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Can piezoelectric ultrasound osteotomies result in serious noise trauma?

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Abstract. The use of ultrasound to cut bone in oral and craniofacial surgery has increased. There is concern that the application of ultrasound to the craniofacial skeleton might represent a potential hazard to the inner ear because of sound transmission by bone conduction resulting in hearing trauma. Conventional and ultrasound osteotomies were performed on human specimens of temporal bone containing an intact middle and inner ear. The equivalent sound pressure was measured with a microphone at the round window, which had been calibrated with a bone conduction audiometer. Conventional osteotomy with a rose burr resulted in maximum sound pressures of 125 dB(A) consisting of major frequency components at 2100, 7600, and 9300 Hz. Ultrasound osteotomy resulted in maximum sound pressures of 122 dB(A) and exhibited major frequency components at around 10 kHz, 20 kHz, and 26.5 kHz. Ultrasound osteotomies have no acoustic advantage over conventional osteotomies. Both osteotomy techniques can produce noise-induced hearing trauma, especially when applied over longer durations of time. This appears to be more relevant for ultrasound osteotomies, because the bone cutting efficiency is usually poorer than in conventional osteotomies. Surgeons should consider the risk of noise-induced potential damage to the inner ear when selecting the method of osteotomy.

Key words: ultrasound; osteotomy; piezoelectric; noise; trauma; inner ear; craniofacial surgery; dental surgery.

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Several years ago, an innovative osteotomy technique that splits bone by microvibrations was introduced into oral surgery. These microvibrations are generated by ultrasound following a piezoelectric stimulus.[1] Depending on the frequency applied and the amplitude, several clinical advantages of the ultrasound osteotomy have been observed when compared to conventional osteotomy techniques. These include an increased precision of the osteotomy, the requirement for a smaller extent of periosteum elevation, and a reduction of intraosseous haemorrhage during the osteotomy due to the cavitation effect.[2] The most important benefit, however, is the tissue-selective cutting action of the ultrasound osteotome, which only splits mineralized tissues and not soft tissues.[3] These characteristics have resulted in an expansion in the use of ultrasound osteotomy across various dental and surgical disciplines, including periodontal surgery, endodontic surgery, dental implantology, and craniomaxillofacial surgery.[4–9]

However, the application of ultrasound might also result in disadvantageous side effects. Besides the mechanical problems and heat effects, the conduction of the noises generated by ultrasound osteotomies towards the inner ear via air and bone conduction have also to be considered. For anatomical reasons, this aspect seems more relevant for ultrasound osteotomies performed on the craniofacial skeleton and the maxilla than those on the mandible. The aim of the present experimental study was to analyze the equivalent sound pressures and frequencies generated by ultrasound osteotomies and to compare the results to those obtained with conventional osteotomy techniques.

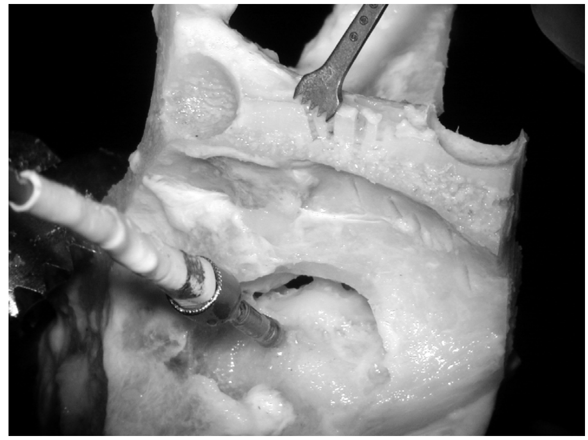

Fig. 1. Specimen of the prepared temporal bone. A hydrophone was inserted into the superior semicircular canal for sound pressure analyses.

Materials and methods

All experiments were performed with the approval of the local ethics committee.

Specimen preparation

The experiments were carried out on three fresh human specimens consisting of temporal and petrous bones including the middle and inner ear, which represents a standard model in ENT inner ear research.[10–12] The specimens used showed no morphological abnormalities. The round window niche was exposed and a microhydrophone was positioned to measure the induced equivalent sound pressure (Fig. 1). For reference measurements, a small piece of reflective tape was placed on the stapes footplate to measure the normal middle ear transfer function by laser Doppler vibrometry (Fig. 2). Special care was taken to leave the sound-conducting system, including the tympanic membrane and the ossicular chain, completely intact.

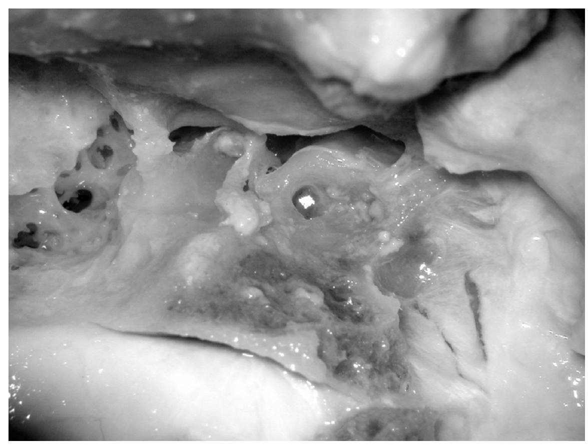

Fig. 2. A small metal reflector was placed in the round window for frequency analysis; a laser Doppler signal was applied to analyze the oscillations of the round window.

Calibration of the measurement system

In order to control the integrity of sound conduction of each bone model, the sound transfer function of the middle ear was determined. The external ear canal was plugged with an insert earphone and the sound pressures applied were analyzed with a probe microphone (ER 7c; Etymotic Research Inc., Elk Grove Village, IL, USA), which was located 2 mm in front of the tympanic membrane. The corresponding vibration of the stapes footplate was measured by laser Doppler vibrometry.[13,14] The transfer function was determined as the stapes footplate displacement per unit of sound pressure at the eardrum. In our temporal bone specimens, the transfer function was found to be unaffected. Thus, any fixation, such as otosclerosis or other adhesions, could be excluded.

When these prerequisites had been fulfilled, the microhydrophone in the round window niche was calibrated. Calibration was performed by bone conduction, because the noise induced by bone preparation is mainly related to bone conduction. An audiometer (MA 21; VEB Präcitronic, Dresden, Germany) with a bone vibrator (KH 70/5) provided defined bone conduction stimuli of 45–70 dB (A-weighted) at audiometric frequencies of up to 8 kHz. The bone vibrator was coupled to the skull bone of the specimen. The corresponding sound pressure in the round window niche was measured with the microhydrophone. In assuming a linear system, these calibrations can be used to calculate the equivalent sound pressure induced by other types of bone conduction stimuli, such as drilling or cutting. Dividing these measurements by the calibration curve gives the induced equivalent sound pressure of this type of stimulus.

Measurement of sound pressure during bone preparation

All bone preparations were subjected to either conventional osteotomy or ultrasound osteotomy at the anterior margin of the temporal bone specimen. The osteotomies were performed manually with soft pressure for about 30–60 s. The conventional osteotomies were performed with standard bud burrs of various diameters running at 25,000 rpm. The ultrasonic osteotome (Piezosurgery; Mectron Medical Technologies, Carasco, Italy) was used according to the recommendations of the manufacturer, with frequencies between 25 and 30 kHz depending on the desired intensity of osteotomy. The oscillation amplitude varied between 60 and 210 μm. For the experimental osteotomies, the osteotome was run at various levels in the bone mode and different working tips were used. Both the conventional and the ultrasound