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Direkte Ankopplung mit einer flexiblen Vorlaufstrecke zur ultraschallbasierten Vermessung der Schädelknochendicke

Direct coupling for ultrasound based measurement of skull bone thickness via a flexible delay line

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Purpose

For a great variety of surgical interventions on the head, it is of utmost interest to know the exact thickness of the skull bone. However, the special resolution of CT-based navigation is restricted. Ultrasound offers better resolution, but there are practical issues still to be solved: Ultrasound examination requires a delay line to compensate for near field length and coupling the sound probe to the target medium. Most commercially available ultrasound machines integrate this delay line into the sound probe. However, as these probes are rigid, coupling to a curved and somewhat uneven bony surface as represented by the temporal region is not feasible. Thats why we were investigating for an ideal material for direct coupling the ultrasound probe.

Material and Methods

A Transmit Receive Module II (TRM II) of Fraunhofer IBMT, integrated in a standard PC was used and providing an ultrasonic transmitter with a free adjustable transmit frequency (0.5 ‘ 40 MHz) and a integrated wave form generator (D/A-transducer 12 Bit / 100 MHz) to generate free programmable transmit forms (Chirps, Barker, Burst, Golay-Codes) with a transmit voltage of 0 ‘ 60 Vpp (50 •). Three materials came into closer consideration as a delay line: the elastomer Biresin and two polyurethanes GM900 and GM951. 48 measurements at 16 human skull bone samples fixed with formalin were done at 3 points with direct coupling. For comparison, the same ultrasound measurements were done in a water tank. The reference measurements were manual measurements with a clamp micrometer screw.

Results

The polyurethane GM900 showed the lowest acoustic damping with an attenuation coefficient of 0.29 dB/mm at 1 MHz and a sound velocity of 1377 m/s (std 2 m/s). The average deviation for the pulse compression technique using coded signals amounts then to 0.7 mm (±8 %) in the water tank and for the direct coupling only to 0.5 mm (±5 %).
Conclusion: We present an A-mode ultrasound scanning system with special signal processing to provide accuracy of 0.5 mm (±5%) for up to 10 mm skull bone thickness. The polyurethane GM900 showed ideal characteristics for its intended use in microsurgery: It is soft and reversibly deformable in order to allow flexible coupling to an uneven surface (Fig, 3a). Its acoustic impedance and sound velocity are similar to water and its acoustic damping is minimal, therefore energy loss is negligible. Sterilization is not necessary because the ultrasound probe can be coated by a sterile thin sleeve. The 3D ultrasound scan may be used for global navigation (image-guided surgery) in robotic surgery of the head when coupled directly to the robot or to a tracking system. However, this ultrasound scanning system is even in itself a very promising tool for conventional surgery by providing valuable information on skull bone thickness.

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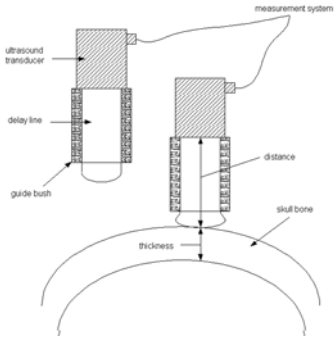
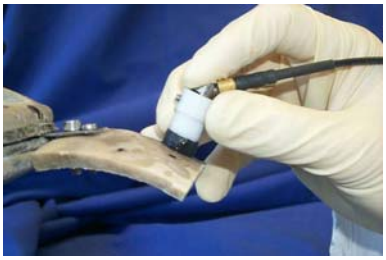

measurement system
ultrasound transducer
delay line
guide bush
distance
skull bone
thickness



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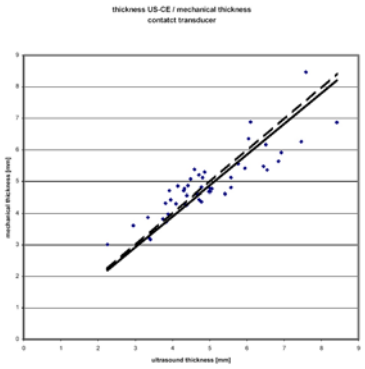
thickness US-CE / mechanical thickness
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