An anatomic study of the positional relationships between the lateral pterygoid muscle and its surrounding nerves

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SUMMARY

We investigated forty-five head halves of 25 Japanese cadavers in order to obtain precise anatomical knowledge of the courses and distribution of the branches of the mandibular nerve positionally related to the lateral pterygoid muscle. After complete removal of the bony elements, several patterns of the positional relationships between the lateral pterygoid and surrounding nerves were noted. The lateral pterygoid is innervated by branches of the anterior and middle deep temporal nerves, the main trunk of the mandibular nerve and the auriculotemporal nerve, and by branches originating from the forks of these nerves. In two specimens, the buccal nerve was composed of the root from the common trunk with the anterior deep temporal nerve and the root of the middle deep temporal nerve. Based on the positional relationships between the masticatory muscles and the branches of the mandibular nerve, the lateral pterygoid is located in the center of the muscles. Variations in the nerve routes related to the lateral pterygoid are considered to reflect the variability of the differentiation patterns of the anlage of the muscle.

Key-words: Lateral pterygoid muscle – Buccal nerve – Innervation - Human gross anatomy

INTRODUCTION

The lateral pterygoid muscle plays a key role in the movement of the temporomandibular joint. In electromyographic studies, the lateral pterygoid muscle is generally described as a single muscle having two different functions (Kamiyama, 1961; Grant, 1973; MacNamara, 1973; Lipke et al., 1977; Juniper, 1983; Mahan et al., 1983; Gibbs et al., 1984; Widmalm et al., 1987). In contrast, the division of the lateral pterygoid into functional units remains unclear. The lateral pterygoid has generally been described as a muscle composed of two separate heads: Upper or superior and lower or inferior heads (Eisler, 1912; Griffin and Sharpe, 1960; Sicher and DuBrul, 1970; Honee, 1972; Rouvière and Delmas, 1974; Clemente, 1985; Leonhardt et al., 1987; Williams et al., 1995). However, the muscle is not clearly separated into two independent muscles based on innervation findings near its insertion (Eisler, 1912; Sicher and DuBrul, 1970; Schumacher et al., 1976; Naito, 1979; Terada and Sato, 1982; Tomo, 1990; Akita et al., 2000). The muscle frequently shows not only a double head pattern but also a single head or a triple head pattern (Troiano, 1967; Sugisaki et al., 1986; Naohara, 1989; Abe, 1992; Birou et al., 1992). In addition, based on nerve distribution findings Foucart et al. (1998) suggested that the lateral pterygoid is composed of five to six independent functional musculoaponeurotic layers. Therefore, from the viewpoints of both physiology and morphology, the lateral pterygoid is unique and complex. This muscle occupies a critical position in the positional relationships between the nerves and the muscle.

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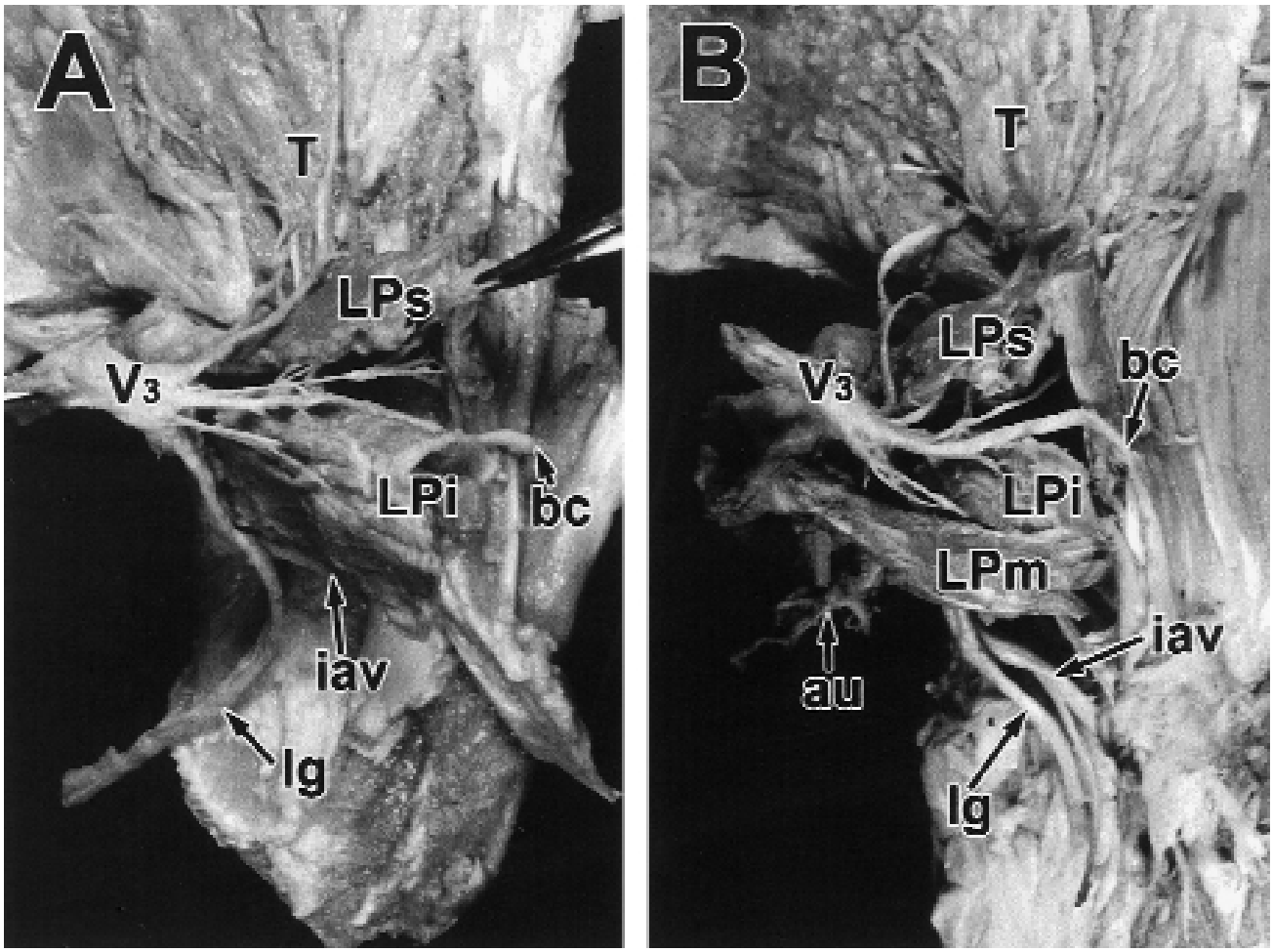

Figure 1. Lateral pterygoid muscle and its parts. Left. Viewed from the anteromedial aspect. **A**: Typical pattern of the muscle: the upper (superior) and lower (inferior) heads are shown. **B**: The medial part of the muscle is shown. This part is located medial to the main trunk of the mandibular nerve (the lingual nerve and the inferior alveolar nerve) and the auriculotemporal nerve.
Au, auriculotemporal nerve; bc, buccal nerve; iav, inferior alveolar nerve; lg, lingual nerve; LPi, lower (inferior) head of lateral pterygoid muscle; LPm, medial part of the lateral pterygoid muscle; LPs, upper (superior) head of lateral pterygoid muscle; T, temporalis muscle; V3, mandibular nerve.

In our previous reports, we discussed the positional relationships among the nerves of the mandibular nerve and masticatory muscles (Shimokawa et al., 1998, 1999; Akita et al., 2000). Here, we examined in detail the relationships between the positional arrangement and the surrounding and innervating nerves of the lateral pterygoid. Further, the nerve communications among nerves and branches of the mandibular nerve around the lateral pterygoid were investigated in detail.

The nerves to the temporalis have been classified and described in different ways (Eisler, 1912; Hovelacque, 1927; Rouvière and Delmas, 1974; Terada and Sato, 1982; Clemente, 1985; Leonhardt et al., 1987; Williams et al., 1995). Here, we classified the nerves to the temporalis into the anterior, middle and posterior deep temporal nerves, as proposed in Shimokawa et al. (1998, 1999) and Akita et al. (2000, 2001). This classification of nerves is based on their positional relationships to the lateral pterygoid and the temporalis and is in accordance with Terada and Sato (1982), based on the classifications of Eisler (1912) and Hovelacque (1927), as follows: (1) the anterior deep temporal nerve arises from the buccal nerve and is distributed in the anterior portion of the temporalis, (2) the middle deep temporal nerve forms a common trunk with the masseteric nerve and separates early from the main nerve to distribute in the middle portion of the muscle, and (3) the posterior deep temporal nerve arises from the masseteric nerve independent of the middle deep temporal nerve and is distributed in the posterior portion of the muscle.

Materials and Methods

Forty-five head halves of 25 Japanese cadavers (14 males and 11 females) were used for this study. The cadavers were fixed in 10% formalin and preserved in 30% alcohol. In order to examine the lateral pterygoid, the bony elements were completely removed from the inside of the cranium according to the superior approach report-

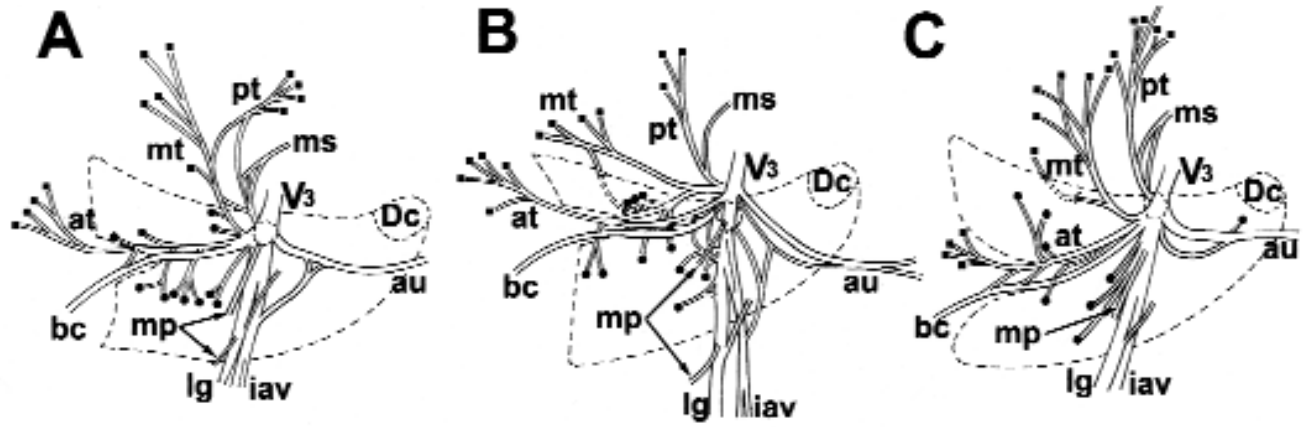

Figure 2. Three examples of various branching pattens of the mandibular nerve from the medial aspects. Right sides. The black dot indicates the innervating branches (twig) to the lateral pterygoid muscle. The black square indicates the branch (twig) to the temporalis. **A**: The lateral pterygoid muscle is innervated by twigs from the anterior and middle deep temporal nerves and from the fork of the anterior deep temporal nerve and the main trunk of the mandibular nerve. **B**: The muscle is also innervated by branches from the main trunk of the mandibular nerve. **C**: A twig from the auriculotemporal nerve also innervates the muscle.
At, anterior deep temporal nerve; au, auriculotemporal nerve; bc, buccal nerve; Dc, temporomandibular joint disc; iav, inferior alveolar nerve; lg, lingual nerve; mp, nerve to medial pterygoid muscle; ms, masseteric nerve; mt, medial deep temporal nerve; pt, posterior deep temporal nerve; V3, mandibular nerve.

ed by Pinto (1962) and Akita et al. (2000). Positional relationships of the lateral pterygoid to the surrounding nerves originating from the mandibular nerve were investigated under an operation microscope. After removal of the lateral pterygoid and the temporalis en bloc with the mandibular nerve and its branches, the innervation patterns of the lateral pterygoid and the temporalis were examined in minute detail.

RESULTS

Form, origin and insertion of the lateral pterygoid muscle

The upper (superior) head of the lateral pterygoid muscle originated from the infratemporal surface and infratemporal crest of the greater wing of the sphenoid bone, and the lower (inferior) head originated from the lateral surface of the lateral pterygoid plate (Fig. 1A). However, both heads were frequently adjoined at their border. Most of the muscle fibers from the upper head of the lateral pterygoid inserted into the disc of the temporomandibular joint, and most of the fibers from the lower head inserted into the neck of the condyle of the mandible. The muscle fibers in the border area between the upper and lower heads were intermingled, especially near the insertion of the muscle, and inserted into the border area between the capsule and the neck. Therefore, although the areas of the typical origins and insertions of the heads were identified, both heads were not clearly divided.

In four specimens, an independent part was observed medial to the lower head (Fig. 1B). Between this part and the lower head, the main trunk of the mandibular nerve (the lingual nerve and the inferior alveolar nerve) and the auriculotemporal nerve ran. The independent part originated from the lateral surface of the lateral pterygoid plate, and inserted into the neck of the condyle of the mandible and the lower part of the articular capsule medial to the insertion of the lower head.

Positional relationships between the lateral pterygoid and surrounding nerves

Several patterns of positional relationships were observed between the lateral pterygoid and branches of the mandibular nerve (Fig. 2). The mandibular nerve and its branches arose radially from the outer surface of the nerve. In general, the buccal nerve originated from the common trunk of the buccal nerve and the anterior deep temporal nerve, and ran between the upper and lower heads of the lateral pterygoid. After passing through the lateral pterygoid, the buccal nerve ran on the anterior margin of the anteromedial muscle bundle of the temporalis (Shimokawa et al., 1998) to reach the skin covering the buccinator (Fig. 3A). In six specimens (13.3%), the buccal nerve pierced the anteromedial muscle bundle of the temporalis (Fig. 3B). The middle and posterior deep temporal nerves and the masseteric nerve usually ran on the superior surface of the upper head (Fig. 4A). In seven specimens (15.6%), the main trunk of the middle deep temporal nerve pierced the upper head of the lateral pterygoid (Fig. 4B). In two specimens (4.4%), the buccal nerve had additional roots from the middle deep temporal nerve, and the main root of the buccal nerve and the anterior deep temporal nerve ran between the upper and lower heads (Fig. 4C). In two

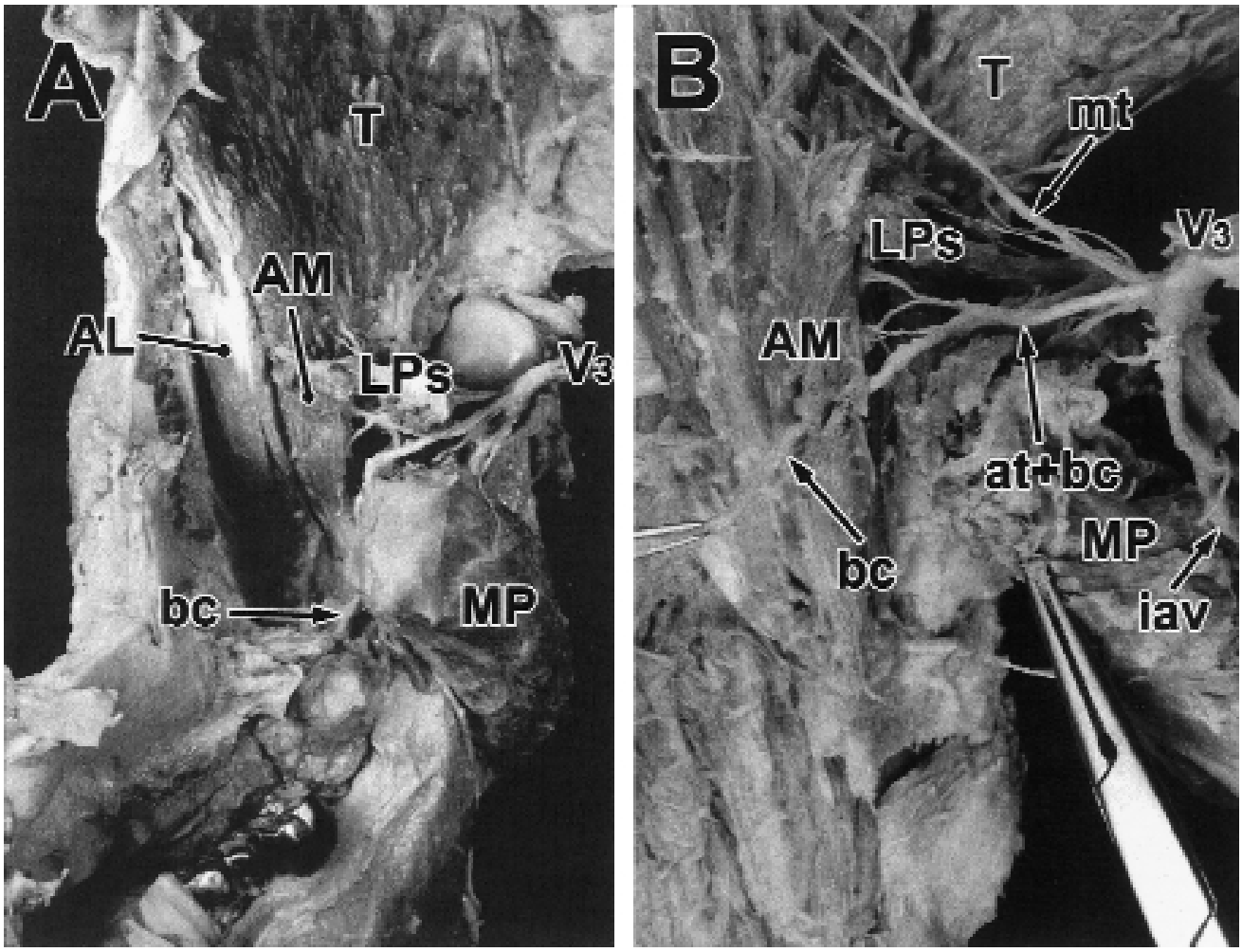

Figure 3. Positional relationships between the buccal nerve and the anteromedial muscle bundle of the temporalis (Shimokawa et al., 1998). Right. Viewed from the anteromedial aspect. **A**: The buccal nerve runs on the anteromedial surface of the anteromedial muscle bundle. **B**: In six specimens, the buccal nerve passed through the anteromedial muscle bundle.
AL, anterolateral muscle bundle; AM, anteromedial muscle bundle; at, anterior deep temporal nerve; bc, buccal nerve; iav, inferior alveolar nerve; LPs, upper (superior) head of the lateral pterygoid muscle; MP, medial pterygoid; mt, middle deep temporal nerve; T, temporalis muscle; V3, mandibular nerve.

specimens (4.4%), the anterior deep temporal nerve and buccal nerve ran on the superior surface of the upper head (Fig. 4D).

The main trunk of the mandibular nerve (the lingual nerve and the inferior alveolar nerve) generally ran inferiorly between the lower head of the lateral pterygoid and the medial pterygoid, and the auriculotemporal nerve ran posteriorly, on the medial surface of the lower head (Fig. 1A). In four specimens (8.9%) which had the medial part, the main trunk and the auriculotemporal nerve ran through between the lower head and the medial part (Fig. 1B).

The border area of the temporalis between the areas supplied by the anterior and middle deep temporal nerves was sometimes distributed by the branches that perforated the upper head originating from each or both of the anterior and middle deep temporal nerves and/or by branches originating between two nerves (10 specimens, 22.2%). In seven specimens (15.6%), the communicating branches among the anterior and middle deep temporal nerves and such perforating branches were observed in the space between the lateral pterygoid muscle and the temporalis muscle (Fig. 5). The nerve to the medial pterygoid originated from the medial surface of the main trunk of the mandibular nerve. The nerve supplied the muscle from the medial surface (Fig. 6A). It was frequently observed that a small twig from the lingual nerve supplied the medial pterygoid from the lateral surface (Fig. 6B).

Innervation of the lateral pterygoid muscle

In most of the specimens, twigs from the anterior deep temporal nerve innervated the upper and lower pterygoid heads from their respective contact surfaces with the nerve. In two specimens (4.4%) in which the buccal nerve and the anterior deep temporal nerve ran on the superior surface of the lateral pterygoid muscle,

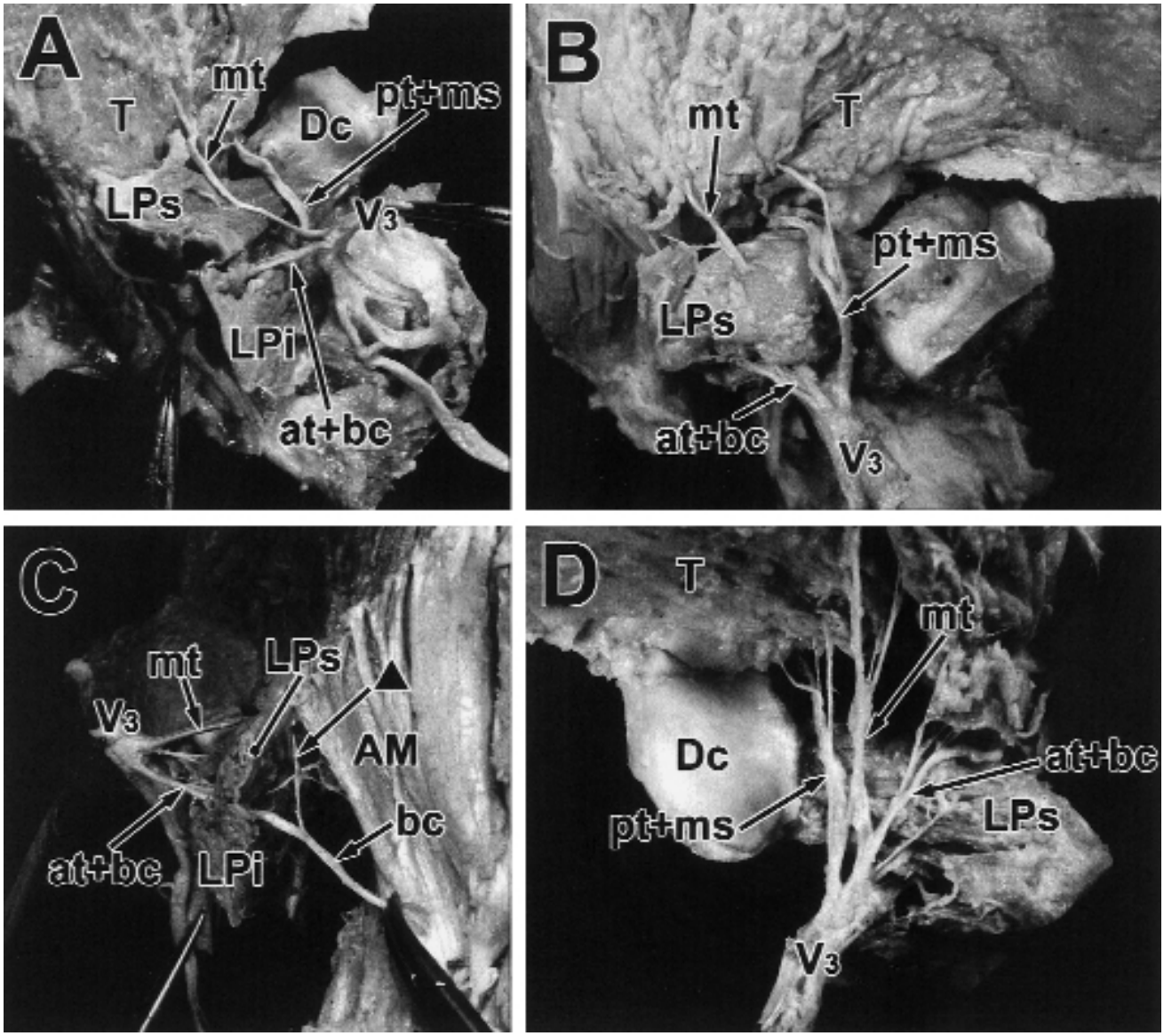

Figure 4. Relationships between the lateral pterygoid muscle and its surrounding nerves. **A**: The middle and posterior deep temporal nerves run on the superior surface of the upper (superior) head of the muscle, and the anterior deep temporal and buccal nerves run between the upper and lower (inferior) heads. **B**: The middle deep temporal nerve pierces the upper (superior) head of the muscle. **C**: A root of the buccal nerve (indicated by the black triangle) originates from the middle deep temporal nerve. **D**: The anterior deep pterygoid and buccal nerves run on the superior surface of the upper head of the muscle.
AM, anteromedial muscle bundle; at, anterior deep temporal nerve; bc, buccal nerve; Dc, temporomandibular joint disc; LPi, lower (inferior) head of lateral pterygoid muscle; LPs, upper (superior) head of lateral pterygoid muscle; ms, masseteric nerve; mt, middle deep temporal nerve; pt, posterior deep temporal nerve; T, temporalis muscle; V3, mandibular nerve.

the small twigs originating from the fork of the anterior deep temporal nerve and the main trunk of the mandibular nerve innervated from the contact surfaces of both heads. In the posterior half of the muscle, it was frequently observed that some of the twigs to the lower head from the anterior deep temporal nerve also supplied the upper head, and vice versa. Therefore, the border area between the upper and lower heads was not clearly divided according to the innervation findings.

Twigs from the main trunk of the mandibular nerve innervated the lower head from the medial surface in 10 specimens (22.2%). The lower head was also innervated by twigs originating from the fork of the main trunk of the mandibular nerve and the anterior deep temporal nerve. The upper head was additionally innervated by twigs from the middle deep temporal nerve in 30 specimens (66.7%). In addition, in 32 specimens (71.1%) the upper head was innervated by twigs originating from the fork of the anterior and middle deep temporal nerves. In four specimens (8.9%), the twigs from the auriculotemporal nerve innervated the lower head from the medial aspect near the insertion.

In the specimens that had a medial part as previously mentioned (four specimens, 8.9%),

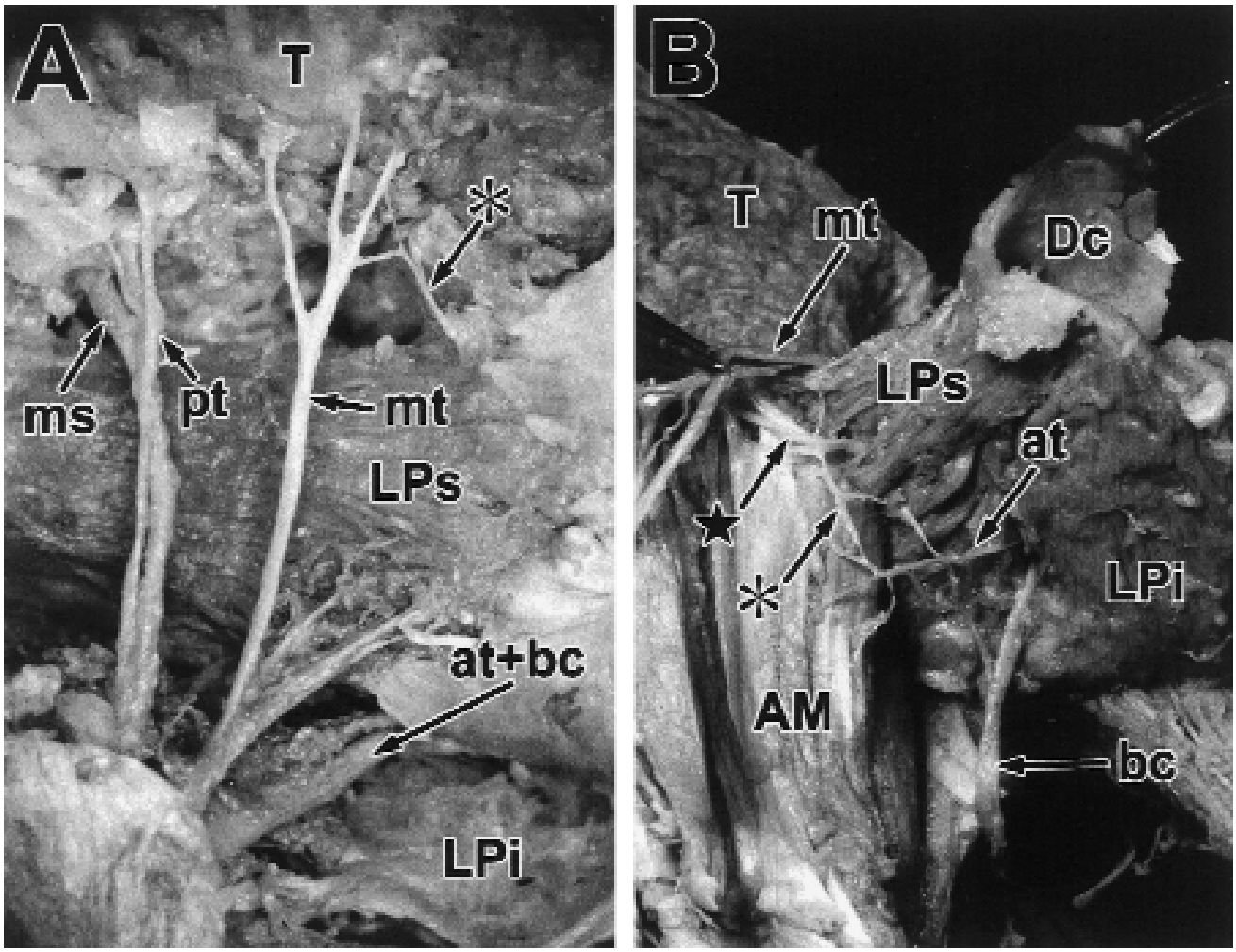

Figure 5. Nerve connection between the anterior and middle deep temporal nerves (indicated by the asterisk). **A**: Communicating branch runs between the lateral pterygoid muscle and the temporalis. **B**: Left anteromedial muscle bundle. Viewed from the posterior aspect. The communicating branch also communicates with a branch which perforates the upper (superior) head of the lateral pterygoid muscle (indicated by the star).
AM, anteromedial muscle bundle; at, anterior deep temporal nerve; bc, buccal nerve; Dc, temporomandibular joint disc; LPi, lower (inferior) head of lateral pterygoid; LPs, upper (superior) head of lateral pterygoid; ms, masseteric nerve; mt, middle deep temporal nerve; pt, posterior deep temporal nerve; T, temporalis muscle.

this medial part was innervated by a twig of the main trunk from the lateral aspect. In the specimens in which twigs of the middle deep temporal nerve innervated the upper head, it was frequently observed that twigs of the anterior and middle deep temporal nerves communicated with each other in the upper head.

Discussion

According to morphological studies, including the present work, the lateral pterygoid muscle is not clearly divided into distinct parts (Eisler, 1912; Troiano, 1967; Schumacher et al., 1976; Naito, 1979; Terada and Sato, 1982; Naohara, 1989; Tomo, 1990; Abe, 1992; Birou et al., 1992; Foucart et al., 1998; Akita et al., 2000). The insertion area of the lateral pterygoid is spread broadly between the disc of the temporomandibular joint and the condyle of the mandible, and there is no clear division between the heads near their posterior halves. Some authors have proposed an integrated activity of the lateral pterygoid during opening and protrusion movements (Auf der Mur, 1980; Lehr and Owens, 1980). In contrast, many reports have stated that this is made up of two functionally different parts; the upper part is active during the closing movement, whereas the lower part is active during protraction, opening and eccentric lateral movements (Kamiyama, 1961; Grant, 1973; MacNamara, 1973; Lipke et al., 1977; Juniper, 1983; Mahan et al., 1983; Gibbs et al., 1984; Widmalm et al., 1987). Therefore, it is very difficult to divide the lateral pterygoid morphologically into definite functional units in physiological studies.

The lateral pterygoid muscle is sometimes observed to have a third head, reported as the medial head, in addition to the upper and lower

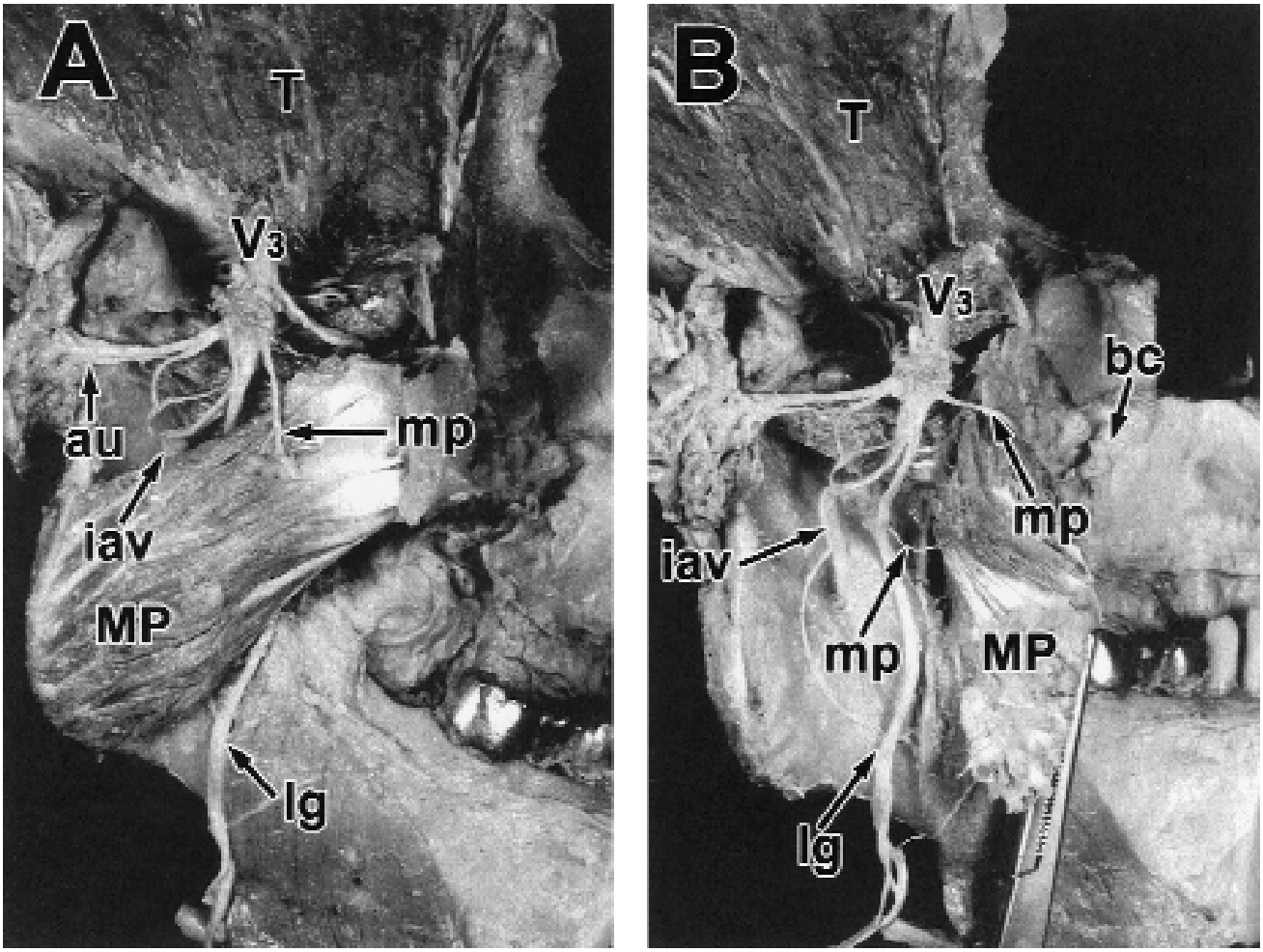

Figure 6. Innervation of the medial pterygoid. Left. Viewed from the medial aspect. **A**: The nerve to the medial pterygoid arises from the medial surface of the root of the main trunk (lingual nerve and inferior alveolar nerve) of the mandibular nerve, and innervates the muscle from the medial surface. **B**: Same specimen as A. The medial pterygoid is pulled anteriorly. Additional branch of the medial pterygoid arises from the lingual nerve, and innervates from the lateral surface of the muscle.
Au, auriculotemporal nerve; bc, buccal nerve; iav, inferior alveolar nerve; lg, lingual nerve; MP, medial pterygoid muscle; mp, nerve to medial pterygoid; T, temporalis muscle; V3, mandibular nerve.

heads (Troiano, 1967; Sugisaki et al., 1986; Naohara, 1989). In the present study, the part located medial to the main trunk of the mandibular nerve was observed in four specimens. This independent part is considered to be similar to the medial head. Among the muscle bundles attached to the disc of the temporomandibular joint, it is well known that most of the upper head of the lateral pterygoid inserts into the disc (Couly et al., 1975a, b, 1976;Couly, 1980; Meyenberg et al., 1986; Sugisaki et al., 1986; Le Toux et al., 1989; Naohara, 1989; Merida-Velasco et al., 1993). The upper head of the lateral pterygoid is active during closing movements (Kamiyama, 1961; Grant, 1973; MacNamara, 1973; Lipke et al., 1977; Juniper, 1983; Mahan et al., 1983; Gibbs et al., 1984; Widmalm et al., 1987), and therefore the bundle functions to guide the articular disc anteriorly during closing, in cooperation with the upper head and the discotemporal muscle bundle of the temporalis. One part of the medial head is inserted into the medial surface of the articular capsule, but this part does not attach to the disc of the temporomandibular joint. Therefore, the medial head is considered to play a role in supporting the medial head. Based on findings of the human fetus, Merida-Velasco et al. (1993) and Ögütcen-Toller and Juniper (1993) believe that the lateral pterygoid is divided into two or three main parts. The lateral pterygoid may first differentiate to form two or three parts, but these parts are not clearly divided during the expansion of their insertion areas on the disc and the condyle of the mandible, and the functional units cannot be clearly identified.

We show several patterns of the positional relationships between the nerves and the lateral pterygoid in Figure 7. Textbooks indicate that the nerve to the lateral pterygoid mainly originates from the buccal nerve (Henle, 1858; Poirier and Charpy, 1901; Rauber, 1903; Paturet, 1964; Rouvière and Delmas, 1974; Clemente, 1985;

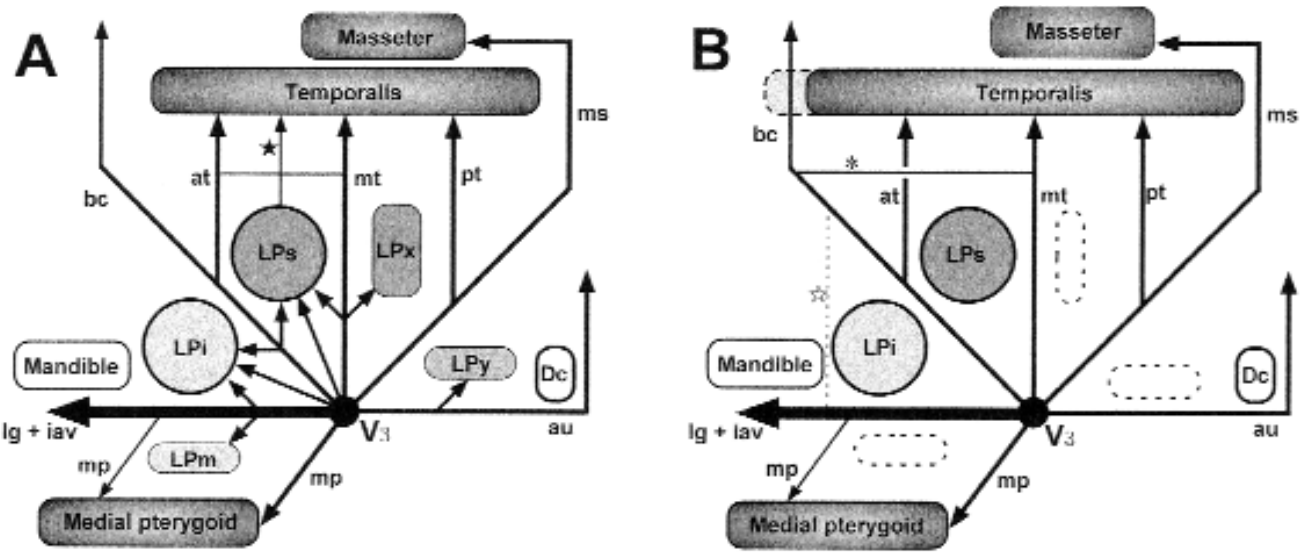

Figure 7. Schematic presentation showing positional relationships between the masticatory muscles and branches of the mandibular nerve based on the present findings and those of our previous reports (Shimokawa et al., 1999; Akita et al., 2000). **A**: Innervating branches of the lateral pterygoid muscle. A part of the upper (superior) head (LPx) is innervated by a branch of the middle deep temporal nerve from the inferior surface. A medial part (LPm) which is located medial to the main trunk (lingual nerve and inferior alveolar nerve) is innervated by a branch of the main trunk from the lateral surface. A branch from the auriculotemporal nerve innervates a small medial part of the lower head (LPy) from the medial surface. Branches that perforate the upper head of the lateral pterygoid (indicated by a black star) innervate the area of the temporalis between the areas innervated by the anterior and middle deep temporal nerves. **B**: Roots of the buccal nerve. The buccal nerve generally originates from the common trunk with the anterior deep temporal nerve. It is sometimes observed that the buccal nerve pierces the anterior region of the temporalis muscle. An additional root from the middle deep temporal nerve (indicated by an asterisk) is observed in the present study, and this root runs between the upper head of the lateral pterygoid muscle and the temporalis muscle. It would be possible to predict another root of the buccal nerve from the main trunk of the mandibular nerve (indicated by a white star). Although we did not find such a root in the present study, Kameda (1952) reported a communicating branch between the inferior alveolar nerve and the buccal nerve in two out of 100 specimens.
At, anterior deep temporal nerve; au, auriculotemporal nerve; bc, buccal nerve; Dc, temporomandibular joint disc; iav, inferior alveolar nerve; lg, lingual nerve; LPi, lower (inferior) head of lateral pterygoid; LPm, medial part of lateral pterygoid; LPs, upper (superior) head of lateral pterygoid; LPx, a small superior part of upper head of lateral pterygoid; LPy, a small medial part of lower head of lateral pterygoid innervated by a branch of auriculotemporal nerve; mp, nerve to the medial pterygoid muscle; ms, masseteric nerve; mt, middle deep temporal nerve; pt, posterior deep temporal nerve; V3, mandibular nerve.

Williams et al., 1995). In the present study, the lateral pterygoid was innervated not only by twigs of the anterior deep temporal nerve which runs along with the buccal nerve but also by twigs of the middle deep temporal nerve, the main trunk of the mandibular nerve and the auriculotemporal nerve. Foucart et al. (1998) recently reported that the lateral pterygoid is additionally innervated by branches from the auriculotemporal and masseteric nerves. However, no muscular branches to the lateral pterygoid from the masseteric nerve were found here. Akita et al. (2000) reported that twigs of the posterior deep temporal nerve that arise from the masseteric nerve frequently innervate the mid-medial muscle bundle of the temporalis. The bundle is located between the upper head of the lateral pterygoid and the temporalis, and is a part of the temporalis rather than a part of the lateral pterygoid according to the nerve distribution (Akita et al., 2000). The present findings also show that branches of the anterior and middle deep temporal nerves and branches originating between the nerves frequently pierce the upper head of the lateral pterygoid, and these branches have communications with one another inside and/or outside the upper head. The anterior and middle deep temporal nerves innervate the anterior and middle parts of the temporalis respectively, and the twigs from the communications innervate the area between the areas supplied by the anterior and middle deep temporal nerves. Based on the findings of their innervation the lateral pterygoid has a close relationship with the temporalis. Therefore, the upper head of the lateral pterygoid is originally situated deep to the temporalis, and during development the positional relationship between the upper head and the temporalis may be shifted to a right angle.

In general, the buccal nerve and the anterior deep temporal nerve originate from the mandibular nerve as a common trunk and pass between the upper and lower head of the lateral pterygoid to reach the skin covering the buccinator. In the present study, an additional root of the buccal nerve originating from the middle deep temporal nerve was observed in two spec-

imens. In addition, from the viewpoint of the positional relationship to the lateral pterygoid, in two specimens the buccal nerve ran on the superior surface of the lateral pterygoid. Kameda (1952) reported a communicating branch between the buccal nerve and the inferior alveolar nerve (two cases in 100 sides), but we did not find this in the present study. Therefore, the buccal nerve seems to be an independent nerve from the anterior deep temporal nerve, although the nerve usually runs along with the anterior deep temporal nerve.

The lateral pterygoid muscle is a single muscle that is innervated by various twigs from the branches of the mandibular nerve, and several nerves frequently pass through the muscle. A complex pattern of innervation and perforation of several nerves are observed in the piriformis muscle (Akita et al., 1992, 1994). The piriformis is situated on the dorsal surface of the sacral plexus. The muscle is innervated by branches of several nerves of the plexus, and is perforated by several nerves (Akita et al., 1992, 1994). According to the positional relationships to the branches and nerves of the mandibular nerve, the lateral pterygoid muscle is situated immediately inferolateral to the ramification center of the mandibular nerve, and has several innervation patterns and nerve perforation patterns. Based on the positional relationships between the masticatory muscles and the nerves of the mandibular nerves, the lateral pterygoid is located in the center of the muscle (Fig. 7). Variations in the nerve routes related to the lateral pterygoid are considered to reflect the variability of the differentiation patterns of the anlage of the muscle.

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