REVIEW

by Prof. Dr. Diyan Enchev, Ph.D.
Head of First clinic of Orthopedics and Traumatology
at UMHATEM “N. I. Pirogov”

Subject: Dissertation of Dr. Lyubomir Simeonov Rusimov: **„Intramedullary allograft augmentation in unstable proximal humerus fractures fixed with locking plate”**. The doctor is orthopedic surgeon at "Second clinic of Orthopedics and Traumatology" at UMHATEM “N. I. Pirogov”, Sofia.

By order № RD 26-524 / 14.02.2022 from the executive director of UMHATEM "N.I. Pirogov" I was appointed as a member of the Scientific jury and with its decision (Protocol № 1) I was determined to present a review about the dissertation work of Dr. Lyubomir Simeonov Rusimov on the topic: **„Intramedullary allograft augmentation in unstable proximal humerus fractures fixed with locking plate”**. Dr. Rusimov is a free doctoral student registered with the right to defend (order № RD 26 – 522/ 14.02.2022) in the Scientific Council of UMHATEM "N.I. PIROGOV", in higher education area 7. "Health and Sports" in professional section 7.1 "Medicine" and scientific specialty "Orthopedics and traumatology "

Upper limb fractures have long been neglected in the orthopedic community. The fact that the limb is hanging and is not responsible for locomotion is a major factor. The other problem is that the stability of the fixation was difficult to achieve. With the available implants for fixation in the past, despite the restoration of the rotator cuff and tubercles, the results were at least disappointing. Thanks to the complex anatomy and the combination of the greatest mobility and at the same time the complex stability of the shoulder joint, the attempts for successful fixation go through various methods. The great variety shows obvious helplessness for decades. Thus, conservative behavior was the method of choice even for leading clinics here and abroad. However, the functional results were not encouraging at all. It was simply accepted that the maxim was to do less harm and to accept reality. This approach is now possible in inoperable patients or those with very low functional demands. In this regard, the primary shoulder prosthesis develops (anatomical or Reverse), but with still debatable problems such as the survival of the artificial joint and the functional results after joint replacement. With

the advent of modern locking plates (LP), stable fixation has become largely achievable in the hands of most orthopedic traumatologists. New surgical exposures have been developed. Thus, the number of supporters of surgical treatment became more and in a number of academic studies this was strictly reflected. Naturally, the indications for the choice of surgical treatment as an appropriate method for proximal humerus fractures (PHFs) have also expanded. Difficulty re-emerged with stable fixation in unstable comminuted fractures and those with concomitant osteoporosis. Undoubtedly, achieving bone healing in an anatomical position is a major factor in reducing complications such as fixation failure, screw cutting, varus collapse and avascular necrosis (AVN). The latter, although not easy, with the accumulation of surgical experience in most cases becomes achievable over time. Stable fixation of a comminuted fracture with a bone defect and the structure of fragments resembling an eggshell is a serious problem, even with locking plates or modern intramedullary nails. Revascularization is possible in a stable environment. The study of Gardner is the first to evaluate strengthening LP fixation with a calcar screw to prevent varus collapse. It opened the door to the idea of augmenting the locking plate osteosynthesis in these fractures. Stability is better with calcar screw, but does not solve the problem of bone deficiency and fracture biology. The balance between these two factors, obligatory for bone healing, has long been the subject of discussions and publications by academia. The idea of augmentation and enchancement of biology is old and can be found in a number of studies since the 70s, 80s and 90s of the last century. The use of autologous bone has long been a daily practice in the treatment of fractures. With the advent of locking plates and minimally invasive fixation methods, the use of grafts remained in the background and the focus was exclusively on better stability and gentle surgical technique. This is true, but in a number of intra-articular fractures, classical open surgery is the guarantor of anatomical reduction and good functional outcome. At the same time, technologies of processing cadaver bone have been developed with reduced risk of transmissible infections. This is the technology of deep-frozen allografts that retain their structure and allow revascularization and incorporation at a later stage. They have no osteoinductive function, but has a mechanical function and a "scaffold" that allows the graft to be incorporated in the bone. With the advent of these options, proponents of fixation with

locking pates in PHFs have been given another option for organ-preserving surgery with fewer complications and a predictable outcome. And undoubtedly for the majority of patients with unstable fractures this is a new and good opportunity.

In recent years, a number of modern biomechanical and clinical studies have proven the benefits of augmentation of locking plate fixation by intramedullary allograft.

In the present dissertation, the author has focused on this contemporary problem. How to achieve optimal fixation in unstable PHFs, to improve the chances of consolidation in good reposition and to reduce the likelihood of developing AVN ?

The dissertation is structured on biomechanical research and clinical research. The studies were carried out in the clinics of orthopedics and traumatology of the University Hospital "N. I. Pirogov ”and in the Department of Biomechanics at the AO Research Institute Davos.

The dissertation has a volume of 152 pages. It is divided into 4 chapters. The bibliography includes 389 titles, of which 3 in Cyrillic and 386 in Latin and is presented on 22 pages. It is illustrated with 49 figures, 34 tables, graphics and photos. The presented figures, tables and graphics are of high quality and excellent informativeness. Many of them are in color, which facilitates the perception of the text.

In the introductory part of the scientific work, the author presents the problems of treatment of unstable PHFs in historical and modern aspects. The balance between biology and mechanical stability has been identified as a fundamental problem in fractures with an initially unfavorable prognosis. The working hypothesis has been developed, that optimal stability can be achieved only by precise reduction, intramedullary allograft (IMAG) and properly placed angularly stable plate.

The aim and tasks are logically formulated and presented immediately after the introductory part. The presented intention of the study is t**o evaluate the construction of an intramedullary graft and a locking plate in the treatment of unstable ischemia-prone unstable fractures of the proximal humerus**. The tasks are defined in such a way that solving them will meet the set aim: to study the results of the literature, to test experimentally a sufficient number of specimens with IMAG and LP construction, forming databases for own biomechanical results, to evaluate the treatment with the same construction in a sufficient number of patients, to find a

connection between the obtained biomechanical and clinical results, to answer the question of whether the method is safe and effective for the treatment of unstable PHFs and whether the method can be an organ-preserving alternative for the high-risk of developing ischemia PHFs.

The literature review is 61 pages long. The section presents the applied anatomy and biomechanics of the shoulder joint and the shoulder girdle. The bone and ligament anatomy, soft tissue anatomy, main vessels and nerves, biomechanics of the shoulder joint, including that of the shoulder girdle, are examined in detail. The epidemiology of PHFs, the mechanism of the injury and the most important classifications used in the literature are comprehensively presented. The main methods of modern image diagnostics are described. The methods of treatment are set out on 27 pages. All methods of fixation that are necessary in practice and in the literature are affected - "fixatio ad minima" with K-wires, external fixation, osteosynthesis with antegrade nail, fixation with conventional and locking plates, the latter with their specific biomechanics are developed in the text by the author and are directly related to the essence of scientific work. Fixation methods are presented critically with their results and complications. A very good impression is made by the in-depth examination of the various methods of augmentation with a locking plate. The material is developed on the "diamond concept" of Giannoudis, which adds the requirement for mechanical stability. The use of frozen fibular allograft, which is the basis of the concept of the present work, has been formulated scientifically substantiated. According to the author, smaller segments of allogeneic cortical grafts, such as fibular allograft, are more easily incorporated into bone due to potentially easier vascularization, and therefore this type of graft is widely used to treat PHFs. This conclusion is confirmed by the scientific reports presented by Dr. Rusimov in the literature on the application of the fibular graft.

Chapter 2 presents the materials, methods and patients. The biomechanical experiment was performed in the Department of Biomechanics at the AO Research Institute Davos in Switzerland and is developed in 6 pages. The research has a clearly formulated aim, precisely performed and with specific conclusions that form the basis of this dissertation. The addition of an intramedullary graft to the locking plate fixation

significantly increased the rigidity of the construct in groups 1 and 3 (but not in group 2) and significantly reduced the varus deformation in all study groups.

The clinical trial was performed for a period of 5 years and 10 months (01.2015 - 11.2020) at the UMHATEM "N. I. Pirogov ” including 114 patients. All patients were treated with LP and IMAG. Of these, 111 patients included in the study met the criteria set by the author. 47 were followed-up. Of these, 37 were women and 10 were men. The average age was 63.2 years (33 - 84). Fractures were displaced and unstable with additional signs of instability and complexity, as well as such types of fractures prone to ischemia of the humeral head, meeting one or more of Hertel's criteria. Classical deltopectoral approach was used in 25 patients and minimally invasive approach (lateral transdeltoid and anterolateral approach) - in 22 patients. In 31 cases a fibular graft was used for augmentation and in 16 cases a lyophilized tibial graft was used. For functional evaluation Constant-Murley Score and DASH Score (Bulgaria) were used.

The mean follow-up was 28 months (12 - 79). The evaluation of the results was made by the author with a clinical study and on the basis of radiological parameters measured postoperatively and at the final follow-up. Secondary displacement, varus collapse, screw penetration, AVN, construct failure, subacromial impingement were reported. Schnetzke's criteria for fracture repositioning are discussed in detail.

The surgical technique is presented comprehensively and thoroughly. From the text, the smallest but important details of the stages of fixation with LP and IMAG become clear. Visualization is also very good.

Complex assessment of functional results, Dr. Rusimov has performed using the established in the scientific literature DASH Score (The Disabilities of the Arm, Shoulder and Hand) adapted in Bulgarian and Constant-Murley Score (CS) with the three varieties of scale: absolute (CSabs); relative (CSrel); individual (CSindiv).

All data were processed and systematized statistically by descriptive statistical analysis, Student's test (t-test) for two independent samples, Student's test (t-test) for two paired samples, analysis of variance (ANOVA) and logistic regression. Thus, the scientific value of the work is clearly verified.

Chapter 3 contains 25 pages and develops the results of the biomechanical experiment and the results and complications of the clinical trial. The author presents

and analyzes in detail all aspects that affect the results: mechanism of injury, medial comminution, primary displacement, local bone quality, fracture type, predictors of ischemia according to Hertel, duration of intervention, number of surgeons and their surgical activity. Functional and radiological results are considered. Complications and reoperations were reported. Moreover, the results and complications are systematized and statistically processed in relation to age, surgical exposure, graft used, bone quality and reposition quality.

Chapter 4 (Discussion) is set out in 34 pages. In this chapter, every physician involved in the topic or interested in it will find answers to almost all questions discussed in the literature and arising in practice in the treatment of unstable PHFs. The role of the medial calcar support as a major factor for varus collapse, screw penetration and its biological significance for the perfusion of the head fragment was analyzed. An analysis of the possible methods for overcoming the calcar deficiency and the role of the calcar screw is also made. Author’s own results are analyzed. The problem of osteoporosis has been thoroughly studied. A number of studies have been analyzed, including the author's own biomechanical study. The author's conclusion on this issue is logical and supported by his own experiment. The “parachute surgical technique” of restoring greater and lesser tubercles is also commented on in all its aspects. The analysis made by Dr. Rusimov about the importance of the anatomical reposition of the fracture deserves special attention - a topic that is especially relevant in recent years. The importance of using the intramedullary graft as a good medial support and an option to restore the anatomical relationship between the humeral head and the diaphysis is derived and explained. The advantages of fibular grafting are also indicated. A critical analysis of other augmentation methods based on reports in the literature has been made.

In the last part of the discussion, the author examined his own results and complications and compared them with those of scientific reports. He has thoroughly and critically developed the still unresolved dispute for surgical or non-surgical treatment of these provocative fractures and has analyzed the possibilities of different exposures and implants for fixation.

In the “Conclusion”, two working hypotheses are formulated which explain the set aim and tasks. Based on the biomechanical experiment and the clinical study, Dr. Rusimov found that the graft provides reliable restoration of the medial support in bone with different mineral densities. Moreover, the created elastic construction allows interfragmentary movements between 0.2 and 0.8 mm, which are within the tolerance of the newly formed callus and therefore stimulate its development. He also points out the important stages of the surgical intervention, emphasizing the special importance of anatomical reposition for reducing the frequency of AVN. Quite logically, the author concludes that the augmentation with intramedullary allograft of the fixation with LP in PHFs prone to ischemia, is based on solid biomechanical foundations. From a clinical point of view, it is predictable, safe and effective. With this statement I completely agree.

In conclusion, I believe that the dissertation work is one of the few in our specialty developed on serious biomechanical research in synergy with in-depth clinical research. The “Literature review” is presented comprehensively in sufficient volume. “Materials and methods” are very well systematized. The results and complications are presented at a level with very precise statistical data processing. Biomechanical research is developed and incorporated in the work in a logical and complete form. In the chapter "Discussion" the author has demonstrated deep knowledge in this field and capacity for analysis at a very good level. I fully accept the conclusions made and agree with the contributions of scientific work. The style and the presentation make the work a fascinating read. A thorough review of the work on the ground revealed several spelling errors and a tautology. Physical examination, although briefly, is unnecessarily described in the literature review. In the section "surgical anatomy" the anatomy is presented in general without a clear focus on its surgical aspect related to PHFs. However, these are insignificant remarks that do not diminish the value of the dissertation in any way.

I believe that the dissertation has all the necessary qualities, scientific and practical, and meets the necessary criteria for obtaining an educational and scientific degree "DOCTOR". I give a **positive valuation** and invite the members of the "Scientific Jury" to award Dr. Lyubomir Simeonov Rusimov with the scientific and educational degree "DOCTOR".

12.04.2022, Sofia

Prof. Dian Enchev, Ph.D.