Elastic properties of the annular ligament of the human stapes

Stapes – the smallest bone in the human body. It is located in the middle-ear. It constantly vibrates transferring sound from the external word to the hearing organ. The vibrations are possible thanks to the extremely compliant annular ligament on which the stapes is suspended. Because the maximum stapes displacement is only about 100 nanometers (i.e. 1/10 000 millimeters), measuring the ligament compliance has so far been very difficult. The experiment requires measuring both the displacement of the order of nano-meters and the force of the order of nano-Newtons. To measure such small values, you must use special measuring tools. One such a modern precise tool is an atomic force microscope. This microscope enables recording the nanoforce-nanodisplacement relationship (see Figure) that can then be used to calculate the ligament stiffness.

In our study, we have used the annular ligament specimens harvested from human cadavers within 48 h after death, protected from drying, and stored without freezing until the measurement. We glued the specimens to thin glass coverslips and placed them on the measurement table. The measurement results indicate that the stapes ligament is a linear elastic material, at least up to static deflections of 100 nanometers. We have determined the stiffness of the ligament of approximately 120 N/m. This is very valuable that we know the value of the ligament stiffness because we can now make a suitable membrane for new chamber stapes prosthesis. The membrane will mimic behavior of the natural ligament in the case of the stapes fixation due to otosclerosis.

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