Regional difference in physiological roles of human temporal muscle related to three-dimensional bite force

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Summary

The present study proposes to assess the regional differences existing in the activity of the human temporal muscle, during biting. The right temporal muscle was investigated in six male subjects, with normal dentition and without craniomandibular disorders. They were asked to bite arbitrarily, during which EMG, the direction and magnitude of bite forces were recorded. After analyzing the results, we concluded that each muscle region had different functions while biting and a proper dynamic range regarding bite-force directions.

Key words: temporal muscle, bite-force direction, EMG

Introduction

Human temporal muscle is fan-shaped and has a complex architecture including muscle fiber orientation. Furthermore, regional differences in histochemical fiber-type composition were reported [1]. These morphological and histochemical characteristics of the temporal muscle may indicate the functional partitioning of the temporal muscle. Recently, indications for the differential activation of the temporal muscle were obtained from experiments in which the electromyographic (EMG) activities of the muscle were recorded.

Blanksma et al. [2] recorded EMG activities from six regions antero-posteriorly across the temporal muscle belly during exerting bite forces in nine directions, and showed the ratio of activities in the six muscle regions changed with the direction of the bite forces. However, it is not clear how the physiological functional partitioning of temporal muscle is related to the morphological characteristics. The purpose of this study was to determine the regional differences in functional roles of human temporal muscle during biting.

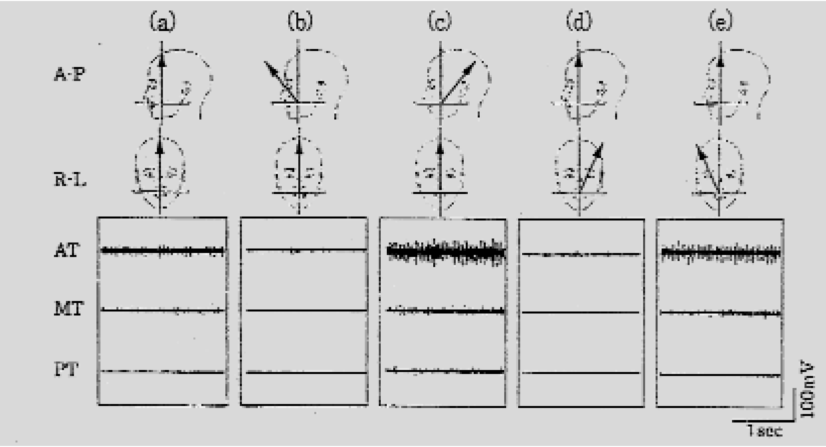
Materials and methods

1. Subjects

The right temporal muscle was investigated in sex male subjects, ranging in age from 21 to 31 years. They had normal dentition and showed no signs and symptoms of craniomandibular disorders. Each subject was asked to bite arbitrarily and the direction and magnitude of bite forces were recorded using a three-dimensional bite-force transducer. Concurrently, EMGs were also recorded from the right temporal muscle.

2. EMG registration

The surface EMGs in the anterior temporal muscle (AT), the middle temporal muscle (MT), and the posterior temporal muscle (PT) were recorded using stainless spiral electrodes (type SEB115, NEC Medical-systems Co., Tokyo, Japan). The positions of AT and PT were determined by palpation as the anterior and posterior borders of the right temporal muscle respectively. The position of MT was determined as a middle site of AT and PT. The direction attaching each pair of electrodes was parallel to the long axis of the muscle fibers. The bandwidth for EMGs recording was from 20 to 1,500 Hz. The amplified EMGs were recorded onto a magnetic tape and provided for the following data analysis.



3. Bite-force registration

Bite force was recorded three-dimensionally with a custom-made three-dimensional bite-force transducer [3]. This device consists of a pair of metal occlusal clutches; a maxillary clutch with three miniature force transducers (type PS-100KAM294, KYOWA Electronic Instruments Co., Tokyo, Japan), and a mandibular clutch with a bearing-ball appropriately placed against the transducers. The device was fixed on the upper and lower posterior teeth in the tapping position [4], with the inter-incisal distance less than 3 mm. The range for recording bite-force direction was from 39 degrees anteriorly to 39 degrees posteriorly, and 39 degrees in the left to 39 degrees in the right. Bite-force direction was defined as the angle against the perpendicular line to the FH plane. The signals from the bite-force transducers were amplified (type 6M82, San-ei Co., Tokyo, Japan), simultaneously recorded on a magnetic tape with EMGs (type XR7000, TEAC Co., Tokyo, Japan).

4. Data analysis

The analog data of EMGs and bite force were digitized (2,000 samples/sec). The average integrated EMG values and the average magnitude and direction of bite forces were calculated when the bite-force magnitude and direction were within 80 ± 2.5 N and 2° respectively for at least 150 msec. Mann-Whitney U-test was used for statistical analysis.

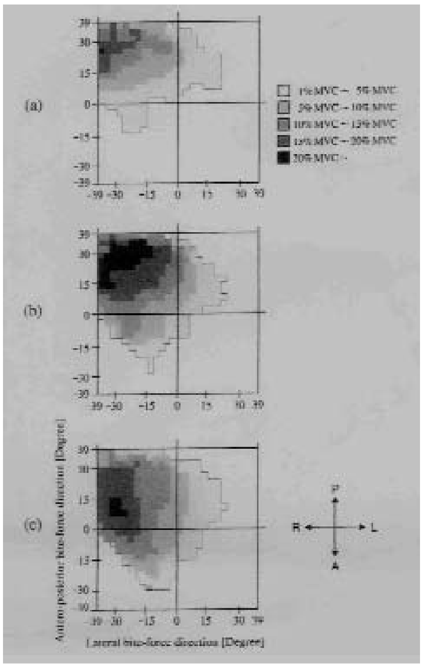
Results

1. Activities in three muscle regions during biting in different directions

The raw EMG signals of the three muscle regions during biting in five directions are shown in *Figure 1.* As the bite-force direction changed anteriorly (Fig. 1c, a, b) or contra-laterally to the recording site (Fig. 1e, a, d), the activities of each muscle region decreased. Conversely, as the bite-force direction changed posteriorly *(Fig. 1b, a, c)* or ipsi-laterally to the recording site *(Fig. 1d, a, e)*, the activity of each muscle region increased. To investigate the relationship between bite-force directions and muscle activities, integrated EMGs of each muscle region were calculated during biting in various directions.

2. Ranges of bite-force direction to which each muscle region responded

Figure 2 shows the relationship between the average bite-force directions and muscle activities during biting followed by various EMGs. The ordinate shows the lateral bite-

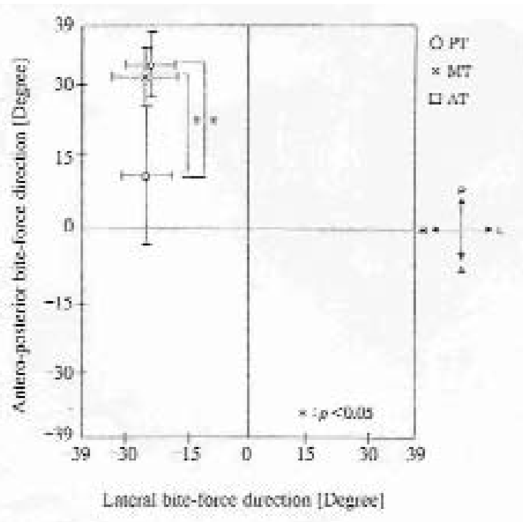


force direction, and the abscissa shows the anterior-posterior bite-force direction. The range of bite-force directions to which each muscle responded (more than 1% MVC – Maximum Voluntary Clench) was wider in AT (Fig. 2c), and narrower in PT (Fig. 2a). It appeared that each muscle had a proper dynamic range as to bite-force directions.

In AT, the range of bite-force directions at high EMG activities (more than 20% MVC) was more anterior direction than the other two. Integrated EMG values to produce particular directions of bite force were different in the three muscle regions. These results suggested that the contribution of muscle activities to bite-force directions was different in each muscle region.

3. Bite-force directions at maximum EMG activities

In all subjects, each muscle region had a specific direction shown by the highest EMG activity. *Figure 3* shows the mean bite-force directions calculated from the highest EMG activities. The mean bite-force directions at maximum EMG activities in AT was 11.0 ± 13.8 degrees posteriorly and 26.5 ± 6.4 degrees ipsi-laterally. That in MT was 31.0 ± 5.9 degrees posteriorly and 27.0 ± 8.3 degrees ipsi-laterally, and that in PT was 33.5 ± 6.9 degrees posteriorly and 25.5 ± 6.2 degrees ipsi-laterally. Significant differences were obtained between AT and MT, AT and PT ($p<0.05$, Mann-Whitney U-test) in anterior-posterior bite-force directions, but no significant difference was obtained in lateral bite-force directions. It was suggested that each muscle region had different functions, especially changing the bite-force antero-posteriorly.



Discussion

In this experiment, the subjects were instructed to bite in various directions with arbitrary magnitudes of bite force. In addition, comparing the studies of van Eijden [5] and Blanksma et al. [2,6], the amount of vertical separation necessary for fixing the force device was much smaller. Therefore, the results obtained from the present study seemed to represent physiological features of the human temporal muscle.

The temporal muscle is usually partitioned into three parts and their action lines differ in orientation. The muscle fibers in AT and in PT have the capabilities to pull the mandible in anterior direction and in posterior direction, respectively. In this study, the bite-force direction calculated from highest EMG activities in AT was significantly anterior direction and those in MT and in PT were significantly posterior direction. It seemed that the directions of the muscle fibers dictated these results.

The range of bite-force direction to which the muscle responded was wider in AT and narrower in PT. This indicates that the function of each muscle region was different during biting. This result coincided with the results of Blanksma et al. [2], who reported the regional difference of the temporal muscle activities during biting in nine directions. We found that AT, MT and PT had specific dynamic ranges of bite-force directions and contributions of each muscle activities to bite-force directions were different. From our results, we concluded that AT, MT and PT had different functional roles in bite-force producing.

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