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Anatomical Connections between the Inferior Fibers of the *Musculus orbicularis oculi* and *Musculus levator labii superioris alaeque nasi*

Conexiones Anatómicas entre las Fibras Inferiores del Músculo Orbicular del Ojo y Levantador Nasolabial

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SUMMARY: This study aimed to determine the anatomical connections between the inferior fibers of *M. orbicularis oculi* (OOc inf.) and the *M. levator labii superioris alaeque nasi* (LLSAN), providing anatomical variations of the connecting fibers. This study examined the OOc and LLSAN of 44 specimens from 22 embalmed adult Korean cadavers. Connecting fibers between the OOc inf. and LLSAN were observed in 29.5 % of the specimens. Connecting patterns of the OOc inf. to the LLSAN were classified into three categories according to the directions of the connecting fibers; Type I (13.6 %), in which some of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN. Type II (11.4 %), in which some of the OOc inf. descended vertically to blend with the LLSAN. Type III (4.5 %), in which both types I and II were found simultaneously. Some of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN, and some of the OOc inf. descended vertically to blend with the LLSAN. These findings provide greater knowledge of the connecting fibers between the OOc inf. and LLSAN, thereby helping us understand complicated expressions, inject BoNT-A into related wrinkles, and analyze EMG activities.

KEY WORDS: Connecting fibers; Levator labii superioris alaeque nasi; Orbicularis oculi.

INTRODUCTION

In the midface, several muscles responsible for movements of the eye, nose, and upper lip are closely located, often overlapping together. Some muscles also have synergic actions and connecting fibers with adjacent muscles, probably for combined movements of the eye, nose, and upper lip.

Compared to other regions, the facial muscles have several connecting fibers interacting with surrounding muscles (Hur *et al*., 2010; Youn *et al.*, 2012; Hur *et al*., 2014, 2015, 2017a,b,c, 2018; Iwanaga *et al.*, 2021; Hur *et al*., 2022). Hur *et al*. (2010) described that the muscle fibers connecting functionally opposing muscles, e.g., nasal dilators and constrictors, are closely related to the opposing fibers' consistent synergic action in intramuscular electrical simulation, as reported by Bruintjes *et al*. (1996). Iwanaga *et al*. (2021) reported on the extended crossing fibers of the mentalis attaching to the contralateral mandible, focusing on the interactions of the mentalis with the surrounding structures. Hur *et al*. (2022) reported anatomical connections among the depressor supercilii, M. levator labii superioris alaeque nasi (LLSAN), and inferior fibers of M. orbicularis oculi (OOc inf.), contributing to our understanding of the anatomical origins of individual variation in facial expressions.

The muscles of the face vary considerably in their development and the degree to which they interlace (Hollinshead, 1982). Standring (2020) stated that the M. orbicularis oculi (OOc) inferiorly and medially overlaps or blends with adjacent muscles, such as the LLSAN, levator labii superioris, and M. zygomaticus minor (Zmi). However, the prevalence, sites, morphological patterns, and variations of the connecting fibers between the OOc inf. and LLSAN have not yet been reported.

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Grooves in the infraorbital region can be classified as nasojugal grooves (or folds), tear trough deformities, and palpebromalar grooves. These can be differentiated based on anatomical characteristics (Lee & Hong, 2018). The nasojugal groove is formed at the margin between the lower lid and the cheek and runs inferolaterally from the medial canthus. The nasojugal groove region corresponds with the inferior margin of the OOc and becomes more pronounced with the existence of the medial muscular band of the OOc. The tear trough is a line originating from the medial canthus and proceeding inferolaterally along with the infraorbital margin. The tear trough has various forms according to how the medial part of the orbicularis retaining ligament and the fibers of the medial muscular band of OOc contact the skin (Kim *et al*., 2016). Another wrinkle in the medial region of the OOc inf. is the naso-orbicular rhytides that cause persistent wrinkling of the root of the nose due to the contraction of the nasal portion of the orbital OOc (Venkataram, 2017; Benedetto, 2018). The nasojugal groove, tear trough, and naso-orbicular rhytides can be related to the connecting fibers between the OOc inf. and LLSAN due to their sites. In addition, these connecting fibers can cause unexpected results when injecting botulinum toxin type A (BoNT-A) into the OOc and LLSAN.

This study aimed to determine the anatomical connections between the OOc inf. and the LLSAN, providing anatomical variations of the connecting fibers. These data will be helpful to better understand the details of facial expressions, inject BoNT-A, and perform electromyography (EMG) studies.

MATERIAL AND METHOD

Specimens and dissection. This study examined the OOc and LLSAN of 44 specimens from 22 embalmed adult Korean cadavers (10 males and 12 females) with a mean age of 72.1 years (range: 40–94 years) at the time of death. Facial skin was removed, and face was dissected to expose the midfacial muscles, with particular focus on the OOc inf. and LLSAN. When the connecting fibers between the OOc inf. and LLSAN were found, their anatomical relationships with surrounding structures were carefully observed.

Ethics Statement. This study was approved by the Institutional Review Board of the Catholic Kwandong University (IRB no. CKU-21-01-1003). All cadavers were legally donated to the Catholic Kwandong University College of Medicine, and this study was performed in accordance with the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

RESULTS

Connecting fibers between the OOc inf. and LLSAN were observed in 13 of 44 specimens (29.5 %, 10 of 22 cadavers; 3 bilateral, 7 unilateral). Connecting patterns of the OOc inf. to the LLSAN were classified into the following three categories according to the directions of the connecting fibers (Fig. 1):

1. Type I (n = 6, 13.6 %; 1 male, 5 females), in which some of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN. Due to the connection, the inferior margin of the OOc and the lateral margin of the LLSAN were in contact.

2. Type II (n = 5, 11.4 %; 3 males, 2 females), in which some of the OOc inf. descended vertically to blend with the LLSAN. These connecting fibers blended with the lateral (two specimens), middle (two specimens), and medial (one specimen) fibers of the LLSAN. The connecting fibers were more distinct when blending with the lateral and medial fibers of the LLSAN than when blending with the middle fibers of the LLSAN. After blending with the lateral and middle fibers of the LLSAN, the connecting fibers descended toward the upper lip, whereas after blending with the medial fibers of the LLSAN, the connecting fibers descended toward the nasal ala.

3. Type III (n = 2, 4.5 %; 2 males), in which both types I and II were found simultaneously. Some of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN, and some of the OOc inf. descended vertically to blend with the LLSAN.

When some of the OOc inf. blended with the LLSAN, the amount of the connecting fibers varied, ranging from one-third to just a few fibers of the LLSAN.

DISCUSSION

The present study examines the connecting fibers between the OOc inf. and LLSAN (*Levator nasiolabialis*; *Musculus levator nasiolabialis*; *M. levator labii superioris alaeque nasi*), with results showing that their prevalence and morphological variations reach about 29.5 %. When these connecting fibers are present and distinctive, they can simultaneously affect the synergic actions of the orbital region, upper lip, and nose, as well as deepening wrinkles, such as the nasojugal groove, tear trough, and naso-orbicular rhytides.

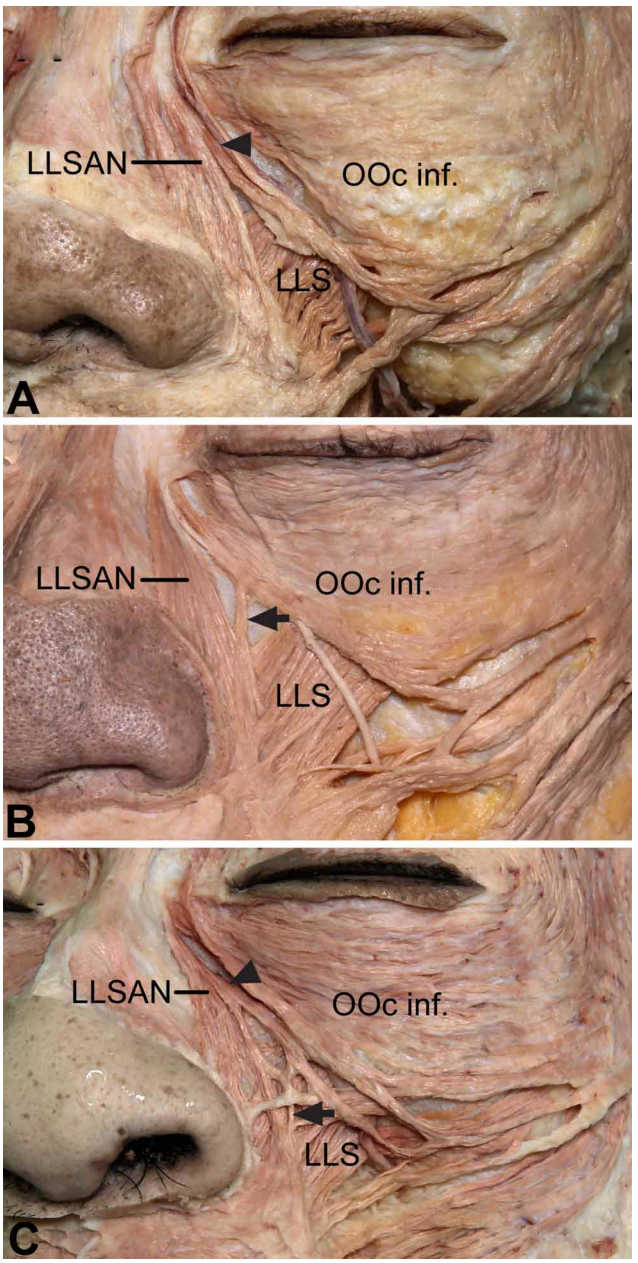

Fig. 1. Connecting patterns of the inferior fibers of orbicularis oculi (OOc inf.) to the levator labii superioris alaeque nasi (LLSAN). (A) Some (arrowhead) of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN. (B) Some (arrow) of the OOc inf. descended vertically to blend with the LLSAN. (C) Some (arrowhead) of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN, and some (arrow) of the OOc inf. descended vertically to blend withthe LLSAN. LLS, levator labii superioris.

In type I, some of the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN. After the OOc fibers surrounded the superior and lateral margins of the OOc, the OOc inf. coursed medially to blend with the lateral originating fibers of the LLSAN that attached to the maxilla as well as the medial palpebral ligament. Thus, these courses and attachments of the OOc inf. to several sites can support and raise the malar fat and suborbicularis oculi fat more tightly.

In type II, some of the OOc inf. descended vertically to blend with the LLSAN. When these connecting fibers blend with the lateral fibers of the LLSAN, the LLSAN is better able to raise the upper lip and deepen the upper nasolabial fold via a contraction of the OOc during the formation of various facial expressions, such as grimacing or smiling. When these connecting fibers are blended with the medial fibers of the LLSAN, the contraction can assist in dilating the nostril and raising the nasal ala with the contraction of the OOc.

The connecting fibers between the OOc inf. and LLSAN lay in the sulcus between the nose and cheek. The sites of the connecting fibers between the OOc inf. and LLSAN corresponded with the naso-orbicular rhytides. The nasojugal groove region corresponds with the lower margin of the OOc. The tear trough corresponds with the lower margin of the orbital margin (Kim *et al*., 2016). The amount of orbital fibers in the medial portion of the OOc inf. is less than that of the lateral portion of the OOc. Thus, the sites of the nasojugal groove and tear trough can be closely located, and the connecting fibers between the OOc inf. and LLSAN can affect the formation and deepening of the naso-orbicular rhytides, nasojugal groove, and tear trough.

The OOc has several connecting fibers that interact with surrounding muscles. The upper fibers of the OOc blend with the frontal part of occipitofrontalis and corrugator supercilii (Standring, 2020). Some lateral fibers of the OOc extend to the Zmi in most specimens (Youn *et al*., 2012; Hur *et al*., 2018). A part of the superomedial fibers of the OOc, the depressor supercilii, was medially connected to the LLSAN by the muscle fibers and thin aponeurosis in 22.7 % of the specimens (Hur *et al*., 2022). The inferomedial fibers of the OOc had fibers connecting to the LLSAN in 29.5 % of specimens in the present study. Thus, both the superior and inferior fibers of the OOc had connecting fibers on their medial sides, implying the delicate and combined movements of the orbital, nasal, and upper lip regions. Waller *et al*. (2006) found that intramuscular electrical stimulation of the OOc pars orbitalis elevates the infraorbital triangle (cheek) superiorly and medially in humans and chimpanzees. Thus, the connecting fibers between the OOc inf. and LLSAN are thought to assist in the action of the OOc inf., medially combining the movements of the eye, nose, and upper lip.

The experimental study of Bruintjes *et al*. (1996) found that the LLSAN's function is primarily that of mimicking. The LLSAN muscles are hardly active during respiration but show high levels of activity during complex mimetic activities, such as closing the eyes or drawing the nose down. Waller *et al*. (2006) found that intramuscular electrical stimulation of the LLSAN draws lip corners laterally and causes wrinkles in the skin alongside the nose in humans. Unlikely other levators of the upper lip, the LLSAN raises the upper lip superomedially, and it also attaches to the upper third of the nasolabial fold (Pessa & Brown, 1992). The connecting fibers between the OOc inf. and LLSAN can assist in raising the upper lip superomedially, dilating the nostril, or attaching to the upper nasolabial fold. Additionally, these connecting fibers can affect EMG activities of the OOc and LLSAN.

The anatomical connections between the OOc and LLSAN are also found in Antropopithecus and Gorilla. The LLSAN of gorillas is derived from the portion of the OOc below the rima oculi, with only a few bundles finding attachment to the medial palpebral ligament. The OOc in the lower lid of Anthropopothecus comes from the ligament, inferior orbital margin, and the nose. The origin on the nose reaching to the midline is covered by the procerus and unites with the LLSAN (Sullivan & Osgood, 1925). The connecting fibers between the OOc inf. and LLSAN in the present study and the connecting fibers among the DS, LLSAN, and OOc inf. in a previous study (Hur *et al*., 2022) imply that the facial muscles between the eyes and upper lip in humans are more differentiated than those in other races.

In the present study, the connecting fibers between the OOc inf. and LLSAN were located where movements of the eye, nose, and upper lip occur simultaneously. Additionally, these connecting fibers had various patterns, probably contributing to forming complicated expressions and deepening wrinkles in the region. These findings provide greater knowledge of the connecting fibers between the OOc inf. and LLSAN, thereby helping us understand complicated expressions, inject BoNT-A into related wrinkles, and analyze EMG activities.

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RESUMEN: Este estudio tuvo como objetivo determinar las conexiones anatómicas entre las fibras inferiores del músculo orbicular del ojo (MOO inf.) y el levantador nasolabial (*Musculus levator nasiolabialis*; *M. levator labii superioris alaeque nasi*) (LNL), proporcionando variaciones anatómicas de las fibras conectoras. Se examinó el *orbicularis oculi* (MOO) y LNL de 44 especímenes de 22 cadáveres coreanos adultos embalsamados. Se observaron fibras conectoras entre los MOO inf. y LNL en el 29,5 % de los especímenes. Patrones de conexión del OOc inf. a LNL se clasificaron en tres categorías según las direcciones de las fibras conectoras; Tipo I (13,6 %), en el que algunos de los MOO inf. cursaban medialmente para mezclarse con las fibras de origen lateral del LNL. Tipo II (11,4 %), en el que algunos de los MOO inf. descendían verticalmente para mezclarse con el LNL. Tipo III (4,5 %), en el que se encontraron simultáneamente los tipos I y II. Algunos de los MOO inf. cursaron medialmente para mezclarse con las fibras de origen lateral de la LNL y algunas de las MOO inf. descendían verticalmente para mezclarse con el LNL. Estos hallazgos aportan un mayor conocimiento de las fibras conectoras entre los MOO inf. y LNL, lo que nos ayuda a comprender expresiones complicadas, inyectar BoNT-A en las arrugas relacionadas y analizar las actividades de EMG.

PALABRAS CLAVE: Fibras conectoras; *Levator labii superioris alaeque nasi*; *Orbicularis oculi.*

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