REVIEW ARTICLE

Facial Muscles and Its Modiolus: A Review of Embryology, Comparative Anatomy, Morphology and Applied Anatomy

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ABSTRACT

The modiolus of the face manifests the interesting landmark for facial muscles attachment. The strong connective tissue fibres play an important role in the clinical setting, especially in the aesthetic and dental surgeries. In the fourth week of intrauterine life, the development of the modiolus evolves in accordance with the growth of muscles of facial expression. Microscopically, a white, tendinous structure with the thick irregular collagenous connective tissue of collagen fibres predominance appeared to be the modiolus. Modiolus is morphologically a fibromuscular muscle situated on the lateral border of the mouth. The formation of the nasolabial fold is important and a well-developed modiolus provide a toned face. Several works of literature forementioned the number of facial muscles attached to the modiolus but no definitive similarity are identified. This review summarizes the updated morphological features and applied anatomy of the facial modiolus with its muscle attachment.

Keywords: Facial muscles, Modiolus, Embryology, Morphology, Applied anatomy

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INTRODUCTION

As early as 1925, the modiolus of the face has become an interesting anatomical landmark to study with. Modiolus is defined as the mass of muscle attachment at the corner of the mouth, which known as "der Knoten." by the Germans (1). The contraction of the facial muscles which centred in the modiolus producing facial expression mimicking smiling, satisfaction, sadness, purposely action and determination (2).

Modiolus is a converged tendinous structure in which muscle fibres running from a horizontal and vertical direction at the lateral corner of the mouth below to the mouth angle (3). Theoretically, nine muscles are known to attach to each side of the modiolus. Most fibres are terminated after the modiolus attachment; occasional bundles are escaped and perhaps are traced from one muscle to another (4).

The synchronous movement and interactions of several facial mimetic muscles create complex facial expressions (5). The modiolus plays a crucial role in facial actions because from therein is provided with the force for closure, eversion, and opening of the mouth (6). In view of the different ideas from the literature, here we elaborate the morphology of the modiolus of the face especially its muscle attachment and relate it to the evolutionary, comparative and applied anatomy.

Facial Muscles

Facial muscle is a group of skeletal muscle which are mainly located bilaterally in the front of the face. These muscles are positioned exactly around vital organs such as a region of mouth, eyes, nose, ear, neck and scalp as in Table I (7). The function of these muscles is mainly as a facial expression which is related to the emotion. Electromyography (EMG) study of levator labii muscles showed a high response of this muscle towards violation of purity and fairness behaviour (8). This response is related to the function of this muscle which showed facial expression of disgust that raising the upper part of the lip. Corrugator supercilii muscle functions to

Table I: The Grouping of Facial Muscle

Facial region	List of facial muscles
Eyes or orbital region	Orbicularis oculi, Corrugator supercilii,
Ear or auricular region	Auricular muscles
Nose or nasal region	Nasalis, Depressor septi and Procerus
Mouth or oral region	*Orbicularis oris, *Depressor anguli oris, *Levator anguli oris, Levator labii superioris, Levator labii superioris alaque nasi, *Zygomaticus major, Zygomaticus minor, *Risorius, *Depressor labii inferioris, Mentalis and *Buccinator
Scalp region	Frontalis, Occipitalis
Neck region	*Platysma

* represents the muscles that are attached to the modiolus

show disagreement expression evidenced via EMG study of harmful behaviour and violation of purity. In contrast, Zygomaticus major which is muscle expression of smiling, shown a little reaction toward some moral judgement test using EMG such as harm and authority behaviour (8).

In another study (9), EMG analysis of lip smack of long-tailed monkeys (Macaca fascicularis) showed lip smack activity was mainly by the lower part of the face involving muscles such orbicularis oris and mentalis. Similar muscles were also involved in drinking and sucking activity where its initial involvement including the zygomaticus which speculated to create a difference in negative pressure. These results show these muscles can be evaluated using equipment such as EMG (9).

The facial nerve innervates all facial muscles, which is only related to motor response in the nerve functional aspect (10). In the clinical environment, these muscles are routinely being tested as to their relationship to the facial nerve abnormality, especially in the cerebrovascular accident or stroke. In classic infantile Pompe disease or inherited lysosomal acid α-glucosidase, the weakness of facial muscle is a sign. The children who suffer this genetic illness shows clinical signs of sunken cheek, lower lip drooping, ptosis and lessen nasolabial fold (11). Uniquely, facial muscles provide afferent feedback to the brain that related to the emotion such as the amygdala. Experiment using botulinum toxin (BTX) showed the afferent feedback was blocked and amygdala was not shown reactive to happiness and sadness expression (12).

Varies of the references mentioned about the muscle attachment to the modiolus of the face, however, they showed overlapping facts. An earlier study in 1988 has mentioned fives muscles that are attached to the modiolus acts as a muscular or tendinous node in the cheek. They are levator anguli oris, zygomaticus major, risorius, buccinator and depressor anguli oris which located at the point lateral to the angle of the mouth (13). Subsequent. aesthetic dermatology has renamed the group of muscle that related to the modiolus; depressor anguli oris, posterior fibres of platysma, orbicularis oris, zygomaticus major, buccinator, levator anguli oris and risorius (14). Interestingly study in the same year also mentioned the similar muscles attachment to the modiolus with the additional of depressor labii inferiors muscle (15).

A group of skeletal muscles in the face acted together to form various facial movements such as smiling, talking, grinning and facial expression. These muscles arranged bilaterally around facial organs including mouth, eyes, nose, ear, neck and scalp (7). This study mentioning of seven facial muscles that are inserted into the modiolus located at the angle of the mouth. One of the major muscles originating from the oblique line of the mandible, namely depressor anguli oris (DAO), was inserted at the modiolus. Contraction of the muscle causing drooping of the mouth angle manifest in a sad facial expression. Levator anguli oris muscle originated from canine fossa of the maxilla and zygomaticus major muscles originated from zygomatic arch also inserted at the modiolus (16). These muscles acted together to antagonize DOA movement giving a happy facial expression. The clinical signs of the muscle actions important for botulinum toxin application (17). Different injection point will cause a different outcome to the patient facial expression.

Risorius muscle originates from superficial fascia above masseter muscle that previously, was thought to be the third head of DAO muscle. Risorius muscle has to course toward the angle of the mouth interlacing together with the DAO, the orbicularis oris, zygomaticus major, levator anguli oris, buccinators and the forming the modiolus (18). The contraction of the muscle cause retraction and elevation of the commissure of the labium to deepen the oral fissure. More knowledge of this muscle will enhance surgical outcomes in patient with facial muscle paralysis and trauma (18).

EMBRYOLOGY

In human development, modiolus evolves following the growth of muscles of facial expression. In the fourth week of intrauterine life, neural crest cells migrate into the destined area of the head and neck, the pharyngeal arches begin to form. Initially, a centre of mesenchyme; embryonic connective tissue is composed of each pharyngeal arch. The pharyngeal arches are protected by ectoderm externally and endoderm internally and are supplied by its own cranial nerve, respectively. Uniquely, each arch's muscular components have their own cranial nerve and they bring their own nerve component anywhere the muscle cells travel (19).

The second pair of pharyngeal arches differentiates into facial muscles which are invaded by myoblast (19). Subsequently, five laminae on the face are formed by

a sheet-like collection of the premyoblasts during sixth to eighth-week intrauterine life and migrate to the future temporal, occipital, cervical, and mandibular regions (20). Of those laminae, infraorbital and mandibular laminar are involved in the development of muscles of the facial expression.

Eventually, the majority of the facial muscles are formed by the infraorbital lamina (20). Whereas, the mentalis, mandibular part of the platysma, the depressor anguli oris, the depressor labii inferioris, the buccinator, the risorius and the levator anguli oris muscles are formed by each mandibular lamina. Along with the facial muscles, facial nerve arises from the second pharyngeal arch are also innervates stylohyoid, stapedius, auricular muscles and posterior belly of the digastric (20).

COMPARATIVE ANATOMY

Interestingly, various studies and findings of modiolus in human are thought to be the critical importance in the clinical management of facial reconstruction and beauty, while the study in non-human primate and non-primate are yet to be notable. Facial muscle expressions are a sensitive predictor of emotional states in animals and human (21). Establishing facial predictors of affection and anger is an upmost challenge and less scientific research has been performed in non-primate species (22).

The anatomically based Facial Action Coding System (FACS) defines minimal units of a facial movement called Action Units (AUs) with comprehensive explanations of the resulting changes in facial appearance (23). The FACS approach is likely to be adapted for use with other primate species and this popular method enables the comparison of facial repertoires across the species (24). In this review, we describe two kinds of primate; chimpanzee and non-primate; dog regarding their facial expression which represents an indirect functional aspect of the modiolus.

Chimpanzee

Human faces and chimpanzee are differing in macroscopic anatomy which chimpanzees have more flattened nasal space, reduced fat on the cheek, absent chin bone, longer mouth, prominent brows and broader forehead (23). Hence, ChimpFACS enhances trans-species research about chimpanzee communication and man facial muscles expression evolutionary (23).

However, the qualitative comparison of chimpanzee musculature (P. troglodytes) only reveals the marginal difference from that of Homo in the example of deep and superficial occipitalis muscle's heads of the chimpanzee. (25). As compared with human, less connective tissue and densely packed fascicles are found in the chimpanzees' orbicularis oris (26). Additionally, human facial musculature has been shown to lack muscle spindles inside the muscle fascicles of the stretch receptor organs (27).

Dog

Interestingly, the comparison between dogs and their relatives' facial expression such as fear, happiness, anticipation and frustration were studied via DogFACS, an anatomically based intervention for facial expressions coding of dogs. The positive condition represents "Ears adductor" action and negative condition represent "Lips part", "Blink", "Nose lick", "Ears flattener" and "Jaw drop" (22).

A recent study suggests dog-human social interaction are determined by eye contact between them. Behavioural tests indicate that dogs generate movement of orbicularis oculi more frequently and with greater intensity where paedomorphism increases and resembles a sad human expression, indefinitely triggers a nurturing response in humans (28).

MACROSCOPIC ANATOMY

Numerous anatomy medical textbooks have mentioned the details about the formation of modiolus, however, only a few of them elaborating the exact muscles attachment which might due to its concealed three-dimensional organization (29). Last's (2011) has mentioned six muscles that are connecting to modiolus; orbicularis oris, buccinator, zygomaticus major, risorius, levator anguli oris, depressor anguli oris. It is situated opposite the second upper premolar tooth at 1 cm lateral to the angle of the mouth. The orbicularis oris and buccinator muscles form a chiasma at the modiolus, which is connected to the upper and lower fibres of the orbicularis oris in their respective lips, while the middle fibre decussate. In contrast, the upper fibres of buccinator passing into the lower lip while the lower into the upper lip. Hence, as it is mentioned, the action and location of modiolus are mainly a concern in prosthetic dentistry (30). Additionally, modiolus also has been recognized in dimple formation in many individuals with interlaced and merged from nine facial muscles in a highly variable and multiplanar arrangement (31), nonetheless, no precise muscles have yet to be mentioned.

Modiolus is a fibromuscular tendinous structure located at the lateral border of the mouth (5, 18). Modiolus attached from orbicularis oris muscle and labial tractor muscles to the angle of the mouth (5, 32). These authors suggested that modiolus are related to nine muscles attachment such as buccinator, risorius, depressor anguli oris, depressor labii inferioris, orbicularis oris, zygomaticus major, levator anguli oris, platysma pars modiolaris and mentalis. The small button-shaped nodule of the thick irregular connective tissue of the modiolus, which predominantly collagen fibres, is

interlacing with these facial muscles on both sides, vertically and horizontally crossed, toward oral mucosa layer (33).

Another cadaveric study in 2008 showed few muscles that attached to the modiolus is related to modern facelift technique. In 100 facial halves of the specimens, the area of the midface and mesolabial fold was examined, which showed that SMAS, levator labii superioris alaeque nasi and zygomatici muscles were found to form a functional unit of the midface in corresponding anatomical layers. Further histology examination revealed that the fibres of zygomaticus major muscle are shown to radiate toward the modiolus. Anterior to the modiolus, where the buccinator muscle, SMAS and zygomaticus major muscle combine with the orbicularis oris muscle, the plane between buccinator muscle and SMAS can be further followed (34).

Modiolus is essential for facial expression and all the functions at the mouth corner. The contraction of modiolus is activated during the activity that involves lips and cheeks movement such as talking, chewing, eating and drinking (4). Part of the formation of the nasolabial fold has also involved a modiolus (35). Therefore modiolus is called an angular cornerstone which considered as the beauty of the lower third of the face (4, 32, 36).

Moreover, the superficial face fascia continues to the nasolabial fold medially and converges at the modiolus. (37). Modiolus is therefore essential for the formation of the nasolabial fold. A well-developed modiolus offers a toned and tangible face, so it is used as a practical and aesthetic feature of the lower face. (32). People that possess prominent nasolabial fold which is one of the characteristics of lower face ageing is associate with weak trophic modioli (5, 38).

Modiolus consist of muscle fibres which were engaged adjacent to the mouth (Fig. 1). These palpable fibres diverge from and converge towards this decussation (32). The modiolus fibres generate a spiral pattern before splitting into two or more bundles of fibres in separate directions (5, 32). Modiolus's surface anatomy in the face was also studied by palpation in living individuals. In average, modiolus is located either 14.4 mm lateral to angle of the mouth or 1.6 mm inferior to the horizontal line of the angle of the mouth. Sixty-two per cent of the population has modiolus located inferior to the horizontal line of the angle of the mouth (3).

Anatomically, modiolus and its perioral region are supplied by a facial artery which then terminates as angular artery (38). Interestingly, a study in 2009 discovered that facial artery runs anterior to modiolus in 20% of cases, lateral in 80% in cases and never medial to it (4). The facial artery is preceded by the buccal fat pad on the periphery of modiolus, which forms a

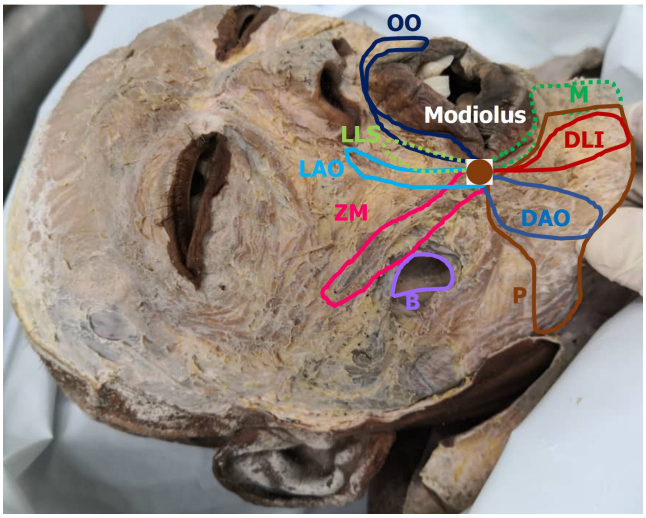

Figure 1: A cadaveric face showing the modiolus and its muscle attachments. Eight muscles are attached to the modiolus; B; Buccinator, R: Risorius, ZM: Zygomaticus Major, P: Platysma, LAO: Levator Anguli Oris, DAO: Depressor Anguli Oris, DLI: Depressor Labii Inferioris and OO: Orbicularis Oris, (Deep risorius muscle is not seen). Two muscles (green stripes line) represent the possibility of facial muscle attachment to the modiolus, LLS: Levator Labii Superioris and M: Mentalis.

boundary between the two structures in the same plane. (39). The large trophic modiolus consists of muscular fibres in large quantity and played a role in maintaining the buccal fat pad in its original position, preventing it from protruding (32).

APPLIED ANATOMY

Generally, peoples will look elder without the teeth are due to the dependent of the facial muscles' attachment on the position of teeth. The loss of support from the teeth in edentulous patients upon stretching the muscle on it makes their face manifests older than their actual age (40). Modiolus is a fibromuscular mass formed by nine muscles that converge straight and vertically on the lateral part of the buccal angle. This area can be palpated by the pinched of the opposed thumb and index finger. This article mentioned the nine muscles of facial expression that form modiolus consists of zygomatic major, depressor anguli oris, levator anguli oris, platysma, orbicularis oris, buccinator, risorius, incisivus superior and inferior. Furthermore, it does mention that the premolars will be touched when the modiolus is contracting. As a result, no food will be escaped from the mouth upon food crushing at the area of premolars and molars (41).

In dentistry, the modiolus is crucially important during certain procedures such as the construction of denture for edentulous patients. The mechanical movements are made by holding the modiolus with the thumb and index finger during the border moulding process. The muscles influence the depth of vestibular sulci and unseat complete dentures during the anterior and

lateral portions of maxillary and mandibular impression borders (42). It is also helped in establishing the height of occlusal rims during the bite registration in denture procedure. The dentists and dental technicians will mark on the occlusal rims and provide anterior landmarks of the first premolar height. Few factors that contributed to the construction of denture and the comfort of wearing the denture, and facial muscle is one of the major contributors.

Facial muscle is important in facial expression of emotion and prosthesis performance and contributing in every step of prosthesis construction (43). The buccinator runs parallel to the border helps in retention of the maxillary denture. The depressor anguli oris moves buccal frenum vertical and horizontally. The tone of orbicularis oris is determined on rest on the labial flange and gingival third of anterior teeth (44). In mandibular arch where the flange area has to be thin, the orbicularis oris is responsible for narrowing the sulcus teeth arrangement in the Neutral zone (45).

The loss of muscles supports and fat atrophy contributes to the age of the person. The depression of lips' causes it becomes wrinkled. The nasolabial fold also deepens and loss of the vermilion border of the lips with the loss of the support structure. It will form the drooping form of the corners of the mouth. When the teeth are lost, there is loss occlusal wear and vertical dimension stimulates the chin appears more protruded. The outlines of the philtrum and mentolabial sulcus are also altered. The lower half of the face also depends on dentures. The poor teeth arrangement causes tense and wrinkled lips. The nasolabial fold must be preserved during arrangement (46).

A cadaveric study in 2019 demonstrated the importance of upper and lower lip reconstruction setting via flap techniques. To demonstrate the typical flap practices, few cadavers were dissected as in actual surgical scenarios; Bernard-Webster and Karapandzic adjusted for upper lip reconstruction as well as reverse fan flap and reverse Karapandzic flap for lower lip reconstruction. Interestingly, all the procedures required the preservation of the modiolus as to achieve successful surgical technique, indicated a principal key of facial muscle attachment (47).

Additionally, another aesthetic cadaveric study revealed the histomorphologic approach to the modiolus as a reconstructive landmark. Meticulous dissections were performed to secure the modiolus which closely related to the facial artery. Furthermore, histology examination revealed a tendinous tissue nodule in an only quarter of the cases, resembles dense irregular collagenous connective tissue. Interestingly, the middle layer is more thick, compact and more obvious between the skin and oral mucosa, thus giving an important concept of facial plastic surgery (5).

The commercialized pharmaceutical product of Botulinum Toxin A (BoNTA) has been used for cosmetic surgery for recent years. This single injection or with a dermal fillers combination improved the ageing features of lower face and neck. However, applied facial anatomy knowledge is crucial to reduce the risk of its complications. Specific facial muscles identification should have been identified by a physician prior to the injection procedure. In the treatment of jawline and pre-jowl area, both muscles of depressor anguli oris and platysma are aimed supraperiosteally at the inferior aspect of the mandible, which inferior to the modiolus. Furthermore, the facial artery also must be secured as its traversing deep to the superficial musculo-aponeuritic system, adjacent to the modiolus (48).

CONCLUSION

A unique anatomical landmark of modiolus creates great impact for Anatomist especially during the dissection of facial muscle. The overlapping subcutaneous facial muscles somehow obscured the modiolus especially in the large size cadaver making it difficult to be identified. Even though the muscle attachments of facial muscles to the modiolus are easy to be assessed theoretically, the arrangement somehow differs in each of the cadavers, especially in the deformed cadaveric characteristic.

Even though several studies had identified the muscles attached to the modiolus, no similar muscles' name is yet to be mentioned. Hence, we can conclude that the eight confirmed facial muscles that are attached to the modiolus are levator anguli oris, orbicularis oris, depressor anguli oris, risorius, zygomaticus major, depressor labii inferioris, buccinator and platysma, which one doubtful additional muscle either mentalis or levator labii superioris, suggesting two theories of nine muscles attachment to the modiolus (Fig. 2).

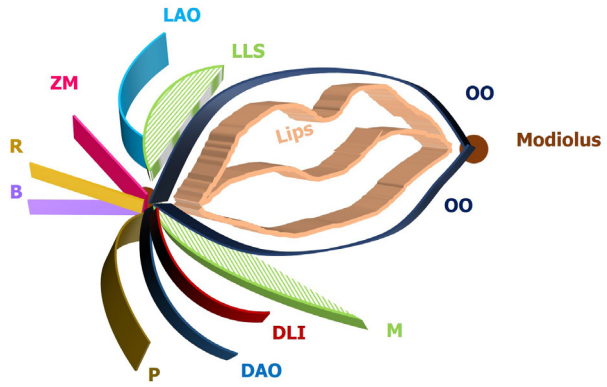

Figure 2: Schematic drawing shows the modiolus of the face with its muscle attachment. Eight muscles are attached to the modiolus; B; Buccinator, R: Risorius, ZM: Zygomaticus Major, P: Platysma, LAO: Levator Anguli Oris, DAO: Depressor Anguli Oris, DLI: Depressor Labii Inferioris and OO: Orbicularis Oris. Two muscles (green stripes-filled) represent the possibility of facial muscle attachment to the modiolus, LLS: Levator Labii Superioris and M: Mentalis.

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REFERENCES

1. Lightoller GHS. Facial Muscles: The Modiolus and Muscles surrounding the Rima Oris with some remarks about the Panniculus Adiposus1. Journal of anatomy. 1925;60(Pt 1):1.
2. Schmidt KL, Cohn J. Human facial expressions as adaptations: Evolutionary questions in facial expression research. American Journal of Physical Anthropology. 2001;116(S33):3-24.
3. Ahn H-J, Cho H-J, Nam Y-S, Han S-H, Chung I-H, Kim I-B. The Location of the Modiolus in Living Korean. Korean Journal of Physical Anthropology. 2013;26(4):141-6.
4. Al-Hoqail RA, Meguid EMA. An anatomical and analytical study of the modiolus: enlightening its relevance to plastic surgery. Aesthetic plastic surgery. 2009;33(2):147-52.
5. Yu S-K, Lee M-H, Kim H-S, Park J-T, Kim H-J, Kim H-J. Histomorphologic approach for the modiolus with reference to reconstructive and aesthetic surgery. Journal of Craniofacial Surgery. 2013;24(4):1414-7.
6. Çalışkan S, Çelebioğlu EC, Akkaşoğlu S, Beşer CG, Sargon MF. Anatomical and radiological evaluation of modiolus anguli oris in facial anatomy. Journal of Surgery and Medicine. 2019;3(9):694-7.
7. Pessa JE, Rohrich RJ. Facial topography: clinical anatomy of the face: CRC Press; 2014.
8. Cannon PR, Schnall S, White M. Transgressions and expressions: Affective facial muscle activity predicts moral judgments. Social psychological and personality science. 2011;2(3):325-31.
9. Shepherd SV, Lanzilotto M, Ghazanfar AA. Facial muscle coordination in monkeys during rhythmic facial expressions and ingestive movements. Journal of Neuroscience. 2012;32(18):6105-16.
10. Reissland N, Francis B, Mason J, Lincoln K. Do facial expressions develop before birth? PLoS One. 2011;6(8):e24081.
11. van Gelder CM, van Capelle CI, Ebbink B, Moor-van Nugteren I, Van den Hout J, Hakkesteegt M, et al. Facial-muscle weakness, speech disorders and dysphagia are common in patients with classic infantile Pompe disease treated with enzyme therapy. Journal of inherited metabolic disease. 2012;35(3):505-11.
12. Kim MJ, Neta M, Davis FC, Ruberry EJ, Dinescu D, Heatherton TF, et al. Botulinum toxin-induced facial muscle paralysis affects amygdala responses to the perception of emotional expressions: preliminary findings from an ABA design. Biology of mood & anxiety disorders. 2014;4(1):11.
13. Shimada K, Gasser RF. Variations in the facial muscles at the angle of the mouth. Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists. 1989;2(3):129-34.
14. Sharad J. Lower Face and Neck Indications. Aesthetic Dermatology: Current Perspectives. 2018.
15. Nakashima M, Lozanoff S. The Face–A Musculoskeletal Perspective. A literature review. Swiss dental journal. 2018;128(9):678-88.
16. Shim K-S, Hu K-S, Kwak H-H, Youn K-H, Koh K-S, Fontaine C, et al. An anatomical study of the insertion of the zygomaticus major muscle in humans focused on the muscle arrangement at the corner of the mouth. Plastic and reconstructive surgery. 2008;121(2):466-73.
17. Choi Y-J, Kim J-S, Gil Y-C, Phetudom T, Kim H-J, Tansatit T, et al. Anatomical considerations regarding the location and boundary of the depressor anguli oris muscle with reference to botulinum toxin injection. Plastic and reconstructive surgery. 2014;134(5):917-21.
18. Kim H-S, Pae C, Bae J-H, Hu K-S, Chang BM, Tansatit T, et al. An anatomical study of the risorius in Asians and its insertion at the modiolus. Surgical and Radiologic Anatomy. 2015;37(2):147-51.
19. Susan Wainwright P. Langman's Medical Embryology. Journal of Physical Therapy Education. 2010;24(3):81.
20. Som P, Naidich T. Illustrated review of the embryology and development of the facial region, part 2: late development of the fetal face and changes in the face from the newborn to adulthood. American Journal of Neuroradiology. 2014;35(1):10-8.
21. Wehrle T, Kaiser S, editors. Emotion and facial expression. International Workshop on Affective Interactions; 1999: Springer.
22. Bremhorst A, Sutter NA, Wьrbel H, Mills DS, Riemer S. Differences in facial expressions during positive anticipation and frustration in dogs awaiting a reward. Scientific reports. 2019;9(1):1-13.
23. Vick S-J, Waller BM, Parr LA, Pasqualini MCS, Bard KA. A cross-species comparison of facial morphology and movement in humans and chimpanzees using the facial action coding system (FACS). Journal of nonverbal behavior. 2007;31(1):1-20.
24. Rosenberg EL, Ekman P. What the face reveals: Basic and applied studies of spontaneous expression using the facial action coding system (FACS): Oxford University Press; 2020.
25. Burrows AM, Waller BM, Parr LA, Bonar CJ. Muscles of facial expression in the chimpanzee (Pan troglodytes): descriptive, comparative and

phylogenetic contexts. Journal of anatomy. 2006;208(2):153-67.
26. Burrows AM. The facial expression musculature in primates and its evolutionary significance. Bioessays. 2008;30(3):212-25.
27. Llsterlund C, Thornell LE, Eriksson PO. Differences in fibre type composition between human masseter and biceps muscles in young and adults reveal unique masseter fibre type growth pattern. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology. 2011;294(7):1158-69.
28. Kaminski J, Waller BM, Diogo R, Hartstone-Rose A, Burrows AM. Evolution of facial muscle anatomy in dogs. Proceedings of the National Academy of Sciences. 2019;116(29):14677-81.
29. Susan S. Gray's anatomy: the anatomical basis of clinical practice. Elsevier; 2015.
30. Sinnatamby CS. Last's Anatomy, International Edition: Regional and Applied: Elsevier Health Sciences; 2011.
31. Moore KL, Dalley AF. Clinically oriented anatomy: Wolters kluwer india Pvt Ltd; 2018.
32. Zufferey JA. Importance of the modiolus in plastic surgery. LWW; 2002.
33. Drake RL, Vogl W, Mitchell AW. Gray's anatomy for students. Philadelphia: Churchill Livingstone. Elsevier. 2010.
34. Gassner HG, Rafii A, Young A, Murakami C, Moe KS, Larrabee WF. Surgical anatomy of the face: implications for modern face-lift techniques. Archives of facial plastic surgery. 2008;10(1):9-19.
35. Rubin LR, Jackson IT. The anatomy of the nasolabial fold: the keystone of the smiling mechanism. Plastic and reconstructive surgery. 1999;103(2):692.
36. Marinetti CJ-M. The lower muscular balance of the face used to lift labial commissures. Plastic and reconstructive surgery. 1999;104(4):1053-162.
37. Hinganu MV, Hinganu D, Froncu LL. Participation of superficial musculo-aponeurotic system of the face in correct dental occlusion. Romanian Journal of Oral Rehabilitation. 2013;5(3):119-24.
38. Llnderoglu S. Topographical relations of the facial artery in the region of the modiolus anguli oris. Okajimas folia anatomica japonica. 1999;76(2-3):141-7.
39. Stuzin JM, Wagstrom L, Kawamoto HK, Baker TJ, Wolfe SA. The anatomy and clinical applications of the buccal fat pad. Plastic and reconstructive surgery. 1990;85(1):29-37.
40. Raja HZ, Saleem MN. Relationship of neutral zone and alveolar ridge with edentulous period. J Coll Physicians Surg Pak. 2010;20(6):395-9.
41. Cascarini L, Schilling C, Gurney B, Brennan P. Oxford Handbook of Oral and Maxillofacial Surgery: Oxford University Press; 2018.
42. Llzkan YK, Evren B, Kauffman A. Anatomical Landmarks and Age-Related Changes in Edentulous Patients. Complete Denture Prosthodontics: Springer; 2018. p. 3-48.
43. Rangarajan V, Padmanabhan T. Textbook of Prosthodontics-E Book: Elsevier Health Sciences; 2017.
44. Verma M, Mohanty S, Urs AB, Singh N, Kaur H, Tripathi T, et al. Prosthodontic Treatment For Edentulous Patients Complete Dentures And Implant-Supported Prostheses. Journal of Lasers in Medical Sciences. 2017;8(5):155-9.
45. Chandra SS. Management of a severely resorbed mandibular ridge with the neutral zone technique. Contemporary clinical dentistry. 2010;1(1):36.
46. Verma N, Chitre V, Aras M. Enhancing appearance in complete dentures using magnetic retained cheek plumpers. J Indian Prosthodont Soc. 2004;4(2):35-8.
47. Tong CC, Vandegriend ZP, Lee YH, Lawson W. Anatomical Basis for Lip Reconstruction: The Role of the Modiolus. Annals of plastic surgery. 2019;82(5):565-9.
48. Baker A. Off-label cosmetic use of botulinum toxin in the lower face. PMFA News. 2015;3(3):30-2.