An Anatomical Study of the Muscles Innervated by the Masseteric Nerve

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Summary: For an accurate assessment of jaw movement, it is critical to understand the comprehensive formation of the masseter. Detailed dissection was performed on fifteen head halves of eight Japanese cadavers in order to obtain precise anatomical information of the course and distribution of the masseteric nerve in the masseter, especially in the zygomaticomandibularis (ZM). Based on detailed innervation investigation, the main trunk of the masseteric nerve ran between ZM and the masseter, and the anterior region of ZM was closely related to the lateral layer of the masseter rather than the medial layer. Considering the positional relationships between the muscles and the innervating branches, it might be proposed that the muscle masses of ZM and the masseter migrate from the posterior side of the temporalis anterolateralward during development. This model is in agreement with the findings in that no nerve branch was observed between the temporalis and ZM.

The architecture of the masticatory muscles is highly complex. The muscles, especially the temporalis and the masseter, are considered to be architecturally and functionally compartmentalized muscles (Herring, 1980; Wineski and Gans, 1984; English, 1985; Herring and Wineski, 1986; Herring *et al.*, 1989). Compartmentalization can function to separate groups of muscle fibers with varying lines of action, allowing the muscles to change their direction of contractions by recruiting the fibers differentially.

The architecture of the muscle bundles of the masseter has been examined in many studies, and the masseter is generally classified into two layers (e.g. Sicher and DuBrul, 1970; Leonhardt *et al.*, 1987) or three layers (e.g. Clemente, 1985; Williams *et al.*, 1995) based on the direction of the muscle bundles. Yoshikawa and Suzuki (1962) classified the masseter into five layers based on the relationships between tendinous and muscular substances. Lam *et al.* (1991) reported the tendon structure of the human masseter by three-dimensional reconstructed images from magnetic resonance imaging (MRI), and identified four tendon planes in each masseter muscle. The stratified structure of

the masseter is still unclear, and the number of layers may change depending on the criteria for the identification of the layers.

The muscle bundles between the temporalis and the masseter are frequently described, and termed in various ways: the zygomaticomandibularis (Toldt, 1904; Sicher and DuBrul, 1970; Tomo, 1990), the maxillomandibularis (Yoshikawa and Suzuki, 1962), the accessory head of the temporalis (Leonhardt *et al.*, 1987) and the deep part of the masseter (Eisler, 1912). The bundles are frequently innervated by both the masseteric nerve and the posterior deep temporal nerve which mainly innervates the posterior third of the temporalis. Tomo (1990) described that the bundles are considered as a transitional muscle. It is suggested that the bundles occupy a critical position between the masseter and the temporalis. Here, the bundles are termed zygomaticomandibularis as adapted by Sicher and DuBrul (1970) in order to distinguish them from the masseter and the temporalis for the convenience of the explanation.

In electrophysiological studies, the compartmentalization of the motor unit territory of the human masseter muscle has been noted especially in rela-

tion to the internal anatomy of the muscle (Stålberg and Eriksson, 1987; McMillan and Hannam, 1991; Blanksma *et al.*, 1992; Tonndorf and Hannam, 1994; Tonndorf *et al.*, 1994). However, there has been little information on the spatial arrangement of the nerve branches to the masseter which connect the motor units. Herring *et al.* (1989) and Tomo (1990) showed that branches which innervate the anterior part of the masseter penetrate and innervate the zygomaticomandibularis before entering the masseter. It has been suggested that there is a close relationship between the zygomaticomandibularis and the anterior part of the masseter.

In the present study, the masseter, the zygomaticomandibularis and the temporalis were removed en bloc from the bony elements, and the detailed innervation patterns were examined. We report the positional relationships among the muscles and their innervating nerves, and discuss the relationships among the muscles.

Materials and Methods

Fifteen halves of eight Japanese cadavers (four males and four females) fixed in 10% formalin and preserved in 30% alcohol were examined. In order to examine the masseter, zygomaticomandibularis and temporalis in detail, the zygomatic arch was removed from the outside, and the bony elements of the cranium were removed from the inside. Before removal of the bony elements, care was taken so as not to divide the muscles in order to preserve small twigs to the muscles. After investigation of the nerve branches which entered the masseter and zygomaticomandibularis, the masticatory muscles were removed en bloc with the mandibular nerve and its branches. The specimens were immersed in water for further dissection, and the intramuscular nerve distributions of the muscles were examined in detail under a binocular microscope, and recorded.

Results

The masseter and the zygomaticomandibularis

Based on the directions of the muscle bundles of the masseter, the muscle seemed to be composed of several layers, and definite borders between layers were observed from the lateral aspect (Fig. 1A). No clear border was identified in the muscular parts in three specimens (20.0%), however the direction of the tendinous parts clearly delineated the borders to underlying muscular parts (Fig. 1B). The number of layers observed from the lateral aspect of the

masseter was two (20.0%), three (66.6%) or four (13.3%).

Figure 1A shows a typical case of the presumptive layer structure. In this specimen, the muscle seemed to be composed of three layers: lateral, middle and medial layers. The lateral layer originated from the anterior third of the lateral surface of the zygomatic arch, ran infero-posteriorly, and inserted into the angle of the mandible. The middle layer originated from the middle third of the inferior border of the zygomatic arch, and inserted into the middle region of the lateral surface of the ramus of the mandible. The medial layer originated from the posterior third of the inner surface of the arch, ran inferiorly and inserted into the lateral surface of the coronoid process. Therefore, the more lateral part of the masseter originated from the more anterolateral region of the zygomatic arch, ran more posteriorly, and inserted into the lower region of the lateral surface of the ramus of the mandible. In addition, the more lateral part occupied the more anterolateral region of the masseter.

After removal of the zygomatic arch and the deep fascia of the temporalis, the zygomaticomandibularis was observed medial to the main trunk of the masseteric nerve (Fig. 1C). The muscle was situated between the masseter and the temporalis. The anterior border of the zygomaticomandibularis adjoined the medial surface of the anterior region (lateral layer) of the masseter, and the posterior border adjoined the posterolateral surface of the posterior region of the temporalis (Fig. 1D). Interestingly, no nerve branch was found between the zygomaticomandibularis and the masseter. The zygomaticomandibularis originated from the posteriormost region of the zygomatic arch and the medial surface of the aponeurosis of the temporalis, and inserted into the lateral surface of the coronoid process and the aponeurosis of the temporalis. The muscle was generally identified as two to five thin layers based on the muscle bundle direction; the borders between these layers could be observed from the posterolateral aspect of the muscle (Fig. 2A). Number of the layers was two (6.7%), three (26.7%), four (40.0%) or five (26.7%).

Distribution of the masseteric nerve

The masseteric nerve originated as a common trunk with the posterior deep temporal nerve from the mandibular nerve. The main trunk of the masseteric nerve wound around the posterior margin of the temporalis, and passed through the mandibular notch to reach the masseter. The main trunk ran anteroinferiorward between the masseter and the zygomaticomandibularis, and gave off muscular

twigs. The twigs from the main trunk to the masseter entered its medial surface (Fig. 2A), and the twig that arose from the more distal part of the main trunk entered the more anteroinferior region of the masseter (Figs. 3–5). The twigs which arose from the proximal part of the main trunk distributed to the medial layer of the masseter. The twigs which arose from the middle part of the main trunk distributed to the middle layer of the masseter, and ran posteroinferiorward in the layer. The twigs that arose from the distal part distributed to the lateral layer, and also ran posteroinferiorward in the layer. The twigs that innervated the medial or middle layer frequently ran lateralward, and also innervated the adjacent layer (Fig. 2B). In addition, the small twigs that penetrated the zygomaticomandibularis entered the anterosuperior part of the masseter.

The twigs to the zygomaticomandibularis arose medially from the main trunk, ran between these layers (Fig. 2A), and innervated them from both medial and lateral surfaces of the presumptive layers (Figs. 3–5). In general, the twigs arose from the more distal part of the main trunk of the masseteric nerve and innervated the more lateral layer of the zygomaticomandibularis. However, the twigs arose from the proximal part of the main trunk, innervated the anterior regions of the layers of the muscle, penetrated the muscle, and then innervated the anterosuperior part of the masseter (Figs. 3–5). The twigs to the medial layer of the zygomaticomandibularis frequently arose from the posterior deep temporal nerve (Figs. 3–4).

Discussion

Numerous studies have shown the stratified structure of the temporalis and the masseter, and the layers of these muscles are classified into various ways. These differences in classifications lie in the definition of the muscle layer of the border region between the two muscles: 1) as independent muscle (Toldt, 1904; Yoshikawa and Suzuki, 1962; Sicher and DuBrul, 1970; Tomo, 1990), 2) a part of the masseter (Sappey, 1876; Clemente, 1985; Williams *et al.*, 1995) or 3) a part of the temporalis (Leonhardt *et al.*, 1987). Most of these studies are based on the muscle bundle direction, merely the external appearance. In the present study, we considered the border muscular region as an independent muscle, according to the relationship to the main trunk of the masseteric nerve and the innervation pattern. Here, we call the region the zygomaticomandibularis as termed by Sicher and DuBrul (1970).

Recently, from the clinical viewpoint, the assessment of the function and movement of the jaw muscles by electrophysiological techniques has been of great importance (Tonndorf and Hannam, 1994; Tonndorf *et al.*, 1994). Accordingly, the functional units of the muscles have been examined in relation to the internal anatomy. However, the detailed relationships between the layer structure and the innervation are still unclear. In the present study, the innervating branches of the masseter, the zygomaticomandibularis and the temporalis were examined after removal from the bony elements en bloc. The main trunk of the masseteric nerve ran between the zygomaticomandibularis and the masseter. The twigs to the zygomaticomandibularis frequently penetrated the muscle, and innervated the anterosuperior part of the masseter. The twigs arose from the more distal part of the main trunk of the masseteric nerve, entered the more anteroinferior part of the masseter, ran lateroposteriorward, and innervated the more lateral layer of the muscle. In addition, the twigs frequently penetrated the tendons in the masseter, and hence small twigs were found to pierce the layers. Therefore, interestingly the zygomaticomandibularis has a close relationship to the lateral layer of the masseter rather than to the middle or medial layers, and the distribution of the innervating branches is not limited to the layers divided by the tendons.

Figure 6 schematically represents the relationships among the masseter, the zygomaticomandibularis, the temporalis, and the masseteric nerve. Interestingly, the innervating branches are generally distributed antero-infero-lateralward, and the layers of the masseter have a U-shaped form. These findings are in agreement with Toldt (1904) and Tomo (1990). Edgeworth (1914) proposed that the anlage of the masseter and the zygomaticomandibularis arises from the posterior part of the common anlage of the masticatory muscles, and migrates anterolateralward. Figure 7 schematically represents a possible model of the development of the masseter, based on the findings of the nerve-muscle relationships of the present study and the findings of Edgeworth (1914). The muscle mass of the masseter moves from the posterior side of the temporalis anteriorward. During the migration it is suggested that the muscle bundles medial to the main trunk of the masseteric nerve might form the posteromedial muscle bundles and the muscle bundle lateral to the main trunk might form the masseter. This model is in agreement with the findings that no nerve branch was observed between the temporalis and the zygomaticomandibularis. With functional adaptation, both the masseter and the zygomaticomandibularis might take a variety of

Fig. 3. Specimen 1 (right). The medial surface of the temporalis, zygomaticomandibularis and masseter, and the intramuscular nerve distribution are shown. Asterisks and stars indicate continuation of the nerves, and the numbers and alphabets of the twigs are common in Figs. B and C. [This holds also for Specimen 2 and 3.] A) The medial surface of the temporalis. The muscle was innervated by the three main nerves: the anterior, middle and posterior deep temporal nerves. One twig (star) of the posterior deep temporal nerve wound around the posterior margin of the muscle with the masseteric nerve. B) The medial surface of the zygomaticomandibularis. The muscle seemed to be composed of four presumptive layers. The more distal twig innervated the more anterolateral layer of the bundle. The most medial layer was innervated by the united branch of the posterior deep temporal and masseteric nerves. The twigs which innervated the most lateral layer penetrated the layer to enter the anterosuperior part of the masseter. C) The medial surface of the masseter. The more distal branches were distributed in the more antero-infero-lateral part of the muscle. The anterosuperior part of the masseter was innervated by the twigs which penetrated the most lateral layer of the zygomaticomandibularis from the medial surface.

Fig. 4. Specimen 2 (right). A) The temporalis. The most posterior branch of the posterior deep temporal nerve innervated the muscle from the posterolateral surface. B) The zygomaticomandibularis. In this specimen, the muscle was composed of three presumptive layers. The most medial layer was innervated by the united branch of the masseteric and posterior deep temporal nerves from the medial surface of the layer. C) The masseter.

Fig. 5. Specimen 3 (right). A) The temporalis. The twigs of the posterior deep temporal and masseteric nerves united to innervate the posterior part of the temporalis. B) The zygomaticomandibularis. In this specimen, four presumptive layers were observed. C) The masseter.

Fig. 6. Schematic transverse section showing the pattern of innervation of the masseter and the zygomaticomandibularis. In this section, the muscle is classified into three presumptive muscle layers.

Fig. 7. A possible model of the developmental formation of the masseter, the zygomaticomandibularis and the temporalis based on the positional relationships between the muscles and the main trunks of their innervating nerves. A) Initial stage. According to Edgeworth (1914), the anlage of the masseter and the zygomaticomandibularis arises from the posterior part of the common anlage of the masticatory muscles. The posterior part of the common anlage is presumptively classified into five parts. B) Definitive stage. The main trunk of the masseteric nerve runs between the masseter and the zygomaticomandibularis. 1, The posterior part of the temporalis. 2, The zygomaticomandibularis. 3, The lateral layer of the masseter. 4, The middle layer of the masseter. 5, The medial layer of the masseter.

directions. Since the stratified structure of the muscles does not correspond to the pattern of the intramuscular nerve distribution, it might not be essential for the muscle structure.

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Abbreviations for figures

At	anterior deep temporal nerve
Cd	condyle
MS	masseter
Ms	masseteric nerve
Mt	middle deep temporal nerve
Pt	posterior deep temporal nerve
Ra	ramus of mandible
T	temporalis
Za	zygomatic arch
ZM	zygomaticomandibularis

Explanation of Figures

Plate I

Fig. 1. Photographs of the lateral surface of the masseter. A) Specimen 1 (right). In this specimen the muscle bundles were classified into three layers based on the muscle bundle directions. The arrows (1 to 3) indicate the main muscle bundle directions. B) Specimen 9 (right). In this specimen, it was difficult to classify the muscle bundles into layers, however the directions of the tendinous parts could be identified because of the clear borders delineating the underlying muscular parts. The arrows (1 to 3) indicate the main tendinous parts and the muscle bundle directions. C) Specimen 5 (right). After removal of the masseter, the zygomaticomandibularis was observed lateral to the temporalis and medial to the main trunk of the masseteric nerve. D) Specimen 9 (left). Anterior aspect of the temporalis, the zygomaticomandibularis and the masseter. The anterior border of the zygomaticomandibularis adjoined the medial surface of the masseter.

A

B

C

D

Plate II

Fig. 2. A) Specimen 1 (right). Photographs of the zygomaticomandibularis. The posterior region of the muscle and the medial surface of the masseter are shown. The zygomaticomandibularis was innervated by the branches from the masseteric nerve (indicated by white arrowheads), and the nerve ran between the muscle and the masseter. B) Photograph of the masseter seen from lateral in specimen 1. A twig (asterisk) which pierced the medial layer entered the medial surface of the middle layer to innervate it.