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Histopathology of the Incudomalleolar Joint in Cases of ‘Indeterminate’ Presbycusis

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Abstract

Age-related hearing loss (presbycusis) is a prevalent condition attributed primarily to inner ear dysfunction. Little is known about age-related changes in the ossicular joints or their contribution to presbycusis. Herein, we performed a histopathologic analysis of the incudomalleolar joint (IMJ) in specimens from the National Temporal Bone Registry with audiometrically confirmed presbycusis but without histologically observed sensory, neural, strial or mixed features. Twenty-two ‘indeterminate’ presbycusis (IP) cases and thirteen young, normal hearing ears were examined. The age for the IP group was 76.3 ± 10.9 and 32.1 ± 9.5 for the young group ($p < 0.05$). The joint space between the two ossicles was 22% wider in the IP group ($138 \pm 58.0 \mu\text{m}$) compared to young ears ($113 \pm 49.0 \mu\text{m}$) ($p < 0.05$). We report that IP ears have a wider IMJ than young ears. Findings have implications for understanding a potential source of presbycusis in indeterminate cases.

Keywords

otopathology; presbycusis; indeterminate presbycusis; cochlear conductive presbycusis; incudomalleolar joint

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INTRODUCTION

Age-related high frequency hearing loss (presbycusis) is a near universally experienced condition that affects around two thirds of individuals older than 70 in the United States and has been shown to increase the risk of social isolation and cognitive decline.^{1,2} Despite its prevalence, the precise etiology of presbycusis remains unclear. There are thought to be four causes of presbycusis (sensory, neural, strial, and indeterminate). While sensory, neural, and strial causes of presbycusis have audiometric and histopathologic correlates, indeterminate presbycusis (IP) lacks a distinct pathologic cause.³⁻⁷

Anecdotal as well as histopathologic evidence suggest that the effects of aging may localize to the ossicular chain and more specifically the incudomalleolar (IMJ) and incudostapedial (ISJ) joint spaces.^{8,9} Additionally, functional and audiometric evidence indicates that aging may increase compliance of the ossicular chain which can result in high-frequency conductive hearing losses.^{10,11} During life, high frequency conductive hearing loss may not be audiometrically identified due to limitations in bone conduction measures above 4kHz.

We hypothesize that ‘indeterminate’ presbycusis could be the result of an increased width of the IMJ. Herein, we conduct a quantitative histopathologic analysis of the IMJ in patients with previously labeled ‘indeterminate’ presbycusis and compare measures to young, normal hearing ears.

MATERIALS AND METHODS

All temporal bone specimens included in this study are a part of the National Temporal Bone Bank and were available for review at the Massachusetts Eye and Ear Infirmary. Methods for preparation and analysis have been described.¹² The original sections were examined microscopically by otopathologists and the histologic and histopathologic features were recorded. Cases were included for analysis if there was audiometrically documented presbycusis without clear histopathological evidence of sensory, neural, strial, or mixed features. Cases were excluded if there was any history of otologic disease, ear surgery, head trauma, exposure to excessive noise or ototoxic medications (Figure 1A). Inclusion criteria for controls were age < 45 with air conduction < 30 dB at 2kHz, 4kHz, 6kHz and 8 kHz. 12 previously described ‘indeterminate’ presbycusis patients (22 ears) were identified and compared with 9 young, normal hearing subjects (13 ears). The protocol was approved by the human subjects committee of the institutional review board at Mass Eye and Ear. Protocol # 2019P003272.

All images were obtained at 5x magnification and measurements were made in ImageJ (<http://rsbweb.nih.gov/ij/>). We adopted a method developed by Fausch and Rösli to capture 24 unique parameters (Figure 1B) on a single temporal bone section.¹³ The section with the longest distance between the synovial membranes resting on the lateral ligaments of the joint capsule (Longline) was selected (Figure 1C). The IMJ was subsequently quartered to visualize three equidistant positions (one central, two peripheral) at which eight measurements of the IMJ could be made (Figure 1D).

All statistical analysis was performed using GraphPad Prism 8.0 (San Diego, California).

RESULTS

Patient demographics for both groups are shown in Table 1. Twenty-four width measurements were performed, analyzed, and statistically compared between the 2 groups. Example IMJ sections are shown for ‘indeterminate’ presbycotic patients (Figure 2A) and young ears (Figure 2B). The distance between the cartilaginous surfaces (discus) of each ossicle was found to be wider ($25.0 \pm 10.6 \mu\text{m}$ [SEM]) in the ‘indeterminate’ presbycotic patients ($138 \pm 58.0 \mu\text{m}$) when compared to young ears ($113 \pm 49.0 \mu\text{m}$) ($p < 0.05$) (Figure 2C). When this distance was compared according to its relative location along the IMJ, ‘indeterminate’ presbycotic ears were on average $34\mu\text{m}$ or 21% wider at the center ($p=0.007$) and $20\mu\text{m}$ or 22% wider at the periphery ($p=0.052$), when compared to young ears (Figure 2D). There were no differences in any of the other parameters, including the total distance between the osseous surfaces (B-line) or the cartilage levels along the length of the IMJ.

DISCUSSION

This study demonstrates that compared to young ears, the IMJ is wider in a population of presbycotic ears without histopathologic evidence of sensory, neural, striae, or mixed features. We hypothesize that a widened IMJ may lead to alteration in joint compliance. Prior work in middle ear mechanics has demonstrated that increases in ossicular compliance may lead to increased absorption and decreased transfer of high-frequency sound.^{10,14,15} Our findings lend support to the hypothesis that the IMJ in patients with ‘indeterminate’ presbycusis may be more compliant, and therefore, provide a potential source of high frequency hearing loss. This finding augments our understanding of age-related hearing loss as a purely sensorineural pathology and bears clinical relevance for future research in middle ear reconstructive strategies as well as targeted treatment plans for presbycusis.

While our results support the role of the IMJ as a potential conductive lesion in presbycusis, further histopathologic work is necessary to evaluate the IMJ in all forms of presbycusis. This will allow us to determine if a widened joint space is unique to ‘indeterminate’ presbycusis or if it may also occur in other types of age-related hearing loss. Additional histopathologic work should be performed to identify changes at other locations in the conductive pathway including the ISJ and middle ear ligaments for patients with ‘indeterminate’ presbycusis.^{8,16,17} Further biomechanical work is necessary to explore how histologically observed differences in the ossicular chain affect middle ear immittance and conductive hearing.

CONCLUSION

The IMJ in patients with ‘indeterminate’ presbycusis was wider than in younger individuals without presbycusis. Further histopathologic and biomechanics research is necessary to understand the prevalence and functional effects of observed differences.

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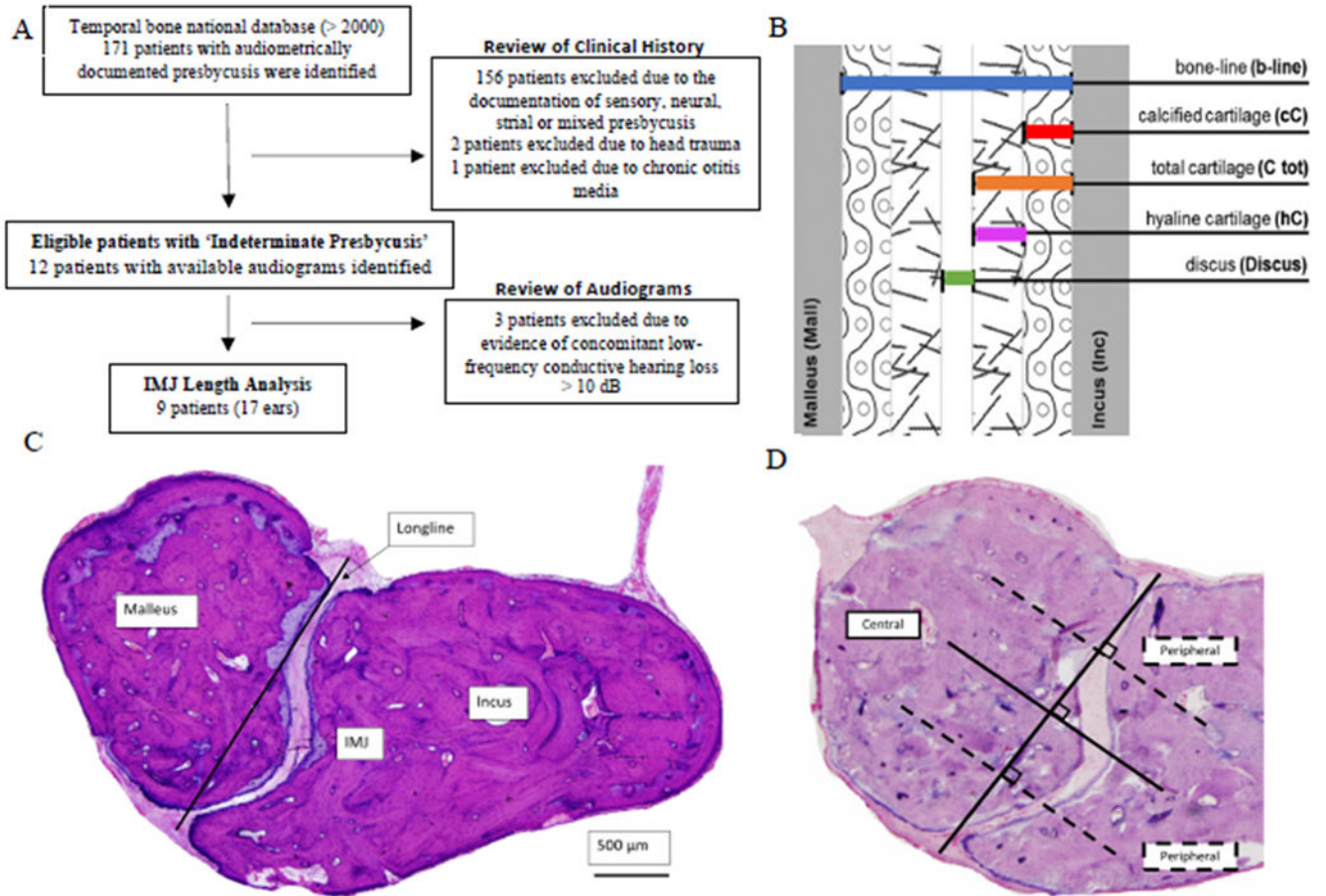


Figure 1.

(A) Temporal Bone Selection Algorithm. (B) IMJ Length Analysis (Adopted from Fausch 2015). (C) Control IMJ section with labelled ossicles and longline. (D) Control IMJ section with central and peripheral positions labelled. IMJ = Incudomalleolar joint.

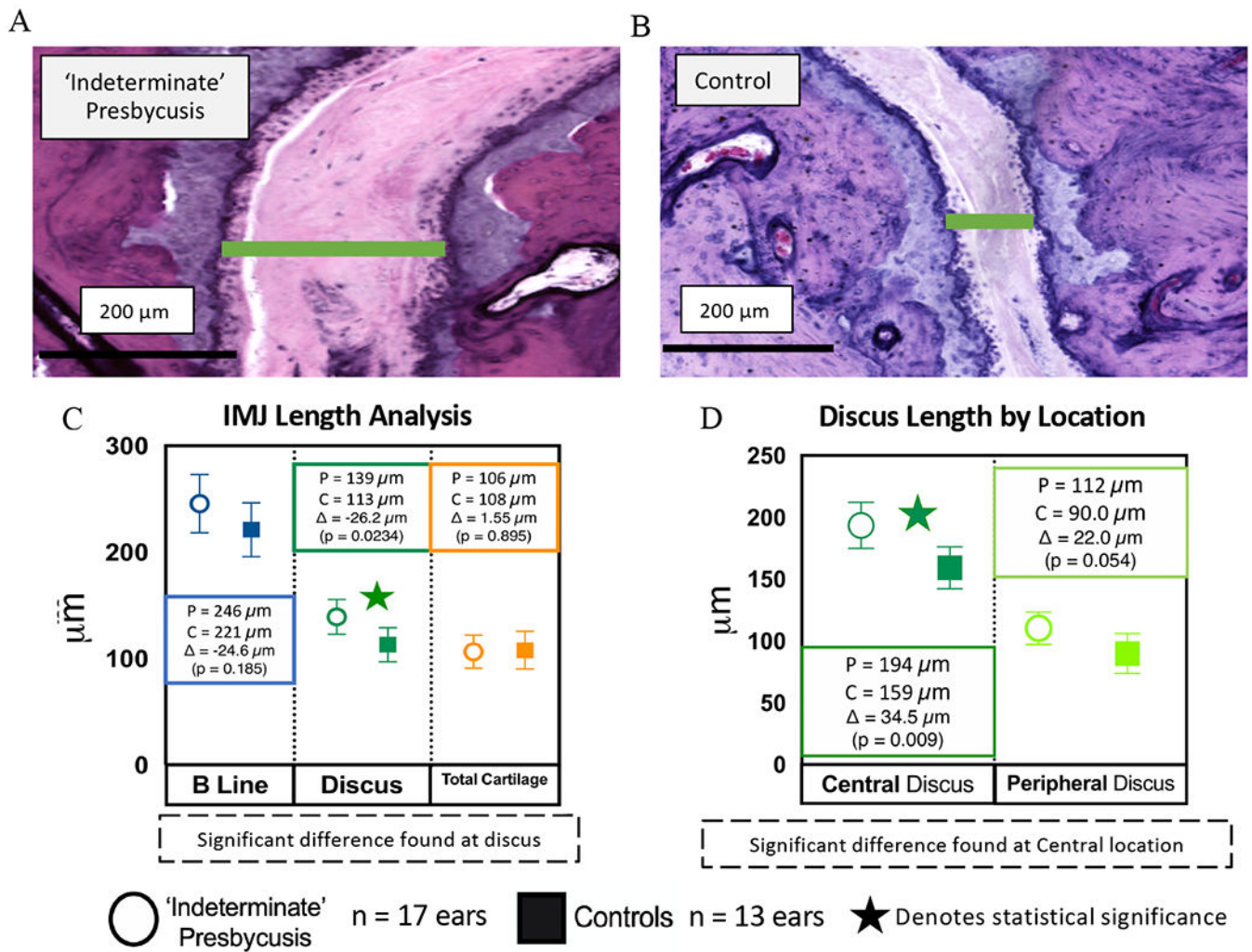


Figure 2. (A) Annotated Indeterminate Presbycusis Section at Central Location showing widened discus (compared to 2B). (B) Annotated Control Section at Central Location. (C) IMJ Length Analysis. Total Cartilage = Total Car Malleus + Total Car Incus. (D) Discus Length by Location (Central vs Peripheral).

Table 1:

Patient Demographics

General Characteristics	IP (n = 9 patients) (%)	Control (n = 9 patients) (%)
Age (mean \pm standard deviation)	73.2 \pm 9.51	32.1 \pm 9.47
Males	6 (66)	3 (33)
Pure Tone Audiometry Results by Ear⁺		
Number of Ears	n = 17 (%)	n = 13 (%)
Normal Thresholds (< 20dB)	-	13 (100)
Downsloping [2kHz] moderate to severe or profound pattern	17 (100)	-

⁺All patients and controls had documented audiometry during life

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