BIOMECHANICAL PECULIARITIES OF PLATE OSTEOSYNTHESIS
FOR FRACTURES OF UPPER AND LOWER EXTREMITIES

Summary. In order to study biomechanics of plate osteosynthesis the review of the literature data about the use of different plates and screws for fracture fixation was done. The focus of the review was on the plate design, the connection interface between the screw head and the plate body, and the relations between the type of a plate and the stability of fracture fixation. The application of different types of plates fixed with locking head screws and non-locking head screws were studied for fractures of upper and lower extremities: humerus, forearm, femur and tibia. The application of plates with bigger section area and 4.5 mm or 5.0 mm screws is needed respecting the biomechanical peculiarities of lower extremity fractures, for which body weight is transferred to the fracture site, causing intensive strains in the components of bone-screws-plate system.

Keywords: fracture biomechanics, internal fracture fixation, plate osteosynthesis, fracture healing, relative stability, absolute stability.

Formulation of the problem. The rates of upper and lower limb fractures are increasing all over the world. It was observed that in the Netherlands from 2004 to 2012 Dutch population aged ≥16 years grew from 13,047,018 to 13,639,412 inhabitants, particularly in the higher age groups of 46 years and older. The absolute number of extremity fractures increased significantly from 129,188 to 176,129, except for forearm and lower leg fractures. The incidences of wrist, hand, upper leg fractures were increased by 3–4% [1]. Another common cause of fractures occurring, especially for young males, is road traffic accidents. In India these injuries contributed to 38% of fatal and 39% of non-fatal fractures.
with an annual mortality rate of 18.1/100,000 population/year [2]. According to the research of the incidence of limb fractures of different locations in Sweden that involved 550,000 adults, there were 23,917 individuals sustained 27,169 fractures during the 4-year study period. The mean age of patients with fractures was 57.9 years (range 16-105 years) and 64.5% of the fractures occurred in women. The most common locations accounted for more than 50% of all fractures were: distal radius, proximal femur, ankle, proximal humerus [3]. The surgical treatment of bone fractures – osteosynthesis is performed now for most fractures, as more quick and reliable treatment.

It makes rehabilitation more effective [4], as early stability gives the possibility for early motion [5]. According to some authors the outcomes after non-surgical treatments are comparable with surgical treatment for some fracture locations, because of higher risk of different complications after surgeries [6]. That is why biomechanics at the fracture site is so important. The implants made of materials with different mechanical properties are used for osteosynthesis, and most common implants are plates and screws [7]. These are used for internal fracture fixation for the main four segments of limbs: humerus, forearm, femur and tibia [8]. After internal fracture reduction, plates are usually placed on the bone surface and are fixed by screws to the main bone fragments, so very complicated biomechanical interactions take place between implant and bone fracture. The proper stabilization of the fracture site helps a lot in the healing process. Better biomechanics can prevent the development of complications, delayed healing, implant failure, non-healing and posttraumatic osteoarthritis, and better treatment results can be achieved. The biomechanics of the plate osteosynthesis for the upper and lower limb fractures is different. The application of the correct fixation device is critical for fracture healing and long-term stability; however, it is a complex issue with numerous significant factors. There are varieties of plates and screws available so it should be evaluated which particular type of plate must be used for each fracture pattern.

Purpose of the article. To make literature review on scientific articles that were related to the fracture healing process in cases where plate osteosynthesis of upper and lower extremity fractures was performed. The articles representing biomechanical peculiarities of fracture healing process and its influence on reparative osteogenesis of long tubular bones were chosen. The absolute and relative stability of the fracture fixation for different plates were analyzed.

Presentation of the latest research and publications. The biomechanics for fractures of different bone segments have their peculiarities. Upper extremity fractures should resist mostly the weight of the extremity. The lower extremity fracture should resist additional load as the weight of the whole body. So the process that is applied to the bone fragments in cases of femur and tibial fractures are much higher that is why the design of plates and screws and particularly the size should be bigger. For the upper extremity segments these forces are lower. For forearm shaft fractures we have additional rotational forces and when radial and ulnar shaft fractures are fixed with the plate these rotational forces affects negatively on the fracture site causing problems with fracture healing and implant as well. Another peculiarity of long bone fractures is that in many cases different areas of bones are involved as diaphysis, metaphysis and epiphyseal areas properties of bone tissue are different for cortical and spongy bone all these facts should be considered when proper designs of the plates are chosen.

For proximal humeral fractures that are mostly occurring in old ladies the area of head and surgical neck of humerus consist mostly of bone tissue of poor quality. The 4 part fractures of proximal humerus were considered to be the most severely injured fractures that require primary total joint arthroplasty. For less severe cases locking compression plates should be used to provide good stability for bone fragments. Proximal humeral interlocking plate (PHILOS) was developed for the fixation of 4 part proximal humeral fractures. But it also gives high rate of complications (16-64%), as screw cut-out, varus fracture collapse, tuberosity re-displacement, humeral head necrosis, plate impingement, and plate or screw breakage [8].

The humeral shaft fractures accounted for 3% of all fractures generally seen in elderly population. Due to the result of a fall most of these fractures are managed non-surgically. The initial stabilization of such fractures is done by splinting a U-shaped splint that should be placed as far into the axilla as possible, and the splint should extend over the deltoid laterally. The surgical stabilization is indicated when there is a failure for proper alignment of the bone and also with varus angulation, which may cause difficulty with functional shoulder abduction. For diaphyseal fractures of the humerus both types of plates can be used: locking compression plates (LCP), as well as dynamic compression plates (DCP), but LCP gives the advantage of performing fracture fixation in minimal invasive way but generally speaking both plates can provide good stability and allow early rehabilitation for humeral shaft fracture. The very common disadvantage of plate osteosynthesis is radial nerve palsy. But even with the use of LCP the rate of non-unions for these fractures is 5.6% that was requiring a second surgery [9; 10].

For distal humerus fractures precise reduction and good stability is important if DCP plates are located in different planes which are perpendicular to each other: one plate is located on the posterior or lateral surface and the other is located on the medial surface. Very common problems are delayed healing and non-union at supra condylar area for this location the use of LCP plates combined with bone grafting give us certain advantages [11; 12].

For forearm shaft fractures when especially both bones are involved those types of plates like DCP and LCP can be used. The use of LCP plates gives us the possibility to use different techniques for different fracture types. For complicated fracture patterns the bridge technique is used with insertion of three screws into each bone segment. For simple fracture types the sliding hole can be used for insertion of the first screw to achieve compression between main bone fragments and then locking head screws are inserted [13].
For distal radius fractures two types of plates were used: volar plates and dorsal plates. The first generation plates were standard T plates and the possibility to use locking screws appeared in the second generation of these plates. It gives us better stability against axial forces and the stress of fixation is increased more than four times. The dorsal T-shaped console plates are used very rarely, mostly for dorsally displaced fractures, and have more complications related with tendon impingement [14].

For femoral shaft fractures the mechanical load is more intensive than at the fractures of upper extremity. They require more strong implants for proper fixation that is why the plates which are used for femoral shaft fractures have higher thickness and width and require screws of greater diameter – 4.5 mm and 5.0 mm screws. LCP provides better stability for these fractures, especially in osteoporotic bone. For the axial load the LCP plates show better fixation, but for torsion and bending loads the strength of fixation is even less then for DCP, and that is why the insertion of one additional bone螺钉 on each side is required [15].

For distal femoral fractures where condyles are involved the best solution is lateral femoral LCP plate which compared with L-shape plate can be used in a minimal invasive way. For better stability, multiple spongyous locking head screws should be used in the condylar area [16].

For internal fixation of proximal tibial fractures lateral, medial and posterior plates can be used. Biomechanical function of these plates is buttress support of the tibial head. Fractures involving the joint surface (AO C-type) require interfragmentary compression that can be made by an additional 4.5 mm or 7.3 mm lag screw. LCP and LISS plates can provide better stability, especially for intra articular fractures, where they can reduce the complication rate [17; 18]. For most of the cases due to the angular stability of screws the lateral proximal tibial plate can be used mostly.

For tibial shaft fractures, if the joint is not involved, plates have rare application, as biomechanically intramedullary nails there are more preferable [19].

For distal tibial fractures involving the joint surface distal medial and distal lateral tibial plates are used mostly. Due to the small amount of soft tissues anatomically pre-shaped LCP plates are preferred. The common problems after surgeries are related to intensive swelling after injury and poor blood supply of this area, which results in delayed healing of distal tibia and high complication rate [20].

Conclusions from the conducted research. Different biomechanical conditions on different bone segments dictate special necessities for proper choice of a specific plate and screws. Use of different types of plates with the insertion of non-locking head screws and locking head screws gives the possibility to modify the biomechanical conditions at the fracture site related with the stability of fixation. That has a powerful effect on the fracture healing process. The different types of upper and lower extremity fractures and their localization should consider different types of plates, screws. And the position of screw insertion is also very important for fracture stability [21]. For simple fractures of some fracture locations the dynamic compression plates are also effective. But for osteoporotic fractures plates with locking head screws should be used, combined with minimal contact and anatomical contouring.

References:


