

Original article

**Zygomaticus major muscle bony attachment site: a Thiel embalmed cadaver dissection study**

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## Summary

**Objective.** The zygomaticus major is a principal muscle of facial expression which is engaged when smiling. The zygomaticus major origin on the zygomatic bone is often discussed relevant to its importance in the field of plastic surgery. In addition, the zygomaticus major attachment site is also significant for forensic craniofacial reconstruction, separating the cheek into frontal and lateral surfaces. However, there are discrepancies amongst published articles regarding the precise origin of the zygomaticus major muscle. The aim of this study is to investigate more distinctive and palpable landmarks as the bony attachment of the zygomaticus major.

**Methods.** This project is the first zygomaticus major dissection study utilising Thiel embalmed cadavers. Fifty-two facial dissections were investigated in 26 Thiel embalmed bodies, bequeathed to the Centre for Anatomy and Human Identification at The University of Dundee between 2013 and 2015.

**Results.** This study found that the origin of zygomaticus major muscle was located at the superior margin of the temporal process on the lateral surface of zygomatic bone. Moreover, the zygomaticus major muscle overlapped the anterosuperior border of the masseter muscle. One out of 52 zygomaticus major muscles presented bifurcation.

**Conclusion.** The origin site of zygomaticus major is considered important to increase resemblance in forensic craniofacial reconstruction. Furthermore, since zygomaticus major is a salient muscle involved in facial expression, the potential effects for cosmetic/surgical procedures are also relevant to the medical field and successful surgical outcomes. The current study provided easily palpable landmarks of zygomaticus major origin site which is beneficial for both surgeons and forensic craniofacial reconstruction practitioners.

Keywords: zygomaticus major, Thiel embalmed, cadaver dissection.

## **Site d'attachement osseux musculaire majeur de Zygomaticus: une étude de dissection de cadavres embaumés par Thiel**

### **Résumé**

**Objectif.** Le zygomaticus majeur est un muscle principal de l'expression faciale qui est engagé en souriant. L'origine du muscle zygomaticus majeur sur l'os zygomatique est souvent discutée en fonction de son importance dans le domaine de la chirurgie plastique. De plus, le site d'attachement majeur du zygomaticus est également important pour la reconstruction craniofaciale médico-légale, séparant la joue en surfaces frontales et latérales. Cependant, il existe des divergences entre les articles publiés concernant l'origine précise du muscle zygomaticus majeur. Le but de cette étude est d'étudier des repères plus distinctifs et plus palpables comme l'attachement osseux du zygomaticus major.

**Méthode.** Ce projet est la première étude de dissection sur le muscle zygomaticus majeur utilisant des cadavres embaumés Thiel. Cinquante-deux dissections faciales ont été étudiées dans 26 corps embaumés Thiel, légués au Centre d'anatomie et d'identification humaine de l'Université de Dundee entre 2013 et 2015.

**Résultats.** Cette étude a révélé que l'origine de zygomaticus major était située au bord supérieur du processus temporal sur la surface latérale de l'os zygomatique. De plus, le muscle majeur zygomaticus chevauchait le bord antéro-supérieur du muscle masséter. Un des 52 principaux muscles zygomatiques présentait une bifurcation.

**Conclusion.** Le site d'origine de zygomaticus major est considéré comme important pour augmenter la ressemblance dans la reconstruction craniofaciale médico-légale. De plus, comme le zygomaticus major est un muscle saillant impliqué dans l'expression faciale, les effets potentiels pour les procédures cosmétiques / chirurgicales sont également pertinents pour le domaine médical et les résultats chirurgicaux réussis. L'étude actuelle a fourni des repères facilement palpables du site d'origine majeur de zygomaticus, ce qui est bénéfique pour les chirurgiens et les praticiens de la reconstruction craniofaciale médico-légale.

## **Introduction**

The zygomaticus major muscle is the main muscle of facial expression engaged in smiling. It is one of the five upper lip elevator muscles, along with zygomaticus minor, levator anguli oris, levator labii superioris, levator labii superioris alaque nasi. Zygomaticus major extends from zygomatic bone and blends with orbicularis oris at the lateral corner forming modiolus. The width of the superior origin of the zygomaticus major is reported to be 8 to 10 mm [1]. Previous articles regarding zygomaticus major muscle were published in the facial reconstructive surgery journals which indicate the importance of zygomaticus major in that field [1-7]. The caudal insertion of zygomaticus major has been clearly defined at the modiolus, slightly lateral to the corner of the mouth, together with the orbicularis oris, risorius, buccinator, depressor anguli oris and levator anguli oris muscles. However, it is the origin of this muscle that is less well explained [4].

In 2019, Ryu and Kahng performed facelift on a 66-year-old female patient and found anatomical variation of the zygomatic branches of the facial nerve which entered the deep fascia approximately 10 mm to the zygomaticus major origin site [20]. Paralytic injection intended for orbicularis oculi muscle may unintentionally expose zygomaticus major to temporary paralysis resembling the Bell's Palsy appearance which may extend to several months. Although temporary, this outcome is unfavorable for both clinicians and patients [5]. Therefore, knowledge of zygomaticus major muscle attachment location as part of spatial anatomy of facial layers plays important role in safe surgery.

In the field of forensic craniofacial anthropology, the zygomaticus major also plays a significant role. One of the branches of forensic craniofacial anthropology is craniofacial reconstruction (CFR) otherwise known as forensic facial approximation. CFR is a process of scientifically estimating and depicting the shape of the face from the underlying skull. Whilst CFR methodology is also used to depict faces from historical/archaeological skulls, the importance lies in its forensic application which may serve to assist the recognition of unidentified victims following either severe facial trauma or putrefaction [8-9]. CFR techniques are varied and include 2D, 3D manual (sculptural, whether physical or virtual) and 3D computerised (automated), but most involve both scientific and artistic input. The accuracy and reliability of CFR is still a controversy among practitioners and researchers [9].

The University of Dundee employs a combinatorial method of three aspects: (i) anatomical muscle sculpting; (ii) facial feature morphology estimation, and (iii) overlaying a skin layer that is guided by average soft tissue depth (ASTD) pegs attached to the craniofacial landmarks [9]. The anatomical modelling stage requires the sculpting of facial musculature onto the 3D skull (on skull replica by manual method or on skull model by using computer software) before adding the skin layer [9]. One of the sculpted muscles is the zygomaticus major.

The literature describes several variations for the attachment of zygomaticus major [2-7]. Freilinger et al. in 1987 dissected 12 formaldehyde-phenol cadavers and located the zygomaticus major origins anterior to the zygomaticotemporal suture [2]. In 1994, Tremolada et al. described that the zygomaticus major attached to the inferior border of the zygomatic bone where it was intersected by a line between the lateral canthus to the angle of the mandible based on the dissection of 8 fresh and 3 embalmed cadavers [3]. Mowlavi and Wilhelmi performed dissection on 13 cadavers in 2004 and discovered that the upper attachment of the zygomaticus major was at the most anterior-inferior part of the temporal fossa at the intersection of the frontal process and the temporal process of the zygomatic bone [4]. Facial dissection of 24 cadavers by Spiegel and DeRosa in 2005 found that zygomaticus major origins were 1.4 and 1.5 cm below the Frankfort horizontal line at 1 cm lateral to and at the lateral canthus [5]. Miller et al. confirmed the reliability of the subzygomatic fossa as the zygomaticus major origin through hemifacial dissection of 23 fresh cadavers in 2007 [6]. In 2018, Ryu et al. reported that mean distances between the centre of the zygomaticus major origin and the posterior border of tragus 61 mm through facelift procedure on 20 patients [7].

Due to the variation of the zygomaticus major origin in the literature, this study aimed to identify a simple and palpable bony landmark of the zygomaticus major muscle attachment site to aid the successful outcome of both CFR and facial surgery. Palpability of the bony landmark is advantageous for clinicians, whereas bony landmark is particularly beneficial for CFR practitioners in which cases only skeletal structures available.

## **Materials and methods**

Fifty-two facial dissections were conducted on 26 cadavers bequeathed to the Centre for Anatomy and Human Identification, University of Dundee and comprised 15 males and 11 females. The age at death for the cadavers ranged from 61 to 101 years with a mean age of  $80.5 \pm 11.49$  years. All cadavers were preserved using the Thiel soft fix embalming method [10].

Routine dissection tools such as scalpel blade, scalpel handle, haemostat forceps, tweezer forceps, and scissors, were used in the dissection procedure. The first author performed the facial dissection. Zygomaticus major muscle was identified by firstly removing the skin and the subcutaneous tissue carefully. The dissected zygomaticus major was photographed using a COOLPIX S33 digital camera (Nikon, Japan) from an oblique angle (approximately 35 to 45°) to capture the whole cheek region. The first author observed and investigated the chosen landmark which represents the precise location of the origin of the zygomaticus major muscle whilst the second author (CR) verified the dissection findings. A third observer, with craniofacial anatomy and morphology experience, evaluated the bilateral digital images of 3 cadaver dissections for inter-observer study.

## **Results**

All cadaver face dissections showed that the zygomaticus major consistently originated from the superior margin of the temporal process on the lateral surface of zygomatic bone (Fig. 1). The zygomaticus major overlapped the superoanterior border of the masseter muscle. The superior attachment of the masseter muscle was located along the inferior margin of the zygomatic bone in all cadavers (Fig. 1). Zygomaticus major was represented by a single band in all cadavers except one (male, 77 years), where a single band bifurcated caudally towards the modiolus, unilaterally on the left side. An inter-observer study to evaluate agreement was conducted, whether the zygomaticus major attachment was located at the superior margin of the temporal process of zygomatic bone which yielded 100% agreement between the 2 observers.

## **Discussion**

The Thiel embalmed preservation technique is used in the Centre for Anatomy and Human Identification University of Dundee for undergraduate and postgraduate teaching and

research. Thiel preservation shows superiority compared to formalin in the flexibility of the soft tissue including the muscles, fascia and connective tissue [10-13]. Dissection of the Thiel bodies is considered easier and faster, compared to the formalin cadavers, due to the easy separation of the superficial tissues and structures which can be performed by precise blunt dissection. The 'life like' feel and response of the cadaveric tissue is rated highly by surgeons [10].

The zygomaticus major is commonly bilateral. In this study, two types of zygomaticus major were identified, single and bifid. The present study found one male cadaver with a bifid zygomaticus major, which was comparable to the results from the previous studies [14-18, 22]. The muscle fibres commenced bifurcation in the middle region of the muscle and ran inferiorly and inserted at the modiolus at two different, but closely located, regions. This variation may present as cheek dimples at skin level [14,16]. The finding of this study suggested an easily distinguishable and palpable bony landmark for the origin of the zygomaticus major muscle. This is beneficial for both fields of clinical reconstructive surgery and forensic CFR.

Earlier studies have attempted to identify the exact location of the zygomaticus major muscle origin [2-7]. The samples of five previous studies and the present study were derived from European ancestral group [2-6]. However, the findings varied among European studies. The results of the present study showed closest similarity to the study performed by Freilinger *et al.* as well as Mowlavi and Wilhelmi [2,4]. In contrast, studies by Tremolada *et al.* and Miller *et al.* reported that the zygomaticus major originated from the inferior margin of the zygoma, whereas the present study showed that the lowest border of the zygomatic bone including the subzygomatic fossa, was in fact the attachment site for the masseter muscle [3,6]. The zygomaticus major muscle passed over the area of the subzygomatic fossa but did not attach there: instead it attached to the superior margin of the temporal process of zygomatic bone.

A Korean cadaveric dissection study by Hu *et al.* was conducted to discover the topography of the masseter for botulinum toxin ("botox") injection application [19]. Some photographs of dissection showed the position of the zygomaticus major as it is located near to the masseter. The result of the present study corresponds well with the photographs of Hu *et al.* and Elvan *et al.* dissection studies, that the zygomaticus major overlaps the superior anterior attachment of masseter [19, 22].

Furthermore, the current study was not a quantitative linear measurements study in which distortion can occur after angle alteration. The differences in the zygomaticus major bony origin between the current study and the earlier cadaveric dissection studies may be due to tissue differences resulting from the different embalming methods and dissection techniques. Having the experience of dissecting both types of the embalmed body, the author felt that the formalin-fixed dissection was more challenging and required a more aggressive dissection approach whereas the Thiel cadavers were more amenable to gentler blunt dissection.

The cheek surface can be divided into 2 areas by the diagonal line formed by the underlying zygomaticus major (frontal cheek and lateral cheek). The attachment site of the zygomaticus major on the zygomatic bone is relevant to CFR due to its influence in depicting facial angle (frontal face and lateral face) and cheek shape. Changes in facial angle may influence the CFR result. Positioning this muscle attachment correctly might therefore enhance the accuracy of CFR, and the results of this study shows an alteration in the resulting facial depiction between the two approaches.

Periorbital rhytids treatment requires a clear definition of zygomaticus major origin landmark. Botulinum toxin injection targeting orbicularis oculi rhytids should avoid the the zygomaticus major fibers. The upper part of zygomaticus major is either overlapped by or adjacent to orbicularis oculi [5, 7, 22]. This study provided information for the clinicians that the zygomaticus major begins from the superior margin of the temporal process on the lateral surface of the zygomatic bone.

For the most part, the location of facial musculature in previous zygomaticus major dissection studies corroborated well with the findings of the current study. However, the consensus from this dissection study supported the idea that the results of the current study can be applied to the revised CFR guideline. The observation of bony attachment of the zygomaticus major on Thiel soft-fix cadavers is relevant to clinical facial reconstructive surgery as well as the forensic CFR field.

## **Conclusion**

The zygomaticus major muscle attachment site is important to surgeons and CFR practitioners. This dissection study utilised Thiel embalmed cadavers which are more akin to



fresh tissue response than formalin-fixed remains. This study found that the zygomaticus major bony attachment was located at the superior margin of the temporal process on the lateral surface of zygomatic bone. The current study provided evidence of a variation from this traditional standpoint and thus advocated an easier bony landmarks for zygomaticus major attachment location compared to previous literature.

### **Author contributions**

Concept/design: ES, CR, PM; data collection: ES; data analysis/interpretation: ES, CR; craniofacial reconstruction: ES; craniofacial reconstruction supervision: CR; drafting the manuscripts: ES; critical revision of the manuscript: ES, CR, PM, SB; approval of the manuscript: ES, CR, PM, SB. All authors have read and approved the manuscript.

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### **Disclosure of interest**

The authors declare that there are no conflicts of interest.

### **Ethical statement**

The bodies were procured from people who signed inform consent to donate their bodies for teaching and research prior to death.

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**Fig. 1** Bony attachment of the zygomaticus major (ZMaj).

