In Vitro Study of Microstructural Changes of the Surgical Steels and disinfection of Microorganism Occurring during its Ultrasound Processing.

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Abstract: The article presents the results of studies and effects of ultrasonic surface disinfection of surgical instruments with the structural transformations of the material occurring under the influence of ultrasonic vibrations which was conducted in order to select the optimal effective modes of ultrasonic processing.

Key words: Ultrasonic treatment, Surgical steels, Cavitation, Decontamination, Micro hardness, Bacteria

Introduction.

The use of ultrasonic energy in medical practice is a factor that allows not only to effectively cleaning the surface of the medical tool of complex technological and biological contamination, but also can be used as disinfecting agent [1, 2]. Increasing the effectiveness of treatment with ultrasonic vibrations to a large extent will be determined by rational choice of operating modes of the ultrasonic bath causing the minimal damage to its surface.

Sample and Research method.

To study the effect of ultrasound cavitation , non-corrosive stainless steel of high chromium contains were selected which are most common in medical practice and brands 12H17, 40Ch13. 12H17 steel refers to the ferrite class steels, the hardness of the initial state is small, so it is not used for the manufacture of medical instrument . The study on the effect of ultrasonic treatment on the properties of steels was carried out in the ultrasonic cleaning sink Kudos of model SK2500HP [3]. Ultrasonic vibrations were excited in distilled water. The frequency of ultrasound exposure in the experiment kept constant at 57 kHz. The intensity of the ultrasonic vibrations was chosen based on the availability of qualitatively different modes of ultrasonic treatment:

- 0.5 W/cm^2 (pre cavitation mode);
- 1.2 W/cm^2 (the appearance of cavitation bubbles in a liquid);
- 1.5 W/cm^2 (in the mode of developed cavitation).

The sequence of operation performed during the experiment were [5]

- Set the intensity of the ultrasound to 0.5 W/cm^2;
- Prepared sample was immersed in the ultrasound bath and was held for 10 minute.
- Micro hardness of the surface was measured and its micro-structure was fixed;
- Then the process was repeated until, it shows the clear signs of destruction of the surface;

-Similarly experiment was carried out for the remaining samples at 1.2 W/cm^2, and 1.5W/cm^2 intensity.

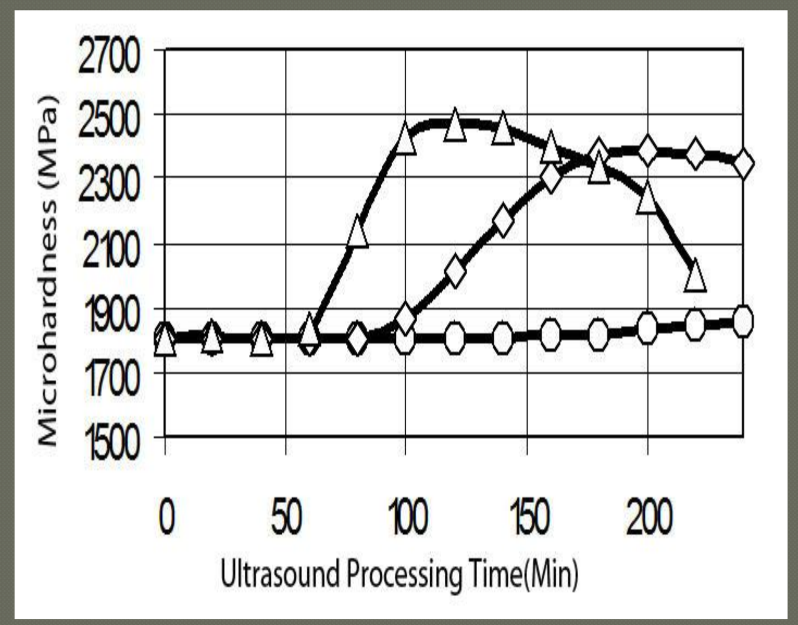

Figure 1. Microhardness of surface of the samples were from 12H17 at an intensity at 0.5 W/cm^2 (○), 1,2W/cm^2 (◊), 1,5 W/cm^2 (Δ) against the time of processing

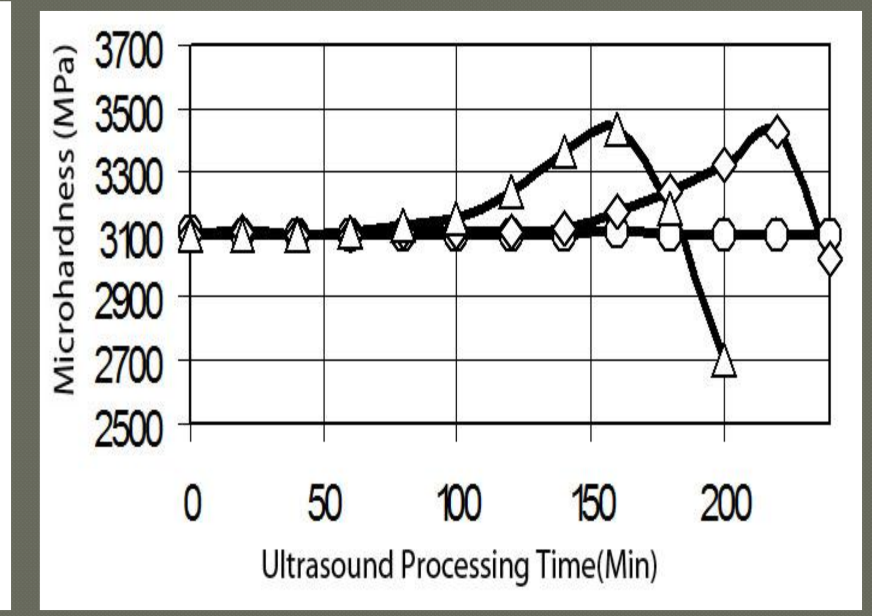

Figure 2. Microhardness of surface of the samples were from 40Ch13 at an intensity at 0.5 W/cm^2 (○), 1,2W/cm^2 (◊), 1,5 W/cm^2 (Δ) against the time of processin

Results:

The results of the experiments are shown in the figure 1 and 2 which can be expressed as following:

- There is a latent period when the ultrasonic vibrations have no effect on the material surface and this period depends on the micro hardness of the material: the higher the hardness the more prolonged the latent period.
- After the latent period, there began an increase in hardness as a consequence of repeated strain and hardening of the surface;
- The degree of hardening of steel with a ferrite-carbide structure 12H17 is higher than steel with the structure of martensitic 40Ch13;
- The increase in the processing time of the ultrasound leads to a decrease in micro hardness and softening of the outer surface of the material;
- With low-intensity ultrasound exposure in the pre-cavitation mode , the process of hardening of steel 12H17 is weak and the process of hardening steel 40Ch13 during the experiment is not detected at all;

-In cavitation mode, all the three stages (latent period - hardening - softening) are found to be intense.

Thus, from the results of the experiment the following conclusions can be drawn:

- Ultrasonic treatment of steel in post cavitation mode almost has no effect on the state of their surface and microstructure;
- The formation of cavitation bubbles in cavitation mode liquid leads to excessive strain and then hardening followed by the softening and destruction of the surface;
- More cavitation-resistant steel was found to be martensitic structure 40Ch13;
- The effects caused by cavitation are distributed in the thickness of the material to a depth of 50 microns;

-The value of deformation caused by cavitation depends on the intensity and time of ultrasonic treatment.

Discussion and conclusions

Verification of the results depending on the time of antibacterial effect and impact of low-frequency ultrasound power on the equipment of Sonoca was conducted in relation to four clinically important strains of bacteria. Exposure time and intensity of the ultrasound were taken into consideration. Were used four strains of bacteria (Staphylococcus Aureus, Streptococcus Pyogenes; Escherichia Coli, Pseudomonas Aeruginosa). Counting was carried out by the number of colony forming units after ultrasound exposure. The experiment showed that regardless of the different sensitivity to ultrasound, different strains of the bacterial suspension make a significant antibacterial effect. When the time of exposure ranges from 1 to 3 minutes and intensity of ultrasonic vibrations is 80-100% of the nominal, the amount of bacteria decreased by 90% for S. aureus and 99% for Streptococci and Pseudomonas. At low intensities (20% of nominal) for the same period of time, there was a moderate decrease in the number of bacteria of all strains, not exceeding 60%. Ultrasound treatment of seeding bacteria was done in distilled water and was carried out at an intensity of 0.5 W/cm^2, 1.2 W/cm^2 and 1.5 W/Cm^2 [6]. The experimental results are shown in Figure 3.

The massive breakdown of microbial cells was observed in the onset of cavitation. It is noted that the death of bacteria obeys a logarithmic function of time, which makes the practical application of ultrasonic sterilization. Thus, we can assume that the maximum degree of decontamination of strains of bacteria in distilled water was achieved in the time from 3 to 8 minutes depending on the power of ultrasonic vibrations. Pre-cavitation mode has almost no effect on the state of the tool's surface, but was inefficient in terms of disinfection. Therefore, further analysis was performed only for the cavitation mode of varying intensity. Figure 4 shows the results of a comparative analysis of the time required for the destruction of more than 99% of bacteria, and the time corresponding to the beginning of hardening and softening of the surface of the steel's tool and 40Ch13 and 12H17

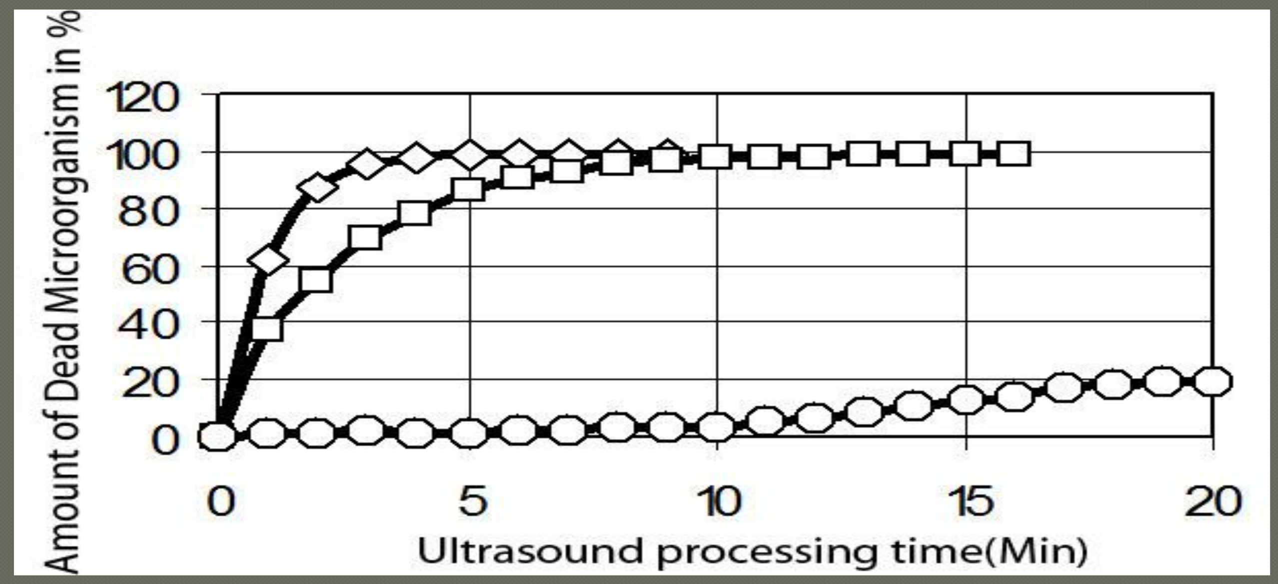

Figure 3. Effect of time of ultrasonic treatment on the number of dead organisms in the field intensity 0.5 W/cm^2 (○), 1,3 W/cm^2 (□), 1,5 W/cm^2 (◊).

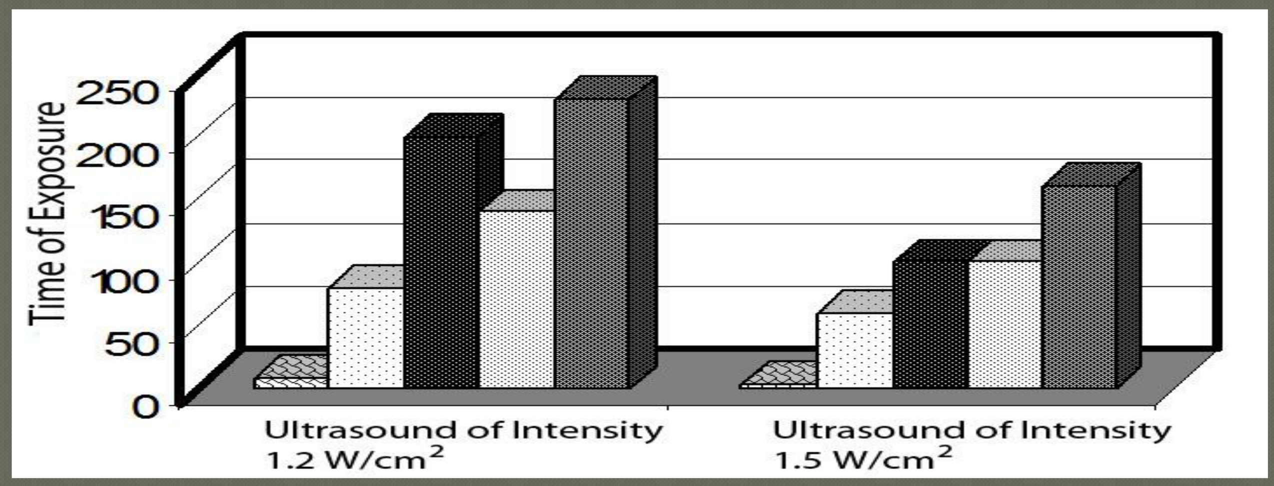

Figure 4. Bar diagram showing the effect of Intensity over a Time period
1—Disinfection 2— beginning of hardening 12H17 3— beginning of softening 12H17-lo 4— the beginning of hardening 40Ch13 5— beginning of softening 40Ch13.

From these results we can draw the following conclusions:

- Steel 40Ch13 is more cavitation-resistant than steel 12H17;

-At an intensity of 1.2 W/cm^2 field of ultrasound corresponding threshold of cavitation and time required to achieve the hardening and subsequent softening of the tool surface is almost an average of one and a half times greater than the intensity of 1.5 W/cm^2, corresponding to the regime of developed cavitation. However, if we compare the time required for decontamination of surfaces, and the time required achieving the strengthening and softening of the material as shown in Table 2. It appears that increasing the intensity of the ultrasonic field allows more cycles of disinfection.

-Thus, prior to hardening of steel instruments 12H17 which can withstand 10 cycles of ultrasound processing at an intensity of 1.2 W/cm^2 and 20 cycles of ultrasound processing at an intensity of 1.5 W/cm^2 whereas 40Ch13 can withstand 17 cycles of processing in the intensity of 1.2 W /cm^2 and 33 round at an intensity of 1.5 W/cm^2. Thus, comparing the status of the material being processed and the degree of disinfection tool, depending on the intensity of ultrasonic vibrations, we can choose the most effective modes of for the processing of medical surgical instruments.

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