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Research Article

# Arthrodesis of Shoulder Joint with 3D Implant Technique

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## Abstract

**Introduction:** Due to the large-scale hostilities in Ukraine, the frequency of gunshot wounds of the extremities has increased dramatically to 60% of all gunshot wounds and related complications, both infectious and non-infectious. Of particular interest are gunshot wounds of the upper extremity, namely the shoulder girdle (up to 20% of all injuries of the musculoskeletal system. Gunshot wounds of the shoulder girdle are accompanied by massive soft tissue damage, vascular and nerve plexuses, and significant bone deficiency. With such injuries, the use of traditional methods of treatment is quite risky due to the lack of proximal humerus, defects in the articular process of the scapula. This requires the development of new techniques for shoulder arthrodesis.

**Objective:** study is published to demonstrate the possibilities of shoulder arthrodesis in severe combat trauma of the upper limb, the possibility of using individual 3D titanium implants in the restoration of cosmetic defects and function of the upper limb.

**Materials and Methods:** The study involved 27 men and no women. The average age of the participants was 37 years with a standard deviation of 10.9 years. The physical condition of the patients was assessed according to the ASA classification, in our case, the average score was 2.15 with a standard deviation of 0.51. The average BMI was 25.7 with a standard deviation of 3.3. The shoulder joint function was assessed by the Oxford Shoulder Score, Constant Shoulder Score, and Shoulder Pain and Disability Index scales after surgery or completion of conservative treatment.

**Conclusion:** The new principle of arthrodesis, using individual 3D titanium implants, can be the treatment of choice in severe gunshot wounds of the shoulder joint, in the presence of biomechanical conditions characteristic of contraindications to shoulder arthroplasty.

**Keywords:** Shoulder Arthrodesis; Reconstruction; Salvage; Fusion; Plate Arthrodesis

## Introduction

Combat trauma to the limb is a polystructural lesion of anatomical structures that leads to massive defects in the skin, muscles, ligaments, bone deficiency**,** nerve and vascular damage (Figure 1).

Explosive weapons caused 75% of the injuries to the extremities, with injuries roughly distributed between the lower (52%) and upper (48%) extremities.

The most common sites of injury on the lower extremities were the lower leg complex (40%) and thigh (26%), the most common sites on the upper extremities were the shoulder joint and shoulder (37%), and hands, wrists and fingers (33%) [1,15].

The availability of such opportunities in the arsenal of orthopedic traumatologists (arthroscopy, endoprosthetics, periosteal osteosynthesis, intramedullary osteosynthesis) has significantly expanded the range of surgical interventions for upper extremity injuries. However, in case of combat trauma it is not always possible and expedient to use the above techniques [6,7,9].

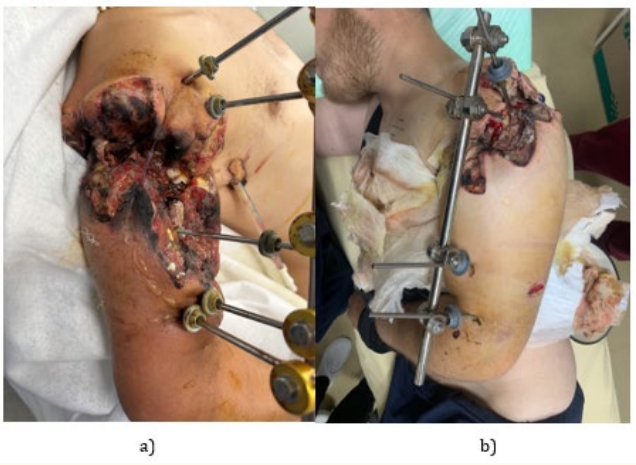


**Figure 1**

Orthopedic traumatologists are forced to return to «unpopular» techniques such as arthrodesis, muscle and tendon transposition [3,4].

Arthrodesis of the shoulder joint is a surgical intervention that involves resection of the articular and fixation of the humerus to the scapula to form an ankylosis, which subsequently ensures painless functioning of the upper limb in new functional and anatomical conditions [9,11,13].

The main problem of gunshot wounds of the shoulder joint are massive defects in the soft tissues surrounding the shoulder joint, with a massive bone deficit in the upper third of the humerus. For this purpose, we used arthrodesis of the shoulder joint with a developed and created individual 3D titanium implant with the formation of a standard ankylosis in the corners [3,10,12]. In the presence of a massive deficit of soft tissue and bone tissue of the bones forming the shoulder joint, this proved to be a high-tech option for restoring the function of the upper limb [2,4].

The aim of the study is to demonstrate and study the possibilities of shoulder arthrodesis in severe combat trauma of the upper limb, the possibility of using individual 3D titanium implants in the restoration of cosmetic defects and function of the upper limb.

Gunshot wounds to the shoulder joint are accompanied by massive soft tissue defects, nerve and vascular damage.

Given the presence of massive soft tissue defects, vascular and nerve plexus damage, the use of shoulder arthroplasty does not allow for restoration of function. In particular, the use of anatomical endoprostheses requires the presence of a preserved rotator cuff of the shoulder joint. The possibility of using reverse shoulder arthroplasties requires the presence of a strong deltoid muscle and sufficient bone mass of the articular process of the scapula. In addition, the vast majority of wounded are young, and primary arthroplasty is usually contraindicated for those who plan to engage in heavy physical labor in the future.

An individual 3D titanium implant is not only the use of modern technologies in orthopedics, which ensures the creation of ankylosis, standardized by the angles of the humeral scapular ratio (Figure 2), but also a highly effective option in the treatment of gunshot wounds of the shoulder joint accompanied by massive defects in bone tissue and muscle frame, which severely limits the use of standard implants [1-16].

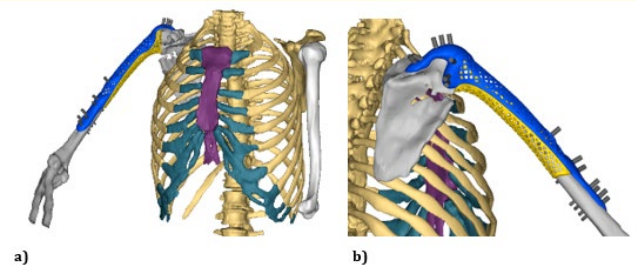


**Figure 2:** Modeling of a 3D titanium implant.

a: Front view; b: Rear view.

## Materials and Methods

Our study involved 27 men and no women. The inclusion criterion was the presence of a severe combat injury of the upper limb, defects of bone tissue of the proximal part of the humerus and glenoid, defects of soft tissues surrounding the shoulder joint, damage to the axillary and subscapular nerves.

Exclusion criteria (contraindication to surgical intervention) were: the presence of untreated infectious foci (accompanying injuries); infectious complications of the postoperative wound; severe post-traumatic stress disorder; addiction; alcoholism.

The average age of the participants was 37 years with a standard deviation of 10.9 years. The physical condition of the patients was assessed according to the ASA classification, in our case, the average score was 2.15 with a standard deviation of 0.51. The average BMI was 25.7 with a standard deviation of 3.3. The shoulder joint function was assessed by the Oxford Shoulder Score, Constant Shoulder Score, and Shoulder Pain and Disability Index scales after surgery or completion of conservative treatment. a The Oxford Shoulder Score is a subjective scale for assessing the functional status of the shoulder joint, in which the patient answered twelve questions, each of which was scored from 0 to 4 points. The maximum number of points was 48, the minimum - 0. The number of points from 0 to 19 was assessed as an unsatisfactory 50 result, 20-29 points - satisfactory. ±The average SPADI (Shoulder Pain and Disability Index) score is 75 10. ± The average Oxford Shoulder Score was 28 8. ±The average Constant Shoulder Score is 53 7.

### Surgical technique

The literature available to us describes many different positions and positions of the upper limb during arthrodesis at the shoulder joint. In our opinion, the most functionally beneficial of these is when the patient can reach the mouth with the upper limb bent at the elbow. From our point of view, the most optimal position of the shoulder during arthrodesis is abduction 30, flexion 30 and its internal rotation 30.

Patient position - «beach chair»

Anesthesia - endotracheal anesthesia

A 20 cm long incision of the skin and subcutaneous fat is made from the scapula to the anterior edge of the acromion and down the anterior side of the humerus diaphysis. We try to preserve the deltoid muscle as much as possible. Elements of the rotator cuff of the shoulder joint are cut off, the lower surface of the acromion, the articular surface of the articular process of the scapula, and the articular surface of the scapula are decorticated, completely removing the cartilage tissue.

Arthrodesis should be performed both between the humeral head and the articular process of the scapula and between the head and the acromion. (Figure 3) The tendon of the long head of the biceps brachii muscle is fixed in the intercondylar groove after cutting from the attachment site. After that, the humeral head is brought proximally to the acromion and articular process of the scapula, and fixation is performed in a functionally favorable position.


**Figure 3**

A locked compression plate (LCP) of the AO system with cortical, spongiosis, and locking screws is used as a pedicle fixator (Figure 3b). It is modeled according to the profile of bone surfaces from the scapula to the humerus diaphysis, reproducing anatomical curves.

Be sure to use two or three spongiosis screws to create a reliable compression between the humerus and scapula. The next spongiosis screw is guided from the scapular head to the beak-shaped process, and then the screw is inserted through the acromion into the humeral head. Cortical and locking screws fix the plate to the humerus diaphysis. It is possible to use autogenous bone grafts, which are formed from the crest of the wing of the acetabulum or a section of the fibula, or bone allografts. The wound is sutured in layers, and aspiration drainage is installed for 1 day.


**Figure 4**

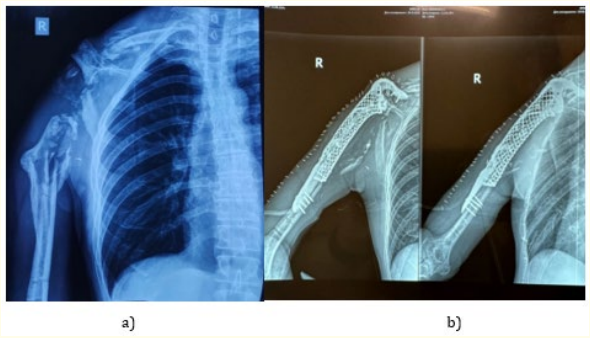


**Figure 5**

In the presence of massive bone defects (Figure 4a, 5a), individual 3-D titanium implants created on the basis of spiral computed tomography were used (Figure 4b, 5b).

Computed tomography was performed in compliance with the following principles

- Both humeri must be captured with elbow and shoulder joints
- Maximum number of slices allowed;
- The cut thickness is no more than 1 mm;
- If there was metal in the scanning area, the artifact suppression mode was used.

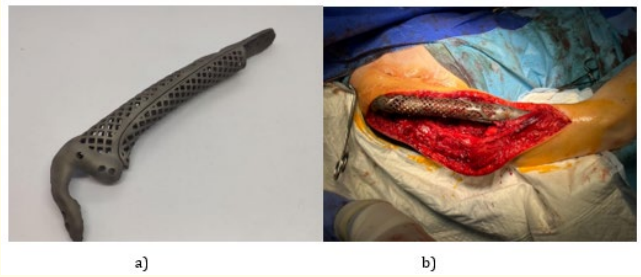


**Figure 6**

Individual 3D titanium implants, created on the basis of medical images and data of a particular patient, allowed to achieve maximum accuracy and compliance with each bone defect, due to precise fit and fixation, to reduce the time of surgery and create optimal opportunities for reparative processes and restoration of function (Figure 6 a, b).

## Results

At the time of publication, the clinic has operated on 27 patients using this technique. All patients had a wound contents cultured (Table 1). All infection was successfully eliminated according to bacterial resistance. In 5 patients, 3D individual titanium implants were used. The average follow-up period was 12 months.

| **Culture** | |
|---|---|
| *Acinetobacter* spp | 36% |
| *Klebsiella pneumoniae* | 21% |
| *Pseudomonas aeruginosa* | 15% |
| *Escherichia coli* | 9% |
| *Enteroccocus spp.* | 6% |
| *Proteus mirabilis* | 5% |
| *Staphylococcus spp.* | 1% |
| *Achromobacter spp.* | 1% |

**Table 1:** The previous bacterial specter of all gunshot wounds.

After X-ray confirmation of bone growth, physical therapy is started to improve the function of the shoulder girdle (Figure 7 a, b, c, d).

In 95% of patients, ankylosis of the shoulder joint was formed, in some patients clinical consolidation was observed, without final restructuring, with a positive tendency to bone fusion. According to VAS, pain in patients decreased after 12 months, compared with sixth months of observation ($p < 0.001$). The VAS value was interpreted after 6 months. -moderate pain, after 12 months. -absence of pain. Based on the results of the Oxford Shoulder Score assessment, an improvement in the condition of the shoulder after 12 months compared to the 6-month follow-up ($p < 0.001$) from 25 to 40 points was also established. All patients note a tendency to increase the physical strength of the limb from 3 months after surgery (Figure 8-9 a, b, c,)


**Figure 7 (a,b):** Left shoulder joint function before arthrodesis.

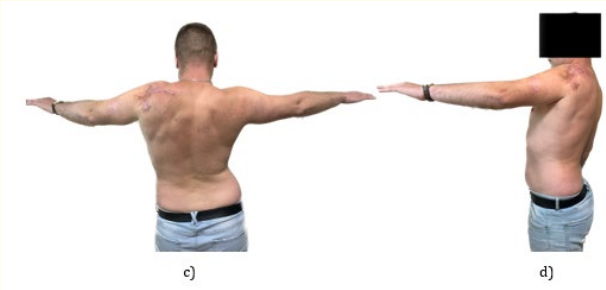


**Figure 7 (c,d) :** Left shoulder joint function after arthrodesis.

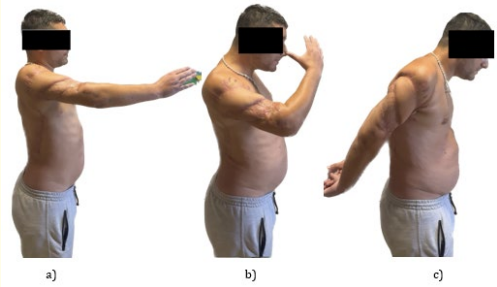


**Figure 8:** Function of a patient operated on using an individual 3D titanium implant (case 1).


**Figure 9:** Function of a patient operated on using an individual 3D titanium implant (case 2).

## Discussion

Due to the peculiarities of gunshot wounds of the shoulder joint, endoprosthesis is not justified, in the majority of cases. This forced us to look for alternatives for the treatment of such injuries. We believe that the use of an individual 3D-titanium implant embodies a highly effective option for the treatment of gunshot wounds of the shoulder joint, which are accompanied by massive defects of bone tissue and muscle framework, which sharply limits the possibility of using standard implants.

We believe, that the most optimal position of the shoulder during arthrodesis is abduction 30, flexion 30 and its internal rotation 30, in which case the patient can eat and perform hygiene procedures independently.

According to the literature, recommendations for postoperative immobilization vary. Some sources are of the opinion that plaster

immobilization for 3-4 months is necessary, while others achieve good results without any immobilization other than a wedge pillow. The majority recommends immobilization in a wedge-shaped bandage for 8-10 weeks. For more complex cases with massive bone loss or other complications, an extended period of immobilization should be performed. We prefer an elastic bandage of the «Deso» type with a wedge-shaped pillow for 8-10 weeks. For undisciplined patients, we prefer plaster immobilization. Movement in the elbow, wrist, and hand joints is allowed immediately after surgery to prevent contractures and loss of functionality.

## Conclusions

The analysis of our work allowed us to formulate the following conclusions:

- We achieved functional stability, resulting in fusion in all patients during follow-up
- Disappearance of pain syndrome, restoration of sufficient function to perform daily tasks, restoration of working capacity.
- For the best functional outcome in shoulder arthrodesis, the trapezius muscle, scapularis major, anterior dentate and rhomboid muscles must be functional
- Shoulder-scapular arthrodesis is contraindicated in patients without functional scapulothoracic muscles.
- The use of patient-specific titanium implants printed on a 3D printer offers a new technology that can be used to address a variety of complex bone defects and deformities of the upper extremity more effectively and with fewer complications. The flexibility and customizability of the implants allow them to meet the specific needs of the patient.

Our preliminary results demonstrate fracture consolidation and are promising. We hope that the benefits of successful limb salvage, improved long-term function, and increased patient satisfaction will be realized. This requires larger multicenter studies, monitoring of long-term outcomes and delayed complications (infection, stress fractures, implant failure, etc.).

## Conflict of Interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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