1. Introduction

As more increased ageing population affected by osteoporosis, the development of osteofixation has more significant role. Nowadays, in traumatic surgery, generally two types of standardized bone fixing screw threads are used: HA and HB thread of the norm ISO 5835 and ASTM F543. Their common name is corticalis and spongiosa screw, their development is related to the well-known AO Foundation. Numerous studies reported about the fixing mechanism and about failures of these bone screws with FEM method and with in vitro or in vivo testing [5]. It was proved for example, that directly after the clinical insertion, the pull-out strength is minimal due to the tissue trauma and thermal necrosis caused by drilling operations [2]. In this study, we revised the design of these standardized threads by following an unusual material modelling for optimising the osteosynthesis. We designed our new bone fixing thread to a fibre reinforced extracellular ceramic matrix. As a ceramic-type material, the bone is more than three times resistant to compression stress than to shear stress [1]. The conventional ASTM F1839 standard does not define this composite-type property for the rigid polyurethane foam testing specimens of the ASTM F543 pull-out protocol. In this study, we compare the pull-out indexes (maximal loading forces) of the conventional HB-type threaded Manninger-screws [3] used for femoral neck fixing and a new type unstandardized threaded screws. We observed, that the pull-out index can be elevated significantly, if we apply new design ratio based on fibre reinforced ceramic composite theory.

2. Theoretical study

The actual study is based on new point of view, as we modeled the bone-tissue technically as an extracellular ceramic matrix with a very low elasticity modulus. As known in material sciences, the ceramic materials mostly resist compressive forces. Secondary theory, that the bone tissue is not homogeneous, in case of osteoporotic femoral neck, the subchondral area has a higher bone-density. It was observed with numerical simulations also [4], that the conventional asymmetrical HA and HB type thread affect relatively high shear stress to bone tissue during the pull-out mechanism, because the lateral profile angle of the conventional asymmetric threads is between 3° (HA) and 5° (HB) (Fig. 1.). Applying our theory, we elevated the lateral profile angle to HC similar profile of ASTM F543 (Fig. 2.). For improve the self-tapping property we also milled a secondary thread with same pitch.

Fig.1. Schematic of HB thread profile (ASTM F543)

Fig.2. Schematic of HC thread profile (ASTM F543)
3. Experimental Results

Generally complex load affects to the inserted screws, not only pull-out stress. The ASTM F543 (equal with ISO 6475) standard prescribes only axial pull-out test on rigid polyurethane foam specimens (and separate insertion-removal torque measurements). As we wanted to check our theoretical hypothesis about the ceramic matrix composite-type bone model, we decided to leave the standardised testing methods, we executed axial and not axial pull-out measurement on Auropur IH1010 specimens, on animal bones and human femoral necks. We compared Manninger-screws fabricated by HB-type thread whirling process, and our HC-type duplex threaded screws with similar outer dimensions. We applied same drilling method in accordance with the relevant surgical technique. We executed the measurements on Zwick Z20 instrument with special fixative (Fig. 3.).

![Fig. 3. The axial pull-out tests on human femoral necks](https://via.placeholder.com/150)

However, in case of Auropur IH1010 foam we did not found significant differences of pull-out force, but during the animal and human bone pull-out tests, we already observed significant differences.

<table>
<thead>
<tr>
<th>No.</th>
<th>Measuring method and femoral neck specimens</th>
<th>Number of comparing pull-out tests (Manninger, Duplex)</th>
<th>Relative pull-out force growth by using duplex threaded screws</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>axial pull-out test on male femoral necks</td>
<td>2-2</td>
<td>+91,7%</td>
</tr>
<tr>
<td>2.</td>
<td>axial pull-out test on senior male femoral necks</td>
<td>3-3</td>
<td>+112%</td>
</tr>
<tr>
<td>3.</td>
<td>axial pull-out test on female femoral necks</td>
<td>2-2</td>
<td>+82,1%</td>
</tr>
<tr>
<td>4.</td>
<td>not axial pull-out test on male femoral necks</td>
<td>2-2</td>
<td>+85,1%</td>
</tr>
<tr>
<td>5.</td>
<td>not axial pull-out test on female femoral necks</td>
<td>3-3</td>
<td>-21,8%</td>
</tr>
</tbody>
</table>

Tab.2. Comparative test results of maximal pull-out forces

Tab 1. compares the measured maximal pull-out forces in case of Manninger, and our duplex screws. We observed significant difference between the two thread profiles, we measured extra 72,9% pull-out force in case of duplex threaded screws, which were designed by applying our theoretical study. This abstract is not finalized version; additional test reports will be presented on DAS conference.

4. Acknowledgements

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5. References


