How deep can I specify the position of the treatment points inside a tissue/substrate to be?

It is not possible to give a precise maximum depth of a treatment point, as this depends strongly on power settings and what medium the waves have to travel through.

When sound travels through any medium, its intensity diminishes with distance. In idealized materials, sound pressure (signal amplitude) is only reduced by the spreading of the wave. All natural materials however weakens the sound through scattering and absorption.

Scattering is the reflection of the sound in directions other than its original direction of propagation. Absorption is the conversion of the sound energy to other forms of energy, e.g. heat. The combined effect of scattering and absorption is called attenuation.

Ultrasonic attenuation is thereby the decay-rate of the wave as it propagates through material and is therefore a very important factor for how deep a treatment point can be positioned.

The amplitude change of a decaying plane wave can be expressed according to Stokes Law as:

$$A = A_0 \, e^{-\alpha z}$$

where A_0 is the unattenuated known amplitude of the propagating wave, A is the reduced amplitude after the wave has traveled a distance z from that initial location, and α is the attenuation coefficient of the wave traveling in the z-direction.

The dimension of α is expressed as Neper/m (Np/m) or dB/m, where 1 Np = 8.6859 dB.

Even if attenuation is known to be frequency dependent, quoted values of attenuation in various data tables, are unfortunately often given for a single frequency, or as an attenuation value averaged over many frequencies. Other tables reference the attenuation in a more practical linear relationship, such as Np/cm/MHz or dB/cm/MHz.

The actual values of the attenuation coefficient for many materials is highly dependent on the way in which it is structured/oriented or prepared for measurement. Thus, quoted values, in particular when relating to living tissue, therefore only give a rough indication of the attenuation, and should be used with caution and consideration to the inherent uncertainties.

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Attenuation in water have very low values around 0.002 dB/cm/MHz, but a very wide range of other values are reported when measuring water e.g. with higher content of oxygen, salt or other dissolved substances.

If the medium contain “other matter” to scatter and absorb sound waves, the attenuation increases. Soft tissue, such as skin, generally have values around 1 dB/cm/MHz, while dense bone structures have attenuation at a significant 20-40 dB/cm/MHz. An overview table of various attenuation coefficients below, but should be used with great caution due to the above-mentioned uncertainties and measurement variations.

In TOOsonix’s standard high frequency handpieces, which operates around 20 MHz, the attenuation of ultrasound in soft tissue is a very significant ~20 dB/cm. This attenuation loss has to be compensated by higher output power in order to obtain a treatment point of a certain size as the focal point is moved deeper inside a tissue.

It can therefore be seen, that deep treatment points, e.g. above 5 mm, has to be compensated for an attenuation loss of at least 10 dB, compared to a more shallow treatment. For this reason, careful selection of the operation frequency should be made in the planning of any HIFU treatment.

The TOOsonix systems are primarily targeted at superficial structures in the range of 0 to 6 mm inside the tissue, but lower frequency handpieces for deeper focal depths can be manufactured on request.

Material or tissue	Attenuation *dB/cm/MHz*
Water	0.002
Aqueous humor	0.02
Vitreous humor	0.13
Blood	0.18
Fat	0.6
Brain	0.85
Liver	0.9
Castor oil	0.95
Kidney	1.0
Muscle (along fibers)	1.2
Lens	2.0
Lucite	2.0
Muscle (across fibers)	3.3
Skull	20.0
Lung	40.0