

Three-dimensional structure of the modiolus

A computerized reconstruction study

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ABSTRACT

Objective: Modiolus is a dense, compact, mobile fibromuscular structure, reachable by the dissection of buccolabial musculature. We undertook this study to provide detailed information about the macroscopic and microscopic anatomy of modiolus and its 3-dimensional (3-D) shape.

Methods: Fifteen micrometer thick serial sections were taken from the fixed cadaveric tissue samples and then stained with hematoxylin and eosin, and Massons' trichrome stain. Stained sections were photographed digitally and images were transferred to computer medium to perform 3-D reconstruction. The study was carried out in the dissection lab of the Anatomy Department of Hacettepe University, Ankara, Turkey between 2002 and 2003.

Results: The modiolus appears to be a tortuous, blunt conelike structure, extending vertically from the buccal mucosa to the dermis of the skin. The base of the cone is adjacent to the mucosa.

Conclusion: As the structure has great clinical importance, and satisfactory complete 3-D analysis of the subject is not yet available; we believe that our study presenting the histological and 3-D description of the modiolus will be of great help to surgeons for satisfactory esthetic and functional results during surgical operations related to the oral commissure.

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Modiolus is a dense, compact, mobile fibromuscular structure reachable by the dissection of buccolabial musculature with particular reference to the tissues embracing the lateral extremities of the oral fissure.¹ Knowledge of the structure and function of the modiolus is of clinical importance, especially in plastic surgery, as it plays a great role in the formation of the nasolabial fold, and prevents the appearance of facial aging.²⁻⁵ Computer-based, three-dimensional (3-D) reconstruction of histological sections is necessary for solving a diversity of questions in morphological sciences. The

information obtained using 3-D reconstructions could theoretically be achieved by studying each histological section, but it would be extremely difficult. The 3-D images allow rapid and clear appreciation of the structure's morphology and its relationship to the surrounding tissues.^{6,7} As the anatomical structure of the modiolus has not been defined in detail and satisfactory complete 3-D analysis of the subject is not yet available, we undertook this study to provide detailed information about the macroscopic and microscopic structure of the modiolus; and its 3-D anatomical shape.

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Methods. The material consisted of 6 adult formalin fixed human cadavers, 4 male and 2 female. The average age was 59, ranging from 41-72 years. None of the cadavers had undergone any surgical procedure prior to resection of the face region. The study was carried out in the dissection lab of the Anatomy Department of Hacettepe University, Ankara, Turkey between 2002 and 2003. After palpating the modiolus at the corner of the mouth by using the opposed thumb and index finger to compress the mucosa and skin simultaneously, an approximately 1 cm cubic mass was excised containing the modiolus and the surrounding tissue, extending from skin deeply to oral mucosa. The specimens were prepared by routine histologic preparation technique. They were dehydrated in a graded series of ethanol and embedded in paraffin. Two different color threads were put into samples as landmarks, to remove the rotation and shifts of the serial sections. The semi-thin serial sections were prepared with a sliding microtome and stained with hematoxylin and eosin, and Masson's trichrome. Stained sections were examined by at least 2 investigators under light microscope (Olympus BH-2, Japan) and their photomicrographs were taken with a digital camera (Nikon Coolpix 995, Japan). The semi-thin serial sections of the modiolus were approximately 15 μm in thickness. The distance between 2 serial sections following each other, which were used in 3-D reconstruction was 75 μm . By this method, 40 serial sections were obtained from each specimen and therefore, the long axis of the 3 dimensionally reconstructed modiolus was 3600 μm . Digital photomicrographs were transferred to computer (Dell Latitude CPX Notebook). The contours of the modiolus (**Figure 1**) were traced manually and 3-D reconstruction was performed (SURFdriver 4.0 for Windows). First, the wire-frame images and then the rendered forms of these wire-frame images were obtained.

Results. Sections of the facial striated muscles with different orientations were observed in light microscopical examination. A fibrous channel-like structure called modiolus adhering to the surrounding connective tissue was noted in serial sections. The wall of this channel-like structure consisted of irregular, dense, collagenous connective tissue, poor in cells and vascular elements. Some cross sections of striated muscle fibers, probably belonging to the stems of the individually recognizable muscles originating from modiolus, were seen within the wall (**Figure 2**). Wire-frame reconstruction of the modiolus did not give any idea of the 3-D shape of this structure (**Figure 3**). However, it was observed as a cone shaped structure when the rendered form reconstruction was built (**Figure 4**). Depending on the irregular course of the lumens and their lack of precise histological boundaries, we could not show the 3-D reconstruction of the lumen of the modiolus. The modiolus appears to be a tortuous, blunt conelike structure, extending vertically from the buccal



Figure 1 - The contours of the modiolus in a histological section (Hematoxylin and eosin x 40).

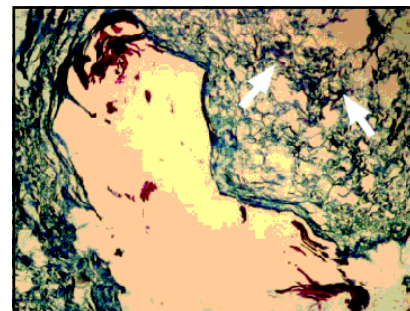


Figure 2 - Some cross sections of striated muscle fibers seen within the wall of modiolus (white arrow) (Hematoxylin and eosin x 40).

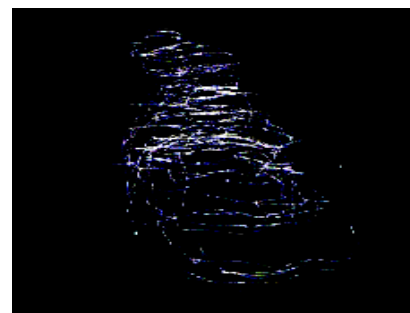


Figure 3 - The wire-frame reconstruction of the modiolus. (SURFdriver 4.0 for Windows).

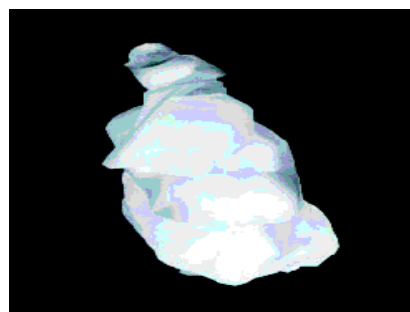


Figure 4 - The rendered form of the reconstruction of the modiolus. (SURFdriver 4.0 for Windows).

mucosa to the dermis of the skin. The base of the cone is adjacent to the mucosa. At least some of the muscles may originate from the modiolar stem and lie in different planes.

Discussion. The modiolus is an anatomically complex structure that has great importance in facial expression due to its location at the angle of the mouth. It is a subcutaneous, dense, compact, mobile, fibromuscular mass formed by the interlacing of a number of muscles on each side of the face. The name modiolus refers to the resemblance to the 'nave of a wheel', and the muscles ending in it to the 'radiating spokes of an imaginary wheel'. Embryologically, muscles from the modiolus derive from a cellular concentration in the region of the second branchial arch. It is then logical to see these muscles converge to the corner of the mouth to form the modiolus, as they emerge from a common area. Zygomaticus major, levator anguli oris, depressor anguli oris, platysma pars modiolars, incisus superior and inferior buccinator, risorius and various parts of orbicularis oris are the muscles attaching to the modiolus with a focus just lateral to the buccal angle. They lie in different planes, their modiolar stems are often spiralized and most divide into 2 or more bundles, each of them interlacing and attaching in a distinctive way.^{1,8}

Functioning of the modiolus is complex as its position may change repeatedly in a minute to allow the modiolar muscles to take any position and perform any movement as if it were inserted on bone.⁸ Fernandez as cited by Villoria, uses the term 'bone center' or 'point of support' for the insertion of zygomaticus and orbicularis oris muscles and states that there is a curious relationship between the development of the orbicularis oris muscle and the development of the modiolus.⁹ However, our histological findings and the data available in the current literature do not support this terminology.^{1,5,8,10}

Performing 3-D reconstruction from serial sections was first achieved by Born in 1883.¹¹ Since then a variety of reconstructive techniques have been developed and the building of physical models has become a valuable tool in morphological and biomedical research, primarily used for analyzing complex structural relationships and morphogenetic processes. The quality of a reconstruction from histological sections depends on several factors: 1. Tissue changes during preservation and embedding. 2. Tissue distortions due to sectioning with the microtome. 3. Accuracy of data acquisition. 4. Reliability of section alignment. 5. Quality of surface generation (manual drawing or computer-based visualization).⁷

No matter how much error is tolerated, the reconstruction must yield a result adequate to answer the scientific question posed. The advent of computer technology, allowing the visualization of stacked sectional images on a screen, had a revolutionary impact on 3D-reconstruction methods. Physical modeling techniques were replaced by the processing of digitized

images on the computer.¹²⁻¹⁵ There is sufficient data concerning 3-D reconstruction from serial sections in the literature.^{13,16-21} By using one of these new techniques, all the parts of the body which have a special clinical importance and which have not been described previously can be shown accurately macroscopically or microscopically.

As there are many muscles attached to each modiolus, the structure has a high degree of 3-D complexity and had proved correspondingly difficult to analyze. Williams et al¹ stated that the modiolus has the rough form of a blunt cone modified by 2 round-edged flanges (or cornua) that extend into the lateral free lip tissues above and below the corner of the mouth. In the present study, the 3-D reconstruction of modiolus did not present round-edged flanges or cornua modifying the anatomical shape of the structure.

One of the goals in plastic surgery is not only to reestablish the normal appearance, but also to restore the functions of the area defected. Modiolus is of critical importance in reconstructive as well as esthetic surgery of the face for several reasons. First, it makes a very important landmark of beauty and youth of the inferior part of the face. A well-developed modiolus makes the mouth pulpy and laterally extends its natural aesthetic unit, shaping the inferior level of the face, and thus, individualizing it from the middle face. Second it has great importance in the formation of the nasolabial fold. A long convex nasolabial fold is always present with a weak trophic modiolus, and a short concave nasolabial fold is always present with a large trophic modiolus. Thirdly, a trophic modiolus prevents the appearance of facial aging; this phenomenon is because of the high degree of muscular fibers under the dermis lateral to the modiolus.⁵

As the structure has great clinical importance and satisfactorily complete 3-D analysis of the subject is not yet available; we believe that our study presenting the histological and 3-D description of the modiolus will be of great help to surgeons for satisfactory esthetic and functional results during the surgical operations related to the oral commissure.

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