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Anatomical and radiological evaluation of modiolus anguli oris in facial anatomy

Yüzde modiolus anguli oris'in anatomik ve radyolojik değerlendirilmesi

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Abstract

Aim: Modiolus is a dense, mobile fibromuscular structure lateral to the mouth corner. It is of great importance in aesthetic and reconstructive surgery. The aim of this study was to enlighten the structural changes in modiolus with demographic variables such as age and gender in living individuals.

Methods: This retrospective cohort study was conducted on MR images of healthy individuals. Age and sex-related changes in modiolus level and volume were retrospectively analyzed in 64 patients [37M; 27F; mean age 48.2(16.3)] who underwent head and neck magnetic resonance imaging. ROC analysis was performed to determine the cut off values for age of modiolus. Correlation analysis (Pearson and point biserial correlation) was used to determine whether there was a significant correlation between age and volume. Significance of the differences between the volumes of right and left modiolus of the same individual were evaluated by dependent t tests.

Results: The mean volume of the modiolus was calculated as 0.51(0.26) mm^3. The volumes of right and left modioli decreased by aging. Ninety-one percent of the patients with modioli located inferior to horizontal line were over 49 years old. Right and left modioli relocated inferior to horizontal line with age. Modiolus volume was prominently less in women and the downward displacement of modiolus in women was 3.3 times higher than in men. Gender and age had significant effects on modiolus level. The right and left modiolus volumes were similar (P=0.975).

Conclusion: Surgeon's knowledge on modiolus and its relations will provide benefit, not only for the procedures such as face lifting and botulinum toxin injection, but also for the surgeries of facial paralysis and trauma patients.

Keywords: Modiolus, Magnetic resonance imaging, Radiologic anatomy, Senile changes, Aging

Öz

Amaç: Modiolus, ağız köşesinin lateralinde yoğun, hareketli, fibromüsküler bir yapıdır. Estetik ve rekonstrüktif cerrahide büyük öneme sahiptir. Çalışmanın amacı; yaş ve cinsiyet gibi demografik değişkenlere bağlı olarak modiolusta oluşan yapısal değişikleri göstermektir.

Yöntemler: Bu çalışma sağlıklı bireylerin MR görüntülerinden retrospektif kohort çalışması olarak tasarlanmıştır. Modiolus düzeyinde ve hacminde yaş ve cinsiyete bağlı oluşan değişiklikler, baş ve boyun manyetik rezonans görüntülemesi yapılan 64 hastada [37E; 27K; ort. yaş 48,2(16,3)] retrospektif olarak incelendi. Yaşta cut off değerini belirlemek için ROC analizi yapıldı. Yaş ve hacim arasında anlamlı bir korelasyon olup olmadığı korelasyon analizi (Pearson ve point biserial korelasyon) ile değerlendirildi. Aynı bireyin sağ ve sol modiolus hacimleri arasındaki önemli farklar dependent t testi ile yapıldı.

Bulgular: Modiolusun ortalama hacmi 0,51(0,26) mm^3 bulundu. Sağ ve sol modiolus hacimleri yaş ile azalmıştır. Modiolus seviyesi horizontal hattın altında olan hastaların %91'i 49 yaşın üzerindeydi. Sağ ve sol modiolus, yaşlanma ile birlikte horizontal çizginin altına yer değiştirdi. Kadınlarda modiolus hacmi belirgin olarak daha azdı ve kadınlarda modiolusun aşağı doğru yer değiştirmesi, erkeklerden 3,3 kat daha yüksekti. Cinsiyet ve yaşın modiolus seviyesi üzerinde önemli etkisi vardı. Sağ ve sol hacim ölçümleri arasında istatistiksel fark bulunamadı (P=0,975).

Sonuç: Cerrahın modiolus ve komşulukları hakkındaki bilgisi sadece yüz germe ve botulinum toksin enjeksiyonu gibi prosedürler için değil ayrıca facial paralizi ve travma hastalarının ameliyatları için de fayda sağlayacaktır.

Anahtar kelimeler: Modiolus, Manyetik rezonans görüntüleme, Radyolojik anatomi, Yaşlılık değişiklikleri, Yaşlanma

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Introduction

Modiolus is a dense, mobile fibromuscular structure that is found on the lateral border of the corner of the mouth [1-3]. It is composed of engaging muscle fibers around the mouth. These fibers converge towards or diverge from this decussation, which can be palpated easily. The fibers attaching to modiolus form spirals and then separate into two or more fiber bundles, each bundle coursing in separate ways. It extends between the orbicularis oris muscle and labial tractor muscles ending at the angle of the mouth [2,3] (Figure 1). In general, nine muscles attach to modiolus: Buccinator, risorius, orbicularis oris, depressor anguli oris, depressor labii inferioris, zygomaticus major, platysma pars modiolaris, levator anguli oris and mentalis. Most of these muscles have dermal terminations [4]. Patients with a prominent nasolabial fold, which is considered one of the principle landmarks of lower face aging, have weak trophic modioli [2,5].

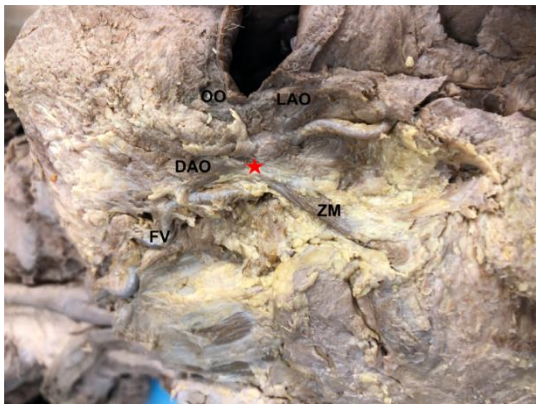

Figure 1: Localization of modiolus anguli oris and the muscles attached to it in cadaver (OO: Orbicularis oris, LAO: Levator anguli oris, ZM: Zygomaticus minor, DAO: Depressor anguli oris, FV: Facial vein, Star: Modiolus)

In the literature, there are microscopic studies examining its histo-morphological structure [2,5], and macroscopic cadaveric studies indicating the relationship of modiolus with the vessels and neighboring expression muscles [4]. Location of the modiolus was also studied in living individuals by palpation [6]. The three-dimensional structure of modiolus is very complex and hard to evaluate. The mobility of modiolus effects the movement of the lips and cheeks and it is active during talking, chewing, eating and drinking. Directly related to all the functions of the mouth corner, it is also highly important in facial expression. [4].

Modiolus has a key role in the formation of nasolabial fold, which is why it is particularly important in aesthetic and reconstructive surgery [2]. The modiolus can be regarded as an angular corner stone because the shape of the nasolabial fold is in direct relation with it [7]. It is considered critical for the beauty of the lower third of the face and prevents the appearance of facial aging [3,4,8].

In this study, we aimed to define the location, level and volume of the modiolus in living individuals based on objective data of Magnetic resonance (MR) images (Figure 2 and 3), and evaluate the changes related to age and gender. It is hypothesized that modiolus displaces below the horizontal line passing through the angle of the mouth, and its volume decreases with aging.

The results of this study will be especially useful in plastic surgery for the treatment of the angle of the mouth.

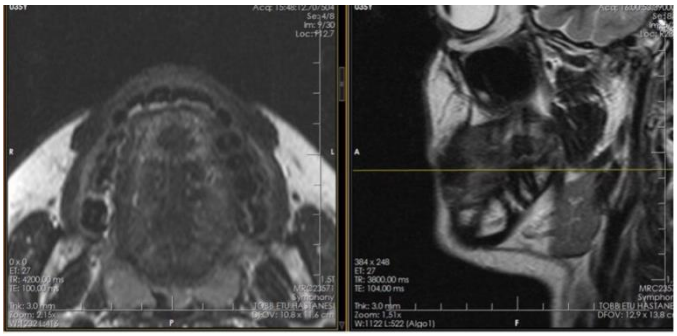

Figure 2: Magnetic resonance images of modiolus anguli oris at the corner of the mouth

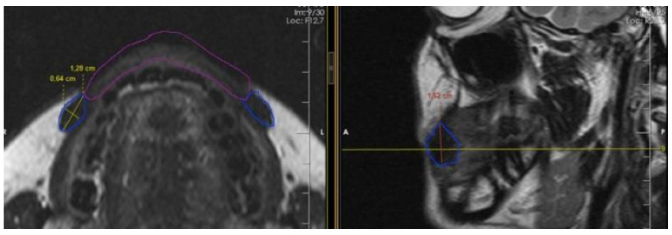

Figure 3: Magnetic resonance images of modiolus anguli oris labelled with blue lines at the corner of the mouth

Materials and methods

Ethics committee approval was received by TOBB ETU Faculty of Medicine Clinical Research Ethics Committee, 16.01.2019, Number: KAEK 118/029.

Magnetic Resonance (MR) images of 64 patients obtained for head and neck pathologies between 2012 and 2015 were evaluated retrospectively. MR imaging was performed with 1.5 T Siemens Magnetom Symphony device. Coronal, sagittal and axial T2-weighted images passing from the angle of the mouth were used. Anatomical structures around modiolus were determined at each interpretation to identify the modiolus correctly. A horizontal line passing from the angle of the mouth was defined to indicate the level of modiolus (Figure 2 and 3). Volume measurements were made automatically with the software by measuring anteroposterior, transverse and craniocaudal axis lengths for each side. The age and gender-related changes of modiolus were examined by the same radiologist, certified with five years' experience at head and neck imaging.

Statistical analysis

The statistical analysis was performed by IBM SPSS Statistics Version 21 and STATA version 13.0. The variables were described by using minimum-maximum values, mean, standard deviation, frequency and percent statistics. 95% confidence interval for mean is used to estimate the mean value for volume of right and left sided modioli in the study population. ROC analysis was used to determine cut off values for age of modiolus. Correlation analysis (Pearson and point biserial correlation) determined whether there was a significant correlation between age and volume. Significant differences between the volumes of right and left modiolus of the same individual were evaluated by dependent t test. Volumes and levels of the right and left modioli of the same individual were assumed correlate. Due to suspicion of the clustered data structure we needed to calculate intra-cluster correlation coefficient for left and right side of the same patient by using multilevel (two-level) linear and logistic regression models. Factors effecting level and volume of modiolus were determined by these multi-level models.

Results

Sixty-four patients who were admitted to the hospital from 2012 to 2015 were subsequently enrolled to the study. Among these, 37 were male and 27 were female. Mean age of all patients were 48.2(16.3) years (range: 17-88 years). Mean volume of the modiolus was 0.51(0.26) mm^3 (range: 0.07-1.17 mm^3). The mean volume of right and left modioli were 0.51(0.29) and 0.51(0.26) mm^3, respectively. The mean difference between the volumes of right and left modioli was 0.00047 mm^3, which was not significant. The volumes of the right and left modioli superior and inferior to the horizontal line passing through the angle of the mouth are presented in Table 1. The related r and p values are presented in Table 2.

Table 1: The volumes of the right and left modioli superior and inferior to the horizontal line passing through the angle of the mouth

	Min(mm^3)	Max(mm^3)	Mean (SD)(mm^3)	95% CI for Mean(mm^3)	
RV					
Inferior to HI	0.07	0.66	0.35 (0.17)	0.28	0.42
Superior to HI	0.14	1.65	0.61 (0.31)	0.51	0.71
LV					
Inferior to HI	0.07	0.71	0.36 (0.17)	0.29	0.43
Superior to HI	0.20	1.17	0.61 (0.27)	0.53	0.70

RV: volume of the right modioli, LV: volume of the left modioli, SD: standard deviation, CI: confidence interval, HI: horizontal line

Table 2: *P*- and r values of correlation between age and volume

Age-Location	RV	RV	SV	SV
R Inferior to HI	r=-0.54	*P*=0.008		
R Superior to HI	r=-0.07	*P*=0.663		
L Inferior to HI			r=-0.37	*P*=0.073
L Inferior to HI			r=-0.15	*P*=0.353

RV: volume of the right modioli, LV: volume of the left modioli, HI: horizontal line, R: Right, L: Left

It was hypothesized that modiolus displaces below the horizontal line passing through the angle of the mouth and its volume decreases with aging. According to the results, twenty-three patients' (35.9%) right modioli were localized inferior and 41 patients' (64.1%) right modioli were localized superior to the horizontal line passing from the angle of mouth. Twenty-four patients' (37.5%) left modioli were localized inferior and 40 patients' (62.5%) left modioli were localized superior to the horizontal line. There was a negative correlation between age and the volumes of right and left modiolus (Figure 4). There was a significant negative correlation between gender and volume. Volume of modiolus in women was prominently less than that in men.

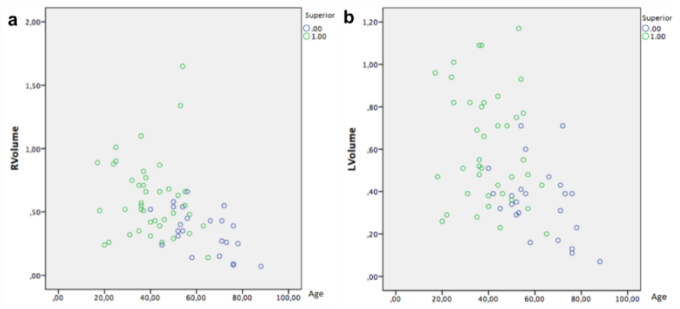

Figure 4: Scatter plot graphic showing the relationship between the volume of (a) right modiolus, (b) left modiolus and age (RVolume: volume of the right modioli, LVolume: volume of the left modioli)

In our study, 91% of the individuals whose modioli were located inferior to horizontal line were over 49 years old. The right and left modioli of 66% of the patients older than 49 years were located inferior to the horizontal line, while this was true for only 6% and 9% of the patients younger than 49 years, respectively. Age was a significant factor in the downward displacement of bilateral modioli.

Logistic regression analysis showed that the risk of downward displacement of modiolus in women was 3.3 times higher than in men [Odds ratio (OR): 3.3, 95% confidence interval (CI) for OR (1.3-8.7)].

In multilevel logistic regression analysis, gender (reference category: male) and age (reference category: less than 49) were found to have significant effects on the level of modiolus.

Discussion

The shape and the dimensions of the modiolus differ according to the structure, age, gender and ethnicity. The modiolus is a tortuous, cone-like structure that extends vertically from the buccal mucosa to the dermis of the skin with a base that is adherent to mucosa [9]. The modiolus does not have precise boundaries, it extends vertically 20 mm above, below, and lateral to a horizontal line that passes through the buccal angle. The apex of this conical structure is about 12 mm lateral to the buccal angle [4,10]. Considering the shape and localization of modiolus, in our study, a horizontal line passing from the angle of the mouth was used to indicate the level of the modiolus. This level was considered a landmark that separates the upper and lower localizations of modiolus.

Nine muscles in different planes attach to the modiolus, as their stems spiralize and separate into many bundles. These fibers course in different ways, and due to this complicated structure, analyzing the three-dimensional (3D) organization of modiolus is difficult [9]. In this study, we aimed to define the location, level and volume of the modiolus in living individuals on MR images, which may help understand its 3D structure [4,10]. Studies in the literature are generally related to the muscular attachments, histology, location of modiolus and its relationship with neurovascular structures.

To the best of our knowledge, the volume, age and gender related changes of modiolus are discussed for the first time. Here, the mean volume of the modiolus was calculated about 0.51 mm^3 with no significant differences between the volumes of the right and left modiolus.

We hypothesized that the volume of the modiolus decreases with aging. Accordingly, there was a negative correlation between the age and volume of right and left modioli. It was also found that the volume of modiolus was prominently less in women than in men.

It was also hypothesized that modiolus displaced below the horizontal line passing through the angle of the mouth with aging. In our study, 35.9% of the right modioli and 37.5% of the left modioli were placed inferiorly and 64.1% of the right modioli and 62.5% of the left modioli were localized superior to the horizontal line passing from the angle of the mouth. Ninety-one percent of the individuals who had modiolus located inferior to horizontal line were older than 49 years. Right and left modioli were observed to significantly displace inferior to horizontal line with aging, as observed on retrospective MR images. Despite the studies in the literature indicating the level of the modiolus in vertical position, the influence of gravity on modiolus was excluded due to the normal positioning procedure of patients undergoing MR imaging [6]. Positioning the patients

in such a way to exclude gravity effect on modiolus carried the results of this study to a more constant ground.

In the literature, there are studies reporting the relationship between hyperactivity of Depressor anguli oris muscle and dropped mouth corner. The appearance of the aging in the perioral region has many reasons, one of which is the drooping of the corner of the mouth, related to Depressor anguli oris muscle. Dropped mouth corner may lead to a sad and tired expression which is a common complaint for the patients referred for facial rejuvenation [11]. Botulinum toxin injection into Depressor anguli oris muscle is the current treatment modality for elevation of mouth corner. The target of the botulinum toxin is depressor anguli oris muscle but the neighboring muscles at mouth corner can also be affected. Unwanted changes in the lower third of the face can be a problem after the injection. Besides, botulinum toxin injection is a temporary treatment. Depressor anguli oris is one of the muscles attaching to modiolus anguli oris. Perioral wrinkles are also corrected by dermal fillers including hyaluronic acid which is also a temporary treatment [12]. The enhancement of modiolus anguli oris, which is a key point for the anatomical features of lower face, may be a long-lasting safe option for treatment [7].

It was found that the facial artery traversed around the modiolar region and was closely associated with the perioral musculature. During plastic and reconstructive surgery procedures of the face, such as the superficial muscular aponeurotic system (SMAS) facelift and facial artery musculo-mucosal flap, the relationship between the facial artery and the muscles attached to modiolus gains great importance [13].

The main purposes of the reconstruction of the labial commissure are the maintenance of functions and, the preservation of symmetry and facial appearance. Knowledge of the anatomy of the modiolus and the muscles attaching to this structure will assure a proper reconstruction technique [10,14,15].

The modiolus plays a fundamental role in facial actions because from therein is provided the force for closure, eversion, and opening of the mouth. The increased knowledge of the surgeon regarding modiolus and its relations will provide benefit not only for the procedures such as face lifting and botulinum toxin injection, but also for the surgeries of facial paralysis and trauma patients. A better comprehension of surgical anatomy and understanding of how facial anatomical relationships change with aging will lead to advances in plastic and reconstructive surgery [2,3,7,10,14,15].

Limitations

This study is a retrospective cohort study, which is its limitation. A prospective study with long-time follow up of patients is needed for further enlightenment on this subject. Also, further studies in large series are required to investigate whether modiolus is a hormone-dependent tissue. To clarify the hormone effects on modiolus, comparative studies between the pre- and post-menopausal states of women should be conducted. Microscopic studies analyzing the hormone receptors of modiolus may lead to a new overview for treatment of lower face aging. Understanding the histo-morphological changes in modiolus and the components of the connective tissue may provide insight to improve its structure by injectable treatment modalities like platelet rich plasma (PRP) treatment. We suggest prospective comparative studies in large series to determine the long-term effects of treatments strengthening the modioli.

Conclusion

In our study, age was a significant factor in the downward displacement of modiolus. Modioli were more prominently displaces downwards in women compared to men. Morphometry and age-related changes in modiolus are important for aesthetic interventions, radiologists, and anatomists.

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