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Estimation of the Polfix Type Plates Exploitation at Plate Fixation of Femoral Shafts

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Abstract: The so-far unsolved issues of the biomechanics of the bone – plate stabiliser system functioning in a multi-plate system constituted the main focus of the performed research. The few available publications treat this issue selectively and often generally. The paper presents a damages problems of the Polfix stabiliser at plates fixation. The surface failure at Polfix stabiliser elements showed typical damages for this system. Damages of screw's steepl heads as well as the surface layers failure of the conical holes on clamping plates and the coned seat on tie plates were observed. The surface failure at a clampig's srews at copressive hole were visible in a lesser degree. The biggest wear areas are visible on the cooperating surfaces of the plate sockets and the bone screw heads. Many types of damage characteristic of processes of corrosion damage and tribological wear, mainly abrasive, adhesive, and fretting wear, are observed here.

Keywords: *exploitation, fixation biomechanics, Polfix, fretting, wear.*

1. Introduction

Osteolysis is one of the foremost problems limiting the survival of current implantation procedures. It is induced by the wear particles and corrosion products which incite an inflammatory response resulting in bone resorption and eventual loosening and failure of the bone fixation. Future research will help to limit the effects of wear particles by identifying the most suitable bearing surfaces. The pathologic cascade of events triggered by wear particles may be a potential site of action for drugs intended to prevent or check the progression of the disease [7, 10, 11].

The use of multiple-component systems in orthopedic surgery gives the surgeon increased flexibility in choosing the optimal implant, but introduces the possibility of interfacial corrosion. The corrosion of implant materials is therefore a topic of major significance in biomaterials science. One of the aspect of corrosion it's relation to mechanical fixation [15].

The quality of the fixation and the resulting complications largely depend on the biomechanical parameters of the fixation in question, ie., individual geometry of the miniplate and its mechanical properties, as well as the fixation technique and the surgeon's skill. Inappropriately chosen fixation system might lead to excessive expenditure of its elements and adhesion complications. Excessive wear of the materials used results in lesions in the surrounding tissue.

A current problem related to orthopaedic alloys is corrosion at the taper connections

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of modular joint replacement components. The corrosion processes in cobalt alloy have consisted of intergranular corrosion, etching, selective dissolution of cobalt, and formation of chromium-rich particles including oxides, oxychlorides, and phosphates. The corrosion products generated at the taper connections have migrated into the periprosthetic tissue and the bearing surface of the acetabular component [8, 13].

The research by Marciniak [9] showed that a connective tissue capsule with reactions as well as metalosis are formed in the vicinity of an implant as a consequence of corrosion development. Metalosis is a local influence of metal ions or products of implant corrosion on organism tissues [5].

Osteolysis around an implant is a complex biochemical process closely related to the mechanical functioning of the implant. Activation of osteoblast differentiation is stimulated by cytokines secreted by macrophages as a result of phagocytosis of hydroxypotite and polimethyloxylane and polyethylene as well as metal particles coming from the implant [3, 8].

Contemporary literature shows that the metal fatigue and chronic inflammation along with granulomatous tissue are connected with increased presence of elements responsible for the reactions described above [12, 13].

The presence in a body of the implanted material, its corrosion, and metalosis in consequence, may also become sources of bioelements and contribute to the development of unfavourable reactions [1, 14].

The paper presents a damages problems of the plate fixation. The surface failure at plate stabiliser elements showed typical damages for this system. Damages of screw's steepl heads as well as the surface layers failure of the the coned seat on tie plates were observed.

2. Materials and Methods

Research was conducted on a group of randomly selected cases of plate fixation of femoral fractures (Figure 1). Research material was obtained from areas of direct contact with the implant. Samples were tested for existing chemical makeup with the use of a scanning microscope Hitachi S-3000N. The tests were conducted in speeding voltage of 15kV and measure time of 100s. Additional experimental research into one and two-plate fixation of the femoral fracture.

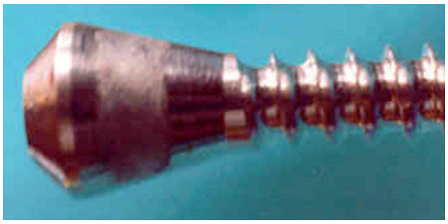

Fig. 1: *A sample view of abrasive damage as a result of the so-called fretting.*

3. Results

The tests of the surfaces of the parts of the Polfix stabilisers used to perform the fixations are indicative of characteristic damage marks. These are damages to the top layer of the holes in the bracing plates and conical sockets in the connecting plates, damages to the conical heads of the cortical screws, and also, to a lesser extent, damages to the surface of the compression holes under the connecting screws, and the heads of the connecting screws themselves.

As a result of the macro- and microscopic observation, two basic types of damage were separated damage of the first and second type. Damage of the first type have a form characteristic to tribological wear; macroscopically, these are marks of friction occurring both on the surfaces of the conical holes in the bracing plates and connector sockets as well as the bone screw heads which cooperate with them. Damage of the second type have a form characteristic to corrosion wear; macroscopically, they are matt places, with some spots of pitting, visible with the naked eye, occurring on the surfaces of the holes in the bracing plates and connector sockets as well as their corresponding bone screw heads.

Fretting-corrosion is a combined damage mechanism involving corrosion at points where two moving metal surfaces make rubbing contact. It occurs essentially when the interface is subjected to vibrations (repeated relative movement of the two contacting surfaces) and to compressive loads. The amplitude of the relative movement is very small, typically of the order of a few microns. When the frictional movement in a corrosive medium is continuous, the resulting process is termed tribocorrosion [2, 6].

Wear processes are most probably initiated as early as during the operation while a stabiliser is mounted. When the connector is fixed on the bracing plates after the bone screws have been previously placed in the bone, all the parts are screwed together using connecting screws. When the connecting screw is screwed in, its head is tightened to the conical hole, and because there are big actual unit pressures, galling might take place when the screw is turned. After the stabiliser is initially assembled, final adjustment of the bone screw immersion is performed through screwing the screws into or out of the bone. Because in the case of bone screw heads and conical holes in bracing plates and sockets in connectors, adhering also appears within small areas, surfaces are easily damaged when screws are turned. After regulating, connecting screws are finally tightened. A force distribution scheme for the bone screw head – bracing plate system is presented in Figure 2.

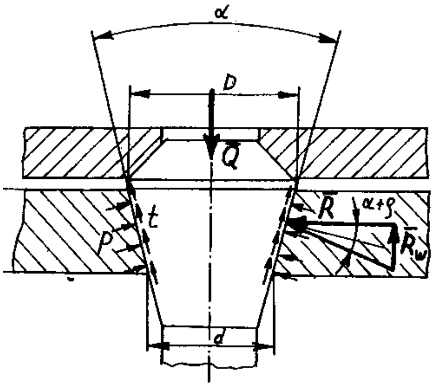

Fig. 2: *Force distribution scheme for the bone screw head – bracing plate system: Q – mounting force of conical fixation, R – radial strain on contact surface, p – unit pressure on contact surface, t – elementary friction force, Rw – negative allowance force Rw=Rtg(ρ+α).*

Abrasive wear marks resulting mainly from micromachining are formed when connecting screws and bone screws are turned while their conical heads are tightened to the plate sockets, which is evident from the wear form and occurrence. Beside that, the passive layer of the surfaces undergoes mechanical damage (abrasion). Wear processes develop particularly intensively in the microcontact areas of fixing parts. Spontaneous screwing out of bone screws under the influence of low-cyclic changeable loadings which a stabiliser undergoes in the period of being used, cannot be excluded, either, as the reasons for abrasive wear. The initial tension of connecting screws and tightening of bone screws should be as big as for screw micromovements or loosening, and thus decreasing the screw tightening, not to take place. It is, however, known that screwed joints can screw out under the influence of changeable loadings. Abrasive processes can be intensified through the presence in the abrasive area of hard wear particles functioning as a 'free abrasive' (the so-called secondary wear).

Definitely, the mechanism of wearing through tacking of the 1st (adhesive) type cannot be excluded, either. It is a process of damaging the surfaces of the cooperating parts intensively when friction takes place, in the conditions of great loadings and plastic strain of the upper layer, especially the highest roughness surface peaks. Local metallic tacking (connecting) of both the abrasive surfaces take place then, and the surfaces are damaged with metal particles being torn off or the metal being smeared on the abrasive surface.

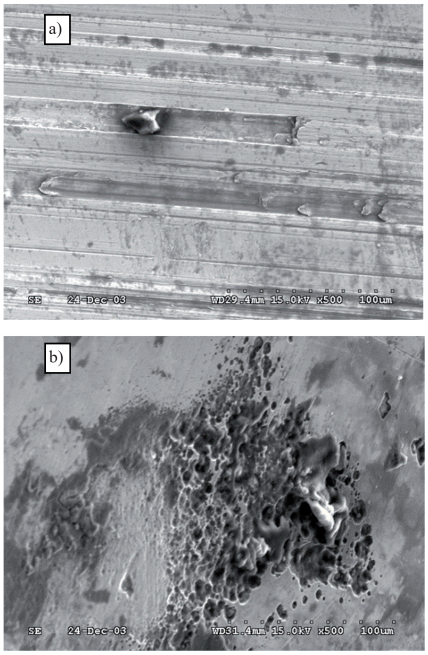

Fig. 3: *A two basic types of damage: a) of the first type (a form characteristic to tribological wear), b) of the second type (a form characteristic to corrosion wear).*

Figure 3 illustrates a view of abrasive damage as a result of the so-called fretting, caused by interactive shifting of the bracing plate, the connector, and the screw head. Wear through fretting is a phenomenon of damaging the top layer, consisting in forming of local material loss areas in the elements undergoing vibration or slight contact slip. Wear through fretting accompanies, among others, cooperation of connections of the pin, screw head r rivet type. Products of fretting are particles in the range of 0.01÷0.1 μm, usually. A very significant consequence of fretting, beside abrasive wear products, is indent (pit) formation on the surface. The indents may be small (when the products leave the contact area), or constitute little areas of deep pitting (when the products are not removed). The character of such damage depends on the number of cycles, the amount of wear products, amplitude, load, and humidity (Figure 4).

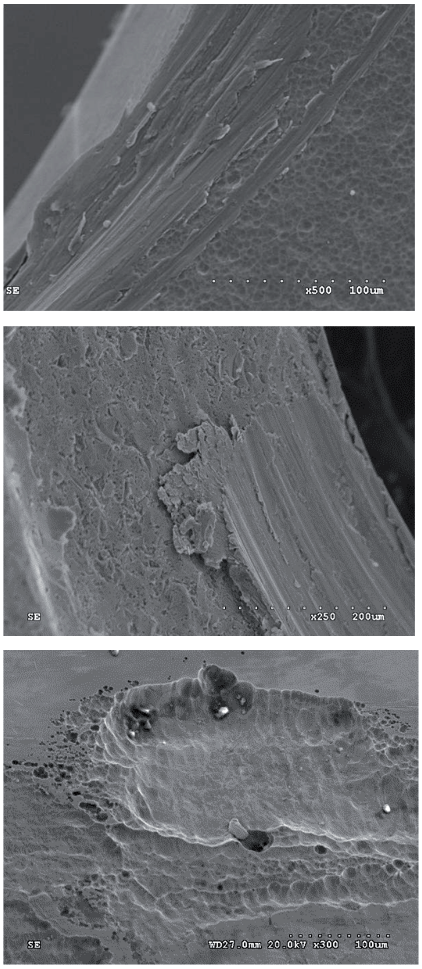

Fig. 4: *Image showing plate wear obtained from the scanning microscope.*

4. Conclusion

The so-far unsolved issues of the biomechanics of the bone – plate stabiliser system functioning in a multi-plate system constituted the main focus of the performed research. The few available publications treat this issue selectively and often generally.

The observations and analyses carried out indicate that the surfaces of the Polfix stabiliser elements used for the two-plate fixation are characterized by a lesser damage. Greater wear of the parts of the fixation system in the case of the one-plate fixation is caused by the character of functioning of this type of fixation. The biggest wear areas are visible on the cooperating surfaces of the plate sockets and the bone screw heads. Many types of damage characteristic of processes of corrosion damage and tribological wear, mainly abrasive, adhesive, and fretting wear, are observed here. The abrasive wear marks are found in the contact areas of the cooperating parts. Wear processes are most probably initiated as early as during the operation while a stabiliser is mounted, and they develop particularly intensively in the microcontact areas of fixing parts. The mechanisms of adhesive wearing cannot be excluded, either. It is a process of damaging the surfaces of the cooperating parts intensively when friction takes place, in the conditions of great loadings and plastic strain of the upper layer. The phenomenon of fretting is caused by interactive microshifting of the bracing plate, the connector, and the screw head.

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References and Notes

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Biographical notes

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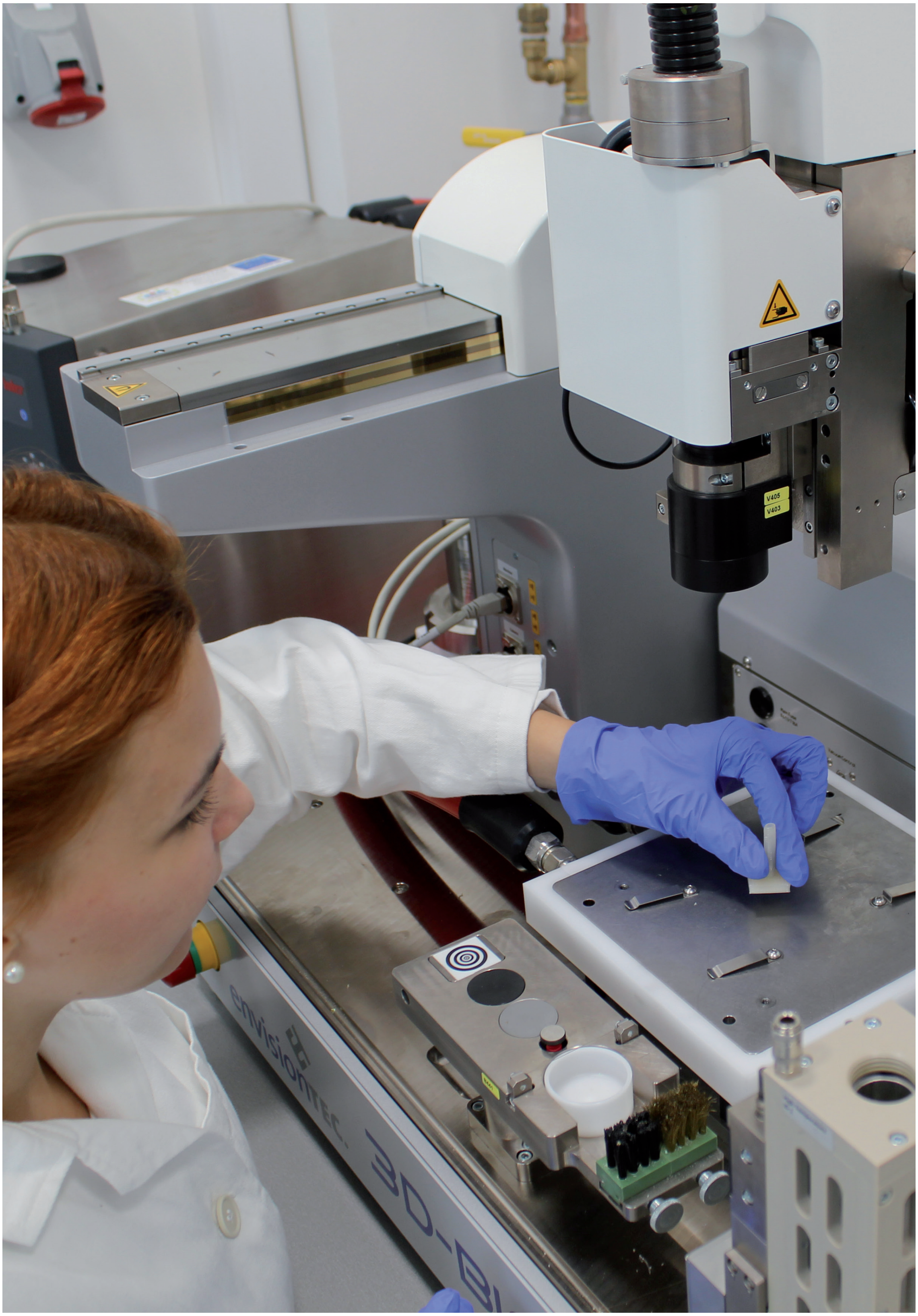
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