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Review

# Biomechanics of the tympanic membrane

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ABSTRACT

The tympanic membrane is a key component of the human auditory apparatus which is a complex biomechanical system, devoted to sound reception and perception. Over the past 30 years, various bioengineering approaches have been applied to the ear modeling and particularly to the middle part. The tympanic membrane, included in the middle ear, transfers sound waves into mechanical vibration from the ear canal into the middle ear. Changes in structure and mechanical properties of the tympanic membrane due to middle ear diseases or damages can deteriorate sound transmission. An accurate model of the tympanic membrane, which simulates the acoustic-mechanical transmission, could improve clinical surgical intervention.

In this paper a detailed survey of the biomechanics and the modeling of the tympanic membrane focusing on the finite element method is conduced. Eight selected models are evaluated and compared deducing the main features and most design parameters from published models, mainly focusing on geometric, constraint and material aspects. Non-specified parameters are replaced with the most commonly employed values.

Our simulation results (in terms of modal frequencies and umbo displacement), compared with published numerical and experimental results, show a good agreement even if some scattering appears to indicate the need of further investigation and experimental validation.

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*Abbreviation:* AL, annular ligament; Fer03post, model of Ferrazzini (2003) after the parameter identification; Fer03pre, model of Ferrazzini (2003) before the parameter identification; GanFS04, model of Gan et al. (2004, 2006); IS, isotropic; KoiWK01, model of Koike et al. (2005, 2001, 2002); LE, linear elastic; LeeCLC10, model of Lee et al. (2010, 2006a,b) and Wen et al. (2006); Liu09, model of Liu et al. (2009); MikFB04, model of Mikhael et al. (2004); OR, orthotropic; PF, pars flaccida; Pre08, model of Ferris and Prendergast (2000), Kelly (2001), Kelly et al. (2003), and Vard et al. (2008); PT, pars tensa; SPL, sound pressure level; SunGCD02, model of Sun et al. (2002); TA, tympanic annulus; TM, tympanic membrane.

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