Three-dimensional shockwave modeling of the efficacy of secondary reflectors in low intensity shockwave therapy to the penis (Janout et al., 2023)

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Introduction

Potential tissue damage has long been linked to induced pulmonary capillary bleeding brought on by increased tensile wave amplitudes in the vicinity of significant impedance mismatches, such as tissue interfaces. The evaluation of potential tissue damage is given by tissue-safety parameters. These parameters are provided by ultrasound based mechanical index (MI) thresholds, which have to be assessed based on the utilized shockwave applicator. Furthermore, electrohydraulic generators have long been associated with large volumetric treatment zones and weak tensile wave strengths. This study aims to show that using a symmetry-matched secondary reflector in the therapeutic treatment of the penis in men with erectile dysfunction can: i) not only reduce the appearance of further induced tensile stress forces but ii) also increase the treatment volume of each applied shockwave.

Material & Method

One of the key aspects in choosing a shockwave applicator is the treatment volume per shot. We evaluate the in-situ pressure field distributions using 3-dimensional numerical non-linear shockwave modelling. Additional water bath reference and phantom-based in-situ hydrophone sound pressure measurements enable a therapeutic application's systematic evaluation. Following these measurements, detailed knowledge of soundwave propagation allows for evolutionary strategy-based optimization of ideal reflector geometries, further increasing the efficacy of low-intensity shockwave therapy to the penis. The resulting reflector designs are 3-dimensional printed and once again evaluated in the water bath and simulated clinical phantom application.

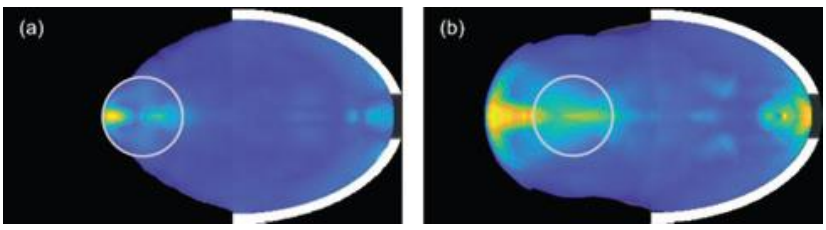
Results

Introducing an applicator-tailored reflector increases therapeutic volume and reduction of tensile wave content in the clinical application. Therapeutic longitudinal shockwaves during treatment at the lateral end of the application undergo phase-inversion at the air interface, and an enhanced tensile wave is created at the boundary. In addition, the geometry of the genitalia creates a collecting reflection. Still, due to the symmetry and phase mismatch, no significant refocusing occurs at this secondary reflector. Adding an applicator-matched reflector eliminates the enhanced tensile wave within the treatment zone. Furthermore, it provides a subsequent tertiary pulse of intensity after the insignificant primary and strongest secondary wave pulses.

Discussion

The applicator's focal zone may be extended by refocusing the pressure waves past the tissue of interest during shockwave therapy treatment of the penis. Selectively using a reflector may improve clinical outcomes by reducing tissue stress caused by tensile forces and potentially harmful cavitation effects. Simultaneously, a weakly refocusing tertiary wave in rapid succession of the main treatment pulse increases the size of the treatment volume of a single pulse, potentially increasing therapeutic efficacy.

Figure 1



Tensile pressure distribution of a shockwave pulse without a reflector (a) and with a reflector (b). Surrounding air is visualized in black, and a gray circle indicates the penile cross-section.

Technology: Focused Shockwave, k-wave Toolkit
Device and Manufacturer: Orthogold100 by MTS Medical UG, Konstanz, Germany; Müller-Platte Needle Probe by Müller Instruments, Oberursel, Germany
COI: No conflict of interest

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Study Performance: **OW100**