REVIEW

On dissertation written by Dr. Lyubomir Simeonov Rusimov

For acquiring the educational and scientific degree PhD / ”Doctorate”

Dissertation topic: **„Intramedullary allograft augmentation in unstable proximal humerus fractures fixed with locking plate”**

Reviewer: **Prof. Dr. Nedelcho Tzachev, PhD**

Head of department of Orthopedics, Traumatology, Reconstructive Surgery and Rehabilitation at Military Medical Academy, 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 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 "

Dr. Lyubomir Rusimov was born on December 26, 1988 in Kyustendil. In 2007 he graduated from High School of Mathematics and Science "Prof. Emanuil Ivanov", Kyustendil with a profile in biology and chemistry. In 2014 he graduated medicine at the Medical University, Sofia. In 2015 he started working at the UMHATEM “N. I. Pirogov”, Second Clinic of Orthopedics and Traumatology, which is his present workplace today. Since 2019 he has been enrolled as a doctoral student, and in 2020 he successfully passed the exam for acquiring the degree - specialist in "Orthopedics and Traumatology". During the period 09.2017-01.2018 he completed a fellowship at the AO Research Institute, Davos, Switzerland. Dr. Rusimov participated in the following courses: **2016-**AO Trauma Seminar – Current Principles of Fracture Management, Roadshow, Bulgaria edition; **2017-**AO Trauma Course – Basic Principles of Fracture Management, Davos, Switzerland; **2018-**AO Trauma Course – Pediatric Fractures, Sofia, Bulgaria; **2019-**AO Trauma Course – Advanced principles of fracture managements, Sofia, Bulgaria; AO Trauma Course—Approaches &

Osteosynthesis with Anatomical Specimen, Graz, Austria; AO Trauma Seminar – Shoulder and Elbow, Sofia, Bulgaria.

He is a member of the following scientific societies: Bulgarian doctor's union, Bulgarian Orthopedics and Traumatology Association, AO Trauma Bulgaria, EFORT. He speaks English and German.

Dr. Rusimov was appointed by order № RD 26-51 / 04.01.2019 of the Director of UMHATEM "N. I.Pirogov" as a free doctoral student in independent training in the specialty "Orthopedics and Traumatology". The dissertation was discussed, voted and directed for defense by the Primary Scientific Unit of Orthopedics and Traumatology at the University Hospital "N. I. Pirogov" (order № RD 26 – 522 / 14.02.2022). After discussing the work by the members of the Scientific Council of the hospital, it was decided that the work is dissertable, has the necessary contributions and can be defended in front of a competent jury.

The topic of surgical treatment of proximal humerus fractures has been a topical issue for the last two decades. Conservative treatment of unstable fractures is the cause of chronic pain and limited movement in patients of different ages. The insight into the details of fracturology of this type of injury and the progress of metal science tip the scales for more frequent use of surgical treatment. The dynamics of life and the requirements of patients with such disabilities have given an incredible impetus in this area. In proximal humerus fractures, most, if not all, known methods of operative stabilization known to our specialty have been applied with varying degrees of success. Needle fixation with Kirchner wires applied for a long period of time has been associated with many inconveniences for both the traumatologist and the patient. Due to the many complications observed, it was gradually replaced by stand-alone screw synthesis. For some time, the use of cannulated screws led to significantly better functional and radiological results. This, in turn, has given impetus to proponents of surgical treatment and the use of plates of various designs, including intramedullary nails of several generations. In recent years we have witnessed the application of increasingly complex but mechanically justified unipolar and total shoulder endoprosthesis - anatomical and "Reverse" -variant. This leads to the conclusion that with so many methods, the results are far from desirable. The "dangerous charm" of the shoulder joint, a definition that the author of this paper uses, seems to be based on the almost perfect balance between stability and mobility. In displaced and unstable fractures, the most serious complication is arterial supply of the humeral head. In practice, we observe all possible complications of bone healing -

consolidation in a vicious position or non-union, as well as varying degrees of deformity based on avascular necrosis. All this creates unfavorable conditions for the healing of soft tissues and inevitably negatively affects the stability and mobility of the joint. Practice has shown that it is wrong to focus only on the type of implant without paying as much attention to the quality of reposition and bone biology. The three factors are interrelated and none of them should be underestimated. An implant functions optimally only with good reposition, which in turn supports the processes of revascularization and bone healing.

In recent years, several biomechanical and clinical studies have reported excellent results, combining the benefits of locking plate and the properties of intramedullary allograft. The present work is also dedicated to this thesis. In the presented material the author seeks an answer to the question: is it possible, by achieving optimal biomechanical stability, to improve the chances of consolidation in the right position and reduce the likelihood of developing AVN in PHFs at risk of ischemia? He believes and defends the thesis that optimal (maximum) stability can be achieved only through precise reposition, intramedullary grafting and properly placed angularly stable plate.

Dr. Rusimov's dissertation is written on 174 standard pages. It is illustrated with 49 figures and 34 tables. It is structured in the usual way for a dissertation, observing the normal proportions between the sections. The bibliography includes 389 titles, of which only 3 are by Bulgarian authors who are not in the field of shoulder surgery.

In relation to the dissertation, one scientific publication and 9 participations in conferences were presented:

1. Rusimov, L. Unstable fractures of the proximal humerus. Addition of intramedullary allograft to locking plate synthesis. Is it a necessity? XXV Conference "Days of Bulgarian Orthopedics and Traumatology", Borovets, Bulgaria, October 1-2, 2021.

2. Rusimov, L., I. Zderic, D. Ciric, J. Barcik, M. Rashkov, M. Hadzhinikolova, G. Richards, B. Gueorguiev, D. Enchev, A. Baltov. Unstable fractures of the proximal humerus – benefits of using intramedullary graft in locked plate fixation. 14th national congress of the Bulgarian Orthopedic and Traumatology Association (BOTA), Varna, Bulgaria, 3 – 6 October 2019.

3. Rusimov, L., I. Zderic, D. Ciric, J. Barcik, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, A. Baltov, B. Gueorguiev. Does supplemental intramedullary grafting increase stability of plated proximal humerus fractures? 2nd International Combined Meeting of Orthopaedic Research Societies (ICORS), Montreal, Canada, 19 – 22 June 2019.

4. Rusimov, L., I. Zderic, D. Ciric, J. P. Barcik, D. Enchev, M. Rashkov, M. Hadzhinikolova, G. Richards, B. Gueorguiev, A. Baltov. Does Supplemental Intramedullary Grafting Increase Stability of Plated Proximal Humerus Fractures? – In: Journal of orthopaedic trauma, 33(4), 2019, pp. 196 – 202, https://doi.org/10.1097/BOT.0000000000001376.

5. Gueorguiev, B., L. Rusimov, I. Zderic, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, A. Baltov. Does intramedullary grafting increase stability of plated proximal humerus fractures? DKOU, Berlin, Germany, 23 – 26 October 2018.

6. Gueorguiev, B., L. Rusimov, I. Zderic, D. Ciric, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, A. Baltov. Supplemental intramedullary grafting increases stability of plated proximal humerus fractures. 39th SICOT Orthopaedic World Congress, Montreal, Canada, 10 – 13 October 2018.

7. Rusimov, L., I. Zderic, D. Ciric, D. Enchev, M. Rashkov, M. Hadzhinikolova, G. Richards, B. Gueorguiev, A. Baltov. Does intramedullary grafting increase stability of plated proximal humerus fractures? EORS, Galway, Ireland, 25 – 28 September 2018.

8. Rusimov, L., D. Ciric, I. Zderic, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, B. Gueorguiev, A. Baltov. Does supplemental intramedullary grafting increase stability of plated proximal humerus fractures? Conference Graubünden forscht – Young Scientists in Contest, Davos, Switzerland, 19 – 20 September 2018.

9. Rusimov, L., I. Zderic, D. Ciric, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, B. Gueorguiev, A. Baltov. Biomechanical evaluation of conventional versus augmented PHILOS plating using intramedullary grafting. 8th World Congress of Biomechanics (WCB), Dublin, Ireland, 8 – 12 July 2018.

10. Rusimov, L., I. Zderic, D. Ciric, D. Enchev, M. Rashkov, M. Hadzhinikolova, R. G. Richards, B. Gueorguiev, A. Baltov. Does supplemental intramedullary grafting increase stability of plated proximal humerus fractures? 19th EFORT Congress, Barcelona, Spain, 30 May – 1 June 2018.

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The **aim** of the work is formulated clearly and precisely: to evaluate the construction of an intramedullary graft and a locking plate in the treatment of unstable and prone to ischemia fractures of the proximal humerus. The 6 tasks set for its solution have been completed and have allowed the author to achieve it convincingly:

1. To study the results of the literature.
2. To test experimentally a sufficient number of specimens with the construction of IMAG and LP, forming a database of own biomechanical results.
3. To treat a sufficient number of patients with the construction of IMAG and LP, forming a database of own clinical and radiological results.
4. To look for a relation between the obtained biomechanical and clinical results.
5. To answer the question: is the method safe and effective in the treatment of unstable fractures of the proximal humerus?
6. To answer the question: can the method be an organ-preserving alternative for fractures with high-risk of ischemia?

The dissertation is written concisely and competently by a person who went deep into the problem.

Section I: Literature review covers 60 pages. The anatomy of the shoulder joint is described in detail. The large volume of movement due to three anatomical and two physiological joints. Emphasis is placed on the anatomical elements of proximal humerus and scapula, their dynamics during the growth of the organism, blood supply and soft tissue anatomy with the adjacent ligament apparatus, muscular and vascular-nervous structures. The biomechanics and structures stabilizing the shoulder joint are described.

PHFs represent about 4 - 5% of the total number of fractures in the human skeleton, and this percentage doubles in patients over 65 years of age. The incidence of PHFs is constantly

increasing due to the aging population, and according to some authors their number may increase from two to three times in the next 30 years. In patients over 65 years of age, PHFs rank third in frequency after proximal femur fractures and distal radius fractures and are the second most common fracture of the upper limb. Of the total number of fractures of the humerus, the largest number are PHFs (47 - 50%), followed by fractures of the distal humerus and humeral diaphysis. Of the traumatic injuries of the shoulder girdle, 53% are by PHFs.

Chronologically are described the classification systems known in the literature and their practical application and prognostic orientation for AVN of the humeral head. The preservation of the dorso-medial metaphysis "attached" to the humeral head and the integrity of the periosteal medial hinge provide some blood supply to the head from a. circumflexa humeri posterior.

In terms of diagnostics, the author describes the clinical methods of research and the rich arsenal of modern imaging.

According to the author, the absolute indications for surgical treatment of PHFs are: three- and four-fragment fractures - dislocations, split fractures of the humerus head, pathological fractures, open fractures, fractures with accompanying severe ipsilateral injuries of the shoulder girdle and concomitant vascular and / or neurological injuries. According to the Neer criteria (displacement over 1 cm and angulation over 45 °) indicated for surgical treatment are displaced PHFs, which account about 15 - 20% of the total number of PHFs.

The three main surgical approaches (deltopectoral, antero-lateral and lateral transdeltoid) are described.

In describing the available implants applicable to this type of injury, the author definitely emphasizes the technique with locking plates and the use of bone grafts.

Section II: Materials and method contains 22 pages. The section begins with the description of a biomechanical experiment aimed at examining the biomechanical behavior of LP fixation and IMG augmentation and comparing it with conventional LP fixation. 30 specimens were used, divided into three groups. In group 1, a 10 mm gap was created by osteotomy distal to the level of the surgical neck, and the created defect simulated fragmentation of the medial cortex. In group 2, osteoporotic bone with a massive cancellous bone defect was simulated, and in group 3, the fracture model included a combination of defects in group 1 and group 2.

Machine data in terms of axial load and displacement were acquired at a rate of 128 Hz. Based on these, axial stiffness was calculated from the ascending linear slope of the load-displacement curve between 40 N and 120 N compression.

Radiographic images were used to determine varus deformation after each incremental load, which was defined as the change in the angle between the humeral head and shaft fragments in the frontal plane in relation to the 10 N preload level. The centroid location of each marker was automatically assessed, based on gray-scale image segmentation. The evaluation was performed with the use of Matlab software (v. R2012b, The Mathworks Inc., Nattick, MA, USA).

Statistical analysis for the parameters of interest, axial stiffness and varus deformation was performed using SPSS software package (v. 23, IBM SPSS, Armonk, NY, USA). A priori power analysis resulted in a minimum of 10 specimens required per group for statistical power of 0.8 under the assumption that the standard deviation of the parameters of interest in each group is not bigger than 75% of the minimum difference in their means between the groups. Normality of data distribution was screened and proved with Shapiro-Wilk test. Differences between the study groups and specimens' states to investigate the effect of grafting and incremental loading were assessed using General Linear Model Repeated Measures with Bonferroni Post Hoc tests for multiple comparisons. Post Hoc power analysis was performed to calculate the actual statistical power in the study. The level of significance was set to 0.05 for all statistical tests.

For a period of 5 years and 10 months in the UMHATEM "N. I. Pirogov ", 114 consecutive and unstable PHFs (meeting the pre-set selection criteria by the author) were subjected to a treatment algorithm using IMAG and LP The final number of follow-up patients was 47. Patients were followed-up for an average of 28 months (12 - 79). Complex assessment of functional results was performed on the basis of objective and subjective (patient-side) criteria, using two functional scales:

1. **DASH** Score (The Disabilities of the Arm, Shoulder and Hand), adapted in Bulgarian.
2. **Constant-Murley Score (CS)** with the three variants of the scale: absolute **(CSabs)**; relative **(CSrel)**; individual **(CSindiv)**.

For the purposes of the present study, the following statistical methods were applied: Descriptive statistical analysis - the frequency distribution of the considered traits is presented in tabular form, Student's test (t-test) for two independent samples, Student's test (t-test) for two paired samples - to detect a statistically significant difference in the mean values of a factor before and after treatment. Analysis of variance (ANOVA) - in order to determine the

presence / absence of influence of two or more factors on the average values of the studied traits, without measuring the narrowness or strength of the dependence, as well as its direction. Logistic regression - to detect statistically significant factors (reposition, Hertel's criteria) that are prognostic for the occurrence or non-occurrence of a complication (eg. AVN). The logistics model, in addition to determining the significant factors, also makes it possible to calculate the estimated probability with which a given value of the factor is expected to cause complications. It is because of the ability to predict the likelihood of complications that the logistics model was chosen in the present study.

Section III: Results and Complications is structured on 24 pages. The results in 47 followed-up patients meeting the accepted criteria were reported. Of these, 37 are women and 10 are men. The average age is 63.2 (33 - 84) years. The mean follow-up was 28 months (12 - 79). They are very well illustrated in tabular form: distribution of fractures according to the mechanism of trauma, distribution of fractures according to the Neer classification, additional instability criteria (the presence of medial comminution, the primary displacement of the fracture in varus and the local quality of the bone), etc. precursors of ischemia, in the presence of the three criteria simultaneously the risk of developing AVN is 97%. Patients with concomitant injuries are also presented in tabular form. These are 7 of the followed-up patients.

The examined radiological parameters are: intraoperative neck-shaft angle (NSA1), intraoperative height of the humeral head (HHH1), neck-shaft angle at the final follow-up (NSA2) and height of the humeral head at the final follow-up (HHH2). The purpose of these measurements is to answer the question: is the fixation with the construction of LP and IMAG reliable in terms of retaining the reposition?

For a complex assessment of the function of the operated shoulder the author uses Constant - Murley Score (CS) with the three variants of the scale: absolute (CSabs); relative (CSrel) and individual (CSindiv). The CS scale includes: 1. Subjective assessment of pain, recovery of daily activities, as well as sleep disturbance as a result of the injury; 2. Objective assessment of movements in the shoulder: abduction, flexion, external and internal rotation; 3. Strength measurement.

The average value of the calculated CSabs is **54.97** points. This result is **satisfactory** (51 - 64 points) determined by Constant et al.

A Bulgarian-language adaptation of the DASH questionnaire was used to subjectively assess the level of recovery in patients. The mean DASH in the study was 16.65 (0-45). Our subjective assessment of the result according to the DASH questionnaire is **good**. An

objective assessment can be made on the basis of the maximum number of 100 points (worst possible score) and the minimum number of 0 points (best possible score). The results are perfectly visualized in tabular form.

Despite the slight differences in the radiological measurements, according to the functional scales such have been established. For the CSabs group, patients with anatomical and acceptable reposition showed significantly better functional outcomes.

In the subchapter **complications** are listed such as secondary varus displacement, penetration of screws through the humeral head, avascular necrosis (applied logistic regression analysis showed a statistically significant relation between reposition and the development of AVN, as poor reposition is a significant factor in the occurrence of AVN), subacromial impingement, arthrosis of the glenohumeral joint, avascular necrosis of the greater tuberosity.

Other complications in the literature on LP fixation, such as nonunion, debricolage, and superficial or deep infection, were not reported in the study.

Reoperations were 12 (26%), and only 1 patient underwent unipolar endoprosthesis after development of AVN with screw penetration.

Section IV: Discussion covers 26 pages in which the author focuses on certain factors. The first two, medial calcar and the role of osteoporosis, are initial as a result of trauma and are factors that the surgeon must consider. The medial calcar support has two main components: the length of the posteromedial metaphysis attached to the humeral head, and the medial hinge with the adjacent periosteum and blood vessels. Combined with each other, they provide stability and blood supply to the humeral head in PHFs.

Placement of a locking plate on the lateral cortex of the proximal humerus establishes a mechanical construct that functions as a tension band. As the rotator cuff fires and attempts to deform the humeral head in varus, these forces may be converted to medial compression forces, essentially offloading the implant and creating a load-sharing construct between the implant and the bone In order to implement this mechanism and to ensure the mechanical stability of the structure, it is necessary to have an intact medial cortex capable of carrying a load. The medial hinge also plays an important role in bone biology, providing perfusion of the humeral head through the vessels of the posterior medial periosteum.

With regard to osteoporosis, the author cites Hertel, who likens the osteoporotic head of the humerus to an egg placed in a cup. If we break the egg in two and empty its contents, and then break the cup, the only sure way to keep the shell (head) in the desired position (reposition) and achieve sufficient stability is to reposition both parts of the cup (tubercules). In 'surgical

language', this means that reposition and stabilization of the tubercles against each other would be sufficient to achieve a stable head position. In his study, the author proves the lack of a statistically significant difference in functional outcome between patients with normal and poor local bone quality and concludes that local osteoporosis does not significantly affect the reliability and strength of fixation, as well as functional results. Rather, age affects function and recovery rate with statistically significant differences in CSabs and DASH between young (< 65 years) and geriatric (> 65 years) patients. Based on our biomechanical and clinical results, we can conclude that osteoporosis is not of primary importance for the final result in the treatment of PHFs. Rather, older age and its accompanying characteristics, together with osteoporosis, have a cumulative effect.

The author attaches special importance to factors that are in the role of the surgeon and are of great importance for the effectiveness of the applied treatment. The role of the tense tendon suture responsible for the importance of repositioning the tubercles in osteoporotic fractures. This should not give the impression that this significance does not affect other fractures. The suture of the tubercles or rather the tendons of the rotator cuff muscles with non-absorbable sutures and their suturing to the plate aim to counterbalance the strength of the respective muscles and thus reduce the possibility of displacement of the fragments. The importance of repositioning is evidenced by a study by Schnetzke, which proves that the quality of reposition affects the final clinical outcome. Patients who have achieved anatomical or acceptable reduction show a significantly lower complication rate and better functional outcome.

Regarding the main thesis of this paper, the author shares the opinion of other authors on the use of intramedullary allograft in complex fractures of the proximal humerus. Especially in cases with a deficient medial cortex and severe varus deformity, they recommend resorting to more aggressive treatments, such as the use of IMAG. Fibular allograft has several advantages. The diameter of most fibulae is ideal for incorporation into the humerus. The fibula is large enough to fill the proximal metaphysis, and at the same time strong enough to provide resistance to compression at the site of the comminuted medial column. On the other hand, it is small enough, which makes it mobile and can be used as a means of indirect reposition of the head fragment, so that when positioned medially it supports the varus-displaced head in its lower medial part.

Chapter **Conclusion** emphasizes the fact that the clinical study evaluates a strictly selected category of proximal humerus fractures, namely fractures in which there is unequivocal X-ray evidence of humeral head ischemia (in some cases up to 97%, according to Hertel). These are

the problematic fractures in terms of survival and healing of the head fragment.These are fractures that continue to have a poor prognosis despite the definite progress of fracture surgery of the shoulder.

At the beginning of the work the author formulates two working hypotheses:

First, organ-preserving surgery is possible and justified in these fractures.

Second, that the creation of the most favorable mechanical conditions will allow both the revascularization of the fragments with borderline blood supply and the creeping substitution of the avascular humeral head.

The use of intramedullary allograft as an augmentation of the lateral locking plate in the conditions of a laboratory experiment found that the graft provides reliable restoration of medial support in bone of different 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.

Encouraging data from the biomechanical experiment allowed the author to apply the technique in clinical practice. According to him, an optimal surgical technique should include:

- parachute technique for tubercles;
- insertion of the graft;
- reposition of the humeral head anatomically (in terms of height and medial cortex);
- reposition of the tubercles;
- fixation with a lateral locking plate and fixation of the tubercles through the plate.

The author is convinced that these elements of the technique are part of a logical sequence and thus each subsequent element is a step towards improving the biomechanics of the structure.

The proven technique to some extent eliminates the osteoporotic bone challenge. Parachute stitching greatly facilitates the reposition. It is no coincidence that in fractures with anatomical reposition it is used in 87% of cases, and in those with malreduction - in 36% of cases. The frequency of AVN directly depends on the reduction of the fracture. In the present study, the hypothetical risk of 97% for humeral head ischemia was reduced to 32%.

Last but not least, this scientific work once again emphasizes that the complications in the treatment of these fractures have a predominantly ischemic origin.

After completing the study, the author concluded that the augmentation with intramedullary allograft of the fixation with LP in PHFs, threatened by ischemia, is based on solid biomechanical foundations. From a clinical point of view, it is predictable, safe and effective.
In conclusion, he is convinced that organ-preserving surgery has its place in these initially unfavorable fractures.

I completely agree with the **Deductions**:

1. The construction of a locking plate and intramedullary allograft increases the stability of the fixation of PHFs and effectively counteracts the forces causing secondary displacement.
2. Intramedullary graft reliably allows the restoration of medial cortical support, which is a factor of paramount importance for stability after synthesis with LP.
3. Achieving anatomical reposition is another first-line factor, both for the reliability of fixation and for the reduction of AVN of the humeral head.
4. Functional outcomes directly depend on the quality of reposition and the development of AVN and to a lesser extent on the patient's age and the presence of osteoporosis.
5. The technique of augmentation with intramedullary allograft of the fixation with LP in PHFs is reproducible in clinical conditions, allowing organ-preserving surgery with predictable results.

I also agree with the **contributions** made in connection with the dissertation:

1. The mechanical properties of the construct of a locking plate and intramedullary graft were tested in a reference laboratory on a sufficient number of specimens and the construct was applied in the treatment of a large enough number of patients to create their own database.
2. An in-depth and detailed statistical analysis was performed on the dependence of the final results and complications in the application of the method on various factors: age of the patients; surgical technique; quality of the achieved reposition; type of allograft; local bone quality.
3. Based on the analysis of the results and complications, the optimal surgical technique was tested with an algorithm for achieving anatomical reposition in unstable and threatened with ischemia fractures of the proximal humerus.

4. For the first time, a retrospective analysis was performed on the dependence of the method as an organ-preserving in ischemic fractures of the proximal humerus, taking into account the Hertel criteria, which have the highest prognostic value for the occurrence of this complication.

5. For the first time in experimental conditions the mechanical properties of the locking plate and intramedullary graft construct were tested in a four-fragment fracture model.

6. For the first time in experimental conditions, the mechanical properties of the locking plate and intramedullary graft construct were tested on a fracture model reproducing an osteoporotic fracture with a massive bone defect of the cancellous bone.

CONCLUSION: I believe that the dissertation of Dr. Lyubomir Simeonov Rusimov on the topic: **„Intramedullary allograft augmentation in unstable proximal humerus fractures fixed with locking plate”** in relation to relevance, scope and significance of contributions fully meets the requirements of the Law for Development of the Academic Committee of Republic of Bulgaria and the Regulations of Medical University of Sofia for its implementation.

In relation to the above, I confidently give my **positive** assessment and propose to the esteemed members of the scientific jury to award Dr. Lyubomir Simeonov Rusimov with the educational and scientific degree "Doctor".

25.04.2022 **Reviewer**:

(Prof. Dr. N. Tsachev, PhD)