anatomical landmarks inside cranium to measure OVD.[12] The distance between incisive foramen in the upper jaw and the point that the left-right foramen mentale projected to sagittal plane was defined as the OVD (Fig. 1 double arrow). The OVD on each day is normalised by the OVD measured at the beginning of the experiment. In the preliminary experiment, the reproducibility of 10 measurements was assessed in three animals in the different day by one experimenter. The coefficient variations of three were from 0.8 to 1.7% (98–208 μm).