Introduction

Implants are widely used in dental practice. The process leading to satisfactory osseointegration of the implant with the surrounding tissues is complex. This process begins with the initiation of the coagulation cascade, aggregation of platelets and the formation of a blood clot around the implant, leading to the formation of a matrix or temporary fibrin network around the implant. Such a temporary network serves two important functions: it provides initial stability of the implant and the gradual release of platelet-derived growth factors and cell markers. Among other processes, cell markers, for this purpose, stimulate the migration of cells to the wound area, their adhesion, differentiation and proliferation and the release of the extracellular matrix with its subsequent mineralization, which ends with the formation of a characteristic bone matrix around the implant. The surface of the implant is critical in determining its performance. Many methods are in use or are being developed to modify implant surfaces. Recently, wet-surface implants have gained popularity, but the specific clinical benefits of such implants have not been sufficiently studied. The wettability of the surface of biomaterials determines the speed of the biological cascade of events in the area of biomaterials - bone. The design of modern implant surfaces is focused mainly on specific micro- and nanotopographic characteristics and is still far from predicting the accompanying wetting behavior of the macroorganism. There is a growing interest in understanding the mechanisms of wetting of implant surfaces and the role of wettability in the biological response at the implant-bone or implant-soft tissue interface. Fundamental knowledge related to surface hydrophilicity or surface wettability of titanium and titanium alloys, as well as various aspects related to wetting regimes, can improve our understanding of the role of hydrophilic rough implant surfaces on biological outcome. Focusing on titanium dental implants, this study reviews the current knowledge on the wettability of biomaterial surfaces, covering basic and applied aspects, with a particular focus on clinical data.

The aim of the article

To determine the qualitative and speed indicators of osseointegration by comparing titanium samples processed by the SLA method in dry and wet form. To study the role of the oxidized, when interacting with oxygen, surface of titanium on the processes of biointegration.

Materials and methods

For the experiment, fragments of dental implants in the amount of 16 pieces made of Grade 4 titanium (Ti-6Al-4V) were used. The surface of the samples is

represented by the micro- and nano-relief of the topography obtained due to sandblasting with aluminum oxide (during which pores with a size of 20-40 microns are formed) and the subsequent process of double acid etching at different temperatures (which leads to the formation of micropores with sizes from 1 to 5 microns) at the manufacturer's factory. Eight samples were dried after surface treatment and before sterilization, the other 8 samples were immersed in a physiological solution (0.9% NaCl) and remained in it constantly.

For the experiment, 8 sexually mature laboratory rabbits of the California breed were selected. In aseptic conditions, 2 samples of implants (dry and wet) were implanted in each rabbit in the tibia of both paws. The study was conducted in accordance with the necessary regulatory acts (the Helsinki Declaration of 2000 on the Humane Treatment of Animals and the "Rules for Conducting Work Using Experimental Animals"). Telazol (100 mg, diluted in 10 ml of 0.9% NaCl solution) was used as anesthesia. Local anesthesia was also used. The results of osseointegration were assessed using morphological studies. Macropreparations were examined after bone sawing into blocks on the 30th and 90th days after implantation, and after appropriate fixation in 12% neutral formalin with four months of decalcification in 10% Trilon B solution. Sections were prepared and stained with hematoxylin and eosin and pyrofuxin by the Van Gieson method.

Scanning electron microscopy results were obtained using a Tescan Vega 3 SB instrument equipped with an Oxford Instruments X-Act EMF analyzer attachment.

Results

It is known that titanium as a metal is able to oxidize both when interacting with oxygen and in water. To compare the characteristics of the surfaces of the studied implants, electron microscopy of the samples (Fig. 1, 2) was carried out before implantation.

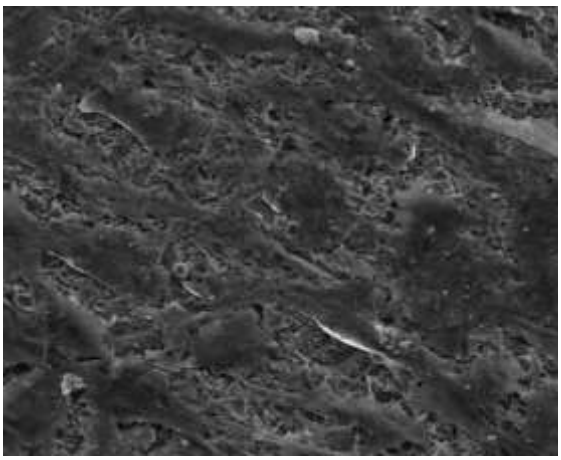

Fig. 1. Surface area of titanium samples of the first clinical group (treated by SLA method, dry) before implantation

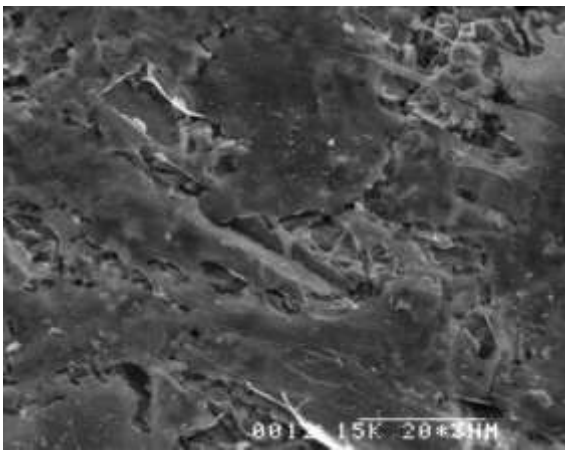

Fig. 2. Area of the surface of titanium samples of the second clinical group (processed by the SLA method, wet) before implantation.

The microscopic picture when enlarged to 3 nm does not give clear data on the superiority of certain samples. The surface of both samples is similar and has no characteristic differences.

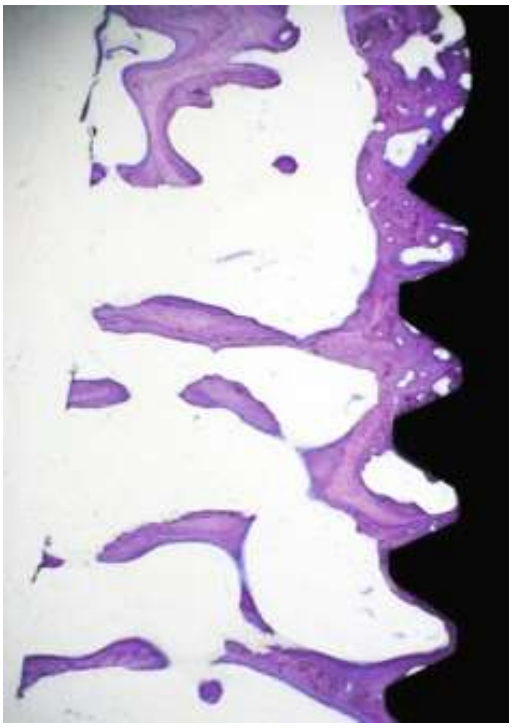

Fig. 3. Tibia bone of an experimental rabbit on the 30th day after implantation. An implant with a dry surface. Staining with hematoxylin and eosin. Coll. × 250.

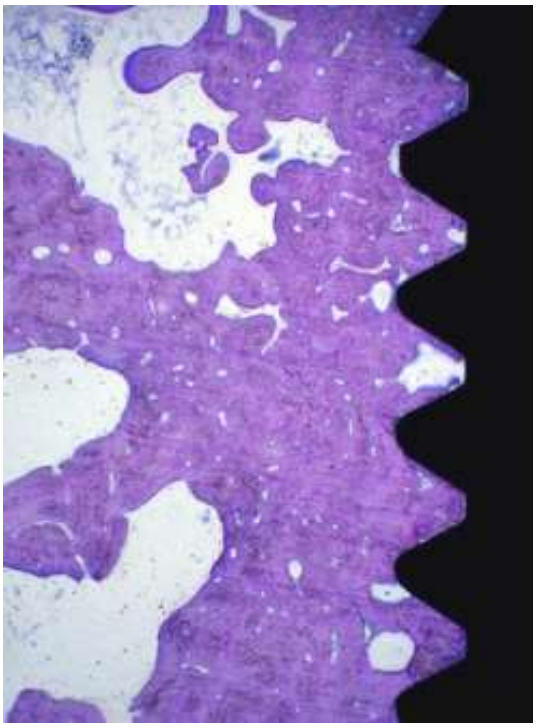

Fig. 4. Tibia bone of an experimental rabbit 30 days after implantation. An implant with a wetted surface. Staining with hematoxylin and eosin. Coll. × 250.

Histological studies conducted one month after implantation demonstrate that a fibrous capsule is formed around the implant, which is combined with the formation of new bone trabeculae. A dense fibrous capsule is lined with a thin epithelial layer.

The connective tissue layer between the implant and the bone is of medium width with a moderate number of cellular elements, mainly fibroblasts with developed fibrillar structures. On all samples with a wetted surface, collagen fibers forming bundles with areas of defibrillation have significantly more contact points with the implant surface. A thin fibrous capsule separates the implant from the newly formed spongy bone (Fig. 3, 4)

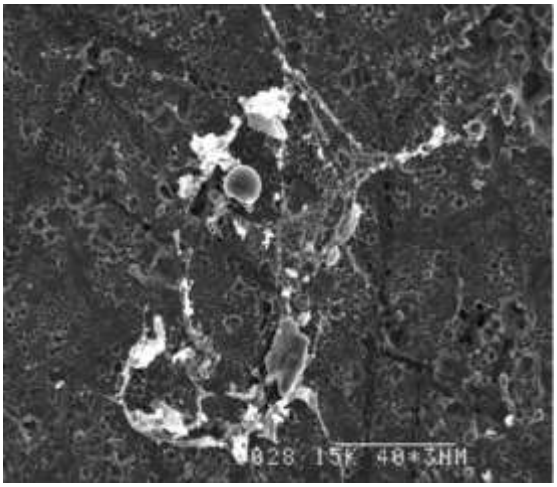

Fig. 5. Surface area of titanium samples of the first clinical group (treated by SLA method, dry) 4 weeks after implantation

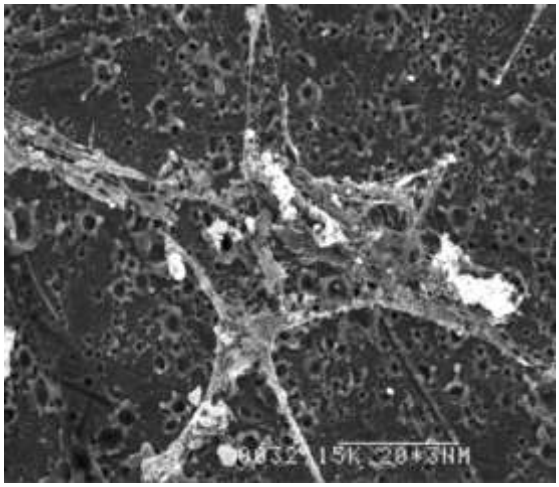

Fig. 6. Area of the surface of the titanium samples of the second clinical group (treated by the SLA method, wet) 4 weeks after implantation

On samples that had a dry surface, under electron microscopy during this period (Fig. 5), separate osteogenic stromal precursor cells can be seen on the surface of the metal, with growths of ectoplasm. At the same time, on samples that were wet, cellular structures "spread out" on the surface of the metal are also noted, with outgrowths of ectoplasm of osteogenic stromal cells of bone marrow precursors fixed for existing irregularities, but slightly more mature (Fig. 6), which indicates about shorter adhesion terms of blood clot cells to these samples.

Three months after placement of the implants, an uneven inner line with teeth is noted in the connective tissue capsule around the implant, which corresponds to the screw-shaped cutting of the implant. There is no connective tissue layer between the implant and the bone. The capsule tightly adheres to the mature compact bone tissue. A clear line of "gluing" was detected on samples with a wetted surface. Thinning of the capsule is associated with the continuation of the process of osseointegration and the growth of bone mass in the thickness of the bone. There are significantly fewer immature bone beams. Numerous gluing lines indicate the gradual layering of the newly formed bone tissue. Bone tissue is mature, compact. (Fig. 7,8)

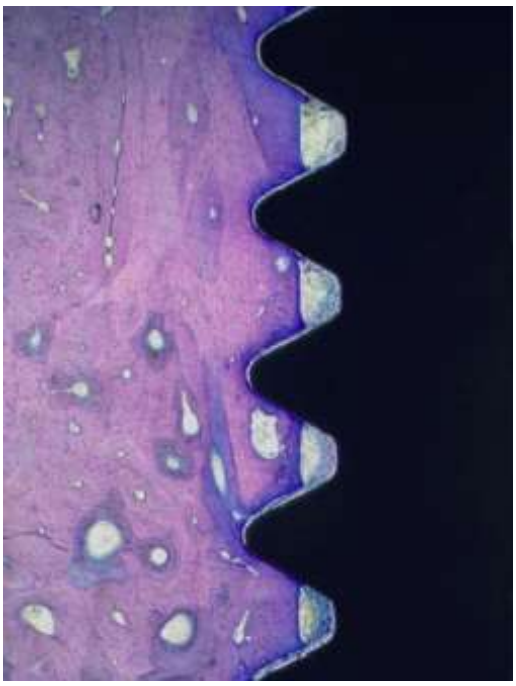

Fig. 7. Tibia bone of an experimental rabbit 90 days after implantation. An implant with a wetted surface. Staining with hematoxylin and eosin. Coll. × 250.

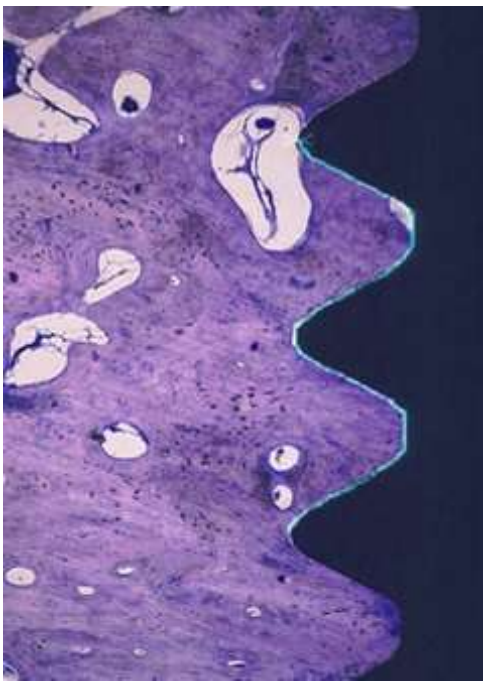

Fig. 8. Tibia bone of an experimental rabbit 90 days after implantation. An implant with a wetted surface. Staining with hematoxylin and eosin. Coll. × 250.

Conclusions

The design of modern implant surfaces provides various variations of their treatment, which stimulates the migration of cells to the wound area, their adhesion, differentiation and proliferation. The wettability of the surface of biomaterials deserves special attention, which determines the speed of the biological cascade of events in the area of biomaterials - bone. **It is obvious and proven by us that titanium interacts with oxygen, and the formed nano-film of titanium oxide on its surface slows down the process of osseointegration. When comparing the same samples of implant fragments, on a wet surface, compared to a dry one, osteoinduction occurs much faster**, which is proven microscopically and morphologically.