The Journal of International Advanced Otology

J Int Adv Otol 2025; 21(5): 1-6 • DOI: 10.5152/iao.2025.241747

Original Article

# Dimensions of Osseous External Auditory Canal in Otosclerosis Using High-Resolution Computed Tomography

**Ayça Başkadem Yılmazer[1], Hamdullah Erk[2], Uğur Uygan[1], Naciye Kış[2], Hasan Sami Bircan[1], Yavuz Uyar[1]**

[1]Department of Otorhinolaryngology, Health Sciences University, Prof. Dr. Cemil Taşçıoğlu Hospital, İstanbul, Türkiye
[2]Department of Radiology, Health Sciences University, Prof. Dr. Cemil Taşçıoğlu Hospital, İstanbul, Türkiye

ORCID IDs of the authors: A.B.Y. 0000-0001-9967-8046, H.E. 0000-0002-1979-7502, U.U. 0000-0001-8893-442X, N.K. 0000-0003-1387-9563, H.S.B. 0000-0002-2918-1947, Y.U. 0000-0001-8732-4208

Cite this article as: Başkadem Yilmazer A, Erk H, Uygan U, Kiş N, Sami Bircan H, Uyar Y. Dimensions of osseous external auditory canal in otosclerosis using high-resolution computed tomography. *J Int Adv Otol.* 2025, 21(5), 1747, doi: 10.5152/iao.2025.241747

**BACKGROUND:** There is a general idea that the external auditory canal (EAC) is wide in patients with otosclerosis. However, as far as we know, there is no objective measurement of the EAC of patients with otosclerosis. In this study, we aimed to measure objectively the dimensions of the osseous EAC (OEAC) in otosclerosis, using high-resolution computed tomography (HRCT).

**METHODS:** High-resolution CT images of cranial bones were obtained from 66 patients with otosclerosis and 48 control individuals using a 256-slice CT scanner with a thickness of 0.67 mm. The dimensions and shape of the OEAC from the end of the cartilaginous portion of the EAC to the annulus of the middle ear were then measured.

**RESULTS:** A total of 228 ears were analyzed using CT images. The osseous external ear canal was most commonly conical in both groups. The width of OEAC was not significantly different in the otosclerosis group. The length of the osseous external ear canal was 6.69 ± 1.49 mm in the control group, and 5.96 ± 1.07 mm in the otosclerosis group. It was significantly shorter in the otosclerosis group ($P = .001$).

**CONCLUSION:** We measured the OEAC in otosclerosis using an objective method. Contrary to what is known, the OEAC tends to be short bilaterally in the ears of patients with otosclerosis, rather than wider.

**KEYWORDS:** Computed tomography, dimensions, external auditory canal, otosclerosis

## INTRODUCTION

The human ear is composed of 3 portions: the external ear, the middle ear, and the inner ear. The external ear consists of the auricula and the external auditory canal (EAC). The EAC connects the auricula with the middle ear and primarily comprises cartilaginous and bony tissues. The cartilaginous portion is located laterally and comprises one-third of the EAC, while the bone surrounds the medial two-thirds of the canal.

The shape and dimensions of the EAC are important for examining the EAC and tympanic membrane, fitting the molds of hearing aids, and performing transcanal ear surgeries. A range of studies has used cadavers and radiologic images to measure the dimensions of the EAC in detail.[1-3] Mahboubi et al[4] (2012) have described a "*mesh*" model with 6 different dimension points to measure the dimensions of the OEAC and compared them between different age groups using high-resolution computed tomography (HRCT). Moreover, in a few studies, disease-related changes in the dimensions and shape of the EAC have also been examined.[5-7]

Otosclerosis is an autosomal dominant disorder marked by pathological enhancement of bone remodeling in the otic capsule, namely aberrant destruction and rebuilding. This may manifest to different extents, from fixing the stapes footplate to bone resorption around the cochlea.[8,9] It can cause conductive or sensorineural hearing loss.[8,10] There is no curative treatment, but stapedotomy

**Corresponding author**: Ayça Başkadem Yılmazer, e-mail: aycabaskadem@hotmail.com
**Received:** September 24, 2024 • **Revision Requested:** October 21, 2024 • **Last Revision Received:** January 12, 2025 • **Accepted:** January 18, 2025 • **Publication Date:** September 8, 2025
Available online at www.advancedotology.org

for palliative treatment or hearing aids for supportive treatment may be suggested to improve hearing. For both treatment choices, the shape and dimensions of the EAC gain importance. After the revision article by Frank Wojniak in 1945, including observational studies, a general idea that the EAC is wide in patients with otosclerosis was established.[11] However, as far as we know, there is no objective measurement of the EAC of patients with otosclerosis. Therefore, we aimed in this study to measure the dimensions of the OEAC in cases of otosclerosis using HRCT.

## METHODS

This investigation was carried out in the department of otorhinolaryngology of Prof. Dr. Cemil Tascioglu Hospital, Health Sciences University, a tertiary referral clinic. Preoperative cranial bone HRCT images were obtained for 66 patients with otosclerosis, with fixation of the footplate of the stapes bone confirmed with a tympanoscope, alongside 48 control patients who underwent septoplasty surgery devoid of ear disease. In the otosclerosis group, only patients unilaterally verified for otosclerosis through both audiological tests and surgery were included. The participants were between 18 and 65 years old. Patients who presented with chronic otitis media (COM), any defect in the EAC, such as exostosis, osteoma, or congenital canal atresia, and any history of otologic surgery or temporal bone trauma were excluded. Moreover, patients who were bilaterally operated on for otosclerosis were excluded.

The present study was designed in accordance with the Helsinki Declaration on ethical principles for medical research. The Local Ethics Committee of Prof. Dr. Cemil Tascioglu Hospital, Health Sciences University approved it with protocol number 383 on November 8, 2021.

All individual participants who were enrolled in the investigation provided informed consent.

### Radiological Evaluation of External Auditory Canal

All the images were acquired with a 256-slice SOMATOM Definition Edge CT scanner (Siemens Medical Solutions, Malvern, PA, USA). The images were displayed on an image archiving and communication system (PACS)® (INFINITT Healthcare, Seoul, South Korea) with a window width of 1600 Hounsfield units and a window center of 400 Hounsfield units. Using the multi-planar reformation software system, the axial, sagittal, and coronal planes were reformed with a thickness of 0.67 mm on an orthogonal plane. The dimension of the rebuilt matrix was 0.2 mm.

Measurements were performed by 2 independent neuroradiologists. If the measurement difference was 1 mm or less, an average of the 2 sizes was accepted; if it was more than 1 mm, a third radiologist verified the measurement.

After assessing these images, the best views of the osseous portion of EAC were selected according to criteria set out by Mahboubi et al.[4] The osseous portion of EAC was identified from the end of the cartilaginous portion of the EAC to the annulus of the middle ear. The first slice where the EAC was closed with bone was marked as the beginning of the OEAC (Figure 1A). The OEAC concludes medially at the annulus of the tympanic cavity through the opening situated at the superior edge of the tympanic cavity called the notch of Rivinus (Figure 1B). The middle of the OEAC was defined as the mid-canal section, as determined by the median slice of the total slices of the canal (if the number of slices was even, 2 middle slices were averaged). The length of the OEAC was calculated using the multiplication of the total number of slices and the thickness of 1 slice (in millimeters) in the CT images.

Elliptical cross-section dimensions of the OEAC were measured using the "mesh" method described by Mahboubi et al.[4] Six distinct dimension points were measured at the beginning, mid-canal, and annulus parts of the OEAC using the mesh method: maxSI represents the maximum superior-inferior height, midAP represents the maximum anterior-posterior width perpendicular to maxSI, midS represents the maximum anterior-posterior width at the midpoint of the superior half of maxSI, midI represents the maximum anterior-posterior width at the midpoint of the inferior half of maxSI, midA represents the maximum superior-inferior height at the midpoint of the anterior half of midAP, and midP represents the maximum superior-inferior height at the midpoint of the inferior half of midAP (Figure 2).

Additionally, the shape of the OEAC was determined according to its maximum superior-inferior diameters (Figure 3). According to the MaxSI diameter at the sections (beginning, mid-canal, and annulus), the shape of the OEAC was classified. If the MaxSI diameter had a decreasing trend from the beginning section to the annulus one, it would have been classified as "conical" (Figure 3A). If it were the largest one in the mid-canal, it would have been classified as "ovoid" (Figure 3B). If it were the smallest one in the mid-canal, it would have been classified as "hourglass" (Figure 3C). If it had an increasing trend from the beginning section to the annulus one, it would have been classified as "reverse conical" (Figure 3D). If there were no change between the 2 sections, it would have been classified as "cylindrical" (Figure 3E).

Mastoid sclerosis was also analyzed in the CT sections. If there wasn't any "pneumatized air cell (low attenuated = dark image on CT)" in the mastoid cavity, it was accepted as "yes" for mastoid sclerosis. If there was any pneumatized air cell in the mastoid cavity (grade 1-4, as described in the study of Virapongse et al, 1985),[12] it was accepted as "no" for mastoid sclerosis.

### Statistical Analysis

The data were assessed using descriptive statistical techniques. The quantitative variables' normal distribution was evaluated using the Shapiro–Wilk test and graphics. In the internal comparison of each group, the paired samples *t*-test was applied for quantitative variables that were normally distributed; in cases where distributions departed from the normal, the Wilcoxon test was applied instead.

### MAIN POINTS

- Computed tomography images were used to examine the dimensions of the osseous external auditory canal (OEAC) in 228 ears of otosclerosis and control patients.
- Unlike the literature, the width of OEAC was not large in otosclerosis patients.
- The length of the OEAC was short in otosclerosis patients ($P = .017$)

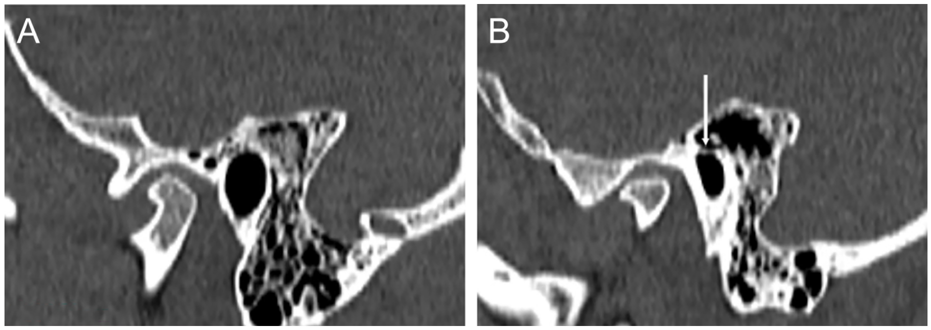


**Figure 1.** A, B. Reconstructed CT slices show that (A) the beginning of the osseous external ear canal, first slice where the external ear canal with bone; (B) ending of the osseous external ear canal, annulus of the tympanic cavity with Rivinus' notch.

Pearson's chi-squared test was used to compare the qualitative variables.

The Student *t*-test was used to compare 2 groups whose quantitative variables were normally distributed; the Mann–Whitney *U* test was applied in cases where the distributions were not normal. Statistical alpha significance was accepted as $P < .05$.

## RESULTS

In this study, a total of 228 ears were analyzed using CT images. The mean age was 38.27 ± 12.20 in the otosclerosis group, and 35.21 ± 9.72 in the control group. The control group consisted of 48 patients (female : male = 26 : 22), while the otosclerosis group contained 66 patients (female:male = 41:25). Descriptive analyses did not reveal any statistically significant differences in gender or age among the two categories ($P = .165$, Mann–Whitney *U* test, and $P = .394$, Pearson's chi-square test, respectively).

About 3.7% of the measurements differed by more than 1 mm between the 2 radiologists, so in those cases, a third radiologist's view was considered.

A conical shape was the most common form of the OEAC in both groups, followed by an hourglass shape. There was no significant difference in the shape of the OEAC between the groups and the bilateral sides of the ears of the groups (Table 1).

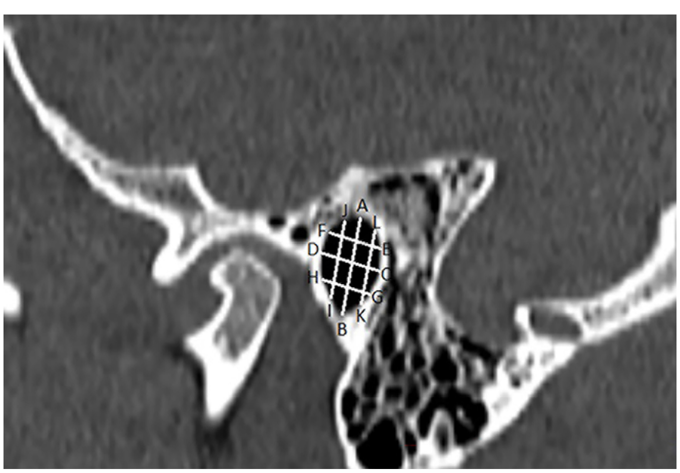


**Figure 2.** Reconstructed CT slice shows the points of the "mesh" technique: AB line for maxSI, CD line for midAP, EF line for midS, GH line for midI, IJ line for midA, KL line for midP.

Each group was also assessed for sclerosis of the mastoid cavity. Mastoid sclerosis was seen in 26.04% of the ears in the control group (n = 96 ears) and 24.24% of the operated ears of the otosclerosis group (n = 66 ears). There was no significant difference between the groups ($P = 0.669$, Table 1).

The length of the OEAC was 6.69 ± 1.49 mm in the control group and 5.96 ± 1.07 mm in the operated ears of the otosclerosis group (Table 1). When comparing the groups, the OEAC length was significantly shorter in both the operated and contralateral ears of the otosclerosis group than in the control group ($P = .001$, $P = .002$, respectively; Student *t*-test).

In both the otosclerosis and control groups, 6 different dimension points at the beginning, mid-canal, and annulus parts of the OEAC were measured. There was no statistical difference in dimensions between OEACs in the operated ears and contralateral ears of the otosclerosis group, or even between both ear sides of the control group. Additionally, there was no statistical difference in dimensions between OEACs of the otosclerosis and control groups (Table 2).

## DISCUSSION

The current study presents the dimensions of the OEAC in patients with otosclerosis using the techniques developed by Mahboubi et al[4] to assess HRCT images. To our knowledge, no study has evaluated the OEAC in otosclerosis using HRCT.

The anatomy of the OEAC has been examined by researchers using different techniques. In some studies, the dimensions of the OEAC in temporal bone specimens from cadavers were measured using both tomography and histology.[1,13] Virapongse et al[1] researched the anatomy of the temporal bone from cadavers and said that the length of the EAC is about 2-3 cm. However, these measurements may be shorter than the sizes in living patients due to the shrinkage of tissue specimens caused by formaldehyde.[14,15] In 1983, Virapongse et al[2] studied the EAC in patients using HRCT at 1.5-2.0 mm thickness and showed that the length of the EAC is about 25 mm and the length of the OEAC is almost 15 mm.

Mahboubi et al[4] (2012) described a novel method using HRCT at 0.6-1 mm slice thickness to measure the OEAC, comparing healthy ears by age and gender. In their study, they grouped patients into the age ranges of 5-8 years, 9-12 years, 13-18 years, and >18 years. In the 5-8-year-old group, the length and the dimensions of the beginning section were different than in other age groups. We also used

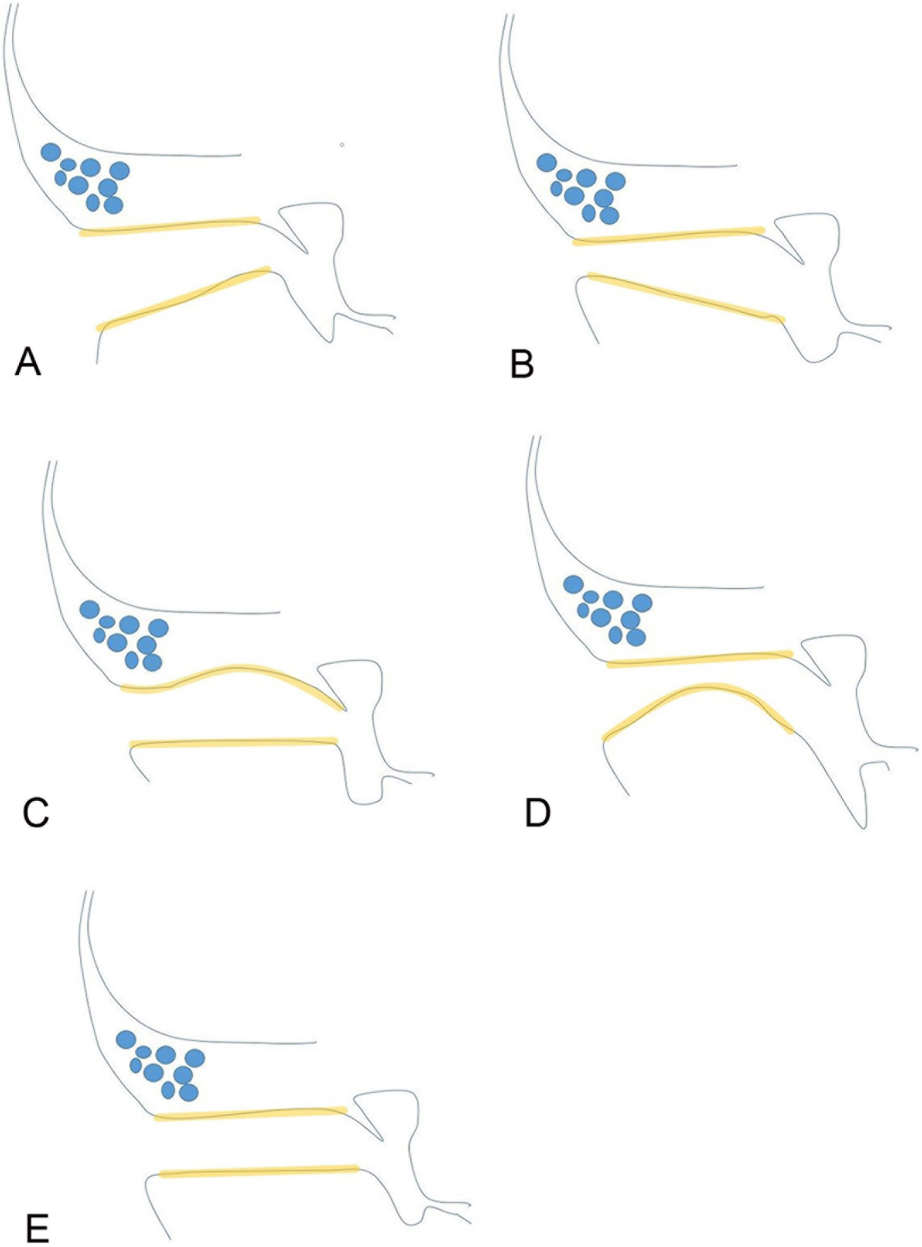


**Figure 3.** The illustration shows the shapes of the osseous external ear canal: (A) conical, (B) reverse conical, (C) ovoid, (D) hourglass, and (E) cylindrical.

**Table 1.** Characteristics of the Ears in the Groups

| | | Control Group (n = 96) | Otosclerosis Group | | *P* | |
|---|---|---|---|---|---|---|
| | | | Operated ears (n = 66) | Contralateral ears (n = 66) | Control/Operated Ears | Control/ Contralateral Ears |
| Length of the OEAC (mm) | | 6.69 ± 1.49 | 5.96 ± 1.07 | 6.04 ± 1.08 | .001* | .002* |
| Shape of the OEAC (%) | Cone | 84.38 | 87.69 | 81.54 | .653** | .539** |
| | Hourglass | 15.62 | 12.31 | 18.46 | | |
| Mastoid sclerosis (%) | Yes | 73.96 | 75.76 | 83.34 | .795** | .158** |
| | No | 26.04 | 24.24 | 16.66 | | |

OEAC, osseous external ear canal.
*Student *t*-test. **Pearson's chi-square test.

**Table 2.** Comparisons of the Dimensions of the OEAC

| Sections | Dimensions | Control Group (Total Ears) (n = 96) Mean ± SD | Otosclerosis Group (Operated Ears) (n = 66) Mean ± SD | P* |
|---|---|---|---|---|
| Beginning | Max-SI | 10.71 ± 1.47 | 10.25 ± 1.44 | .051 |
| | Mid-AP | 6.15 ± 0.95 | 5.9 ± 0.84 | .095** |
| | Mid-S | 5.38 ± 0.87 | 5.33 ± 0.80 | .737 |
| | Mid-I | 4.70 ± 0.95 | 4.79 ± 0.77 | .545 |
| | Mid-A | 8.45 ± 1.25 | 8.17 ± 1.42 | .190 |
| | Mid-P | 8.07 ± 1.14 | 7.77 ± 1.28 | .065** |
| Midcanal | Max-SI | 8.69 ± 1.23 | 8.69 ± 1.30 | .954 |
| | Mid-AP | 5.10 ± 0.93 | 4.96 ± 0.79 | .326 |
| | Mid-S | 4.56 ± 0.87 | 4.51 ± 0.81 | .742 |
| | Mid-I | 4.09 ± 0.77 | 4.04 ± 0.64 | .640 |
| | Mid-A | 7.37 ± 1.16 | 7.25 ±1.19 | .509 |
| | Mid-P | 6.73 ± 0.95 | 6.79 ± 1.15 | .989 |
| Annulus | Max-SI | 8.01 ± 0.89 | 8.15 ± 1.03 | .336 |
| | Mid-AP | 4.52 ± 0.91 | 4.58 ± 0.77 | .631 |
| | Mid-S | 3.64 ± 0.75 | 3.76 ± 0.66 | .216 |
| | Mid-I | 3.89 ± 0.78 | 4.01 ± 0.58 | .274 |
| | Mid-A | 6.94 ± 0.92 | 6.99 ± 0.98 | .680 |
| | Mid-P | 6.10 ± 0.72 | 6.01 ± 0.85 | .461 |

SD: standard deviation.
*Student *t*-test. **Mann–Whitney *U* test.

the technique of Mahboubi et al[4] to measure the sizes of the OEAC using HRCT at 0.67 mm slice thickness. In our study, the age of the groups was between 18 and 65 years old; there were no significant differences by age or gender.

In the study by Mahboubi et al,[4] the dimensions of the OEAC of 120 healthy ears were measured using HRCT. They reported that the length of the OEAC was 9.8 ± 3.4 mm (mean ± SD; range, 4.0-17.4 mm) in the ears of patients older than 18 years (n = 62 ears). The range was 18-85 years. In our study, the mean value of the length of the OEAC in 96 healthy ears was 6.69 ± 1.49 mm (mean ± SD; range, 4.6-10.8 mm). The age range in the present study was 18-65 years. Although we used a similar technique, the lengths of the OEAC in our study differ considerably from those in the study by Mahboubi et al.[4] This discrepancy may be because of differences in the age, gender, or race of the samples. Since there are few studies in the literature about the length of the OEAC, the average size of the OEAC is still unclear. For example, Lee et al[5] also used Mahboubi's method in their study, but they didn't measure the length of the OEAC. More studies should be conducted to average the sizes of the OEAC.

There are some studies on measuring the EAC in different otologic diseases. Kimberley and Fromovich[16] (1999) declared that the EAC is narrow and should be drilled for canaloplasty in COM patients. In another study, the relationship between COM and the dimensions of the OEAC was explored using the technique adopted by Mahboubi et al[4] for HRCT images. They reported that there was no relationship between COM and the dimensions of EAC.[5] Van Spronsen et al[6] have studied the relationship between the shape of the OEAC and chronic external otitis but did not measure the dimensions of the EAC. As an alternative technique to radiology, Dy and Lapena[7] measured the diameter of the EAC in patients with Down syndrome using variable diameters of ear speculum.

In our study, we measured the dimensions of the OEAC in patients with otosclerosis. There are a few early studies that mention aspects of the EAC in cases of otosclerosis, which were summarized in a review by Frank Wojniak[11] in 1945. In that review, he also included his observations of 100 patients with otosclerosis. He noted that in terms of the EAC, the auditory meatus was wide, straight, dry, shiny, and wax-free, and the cartilaginous canal was narrow in children.

As far as we know, there is no existing study on the dimensions of the OEAC in otosclerosis patients using HRCT. We analyzed the images of patients who had been diagnosed with otosclerosis after a fixed footplate was seen in stapedotomy surgery. We measured the dimensions of the OEAC. Although there was no difference in the width and shape of the OEAC, its length was shorter in both ears of patients with otosclerosis. Since it was seen in both ears of the patients with otosclerosis, this may be a genetically obtained anatomical variation in otosclerosis.

In 1980, Eckerdal et al[17] studied cadaveric temporal bones and organized the OEAC into 3 types based on shape, in the following order of incidence: conical, hourglass-shaped, and ovoid-shaped. Mahboubi et al[4] similarly categorized the shape of the OEAC into 5 groups using the maximum superior and inferior diameter (MaxSI): conical, ovoid, hourglass, reverse conical, and cylindrical. They showed that 64% of the patients had a conical OEAC. Lee et al[5] also studied the shape of the OEAC in patients with COM using the technique of Mahboubi et al[4] They declared that the most common type of OEAC shape was cylindrical, which accounted for about 36% of their COM group. In our study, the shape of the OEAC in otosclerosis and control groups was either conical or hourglass-shaped, in that order of frequency. There was no change according to the pathology.

Mahboubi et al[4] also analyzed participants for sclerosis of the mastoid cavity, as this often presents in cases of COM, which may narrow the EAC.[16] They reported that 33% of ears had mastoid sclerosis.[4] In our study, 26.04% of the healthy ears had mastoid sclerosis. Similarly, 23.08% of the operated ears of the otosclerosis group had mastoid sclerosis, and there was no difference with the control group.

Our study had some limitations. The most significant limitation was the limited number of subjects in the study. Additionally, although there were no extremely tilted canals in our study, in addition to Mahboubi's method to measure the length of the OEAC, we could measure not only linear lengths but also parabolic lengths with tilted canals. However, our software had no suitable format for measuring tilted canals. Another limitation was that only a few studies were available to compare the results for otosclerosis. Moreover, we could measure only the bony portion of the OEAC without the skin layer.

## CONCLUSION

In conclusion, using an objective method, we measured the OEAC. The length of the OEAC in healthy ears is approximately 6.7 mm. Contrary to what is known, the OEAC tends to be short bilaterally in the ears of patients with otosclerosis, rather than wider. The exact width of the canal is needed to perform any manipulation through the canal in different ear diseases, so skin thickness should also be measured histologically and radiologically.

**Availability of Data and Materials:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Ethics Committee Approval:** This study was approved by the Ethics Committee of Prof. Dr. Cemil Taiçıoğlu Hospital, Health Sciences University (approval no.: 383; date: November 08, 2021).

**Informed Consent:** Written informed consent was obtained from the patient(s) who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – A.B.Y.; Design – A.B.Y.; Supervision – Y.U.; Materials – U.U., H.S.B.; Data Collection and/or Processing – H.E., N.K.; Analysis and/or Interpretation – H.E., N.K.; Literature Search – U.U., H.S.B.; Writing – A.B.Y.; Critical Review – Y.U.

**Declaration of Interests:** The authors have no conflicts of interest to declare.

**Funding:** The authors declared that this study received no financial support.

## REFERENCES


1. Virapongse C, Rothman SL, Kier EL, Sarwar M. Computed tomographic anatomy of the temporal bone. *AJR Am J Roentgenol*. 1982;139(4):739-749. [CrossRef]
2. Virapongse C, Sarwar M, Sasaki C, Kier EL. High resolution computed tomography of the osseous external auditory canal: 1. Normal anatomy. *J Comput Assist Tomogr*. 1983;7(3):486-492. [CrossRef]
3. Smelt G, Hawke M, Proops D. Anatomy of the external ear canal: a new technique for making impressions. *J Otolaryngol*. 1988; 17(5):249-253.
4. Mahboubi H, Wu EC, Jahanbakhshi R, et al. A novel method to determine standardized anatomic dimensions of the osseous external auditory canal. *Otol Neurotol*. 2012;33(5):715-720. [CrossRef]
5. Lee YF, Wei PY, Chu CH, Liao WH, Shiao AS, Wang MC. A retrospective study to identify the relationship between the dimension of osseous external auditory canal and chronic otitis media. *Ear Nose Throat J*. 2020;99(8):532-536. [CrossRef]
6. van Spronsen E, Geerse S, Mirck PG, van der Baan S, Fokkens WJ, Ebbens FA. The shape of the osseous external auditory canal and its relationship to chronic external otitis. *Otol Neurotol*. 2014;35(10):1790-1796. [CrossRef]
7. Dy AES, Lapeña JFF Jr. External auditory canal dimensions, age, and cerumen retention or impaction in persons with Down syndrome. *Ann Otol Rhinol Laryngol*. 2018;127(4):253-257. [CrossRef]
8. Chole RA, McKenna M. Pathophysiology of otosclerosis. *Otol Neurotol*. 2001;22(2):249-257. [CrossRef]
9. Parahy C, Linthicum FH Jr. Otosclerosis and otospongiosis: clinical and histological comparisons. *Laryngoscope*. 1984;94(4):508-512. [CrossRef]
10. Swartz JD, Faerber EN, Wolfson RJ, Marlowe FI. Fenestral otosclerosis: significance of preoperative CT evaluation. *Radiology*. 1984;151(3):703-707. [CrossRef]
11. Wojniak F. The external ear and drum membrane in otosclerosis. *Ann Otol Rhinol Laryngol*. 1946;55:406-422. [CrossRef]
12. Virapongse C, Sarwar M, Bhimani S, Sasaki C, Shapiro R. Computed tomography of temporal bone pneumatization: 1. Normal pattern and morphology. *AJR Am J Roentgenol*. 1985;145(3):473-481. [CrossRef]
13. Eckerdal O, Ahlqvist J, Alehagen U, Wing K. Length dimensions and morphologic variations of the external bony auditory canal. A radiographic and histologic investigation. *Dentomaxillofac Radiol*. 1978;7(1):43-50. [CrossRef]
14. Buytaert J, Goyens J, De Greef D, Aerts P, Dirckx J. Volume shrinkage of bone, brain and muscle tissue in sample preparation for micro-CT and light sheet fluorescence microscopy (LSFM). *Microsc Microanal*. 2014;20(4):1208-1217. [CrossRef]
15. Lane J, Rális ZA. Changes in dimensions of large cancellous bone specimens during histological preparation as measured on slabs from human femoral heads. *Calcif Tissue Int*. 1983;35(1):1-4. [CrossRef]
16. Kimberley BP, Fromovich O. Flexible approach to tympanomastoidectomy. *Otolaryngol Clin North Am*. 1999;32(3):585-595. [CrossRef]
17. Eckerdal O, Ahlqvist J. External bony auditory canal and the tympanic bone. Morphologic properties and influences on the tomographic reproduction. *Acta Radiol Diagn (Stockh)*. 1980;21(3):425-431. [CrossRef]