LOCAL DYNAMIC MICRO-MASSAGE

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INTRODUCTION

Ultrasound with its various mechanical, thermal and chemical effects on cells and tissues has had different applications in medicine and aesthetics for a long time.

One of the most important effects of ultrasound is a micro-massage caused through large pressure gradients in an ultrasound wave. The amplitudes of the transient pressure oscillations in an ultrasound wave of moderate intensity are much higher than the atmospheric pressure and they fall down over half a wavelength (app. 1 mm). Such big pressure gradients can neither be reached by hand nor by any supportive apparative method. The pressure used during conventional vacuum-massage is e.g. 100 to 1000 times lower.

This strong micro-massage effect of ultrasound can be increased further through the LDM®-Technology. **LDM®** – **L**ocal **D**ynamic **M**icro-Massage – is a new treatment method, which is qualitatively different from other types of massage. This technology uses two ultrasound waves of different frequencies with a rapid frequency modulation. Through this modulation new micro-massage effects, which are not present in a conventional ultrasound wave, can be obtained.

WHAT EFFECTS DOES THE ULTRASOUND WAVE HAVE IN THE BODY?

To explain the difference between the LDM®-Technology and conventional ultrasound let us first of all consider such parameters as the amplitude, the speed and the acceleration of the particles of the medium as well as the pressure values in the wave.

OSCILLATION AMPLITUDES

Ultrasound waves travel in a medium of high water content at a velocity of app. 1500 m/s.

The *amplitudes* of the particle oscillation in such a medium are ultrasound intensity and frequency dependent. For an ultrasound intensity of 1 W/cm^2, which is typical for medical and aesthetic applications, and a frequency of 1 MHz = 10^6 Hz, the medium particles will oscillate with amplitudes of app. 0.018 μm = 0.000018 mm.

To compare:
The typical diameter of a cell is app. 10 μm and a cell membrane is only 0.005 μm thick. The oscillation amplitudes of the medium particles are therefore *much smaller than the cell itself and much bigger than the cell membrane*. This is an indication for the possible membrane effects of ultrasound (e.g. increase of the cell membrane permeation). In fact, increase of a cell membrane permeation of 200% after ultrasound treatment is known.

The oscillation amplitude decreases with increasing frequency as follows:

$$a = \frac{1}{2\pi f}\left(\frac{2I}{\rho c}\right)^{1/2}$$

a is the oscillation amplitude, *f* is the ultrasound frequency, *I* is the ultrasound intensity, ρ is the medium density and *c* is the ultrasound speed in the medium.

This means that at a frequency of 3 MHz the oscillation amplitude is three times lower than at 1 MHz. At the frequency of 10 MHz these amplitudes are ten times lower than at 1 MHz; they reach the value of only 0.0018 μm and are therefore smaller than the cell membrane.

VELOCITY AND ACCELERATION

The maximum velocity of the medium particles in such an ultrasound field is app. 10-15 cm/s. This velocity is much lower than the velocity of the sound itself. However it is not constant and oscillates permanently between 0 and the above-mentioned maximum value.

Through this oscillation the particles will be accelerated; the maximum value of this acceleration at an intensity of 1 W/cm^2 and a frequency of 1 MHz is app. 725 km/s^2.

To compare:
A car which increases the speed from 0 to 100 km/h in 10 seconds accelerates by only 0.003 km/s^2.

Such a very non-uniform movement of particles causes strong frictions, which can consequently bring an essential temperature rise in the tissue.

The speed *v* is frequency independent, whereas the acceleration *g* increases with increasing ultrasound frequency; at a frequency of 3 MHz this acceleration is three times higher than at 1 MHz. At a frequency of 10 MHz it will even reach a value of app. 7,250 km/s^2!

$$v = (2I / \rho c)^{1/2}$$
$$g = 2\pi f (2I / \rho c)^{1/2}$$

PRESSURE

An ultrasound wave produces alternatively over- and under-pressures in the tissue. For the above-mentioned ultrasound parameters, the pressure *p* can reach the value of 1.7 bar = 1.7x10^5 Pa, and therefore is almost twice as high as the normal atmospheric pressure. At an ultrasound intensity of 2 W/cm^2 the pressure can be even three times higher than the atmosphere pressure.

At first glance this looks surprising because during an ultrasound treatment one feels almost nothing. At the same time the vacuum- and the vacuum-compression-massage respectively with an under- / over-pressure of only 0.1 bar (app. 10% of the normal atmospheric value) are clearly perceptible. The explanation is however very simple. Vacuum- and vacuum-compression-massage respectively are treatment methods with the main effects being induced through the skin receptors and the acceleration of the blood flow. The real pressure values in the tissue are however not as high as it seems. It is very different in the case of ultrasound. The mechanoreceptors of the skin as well as the receptors of the blood vessels don't "see" the ultrasound wave and remain *inactive*. However, the pressure differences in the tissue can locally be so high, that one can speak of the real "micro-massage" effect of ultrasound.

Such high pressure values give the impression that the external particles can simply be "pushed" into the body, which could be the explanation of the sonophoresis. This is however wrong. The above-mentioned pressure is *frequency independent,*

$$p = (2I\rho c)^{1/2}$$

i.e. it has the same value for every *ultrasound frequency*. This is in contradiction to experiments which show the clear frequency dependent effectiveness of the sonophoresis.

Mechanical effects through the pressure variation in the skin are not very important for the conventional ultrasound with frequencies of 1 MHz and 3 MHz. Stratum corneum is app. 15 µm thick and so it is much smaller than the typical half-wavelength of ultrasound at 1 MHz (750 µm) or at 3 MHz (250 µm). Only the thickness of the epidermis is comparable with these values. At 10 MHz the half-wavelength is only 75 µm, which increases the importance of mechanical effects in the tissue and can consequently increase the effectiveness of sonophoresis.

Does this frequency independence of the pressure really mean the *pressure distribution* in the tissue is the same? The maximum pressure values are really *frequency independent*, at the same time the pressure distribution is *frequency dependent*. This is because of the frequency dependence of the *wavelength*.

The wavelength of ultrasound with the frequency of 1 MHz is app. 1.5 mm; at a frequency of 3 MHz it is app. 0.5 mm and at 10 MHz it is app. 0.15 mm. That means, for the ultrasound with a frequency of 1 MHz and intensity of 1 W/cm^2 the max. and min. pressure values (theoretically of +1.7 bar and -1.7 bar) in the wave are separated by a distance of a half-wavelength (app. 0,75 mm). A gigantic *pressure gradient* will be so produced over a small distance. For the ultrasound of 3 MHz and 10 MHz this distance will be 0.25 mm and 0.075 mm respectively (Fig.1).

LDM®–TECHNOLOGY

If the ultrasound frequency changes from 1 MHz to 3 MHz or from 3 MHz to 10 MHz with the intensity remaining unchanged, the pressure amplitudes in the tissue will be the same. The dimension of every micro-massage unit in the tissue will however be reduced from 0.75 mm to 0.25 mm (respectively from 0.25 mm to 0.075 mm). This presents the unique possibility to produce a dynamic modulation of the ultrasound micro-massage effects.

This possibility arises for the first time with the introduction of the new ***LDM®-Technology***. In this technology the frequencies produced in one sonotrode (ultrasound head) will be exchanged vary rapidly (between 100 and 1.000 times per second). Thereby a rapid pulsation of the pressure gradients in the tissue with the same modulation occurs. This is the new art of the micro-massage which cannot be produced by conventional ultrasound applications.

Mechanical effects of ultrasound could be influenced till now only through the regulation of the ultrasound intensity. According to Fig.2 it can be named "***vertical***" control of the micro-massage.

Applying the LDM®-Technology one can vary the *scale* of the massage effects, which is defined through the wavelength of the ultrasound. While this change takes place in the direction of the wave translation (Fig. 1), one can consider this additional possibility as a "***horizontal***" control of the micro-massage.

To summarize, the particle velocity in an ultrasound field is frequency independent and can be influenced only through the ultrasound intensity. Against that the oscillation amplitude and the particle acceleration are frequency dependent and can be influenced either through ultrasound intensity or through ultrasound frequency (Table 1). The maximum pressure value in the tissue is in fact frequency independent, the pressure distribution can however be strongly influenced through the frequency change.