INTRODUCTION

The tympanic membrane is composed of collagen fibers that are exactly aligned to enable sound waves to be transmitted to the ear ossicles. Mechanical movement is afterward transmitted by the ossicles to the inner ear where motion of the perilymph results in stimulation of the hair cells, which convert mechanical energy into neuronal impulses. Tympanic perforations, regardless of the cause (infectious, traumatic, iatrogenic), result in hearing loss due to ineffective sound transmission.

Surgical management of tympanic perforations is still a controversial topic. Currently, no surgical technique has 100% success rate. A successful tympanoplasty builds a barrier between the canal and the middle ear and also re-establishes sound transmission to the ossicular chain. Graft materials that are used in tympanoplasty (e.g. perichondrium, cartilage or fascia temporalis) do not possess similar structural arrangements as the native tympanic membrane and may have intrinsic defects. There are several potential healing problems after tympanoplasty as: lateralization of the graft, anterior blunting, epithelial cysts and reperforation. Revision surgery rates are 10-30%.

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NEW TRENDS IN TYMPANOPLASTY

New possibilities are on the horizon. Modern 3D printing should be able to produce grafts that have the stiffness to reduce retractions, material properties to promote normal functionality of the tympanic membrane and biological properties that encourage graft acceptance.

The number of studies is growing rapidly: at the recent 10th International Conference on Cholesteatoma and Ear Surgery (5-8 June), Edinburgh, UK, a new study was reported by John J. Rosowski. The research group of Wyss Institute, Harvard University and Massachusetts Eye and Ear Infirmary has been able to make significant progress using 3D printing graft scaffolds. The constructed scaffolds can be printed using biocompatible or biological materials (fibrin and/or collagen biogels). Radial and circumferential fibrous arrangements of two separate filament counts (8 circumferential [C] x 8 radial [R] or 16 C x 16 R) were chosen for evaluation. As for materials, resorbable polycaprolactone (PCL) and nonresorbable polydimethylsiloxane (PDMS), that were studied to optimize 3D printed fiber configurations, were used.

The study has shown that higher fiber counts (>8C/8R) improve fibroblast confluence on tympanic membrane grafts. Extremely high fiber counts (16 C/16R) limit the available hydrogel space between fibers, preventing fibroblast ingrowth. Deposition of collagen I in samples with fibrin-only hydrogel infill was confirmed by immunofluorescence; addition of collagen...
gen I to the hydrogel infill improved cell proliferation. The scaffold can give strength and mechanical properties similar to those of real tympanic membranes, while infills of biological materials (including growth factors as basic fibroblast growth factor bFGF) can encourage growth acceptance.

To study the mechanical properties of scaffolds, researchers used laser Doppler vibrometry (the laser directly measures the velocity of a single point near the umbo as opposed to some average motion of the entire tympanic membrane) and stroboscopic holography (quantifies mechanical oscillations).

Another recent study was led by Lorenzo Moroni and the team from MERLN Institute for Technology-Inspired Regenerative Medicine at Maastricht University reported on 3D printed scaffolds with design features similar to the human tympanic membrane. The team has also been able to recreate, using the 3D printer, scaffolds using polymer-based materials that interfere with stem cells. Stem cells stimulate the proliferation of connective tissue and fibers in the lamina propria, possibly mediated by secreted substances, although the stiffness properties do not seem to be altered.

CONCLUSIONS

These are exciting times in otology. Moving from the laboratory to clinical application is always a challenge. Although, of course, it is important to be pragmatic about what will really help patients. Perhaps we can all hope for a future in which 3D printing of the tympanic membrane is feasible.

Conflicts of interests: None

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REFERENCES