



Original Article

# Correlation between the Size, CT Density of Otosclerotic Foci, and Audiological Tests in Cases of Otosclerosis

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**OBJECTIVE:** To evaluate the relation between the Computed tomography (CT) densities, sizes of otosclerotic foci, and the bone conduction threshold (BC) and air bone gap (ABG) in cases of otosclerosis as well as between the lesions sizes and their CT densities.

**MATERIALS and METHODS:** We included CT examinations of the temporal bones of 25 patients (34 ears, 9 cases were bilateral) with clinical and audiological diagnosis of otosclerosis. We measured the otosclerotic foci in their maximum dimensions as well as their CT densities and correlated them to the BC thresholds and ABG. We also studied the correlation between the sizes of the otosclerotic foci and their CT densities.

**RESULTS:** There were no significant statistical correlations between the lesion size or CT density to either the BC or ABG in any of the CT grades of otosclerosis or any statistical correlation between the CT density and lesion size in any of the grades of otosclerosis.

**CONCLUSION:** CT is essential, in addition to clinical and audiological tests, in confirming the diagnosis of otosclerosis; however, neither the sizes of the lesions nor their CT densities correlate with the hearing deficit. The lesions sizes do not correlate to their CT densities, and there is no statistically significant difference in CT densities of early and extensive grades.

**KEY WORDS:** Otosclerosis, CT temporal bone, CT density, bone conduction threshold, air bone gap

## INTRODUCTION

Otosclerosis is a bony dyscrasia of the inner ear otic capsule presenting only in humans <sup>[1]</sup>. It is most common in the fissula ante fenestram (FAF) just anterior to the oval window. If the disease extends into the annular ligamentum of the oval window, it results in stapes fixation and conductive hearing loss. If the disease extends into the endosteal layer of the cochlea, sensorineural hearing loss will be included in the symptoms. The disease may also manifest as cochlear otosclerosis by developing as sensorineural hearing loss alone <sup>[2]</sup>. Otosclerosis is a bilateral disease in approximately 80% of cases <sup>[3]</sup>.

Although the diagnosis of otosclerosis is based generally on the clinical history, physical examination, and audiological findings, it is more difficult to diagnose advanced otosclerosis or cochlear otosclerosis. Otosclerosis manifests mostly as conductive hearing loss (CHL) when the otosclerotic foci extend into the footplate of the stapes and involve the annular ligamentum in the fissula ante fenestram just anterior to the oval window. The disease sometimes involves only the cochlear endosteum and can manifest with sensorineural hearing loss (SNHL). This condition is called cochlear otosclerosis and accounts for 1% of patients with otosclerosis <sup>[4]</sup>.

Treatment options for otosclerosis include medical treatment, hearing aids, and surgical management. Medical treatment is useful in the early active stage of the disease, while hearing aids tend to be indicated when patients reject surgery. The surgical treatment of otosclerosis is the most commonly used and most effective treatment and includes stapedectomy, stapedotomy, and laser-assisted stapedotomy <sup>[5]</sup>.

Computed tomography (CT) has been reported to be useful for the diagnosis of otosclerosis <sup>[6]</sup>. CT images play an important role in assessing the extent of the lesion in otosclerosis and the severity of destructive and sclerotic foci <sup>[6]</sup>. CT images show overgrowth of abnormally hypoattenuating bone in the region of the fissula ante fenestram in the fenestral type and show a hypoattenuating halo around the cochlea in the retrofenestral type <sup>[7]</sup>.

Several CT grading systems have been developed recently. Symons and Fanning <sup>[8]</sup> have recently published a CT grading system for otosclerosis: grade 1, solely fenestral, either spongiotic or sclerotic lesions, evident as a thickened stapes footplate, and/or decalcified, narrowed or enlarged round or oval windows; grade 2, patchy localized cochlear disease (with or without fenestral involvement) to either the basal cochlear turn (Grade 2a) or the middle/apical turns (Grade 2b) or both the basal turn and the middle/apical

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turns (Grade 2c); and grade 3, diffuse confluent cochlear involvement of the otic capsule (with or without fenestral involvement). Grade 3 is differentiated from grade 2c by the diffuse confluent involvement in grade 3 of the entire cochlea, whereas grade 2c has patchy focal involvement of the entire cochlea.

The aim of our study is to detect the correlation between the sizes and densities of otosclerotic foci and the audiological studies of the patients as well as between the sizes of the lesions and their CT densities.

## MATERIALS AND METHODS

### Patients

This study was performed between September 2012 and November 2013 in Misr Radiology Center, Cairo, Egypt. Twenty-five patients (34 ears) were involved who were clinically diagnosed as otosclerosis, based on clinical history and audiological studies, and progressive hearing loss was the most common presenting symptom; 16 patients had CHL, and 9 patients had MHL (mixed hearing loss), while pure SNHL patients were excluded. All patients had normal tympanic membranes on examination. Patients underwent MSCT temporal bones as requested by the otorhinolaryngology consultants to exclude other pathological causes for hearing loss. Clinical, audiological, and radiological data were collected.

### Audiological Evaluation

Audiometric findings from both ears of study group patients were obtained from clinical data provided by the clinician. Each patient's threshold for air conduction (AC), bone conduction (BC), and air bone gap (ABG) were determined, and their means were calculated.

### Radiological Evaluation

Computed tomography (CT) examinations of the petrous bone were performed on a 128-section CT scanner (Phillips Ingenuity PET/CT Scanner, Netherlands) with 0.32-mm section thickness. Scan conditions were 140 kV, 300 mAs, and 1 s/rotation in helical mode. All studies were performed without contrast and included the entire petrous bone.

In the axial images, we identified the footplate of the stapes and hence the FAF. Otosclerotic lesions were interpreted by their appearance (hypodensity in the region of the FAF, hypodense halo surrounding the

cochlea or thickening in the footplate of stapes), and they were measured for their maximum dimensions in millimeters; lesions were also graded according to the Symons and Fanning<sup>[8]</sup> grading system for CT. The staging is presented in. Isolated cochlear otosclerosis was excluded. Any other pathology in the temporal bones was reported. Densitometric measurements of otosclerotic foci at the FAF were measured for each patient and displayed as mean Hounsfield unit (HU).

### Statistical Analysis

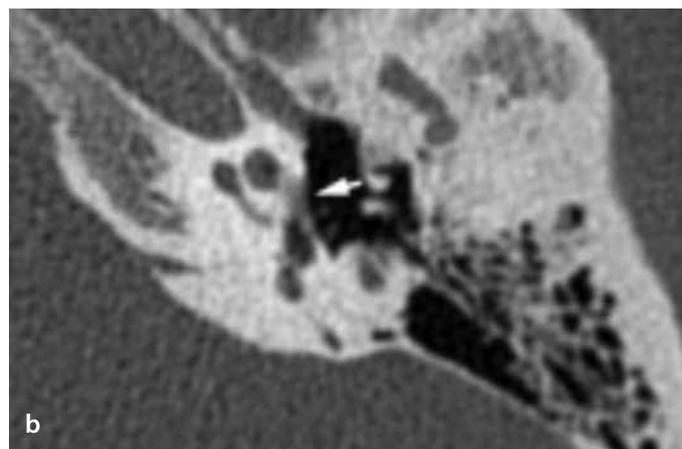
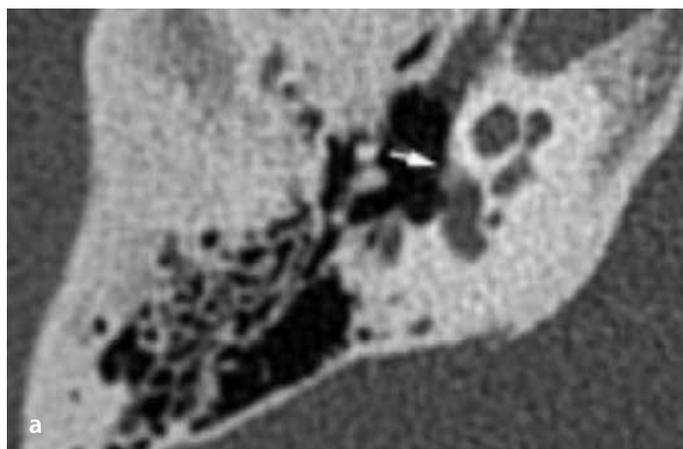
The linear regression relationships between the size of otosclerotic foci in millimeters in each CT grade and hearing thresholds BC and ABG was determined. Also, the relationship between the densities of lesions in each CT grade and the corresponding hearing thresholds were studied. The association between the lesion size to lesion density was also detected, and the difference between the CT densities of lesions of different CT grades was determined. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) 20.0 program. Pairwise Pearson correlation coefficient *p* values of <0.05 were considered to be statistically significant.

## RESULTS

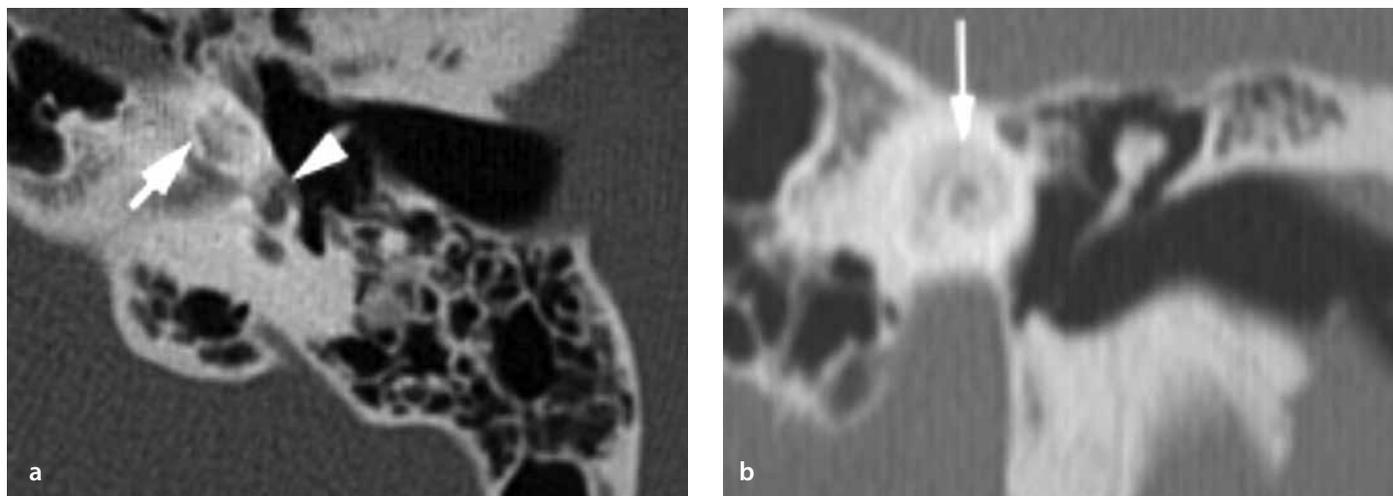
Our study included 25 patients (34 temporal bone; 9 patients had bilateral otosclerosis): 14 females (56%) and 11 males (44%); their mean age was 39.4 years, ranging from 17 to 51 years. Audiometric tests revealed decreased hearing in all affected ears; the means of BC and ABG of our 25 patients (34 ears) according to the CT grading are tabulated in Table 1.

Interpretation of CT temporal bones of our patients showed otosclerotic foci grade 1 in 17 ears, grade 2 in 9 ears, and grade 3 in 8 ears. CT appearance of otosclerotic lesions is shown in Figures 1 and 2. The mean values of otosclerotic lesion sizes in millimeters and their CT densities in HU according to the CT grading are shown in Table 1.

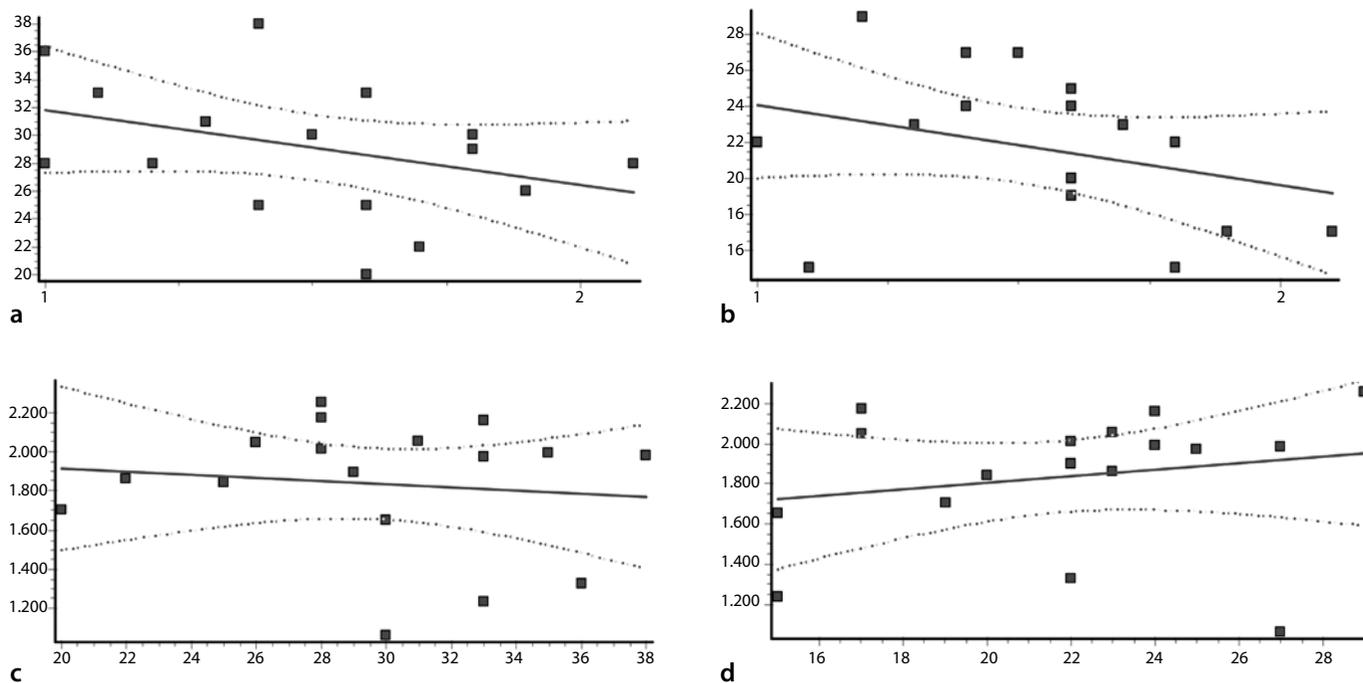
Statistical results and linear regression correlations performed in our study are plotted in Figures 3-6. Statistical analysis revealed that there was no statistically significant difference between the sizes of otosclerotic foci in CT-whatever their CT grading-and the hearing thresholds BC and ABG. Also, it was found that there was no statistically significant difference between the CT density of otosclerotic foci of each CT grade and the hearing thresholds BC and ABG. Lastly,



**Figure 1. a, b.** Twenty-seven-year-old case of bilateral otosclerosis. CT temporal bones revealed: Grade 1 otosclerosis on the right side, a hypodense focus is seen in the FAF region (arrow) measuring 1.2 mm and with CT density of 2254 HU (a); grade 2 otosclerosis on the left side with a hypodense focus seen in the FAF (arrow) and extending to abut the cochlear endosteum, measuring 1.7 mm and with CT density of 1986 HU (b)



**Figure 2. a, b.** Thirty-nine-year-old case of left sided otosclerosis. a) CT temporal bones revealed grade 3 otosclerosis of the left ear with FAF focus (arrow head) measuring 2.4 mm and diffuse cochlear involvement (arrow) with CT density of 1846 HU (a); coronal view confirming the diffuse cochlear involvement (arrow) (b)



**Figure 3. a-d.** Linear regression correlation charts of CT grade 1 otosclerotic lesions between: size of lesion and BC,  $p = 0.1544$  (a); size of lesion and ABG,  $p=0.1864$  (b); CT density and BC,  $p=0.6668$ ; and (c) CT density and ABG,  $p=0.4387$  (d)

**Table 1.** The mean values of otosclerotic lesions sizes, CT densities, BC, and ABG of our patients in respect to the CT severity of otosclerosis

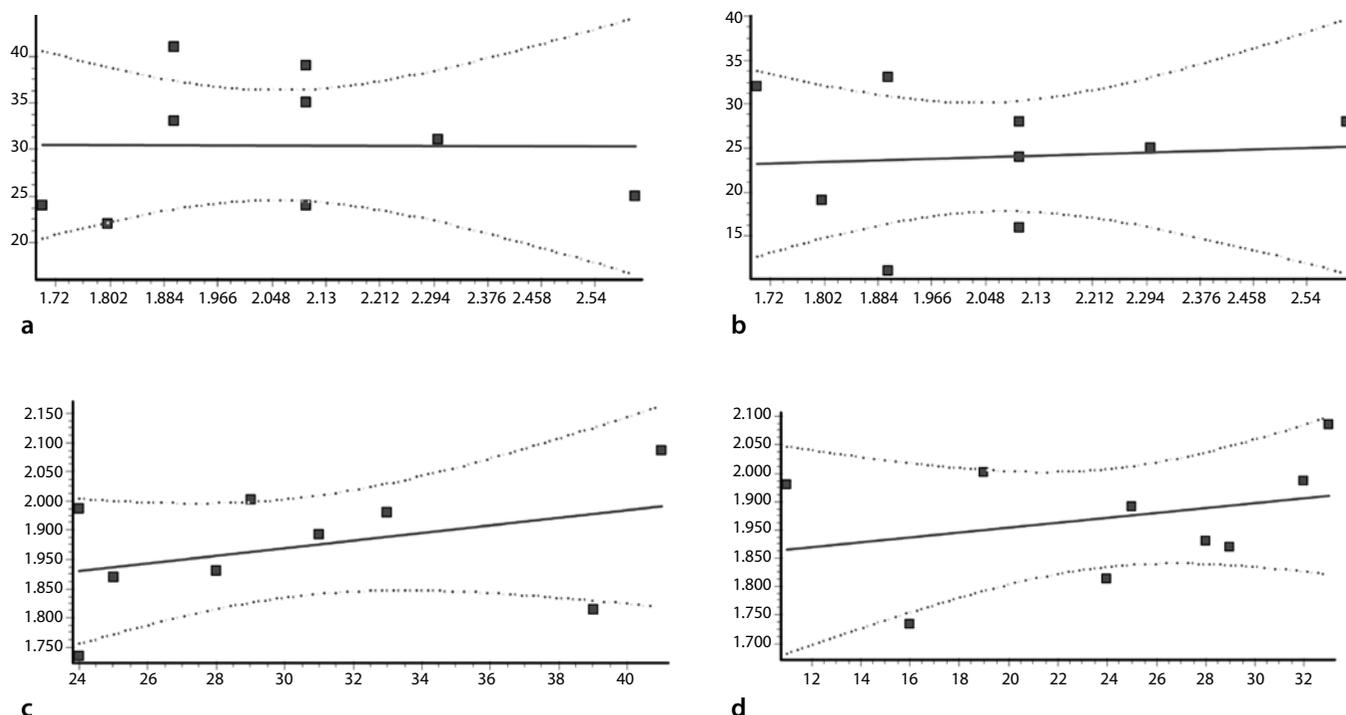
	Grade 1 (17 ears)	Grade 2 (9 ears)	Grade 3 (8 ears)
Size mean value (mm)	1.53±0.28	2.05±0.27	2.53±0.23
Density mean value (HU)	1895.82±278.33	1921.44±107.44	1775.62±219.57
BC mean value (dB)	29.70±4.80	30.44±7.03	28.12±1.95
ABG mean value (dB)	21.82±4.17	24.00±7.38	32.00±7.70

CT: computed tomography; BC: bone conduction; ABG: air bone gap

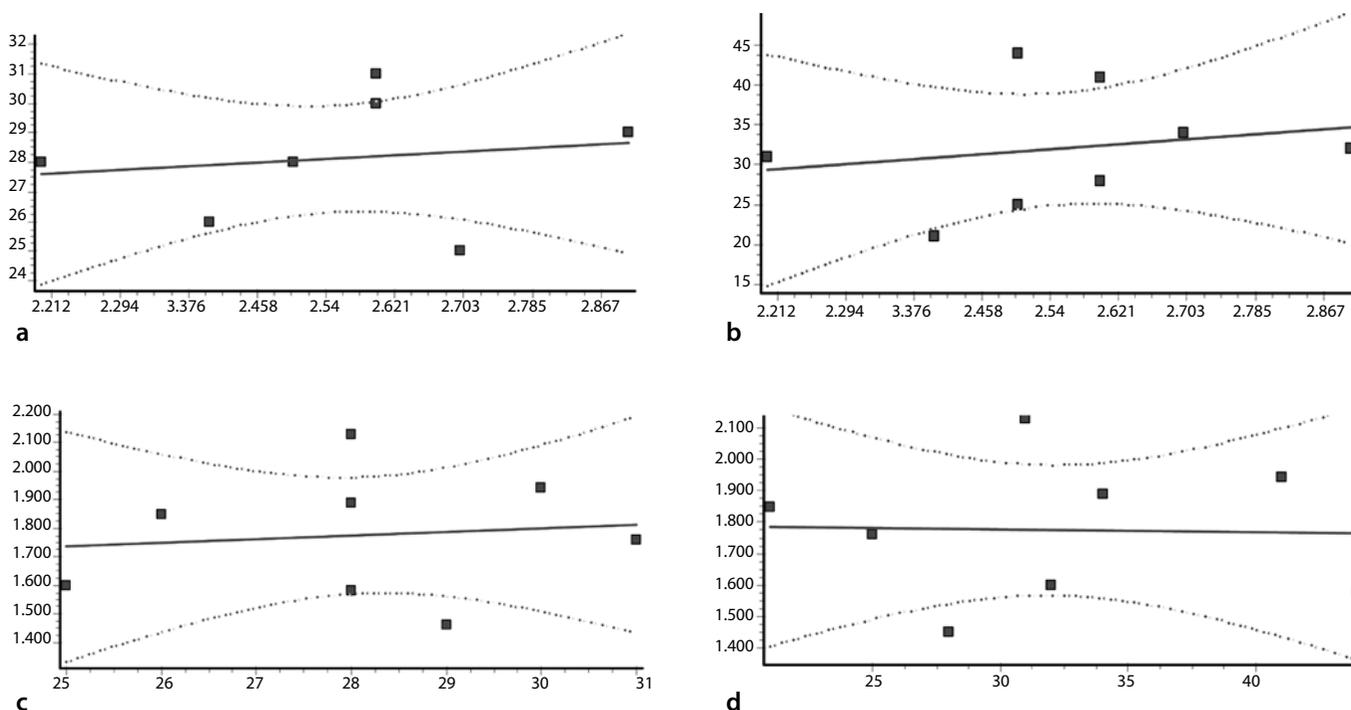
no statistically significant difference was found between the sizes of the lesions and their CT densities or between the CT densities of lesions among the different CT grades.

**DISCUSSION**

Previous literature showed controversial results regarding the correlation between the size or extent of otosclerotic foci and the degree of hearing loss. Schuknecht and Barber [9] and Min et al. [10] did not observe any association between hearing levels and the size of the lesion. De Groot et al. [11] examined 42 patients (84 ears) with surgically confirmed otosclerosis by CT; normal bone conduction did not exclude extensive labyrinthine otospongiosis. In cases with defective bone conduction, the bony labyrinth was normal in half of the ears. In the other half, areas of bone resorption were present.



**Figure 4. a-d.** Linear regression correlation charts of CT grade 2 otosclerotic lesions between: size of lesion and BC,  $p=0.9839$  (a); size of lesion and ABG,  $p=0.8374$  (b); CT density and BC,  $p=0.3147$ ; and (c) CT density and ABG,  $p=0.4289$  (d)

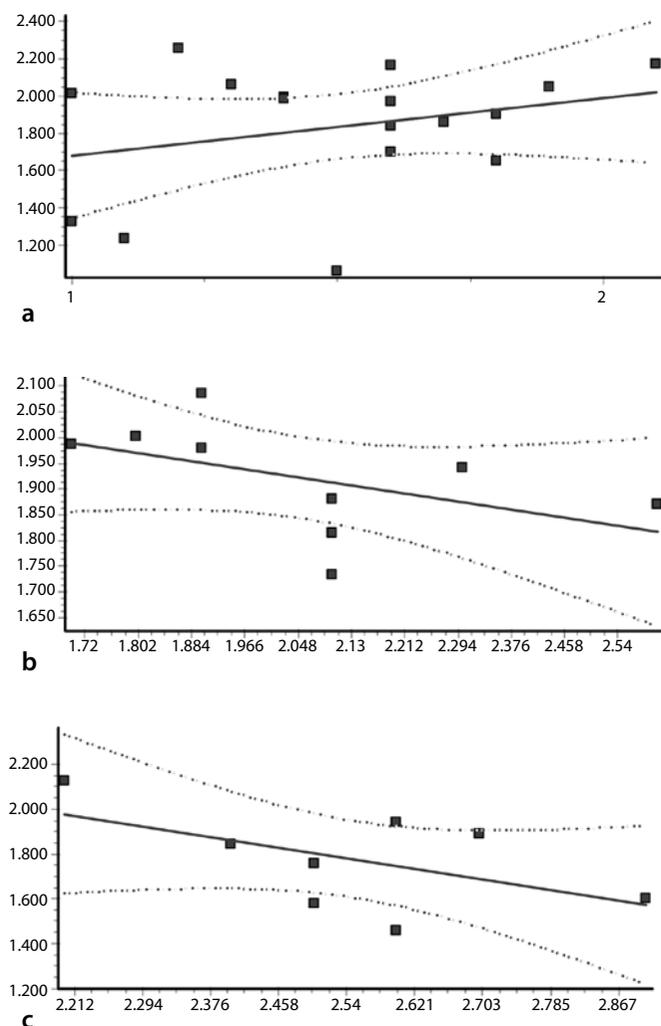


**Figure 5. a-d.** Linear regression correlation charts in grade 3 otosclerotic lesions. Size of lesion and BC,  $p = 0.7078$  (a). Size of lesion and ABG,  $p=0.6247$  (b). CT density and BC,  $p=0.7832$  (c). CT density and ABG,  $p=0.9461$  (d)

Vartiainen and Saari [12], by comparing the CT scans and audiograms of 40 patients, concluded that CT examination is of little value in predicting SNHL in patients with otosclerosis.

In contrast, Parahy and Linthicum [13] and Goycoolea [14] put in evidence an association between cochlear endosteal involvement and

elevated BC thresholds. Shin et al. [15] showed that BC thresholds were poorer in patients with endosteal involvement compared with BC in patients with fenestral otosclerosis. Kiyomizu et al. [16] stated that greater BC levels were associated with a greater extent of demineralization. Hueb et al. [3] showed a positive correlation between the size of the lesions, the activity, and the degree of cochlear endosteal



**Figure 6.** a-c. Linear regression correlation charts between CT densities and lesions sizes in the three CT grades of otosclerosis (subfigures a, b, and c correspond to CT grades 1, 2, and 3 with  $p=0.2643$ ,  $0.1781$ , and  $0.1584$ , respectively)

involvement when compared to BC thresholds. Naumann et al. [17] stated that there was a significant correlation between the size of the fenestral otosclerotic focus and the air-bone gap but no correlation between the extent of cochlear involvement and the bone or air conduction levels. AC and BC thresholds were worse in cases of extensive otosclerotic foci, as declared by Marx et al. [18]. Kultar et al. [19] concluded that there was no significant relationship between early stage (fenestral, focal) and hearing thresholds, but there was a significant relationship in advanced (diffuse) stage. In our study, we were unable to find any significant relationship between the size of otosclerotic lesions in any of the CT grades and hearing thresholds (BC and ABG).

We chose to measure the CT density of otosclerotic lesions at the FAF region, as it is the most commonly affected area in otosclerosis [20] and because lower density in this region often appears in otosclerosis [19,21].

Our study showed that the CT density of otosclerotic lesions in any of the CT grades did not correlate to the hearing thresholds (BC and ABG). This result does not agree with Kawase et al. [22], who found a significant correlation between the density in the area anterior to the oval window and hearing thresholds (both AC and BC).

To our knowledge, we did not find any study correlating the size of otosclerotic foci to their CT densities or correlating the densities of early-grade lesions to the densities of extensive lesions. In our study, we found no significant correlation between the size of otosclerotic lesions and their CT densities; also, no significant difference was found between CT densities of early and extensive lesions.

In conclusion, CT is essential for diagnosing and determining the extent of otosclerosis; however, the size, extent, and CT density of lesions do not correlate to the hearing thresholds. Therefore, it cannot predict the degree of hearing loss, which can only be evaluated by audiometric tests. Also, we deduced that the sizes of the lesions do not correlate to the CT density, and there was no significant difference between the CT densities of early-grade lesions to extensive lesions.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of department of Radiodiagnosis, Ain Shams University Faculty of Medicine.

**Informed Consent:** Written informed consents were obtained from the patients who participated in this study.

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

**Author Contributions:** Concept - S.M.B.; Design - A.F.A.G.; Supervision - N.M.O.; Materials - A.F.A.G., N.M.O., S.M.B.; Data Collection and/or Processing - N.M.O.; Analysis and/or Interpretation - A.F.A.G.; Literature Review - S.M.B.; Writing - N.M.O.; Critical Review - A.F.A.G.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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