

Important Landmarks for Facial Canal in the Middle Ear and Mastoid: Human Cadaveric Temporal Bone Study

Orta Kulak ve Mastoid'de Fasiyal Kanal İçin Önemli İşaret Noktaları: İnsan Kadavra Temporal Kemik Çalışması

Mehmet Şentürk

M.D.
Department of Otolaryngology Head-Neck Surgery,
Aksaray State Hospital,
mskbb1974@yahoo.com

Mehmet Akif Somdaş

Assist. Prof., M.D.
Department of Otolaryngology Head-Neck Surgery,
Erciyes University Medical Faculty,
somdas@erciyes.edu.tr

Nihat Ekinci

Assoc. Prof., Ph.D.
Department of Anatomy,
Erciyes University Medical Faculty,
ekinci@erciyes.edu.tr

Ali Bayram

M.D.
Department of Otolaryngology Head-Neck Surgery,
Kayseri Education and Research Hospital,
dralibayram@gmail.com

Ünal Erkorkmaz

Assist. Prof., Ph.D.
Department of Biostatistics
Gaziosmanpaşa University Medical Faculty,
uerkorkmaz@gmail.com

Yaşar Ünlü

Prof., M.D.
Department of Otolaryngology Head-Neck Surgery,
Erciyes University Medical Faculty,
unluy@erciyes.edu.tr

Submitted : August 04, 2008
Revised : February 20, 2009
Accepted : September 05, 2009

Corresponding Author:

Assist. Prof. Dr. Mehmet Akif Somdaş
Department of Otolaryngology Head-Neck Surgery,
Faculty of Medicine, University of Erciyes
Kayseri, Turkey

Telephone: 0 542 4220033
E- mail: mskbb1974@yahoo.com

Abstract

Purpose: The aim of the present study was to measure the distances of human temporal bone between important landmarks for facial canal in the middle ear and mastoid.

Material and Methods: Length and diameter of the tympanic and mastoid portion of the facial canal, of the lateral semicircular canal, proc. cochleariformis, eminentia pyramidalis, distances to the related facial canal; the distance between proc. cochleariformis and tegmen tympani; proc. cochleariformis and anterior side of the fenestra vestibuli; the uppermost point of lateral semicircular canal and tegmen tympani were measured and recorded.

Results: Length and diameter of tympanic and mastoid portion of the facial canal revealed concordance with the literature. In addition, distance between lateral semicircular canal-second genu of the facial canal, eminentia pyramidalis-facial canal, proc. cochleariformis - facial canal were also in concordance with the literature. The distance between proc. cochleariformis - tegmen tympani ranged 1.50-10.30 mm; proc. cochleariformis-fenestra vestibuli ranged 1.20-4.00 mm; lateral semicircular canal-tegmen tympani ranged 1.25-10.50 mm.

Conclusion: Distances between proc. cochleariformis-tegmen tympani, proc. cochleariformis-fenestra vestibuli, lateral semicircular canal-tegmen tympani, offer additional important knowledge to the physicians interested in mastoid and middle ear anatomy.

Key words: **Cadaver; Cranial Nerve VII; Mastoid; Middle ear; Semicircular canals; Temporal bone.**

Özet

Amaç: Sunulan çalışmada insan temporal kemiğinde, orta kulak ve mastoidde fasiyal kanal için önemli işaret noktaları arasındaki mesafelerin ölçülmesi amaçlandı.

Gereç ve Yöntemler: Fasiyal kanalın timpanik ve mastoid parçalarının uzunluk ve çapları ile fasiyal kanalın ilişkide olduğu lateral semisirküler kanal, proc. cochleariformis ve eminentia pyramidalise olan mesafeleri; proc. cochleariformisin tegmen tympani ve fenestra vestibulünün ön yüzüne olan mesafesi; lateral semisirküler kanalın en üst noktası ile tegmen tympani arasındaki mesafe ölçülerek kaydedildi.

Bulgular: Fasiyal kanalın timpanik ve mastoid parçalarının uzunlukları ve çaplarının ölçümleri ile lateral semisirküler kanal-fasiyal kanal ikinci dirsek arasındaki mesafe; eminentia pyramidalis-fasiyal kanal arası mesafe; proc. cochleariformis-fasiyal kanal arası mesafe sonuçları literatür verileri ile uyumlu idi. Proc. cochleariformis - tegmen tympani arası mesafe 1,50-10,30 mm arasında; proc. cochleariformis - fenestra vestibuli arası mesafe 1,20-4,00 mm arasında; lateral semisirküler kanal-tegmen tympani arası mesafe 1,25-10,50 mm arasında idi.

Sonuç: Proc. cochleariformis - tegmen tympani arası mesafe, proc. cochleariformis - fenestra vestibuli arası mesafe, lateral semisirküler kanal-tegmen tympani arası mesafe, diğer ölçüm mesafeleri ile birlikte mastoid ve orta kulak anatomisine ilgi duyan hekimlere ilave önemli bilgiler sunmaktadır.

Anahtar kelimeler: **Kadavra, Kranial Sinir VII; Mastoid; Orta kulak; Semicirküler kanallar; Temporal kemik.**

Introduction

Temporal bone is the most complex bone of the body. The facial nerve is one of the most sensitive structures in the temporal bone that can be easily injured during the middle ear surgeries. This situation is very important for the surgeons where an injury of the facial nerve causes additional responsibilities. Either anatomic changes after the former surgery or presence of the pathological structures such as granulation tissue is the risk factors that can increase the possibility of facial nerve injury (1, 2). For these reasons, it is necessary to know whole anatomy of facial canal and surrounding important structures (3).

Anatomic landmarks offer to the surgeon different options when changes of the facial nerve position occurred by the iatrogenic, traumatic, inflammatory, and the other reasons (4). The portions of the facial canal, lateral semicircular canal, proc. cochleariformis are the important landmarks for middle ear and mastoid operations. The length of the tympanic segment (5-8) and mastoid segment (9-11) of the facial canal, the relationship between lateral semicircular canal and second genu (12), the bony thickness between facial canal and eminentia pyramidalis (7), the shortest distance between facial canal and proc. cochleariformis (13), the diameter of the horizontal and mastoid segment of the facial canal (5,14) were investigated in the former studies. However the distance between proc. cochleariformis and tegmen tympani, the distance between proc. cochleariformis and the anterior side of the fenestra vestibuli, the distance between the uppermost point of lateral semicircular canal and tegmen tympani were not examined yet. During mastoid and middle ear surgeries, we consider that these new measurements are also important and can offer useful information for physicians interested in middle ear and mastoid anatomy.

Materials and Methods

Study Specimens. This study was performed on totally 48 adult human cadaveric temporal bones, consisting of 18 fresh and 30 dry bones that were provided by Otolaryngology Head and Neck Surgery and Anatomy Laboratories. The numbers of the dry and fresh bones of the left and right ears were equal.

Temporal Bone Dissection. Total auricula resection was performed in the fresh specimens first. Afterwards cutaneous and subcutaneous tissues on the mastoid bone were removed with a periosteal elevator. Macewen's triangle were drilled to find out the antrum, mastoid drilling was

carried out up to the tegmen mastoideum at the superior, sigmoid sinus at the posterior, posterior wall of the external auditory canal at the anterior, digastric ridge cells at the inferior, and thus simple mastoidectomy was completed. Incus was taken out and the second portion of the facial canal and second genu were made visible by the facial recess approach, without drilling posterior wall of the external auditory canal. After this part of the procedure, posterior wall of the external auditory canal was drilled. Then malleus was taken out. Facial canal was opened from tympanic portion up to geniculate fossa. Mastoid portion of the facial canal was exposed by opening from the second genu down to the stylomastoid foramina. Thinning the bony plate of the tegmen tympani; duramater was made visible. Superficial part of the lateral semicircular canal was opened by drilling through its lateral bony wall.

Measurement Methods. Dissections were performed under Zeiss Opmi 99® and Zeiss Vario® microscopes and Canon EOS10D® digital camera was mounted for taking photos. Distances were measured with 0.1 mm sensitive calliper and Storz® stapedectomy measuring device. The measurements enrolled as millimeter category. The measured distances categorized into two groups. The first category was the distances which are only concerned facial canal, the second was the distances that could be additional to the first category parameters.

Facial Canal Distances (Figure 1). The length of the tympanic portion of the facial canal between just behind the geniculate ganglion and eminentia pyramidalis (A); between the superior part of the eminentia pyramidalis and foramen stylomastoideum (B); the shortest distance between lateral semicircular canal and facial canal at the level of second genu (C) or between eminentia pyramidalis and facial canal at the level of second genu or between proc. cochleariformis and facial canal in the tympanic portion (E).

Additional Parameters (Figure 2). The distance between proc. cochleariformis and tegmen tympani (F) or proc. cochleariformis and the anterior side of the fenestra vestibule (G) or the uppermost point of lateral semicircular canal and tegmen tympani (H); the diameter of the tympanic portion of the facial canal at the just behind the geniculate ganglion (Ia), anterior part of the fenestra vestibuli (Ib) or posterior part of the fenestra vestibule (Ic); the diameter of the mastoid portion of the facial canal at the superior side of the eminentia pyramidalis (Ja), inferior side of the eminentia pyramidalis (Jb) or digastric ridge (Jc).

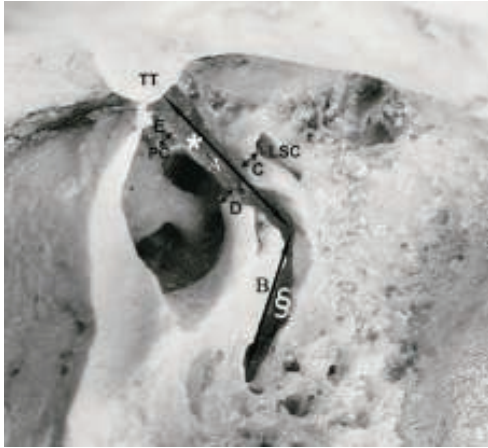


Figure 1. On dry left temporal bone A: the length of the tympanic portion of the facial canal, B: the length of the mastoid portion of the facial canal, C: The distance between facial canal and lateral semicircular canal, D: the distance between facial canal and eminentia pyramidalis, E: at the second genu area, the distance between facial canal and processus cochleariformis, *: Tympanic portion of the facial canal, †: Mastoid portion of the facial, LSC: Lateral Semicircular Canal, PC: Processus cochleariformis, TT: Tegmen Tympani

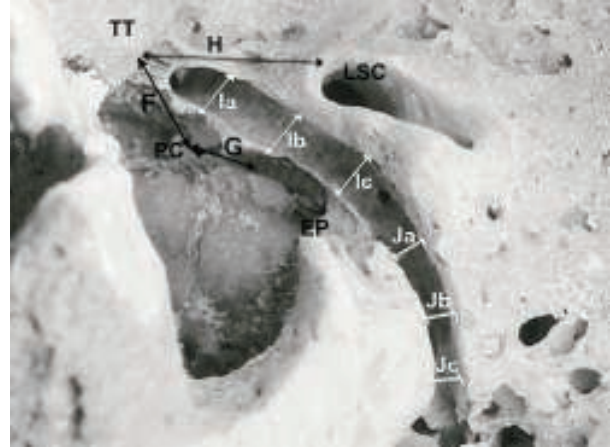


Figure 2. On dry left temporal bone; F: The distance between processus cochleariformis and tegmen tympani, G: The distance between processus cochleariformis and anterior side of the fenestra vestibuli, H: The distance between lateral semicircular canal and tegmen tympani, Ia, Ib, Ic: The diameter of the tympanic portion of the facial canal, Ja, Jb, Jc: The diameter of the mastoid portion of the facial canal, LSC: Lateral Semicircular Canal, PC: Processus cochleariformis, TT: Tegmen Tympani, EP: Eminentia Pyramidalis

Results

The all distances measured on temporal bone were shown in Table I.

Table I. The distances measured on temporal bone (in mm scale)

Legend	Description of distance	Range	Mean	SD
A	The length of the tympanic portion of the facial canal	7.30-13.5	9.56	1.54
B	The length of the mastoid portion of the facial canal	8.55-16.20	12.28	1.90
C	Between facial canal and lateral semicircular canal	0.20-2.00	1.02	0.39
D	Between facial canal and eminentia pyramidalis	0.13-1.40	0.68	0.36
E	Between facial canal and processus cochleariformis at the second genu area	0.20-1.20	0.58	0.24
F	Between processus cochleariformis and tegmen tympani	1.50-10.30	5.34	1.85
G	Between processus cochleariformis and anterior side of the fenestra vestibuli	1.20-4.00	2.35	0.69
H	The distance between lateral semicircular canal and tegmen tympani	1.25-10.50	4.86	1.56
	The diameters of the tympanic portion of the facial canal at...			
Ia	The level of just behind the geniculate ganglion	0.80-1.50	1.04	0.20
Ib	The level of anterior part of the fenestra vestibuli	0.70-1.30	1.00	0.19
Ic	The level of posterior part of the fenestra vestibuli	0.50-1.80	1.02	0.23
	The diameters of the mastoid portion of the facial canal at			
Ja	The level of superior part of the eminentia pyramidalis	0.70-1.90	1.15	0.21
Jb	The level of inferior part of the eminentia pyramidalis	0.75-2.13	1.28	0.29
Jc	The level of digastric ridge	1.00-2.20	1.40	0.29

SD: Standart deviation

Discussion

Length of tympanic portion of the facial canal. The course of the tympanic portion of the facial nerve in temporal bone is horizontal. This part of the nerve begins from geniculate ganglion and ends at eminentia pyramidalis (15, 16). The tympanic portion of the facial nerve canal may not have bony coverage at superior and anterior part. The location where the facial nerve injury mostly occurs during the chronic otitis media and stapes surgery is, the second part of the facial nerve. Therefore, the length of the nerve in the second portion is very important during the chronic otitis media surgery, stapes surgery and facial decompression (17, 18). The length of this portion reported by Proctor (8) varied from 10-12 mm and 8-11 mm by Schaitkin and May (6), 9-13 mm by Candan et al. (7) and 11.4 ± 1.24 mm by Dimopoulos et al. (5). In this study, the mean value of this portion was 9.55 ± 1.54 mm (7.30-13.50 mm).

Schaitkin and May (6) and Proctor (8) did not mention about number of cases and method used. Candan et al. (7) studied on 20 human cadaveric temporal bones and the method used and results were similar to ours. Dimopoulos et al. (5) used 102 plastic casts from unselected human temporal bone specimens and their plastic cast study results were also similar to our study. Therefore, plastic cast study results may offer considerable close results to the direct cadaveric studies.

The length of the mastoid portion of the facial canal; between the superior part of the eminentia pyramidalis and foramen stylomastoideum. The mastoid portion of the facial canal begins from eminentia pyramidalis and continues to foramen stylomastoideum. The course of the mastoid portion is almost vertically from up to down. The length of this portion was shown as follow in different studies; 13.9 ± 1.97 (6.4-20 mm) by Dimopoulos et al (5), 12.2 mm (8.9-16 mm) by Kullman et al. (9), 13.8 ± 2.1 mm (6- 18 mm) by Muren and Wilbrand (10), 16.2 mm by Qiu et al. (11). In the histological sections the length was found 13 mm by Proctor (8) and 10-14mm by May (16). The mean length of this portion was 12.28 ± 1.91 mm (8.55-16.2 mm) in our study. In addition, Candan et al. (7) and Kullman et al. (9) studied on human temporal bones and their results were similar to ours.

The shortest distance between lateral semicircular canal and facial canal at the level of second genu. The facial nerve runs between the ampulla of the lateral semicircular canal and facial canal at the anterior part of

the fenestra vestibule and it is 1 mm far from these structures (17). Donaldson and Anson (12) reported that the shortest distance between lateral semicircular canal and facial canal was 1.25 mm (0.92-1.70 mm) on average. In this study, the shortest distance between lateral semicircular canal and facial canal was measured at the level of second genu and the mean distance was 1.02 ± 0.39 mm (0.2-2 mm). Therefore, when the pathologies of the facial nerve at the second genu are being cleaned, both risk of labyrinth opening and facial nerve injury can increase.

The shortest distance between eminentia pyramidalis and facial canal at the level of second genu. Facial nerve is under risk during the otosclerosis surgery, such as stapedectomy and stapedotomy. An exposed bony part over the facial nerve usually does not cause a problem in the first operation. The possibility of facial nerve injury is low if the removal of the stapes floor and the placing of the prosthesis will be made carefully. But if it is a revision stapedotomy or stapedectomy, because of the opened part of the facial nerve is usually covered by granulation tissue, the injury risk of the facial nerve's tympanic portion over the fenestra vestibuli will be higher (19,20). Eminentia pyramidalis, where musculus stapedius is originated from, must be shown during stapedotomy and stapedectomy procedures. If the shortest distance between eminentia pyramidalis and facial canal is known, the risk of facial nerve injury may decrease. Candan et al (7) measured this distance in histologic sections and determined 1.50-2.30 mm. In this study, the bony thickness between facial canal and eminentia pyramidalis was measured. The mean distance was 0.69 ± 0.36 mm (0.13-1.40 mm). Surgeons must be careful around this area according to these values.

The shortest distance between proc. cochleariformis and facial canal in the tympanic portion. The distances between proc. cochleariformis and its surrounding structures must be known during the surgeries near the geniculate ganglion area, and the beginning of the tympanic portion. Proc. cochleariformis is one of the most important landmarks to identify the facial nerve in the middle ear. Wong and Chen (14), and Schaitkin and May (6) declared that proc. cochleariformis is a constant landmark to identify the facial nerve even though other landmarks can not be found by the reason of middle ear pathologies. Wong and Chen (14) measured the shortest distance between facial canal and proc. cochleariformis, and the distance was 0.87 mm (0.5-2.25 mm) on average in their study. Also, Bento et al (21) determined that proc. cochleariformis is the most

important landmark for facial nerve decompression by middle fossa approach. The mean distance between facial canal and proc. cochleariformis was 0.58 ± 0.24 mm (0.2-1.20 mm) in this study.

The distance between proc. cochleariformis and tegmen tympani. The pathological tissues such as granulation tissue or cholesteatoma, which is situated in the epitympanium or over the tympanic portion of the facial nerve, must be removed without causing facial nerve injury. When the tympanic portion of the facial nerve is covered by tumoral tissue in a facial paralysed patient, nerve can be sacrificed during the dissection (22). If the distance between proc. cochleariformis and dura is known, dural injury and neural tissue herniation can be prevented. The shortest distance between the uppermost point of proc. cochleariformis and tegmen tympani was measured in this study. The mean distance was 5.34 ± 1.85 mm (1.5- 10.3 mm). The minimal value of 1.5 mm, points that careful dissection should be done in this area.

The distance between proc. cochleariformis and the anterior side of the fenestra vestibuli. The ossicular chain of the middle ear may be damaged partially or totally because of chronic otitis media or cholesteatoma. Ossicular chain destruction can be accompanied with chronic otitis media, with or without cholesteatoma, 95 % and 42 % respectively. The long arm of the incus and the suprastructure of the stapes are eroded respectively because of cholesteatoma arising from pars tensa. The stapes floor usually remains intact for a long time (18). If proc. cochleariformis is searched toward to the anterior side of the fenestra vestibuli, it may be easily localized during the tumor surgery. No reported study about the distance between processus cochleariformis and fenestra vestibuli in the literature. The distance between the hindmost portion of proc. cochleariformis and the anterior side of the fenestra vestibuli was measured in this study. The mean distance was 2.35 ± 0.69 mm (1.2-4 mm). This value shows that the distance between the hindmost portion of proc. cochleariformis and the anterior side of the fenestra vestibuli must be taken into account for not to harm patient's hearing during the dissections in this area. Furthermore it can be leading, if proc. cochleariformis is searched 2.35 mm superiorly from the anterior side of the fenestra vestibuli during the decompression and other kind of surgeries.

The distance between the uppermost point of lateral

semicircular canal and tegmen tympani. The most important landmark to find the facial nerve in the mastoid portion is lateral semicircular canal. This structure is an important landmark during the routine mastoid surgery and also varying facial dissections. The second genu of the facial nerve surrounds the inferior part of the lateral semicircular canal. Nevertheless, sometimes it can be hard to recognize the lateral semicircular canal because of cholesteatoma, granulation tissue and tumor. Especially one of them; cholesteatoma tends to be situated on the superior part of the lateral semicircular canal (4, 23). Facial canal is very close to the ampulla of the lateral semicircular canal, the lateral wall of the vestibule and anterior side of the fenestra vestibuli. This distance is usually less than 1 mm (8). The bulging of the ampulla of the lateral semicircular canal and superior semicircular canal blocks the dissection during perigeniculate area decompression (4). This area is also very important in the classic mastoid surgery. Dura injuries may occur during the dissection of the dura face of lateral semicircular canal. Knowing the distance between the uppermost point of lateral semicircular canal and middle fossa dura can prevent lateral semicircular canal damage, cerebrospinal fluid fistula and neural tissue herniation. There is no study in the literature about the distance between the uppermost point of lateral semicircular canal and tegmen tympani. The shortest distance between the uppermost point of lateral semicircular canal and tegmen tympani was measured in this study. This distance was 4.86 ± 1.56 mm (1.25-10.50 mm) on average. Considering the mean value in these data, there is comfortable dissection area between lateral semicircular canal and middle fossa but, it must be taken enough care during the dissection regarding the minimal value of 1.25 mm value also.

The diameter of the tympanic portion of the facial canal. Dimopoulos et al. (5) measured the diameter of the tympanic portion of the facial canal with high resolution computed tomography (HRCT) at the following locations: a) Just behind the geniculate ganglion; b) anterior side of the fenestra vestibuli; c) posterior side of the fenestra vestibuli, and found the values 1.86 ± 0.28 mm (1.40-2.45 mm), 1.30 ± 0.22 mm (0.70-1.81 mm) and 1.56 ± 0.24 mm (1.08-2.16 mm), respectively. Nakashima et al. (14) measured the the diameter of tympanic portion of the facial nerve with HRCT at the following locations: a) Just behind the geniculate ganglion; b) in the middle of

the tympanic portion; c) the shortest level to the second genu and found the values 1.73 mm, 0.92 mm and 1.24 mm, respectively.

In this study the measurements were made just behind the geniculat ganglion, anterior part of the fenestra vestibuli, posterior part of the fenestra vestibuli and the mean values were 1.04 ± 0.20 mm (0.80-1.50 mm), 1.00 ± 0.19 mm (0.70-1.30 mm) and 1.02 ± 0.23 mm (0.50-1.80mm), respectively.

The diameter of the mastoid portion of the facial canal.

Dimopoulos et al. (5) also measured the diameter of the mastoid portion of the facial canal with High Resolution Computed Tomography (HRCT) at the following locations: The inferior side of second genu, the level where the stapes muscle is attached and the superior side of foramen stylomastoideum. They found those values to be 1.81 ± 0.30 mm (1.29-2.84 mm), 1.90 ± 0.28 mm (1.10-2.84 mm) and 3.26 ± 0.62 mm (1.93-4.90 mm), respectively. Nakashima et al. (14) also measured the diameter of the mastoid portion of the facial nerve with HRCT at the superior and inferior side of eminentia pyramidalis and found those values to be 2.83 mm and 2.43 mm respectively. In this study the measurements were made at the following locations: the superior side of eminentia pyramidalis, the inferior side of eminentia pyramidalis and digastric ridge and the values were 1.15 ± 0.21 mm (0.70-1.90 mm), 1.40 ± 0.29 mm (1-2.20 mm), 1.29 ± 0.29 mm (0.75-2.13 mm) on average, respectively.

New for this study, distances between proc. cochleariformis – tegmen tympani, proc. cochleariformis – fenestra vestibuli, lateral semicircular canal–tegmen tympani, with other measurement distances offer additional important knowledge to the physicians interested in mastoid and middle ear anatomy. On regard to the mastoid and middle ear surgeries, it was noticed that facial nerve was the most prone structure to be injured and this situation is very important for the surgeons where an injury of the facial nerve causes additional responsibilities. In this paper, we concluded that the ranges are wide, and the standart deviations are high in the surgical distances of temporal bone. Surgeons should customize the dissection strategy for each temporal bone.

References

1. Green JD Jr, Shelton C, Brackmann DE. Iatrogenic facial nerve injury during otologic surgery. *Laryngoscope* 1994; 104: 922-926.
2. Aslan A, Goktan C, Okumus M, Tarhan S, Unlu H. Morphometric analysis of anatomical relationships of the facial nerve for mastoid surgery. *J Laryngol Otol* 2001; 115: 447-449.
3. Dai P, Zhang T, Wang K, Song J, Qian W, Wang Z. Positional relationship between the facial nerve and other structures of the temporal bone. *J Laryngol Otol* 2004; 118: 106-111.
4. Wetmore SJ. Surgical landmarks for the facial nerve. *Otolaryngol Clin North Am* 1991; 24: 505-530.
5. Dimopoulos PA, Muren C, Smedby O, Wadin K. Anatomical variations of the tympanic and mastoid portions of the facial nerve canal. A radioanatomical investigation. *Acta Radiol Suppl* 1996; 403 49-59.
6. Schaitkin B, May M. Disorders of the facial nerve. Kerr AG, editor. In: *Scott Brown's Otolaryngology*. 6th ed. Vol. 3. Oxford: Butterworth- Heinemann International Editions; 1997. p. 24/1-38.
7. Candan H, Aktaş D, Kanımtürk E. Fasiyal kanal boyutları ve dehisansları. *Türk Otolarengoloji Arşivi* 1985; 23: 44-47.
8. Proctor B. The anatomy of the facial nerve. *Otolaryngol Clin North Am* 1991; 24: 479-504.
9. Kullman GL, Dyck PJ, Cody DT. Anatomy of the mastoid portion of the facial nerve. *Arch Otolaryngol* 1971; 93: 29-33.
10. Muren C, Wilbrand H. The semicircular canals of the inner ear and the pneumatization of the temporal bone. A radioanatomic investigation. *Acta Radiol Diagn (Stockh)* 1986; 27: 325-329.
11. Qiu MG, Zhang SX, Liu ZJ, et al. Plastination and computerized 3D reconstruction of the temporal bone. *Clin Anat* 2003; 16: 300-303.
12. Donaldson JA, Anson BJ. The triple "S" triangle, a topographical guide to the facial nerve in temporal bone surgery. *Ann Otol Rhinol Laryngol* 1965; 74: 59-62.
13. Wong DLH, Chen JM. Surgical anatomy of the epitympanic space. *Am J Otol* 1996; 17: 193-196.
14. Nakashima S, Sando I, Takahashi H, Fujita S. Computer-aided 3-D reconstruction and measurement of the facial canal and facial nerve. I. Cross-sectional area and diameter: preliminary report. *Laryngoscope* 1993; 103: 1150-1156.
15. Jager L, Reiser M. CT and MR findings of the normal and pathologic conditions of the facial nerve. *Eur J Radiol* 2001; 40: 133-146.
16. May M. Anatomy of the facial nerve for the clinician. In: May M, editor, *The Facial Nerve*. New York: Thieme Inc; 1986. 21-62.
17. Akyıldız N. Fasiyal sinir klinik ve cerrahi anatomisi. In: Akyıldız N, editor, *Kulak Hastalıkları ve Mikrocerrahisi*. Ankara: Bilimsel Tıp Kitabevi; 2002. 215-253
18. Tos M. Anatomy. In: Tos M, editor, *Manual of middle ear surgery*. Vol. 2. New York: Georg Thieme Verlag Stuttgart; 1995. 23-49.
19. Çakır N. Boyun ilgili konular. In: Çakır N, editor, *Otolaringoloji, Baş ve Boyun Cerrahisi*. 2. Baskı. İstanbul: Nobel Tıp Kitabevleri; 1999. 393-440.
20. Kaya S, Sennaroglu L. Iatrogenic facial paralysis in middle ear operations. *Türk Otolarengoloji Arşivi*. 1998; 36:74-76.
21. Bento RF, de Brito RV, Sanchez TG. A rapid and safe middle fossa approach to the geniculate ganglion and labyrinthine portion of the facial nerve. *Ear Nose Throat J* 2002; 81: 320-326.
22. Marsh M, Coker N, Jenkins H. Temporal bone neoplasms and lateral cranial base surgery. In: Cummings CW, Frederickson JM, Harker LA, Krause CJ, Richardson MA, Schuller DE, editors. *Otolaryngology Head & Neck Surgery*. St Louis Missouri: Mosby Year Book Inc; 1998. p. 3245-82.
23. Işık A, Muhtar H. Temporal kemiğin cerrahi anatomisi. *Otoskop* 2000; 1:43-47.