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Analiza wyników leczenia wieloodłamowych złamań końca bliższego kości ramiennej w zależności od zastosowanej techniki stabilizacji. Porównanie osteosyntezy śródszpikowej i płytkowej w trakcie trwania pandemii SARS-Covid-19.

**Rozprawa na stopień doktora nauk medycznych i nauk o zdrowiu
w dyscyplinie nauki medyczne**

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Summary

Analysis of the treatment outcomes of comminuted fractures of the proximal end of the humerus depending on the applied stabilization technique. A comparison of intramedullary fixation and plate osteosynthesis during the SARS-Covid-19 pandemic.

Fractures of the proximal end of the humerus are among the most common fractures in humans. Their occurrence increases with age and progressive bone loss. Improper healing of these fractures or inconsistent and improperly conducted rehabilitation may result in limb disability. Due to the growing number of patients with fractures of the proximal end of the humerus in recent decades (the number of fractures increased three-times from 1970 to 2020, and according to epidemiological estimations, it is expected to triple again in the forthcoming decade), these fractures are considered a significant social problem and even a civilization disease [1-4].

According to contemporary treatment principles, conservative treatment can be applied for non-displaced and minimally displaced fractures. It has been shown that the conservative treatment in these cases can achieve comparable results to the surgical one [5,24,25]. It consists in the immobilization of the limb in the Dessaulte brace for three weeks that is followed by intensive rehabilitation under the guidance of an experienced physiotherapist. However, surgical treatment is increasingly becoming the method of choice, even in non-displaced fractures. This is especially true for young, professionally and socially active individuals, who do not accept long-lasting immobilization and want to return to regular activity as soon as possible. Stable fixation of bone fragments after their anatomical reduction allows to omit immobilization, thereby reducing the risk of soft tissue contractures, joint stiffness and muscular atrophy that require further physiotherapy.

In the operative stabilization of comminuted fractures of the proximal end of the humerus, angular-stable plates and intramedullary stabilizations are currently used. Both methods are considered equal, as the results obtained with their use are comparable. Despite the fact that better functional outcomes were reported after operative treatment with one or another method, meta-analyses performed on large groups of patients (1384 patients) contradict these opinions [47]. Thus, so far no superiority of one method over another has been proved.

In the series of publications included in this Doctoral Dissertation, I have compared both stabilization techniques basing on the data collected during the analysis of treatment outcomes in patients treated in the Department of Orthopedic Surgery and Musculoskeletal Trauma, Medical University, Warsaw, Poland between January 2017 and June 2021. I presented the results of studies illustrating objective (functional and radiological) treatment outcomes evaluated using commonly used and accepted Constant-Murley (CM) and QuickDash (QD) scales. I also provided an information on the pathogenesis, diagnosis, complications, and presented the case with an innovative approach to treating fractures in patients with advanced bone loss.

Review entitled " Comminuted fractures of the proximal humerus - principles of the diagnosis, treatment and rehabilitation" presents a summary of the current state of knowledge on the principles of treatment of fractures of the proximal end of the humerus. It describes the commonly used classifications in adult patients: Neer and AO/ASIF classifications, as well as the Salter-Harris classification for pediatric fractures. The article specifies the principles of patient selection for different treatment modalities based on the type of fracture, age, bone quality, patient expectations, and cooperation. The conservative and surgical treatment principles are presented, highlighting the currently used surgical techniques. Additionally, an example of postoperative rehabilitation is outlined.

In the study " Failures of Operative Treatment of Comminuted Fractures of Proximal Humerus in Own Material" an analysis of the most common complications of operative treatment for comminuted fractures of the proximal humerus was presented. The analysis was performed in a group of 131 patients, who underwent surgery at the Department of Orthopedic Surgery and Musculoskeletal Trauma, Medical University, Warsaw, Poland. Among them, 25 patients experienced complications. The treatment course, influencing factors, and final therapeutic outcomes were evaluated. Improper stabilization was observed in 16 patients, with seven cases leading to functional impairment due to lack of anatomical reduction. In three patients occurred implant impingement with the acromion process. In nine patients, the observed improper stabilization did not affect the final functional outcome. Two patients experienced secondary destabilization despite initially anatomically performed reduction and proper stabilization. Two patients developed avascular necrosis of the humeral head. One case revealed a pathological fracture requiring further oncological treatment. Four patients had apparent errors due to improperly performed postoperative X-rays. The presented conclusions

outline possible operative complications in the treatment of comminuted fractures of the proximal humerus.

In some patients, the progress of demineralization (osteoporosis) occurred to be significant enough to foreclose stable fixation using standard surgical techniques, necessitating specialized implants or bone cement [6]. In article "Intentional Overscrewing of Humeral Head in Comminuted Fracture of Proximal Humerus and its Impact on Shoulder Function. A Case Study" we presented a case, in which stability of screws inserted in the osteoporotic humeral head was achieved anchoring them in the subchondral bone and articular cartilage in way avoiding interference with the loaded regions of the joint during movements. The patient underwent humeral head screw fixation for achieving union stability. A similar injury occurred in this patient on the opposite site 3.5 years later. In this case the configuration of bone fragments enabled stable fixation without humeral head overscrewing. In both cases, stabilization was performed using an angular stable plate (ChM, Poland), followed by three weeks of immobilization in a brace and subsequent intensive rehabilitation. Radiological images, reported pain, range of motion, and functional outcome assessments at 12. and 18. month postoperatively showed that screw fixation of the humeral head, as described above, do not significantly impair the function of the shoulder. This method is not the most advantageous one, but can be used in exceptional situations, and when alternative methods are not available.

In the study " Stabilization of Comminuted Fractures of the Proximal Humerus with Intramedullary Nails and Angularly Stable Locking Plates—Functional Results before and during the SARS-Covid-19 Pandemics" a comparison was made between the functional outcomes of both fracture stabilization techniques under the restrictions imposed during the Covid-19 pandemic, from March 1st, 2020, to June 30th, 2021. Analysis was conducted comparing results with these obtained just before the pandemic, from January 1st, 2017 to September 30th, 2019.

The study included 112 adult patients treated for three- and four-part fractures according to Neer's classification, stabilized with intramedullary nails (IMN, n=64) or angularly stable locking plates (ASP, n=48). The treatment outcomes were evaluated at the sixth month after the surgery basing on the advance of bone union observed on X-ray, assessed precision of fracture reduction (neck-shaft angle; NSA) and position of the implant. The functional outcome of the treatment was assessed using the QuickDash and Constant-Murley questionnaires.

Obtained results showed satisfactory bone union in all fractures, with complications in six cases. During the observation, three patients required secondary surgical intervention due to inadequate reduction: one after IMN and two after ASP. Additionally, one patient stabilized with ASP experienced secondary displacement of the greater tuberosity, and in two cases the implant impinged on the acromion during abduction of the shoulder joint.

Basing on these results I concluded that ASP provided better functional outcomes during COVID-19 according to the Constant-Murley scale ($p = 0.0048$; Student's t-test). However, no statistically significant differences could be observed between the two stabilization methods in the pre - Covid-19 period.

The results showed that ASP seems to be more favorable method for stabilizing complex fractures of the proximal humerus during the SARS-Covid-19 pandemic.

During surgical procedures, it sometimes happens that due to complications, we need to deviate from the preoperative plan and make intraoperative decisions. The case report "Unstable Fractures of the Greater Tubercle of the Humerus. A Case Report" presents the patient, to whom displacement of the greater tuberosity occurred as a result of the reaming of the medullary canal and insertion of the intramedullary nail in it. Fragments of the tubercle proved to be unstable and resisted closed reduction attempts under the guidance of the fluoroscopy. In this case surgeon had been forced to decide to convert the fixation, i.e., removing the intramedullary nail and applying plate stabilization, or to suture the greater tubercle. In this case operator decided to suture the greater tubercle, which required expanding the surgical procedure by extending the incision made for intramedullary nail insertion. This provided access to the fragments of tubercle, which were reduced and stabilized using absorbable sutures anchored to channels in the shaft of the humerus. The fixation proved to be stable, and bone fragment alignment was anatomical. In the patient's follow-up X-rays, complete bone union was observed, and in the functional evaluation, the patient achieved 94 and 96 points on the Constant-Murley scale (for the operated and contralateral limb, respectively) and 4.5 points on the Quick-DASH scale, indicating a very good treatment outcome.

The above-described work demonstrates that suturing unstable bone fragments of the greater tuberosity using absorbable sutures allows for satisfactory reduction and stabilization after intramedullary nailing, which can be used as an alternative to converting the fixation from intramedullary one to plate fixation in cases similar to the described one.

In summary, in presented series of publications I discussed the issue of fractures of the proximal humerus, their treatment, including surgical stabilization methods, and compared them, namely treatment outcomes obtained after angularly stable plating and intramedullary nailing. Basing on the obtained results I concluded that both methods allow obtaining good treatment outcomes, and patients are satisfied with the final therapeutic effect. However, a few complications indicate imperfections in both stabilization techniques. Analyzing functional outcomes I have noticed that the necessity of performing the treatment under specific conditions due to limitations coming from SARS-Covid-19 occurred to be better after plating than nailing, probably due to limited access to physiotherapy. Moreover, during the pandemic, stabilization procedures were performed on Covid-positive patients in an adapted operating room with reduced staff, wearing full viral protection (coverall, goggles), and often without the access of X-ray fluoroscopy. Limited visibility (fogged goggles), lack of thermal and respiratory comfort restricted the possibility of effectively stabilizing the fracture using intramedullary nails. Under these circumstances, plate fixations with wider surgical approach became much easier and, as the analysis of long-term functional treatment outcomes showed, also significantly more functionally beneficial.