Microstructures of the Bony Modiolus in the Human Cochlea: 
A Scanning Electron Microscopic Study

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The structures of the bony modiolus in the human cochlea were examined by scanning electron microscopy (SEM). The spiral canal for the spiral ganglion and spirally running spaces for the modiolar artery and anterior and posterior spiral veins in the modiolus showed openings or windows leading to the perilymphatic space.

INTRODUCTION
The nerves and vasculatures in the modiolus of the cochlea are surrounded by large perineural and perivascular spaces. Studies using intravascular tracers suggested that the perivascular spaces contain plasma filtrate and transfer it to the perilymph1. Others showed that immune cells gain access to the scala tympani through perivascular and perineural spaces when cytomegalovirus is inoculated into this scala2. It is indicated that the perivascular and perineural spaces are connected to the scala tympani and vestibuli but the morphology and functional significance of these connection routes are unknown. Here, we examined the bony modiolus by SEM to understand relationships between the scala tympani and vestibuli and the neural and vascular spaces in the modiolus.

MATERIALS AND METHODS
Five human temporal bones were used. The cochleae were extirpated from the bones and the modiolus was exposed with a drill and immersed in 5% NaOCl to macerate the soft tissues. The specimens were then washed, dehydrated in acetone, coated with platinum-paladium, attached to aluminium stubs and observed by SEM.

RESULTS
The bony modiolus was cone-shaped and formed the inner wall of the cochlear spiral canal (Figs. a,b). The modiolus projected the osseous spiral lamina which wound two and half turns from the base to apex and divided the medial wall of the cochlear canal into the scala vestibuli and tympani parts (Figs. a-f).

The modiolus facing the scala vestibuli showed furrows (Fig. b), about 45 μm wide, running straight to the roof of the scala vestibuli from short ducts rising from canals deep in the modiolus (Fig. f). The canals formed a labyrinth in the medial wall of the scala vestibuli (Fig. f). The surface of the modiolus facing the scala vestibuli was flat or partly covered with a meshwork of flattened bone trabeculae, and continued to the vestibular leaf of the spiral lamina (Fig. a). Between the edges of the vestibular and tympanic leaves of the spiral lamina was a row of habenular openings (Figs. a,d). The tympanic leaf of the spiral lamina and medial wall of the scala tympani were thin, showing a lace-like appearance with many minute pores, 10-45 μm wide (Figs. b-f). In the scala tympani, the modiolus adjacent to the spiral lamina showed round or oval windows, about 200 μm wide, which were arranged in an interval of 200-300 μm (Figs. b-d). The bones between the windows formed round columns, flared upward and downward, supporting the spiral lamina (Figs. b-d). Behind the windows and columns was a spirally running space, about 300 μm wide, in the modiolus (Figs. b-f). Adjacent to the floor of the scala tympani, the modiolus also showed many fenestrations, about 100-150 μm wide (Fig.e).

When the modiolar bone was broken or cut, the inner structures of the modiolus were revealed. The spiral modiolar canal for the spiral ganglion was situated just under the spiral space with windows, mentioned above, and behind the thin bone forming the medial wall of the scala tympani, measuring about 400 μm in diameter (Figs. b,c,e,f). The medial and basal wall of the modiolar canal was cribriform, showing many openings of the channels for the cochlear nerve fibers from the center of the modiolus (Figs. b,c,e,f). The channels also showed openings leading to the inside of the columns between windows; the columns were like tubes with thin bony skin (Figs. b,c,f). The spaces in the columns continued to the spaces in the spiral lamina and reached the habenular openings (Figs. b-d,f). Just under the modiolar canal was another spirally running space with the fenestrations, opening to the scala tympani, mentioned above (Fig. e,f).

DISCUSSION
This study is the first SEM demonstration of the microstructures of the bony modiolus in the human cochlea. The previous investigations about vasculatures of the cochlea and the present observations indicate the followings. The modiolar artery runs spirally in the labyrinthine canal in the modiolus facing the scala vestibuli. This artery projects radiating arterioles to the furrows in the roof of the scala vestibuli and these arterioles run toward the stria vascularis and spiral ligament in the lateral wall of the cochlear canal. The collecting venules from these areas run on the floor of the scala tympani, enter the modiolar bone through the fenestrations, and anastomose with the posterior spiral vein in the spiral space beneath the spiral ganglion. However, the spiral artery also supplies branches to the spiral lamina with the spiral limbus and spiral ganglion. The venules from these regions drain into the anterior spiral vein in the spirally running space with windows above the ganglion and into the posterior spiral vein. The anterior spiral vein also collects certain venules from the scala vestibuli.

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Thus, our findings indicate that the perivascular spaces filled with loose connective tissue surrounding the artery and veins in the modiolus open to the perilymphatic spaces through the parts lacking the bone. These structures may be involved in formation of the perilymph similar to plasma filtrate and in entrance of immune cells to the scalae in viral labyrinthitis. On the other hand, the nerve fibers from the organ of Corti to the spiral ganglion form compact bundles after leaving the spiral lamina. Our findings indicate that each nerve bundle is enclosed in a bony column. The lace-like, thin bone covering of the nerve bundles and the spiral ganglion may allow passage of the cerebrospinal fluid from the perineural space to the scala tympani and spread of viral labyrinthitis to the central nervous system, as postulated by recent studies.

REFERENCES