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To Study The Treatment Outcomes Of Patients With Fractures Of The Distal Forearm Bones

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Abstrak. Distal forearm fractures are among the most common skeletal injuries and are frequently associated with unsatisfactory treatment outcomes, particularly when managed through prolonged conservative immobilization. Complications such as secondary displacement of fragments, neurovascular disorders, limited wrist mobility, and the development of complex regional pain syndrome (CRPS) significantly affect patient recovery and quality of life. Despite numerous clinical studies, reliable methods for early diagnosis of CRPS and clear criteria for selecting optimal fixation techniques remain insufficiently defined.

This study aimed to evaluate treatment outcomes in patients with distal forearm fractures and to investigate clinical and microcirculatory changes during the post traumatic period. Microvascular blood flow regulation and tissue temperature changes were analyzed using spectral amplitude frequency wavelet analysis and instrumental diagnostic methods. The study also assessed the effectiveness of a minimally invasive osteosynthesis device designed for stable fixation of metaphyseal fractures without immobilization of adjacent joints. Early postoperative rehabilitation and functional therapy were incorporated into the treatment protocol.

The findings demonstrated that microcirculatory changes and persistent hyperthermia play an important role in the development of CRPS and in the regeneration processes of the distal radius. The proposed osteosynthesis device provided stable fixation of bone fragments and allowed early joint mobilization, which reduced pain, prevented secondary displacement, and improved functional recovery. Compared with conservative treatment, patients treated with the device showed faster rehabilitation and better restoration of wrist mobility. These results suggest that minimally invasive stable osteosynthesis combined with early functional therapy can significantly improve clinical outcomes and reduce complications in patients with distal forearm fractures.

Keywords: distal forearm fracture, distal radius fracture, complex regional pain syndrome, osteosynthesis, microcirculation, fracture fixation, postoperative rehabilitation

1. Introduction

Distal forearm fractures, particularly fractures of the distal radius, are among the most common injuries of the musculoskeletal system and represent a significant clinical problem in traumatology and orthopedics. Their high incidence is observed in both young patients with traumatic injuries and elderly individuals with osteoporosis. The complexity of these fractures is associated not only with damage to bone structures but also with disturbances in surrounding soft tissues, neurovascular elements, and joint function. In clinical practice, restoration of the anatomical structure of the distal radius and preservation of wrist mobility are considered key factors determining the success of treatment and the patient's quality of life.

Despite the widespread use of conservative treatment methods such as plaster immobilization, many studies have reported a considerable number of unsatisfactory outcomes related to secondary displacement of fragments, prolonged immobilization, and the development of complications, including complex regional pain syndrome. Previous research has examined various surgical techniques and fixation devices aimed at improving fragment stabilization and enabling earlier functional recovery. However, clear criteria for selecting optimal fixation methods and reliable indicators for early detection of neurovascular complications remain insufficiently defined. This knowledge gap highlights the need for further investigation into microcirculatory changes and functional outcomes following different treatment approaches for distal forearm fractures.

The present study aims to evaluate treatment outcomes in patients with distal forearm fractures by analyzing clinical features, microcirculatory dynamics, and functional recovery during the post traumatic period. The research applies instrumental diagnostic techniques and clinical observation to assess blood flow regulation and tissue regeneration processes. It is expected that improved fixation techniques combined with early functional rehabilitation will enhance fracture stabilization, reduce complications, and accelerate restoration of wrist joint mobility. The findings of this study may contribute to the development of more effective treatment strategies and improve long term outcomes for patients with distal forearm fractures.

2. Methodology.

The study applied a clinical observational methodology to evaluate treatment outcomes in patients with distal forearm fractures and to analyze neurovascular and microcirculatory changes during the post traumatic period. Patients were treated either conservatively with plaster immobilization or surgically using a minimally invasive osteosynthesis device designed to stabilize metaphyseal fractures of the distal forearm without fixation of adjacent joints. Clinical evaluation included monitoring pain intensity, swelling, wrist joint mobility, and overall functional recovery during the rehabilitation process. Special attention was given to early identification of complex regional pain syndrome through clinical examination and instrumental diagnostic methods.

Microcirculatory changes in the injured limb were studied using spectral amplitude frequency wavelet analysis of blood flow oscillations in skin microvessels, along with Doppler ultrasound assessment of blood flow in forearm vessels and monitoring of temperature distribution in the distal segment of the limb. These methods allowed evaluation of vascular regulation, perfusion pressure, and endothelial activity during different stages of fracture healing. When signs of complex regional pain syndrome were detected, patients received comprehensive conservative therapy aimed at improving microcirculation and reducing neurogenic inflammation before further surgical treatment.

Postoperative management included short term immobilization, limb elevation, and early initiation of physiotherapy and joint mobility exercises. Treatment outcomes were assessed through clinical follow up, enabling comparison of rehabilitation progress and functional recovery between conservative treatment and surgical osteosynthesis.

3. Result and Discussion

The great interest in this fracture is driven not only by its frequency but also by the high rate of unsatisfactory outcomes, which is largely due to prolonged immobilization as the basis of conservative treatment, which remains the generally accepted method for this condition. The use of a plaster cast, especially in cases of significant displacement of bone fragments, often leads to the development of innervation, nutritional, and microcirculatory disorders, secondary displacements, and limited wrist motion. One of the serious complications of a distal forearm fracture is complex regional pain syndrome (CRPS), which can range from type I (without peripheral nerve damage) to type II (with nerve damage). Its onset leads to months-long disability, especially in those engaged

in manual labor, and in some patients (up to 4-5%), to permanent disability. However, there are still no well-founded approaches to the early diagnosis of CRPS, nor are there any signs that differentiate its development in the acute period of a fracture. Clinical and instrumental patterns of neurovascular disorders in the post-traumatic period, both uncomplicated and complicated by CRPS, have not been described.

To prevent the development of deformities, persistent contractures, deforming arthrosis, and neurovascular complications, it is necessary to restore the anatomy of the distal radius. Periarticular metaphyseal, metadiaphyseal, and metaepiphysial fractures remain the most challenging to treat. Conservative treatment methods fail to consistently fixate bone fragments, leading to secondary displacement, persistent pain, and a deterioration in the patient's quality of life. All of this necessitates the introduction of surgical treatments for distal metaepiphysial fractures.

In recent years, a significant number of studies have appeared, the authors of which propose improved methods of surgical treatment using internal fixation devices and devices for transosseous osteosynthesis.

However, clear indications for extrafocal osteosynthesis and internal fixation have not been developed, nor is there a unified method for selecting devices. Furthermore, an ideal implant for stabilizing the distal radius does not exist. A minimally invasive treatment method is needed that would ensure sufficient fixation of the fragments, even in patients with osteoporosis, to prevent secondary displacement, significantly reduce pain, and allow patients to begin moving the operated joint in the days immediately following surgery. This prevents complications and improves quality of life for patients in the postoperative period.

This indicates a natural redistribution of blood flow and tissue energy in the distal segment of the limb in favor of the fracture zone. Thus, the activation of temperature-energy parameters in the distal segment generally corresponds in timing to the most pronounced proliferative and regenerative processes, but at all stages of the post-traumatic period, a redistribution of higher temperatures is present in favor of the fracture zone. Of interest are the characteristics of the regulation of blood circulation and tissue microcirculation during the regeneration of the distal metaepiphysis of the radius. These parameters were studied using spectral amplitude-frequency wavelet analysis of blood flow oscillations in skin microvessels. For more superficial microvessels of the skin of the nth finger, an increased role of sympathetic vasoconstriction of muscle-containing vessels (primarily arterioles) is characteristic at all stages of the post-traumatic period, especially at one month after injury. This was manifested both by an increase in the amplitude of the neurogenic adrenergic rhythm of blood flow oscillations and by an increase in the perfusion pressure by 30% or more. Furthermore, a characteristic decrease in the amplitude of the cardiac rhythm and its relationship with the respiratory rhythm was observed, indicating a decrease in perfusion pressure in the microvessels. However, the amplitudes of venous respiratory rhythms differed little from the control. Beginning at 1-2 months and especially later after the injury, endothelial rhythms began to dominate the structure of microvascular oscillations, which facilitated the onset of a period of vasodilation in these tissue regions.

Microvessels in the deeper layers of the skin generally exhibited similar patterns; however, sympathetic modulation of blood flow fluctuations was less pronounced and predominated in the early stages (up to one week after injury). Vasodilation at one to two months after injury was associated with activation of endothelial mechanisms. Marked hyperthermia, exceeding in absolute values the values observed during similar periods of normal healing, began to manifest itself three days after the injury, and significant differences persisted for two weeks. A characteristic feature of the hyperthermia was its persistent nature over time; a downward trend in temperature began to emerge at the end of stage 2 of CRPS, usually 4-6 months after the fracture. Furthermore, unlike

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uncomplicated injury, the development of CRPS is characterized by diffuse, diffuse hyperthermia of the palmar surface of the hand and fingers, affecting both the fracture zone projection and the hand and fingers. Early on (the first two weeks after injury), the vascular component of hyperthermia is due to blood flow through deeper microvessels of the skin (the LDF IR channel), primarily of the non-nutritive link, since up to two months after injury, perfusion of superficial microvessels, including nutritive ones, was significantly lower than control values. This is consistent with ultrasound Doppler data showing an early and prolonged increase in linear blood flow velocity in the forearm vessels during the development of CRPS, in contrast to the normal post-fracture period. Continued hyperthermia correlated with a persistent increase in blood flow in the main vessels. Thus, during the development of CRPS, the nature of hyperthermia is ambiguous and dynamic. In the early stages (up to 2 weeks after the fracture), it is caused by both arterial and microvascular components (due to dilation of deep muscle-containing microvessels—arterioles and arteriovenous shunts). Later, microcirculatory support for pre-fracture hyperthermia decreases, and the temperature increase is mediated by vasodilation in the small cutaneous arteries.

When clinical signs of CRPS were identified and confirmed by instrumental examination methods, in order to avoid complications in the postoperative period, a course of complex conservative therapy was administered, aimed at improving microcirculation and trophism of the damaged area, and surgical intervention was performed only after positive dynamics of the course of reparative tissue processes and the relief of acute neurogenic inflammation were identified.

To eliminate neurogenic inflammation in the acute stage, steroid hormones, nonsteroidal anti-inflammatory drugs, local and topical anesthetics, sperbaric oxygenation, capsaicin-containing ointments (ESPOL, etc.), and physiotherapy (phonophoresis with hydrocortisone, cryotherapy) were used. Venotonics and shigellants were used to normalize blood rheology. Tranquilizers and antidepressants were prescribed to relieve frequently observed psychosomatic disorders. A device was developed for osteosynthesis of metaphyseal fractures of tubular bones, which allowed for minimally invasive, stable osteosynthesis of fragments in any (including comminuted) fractures of the distal forearm bones without fixation of adjacent joints, regardless of the nature of their displacement and the quality of bone tissue, even in elderly patients with osteoporosis. The device for osteosynthesis of metaphyseal fractures of tubular bones (Russian Federation Patent No. 2261678) is made of an X-ray-transparent material and consists of a detachable rod consisting of two L-shaped plates connected by their long shelves and a transosseous element fixator consisting of five arcuate bars with holes that are tightened using nuts and threaded guides to secure the required number of pins reinforcing the distal metaphyseal bone . It should be noted that this unit can be used in combination with devices of any other design.

The device's compact size allowed patients to wear regular clothing without compromising the quality of life and stabilizing their psycho-emotional state, facilitating rehabilitation and contributing to a positive treatment outcome. The conducted bench studies have proven that the range of loads in the apparatus-bone system is significantly higher than the dislocating muscle-traction forces arising due to tone, physiological muscle tension, interstitial edema or cicatricial changes in the tissues of the forearm after injury. Sterile alcohol-soaked wipes were applied to the skin puncture sites. The hand was immobilized in a mid-physiological position for several days using a wrist holder or a removable plaster cast. It was elevated. Active physical therapy and joint mobility training were performed from the first days after surgery. The average time for fragment fixation in the apparatus for fresh fractures was 6 weeks. For interventions for post-traumatic deformities of the wrist joint, involving osteotomy and bone grafting, the period of fragment fixation ranged from 7.5 to 9 weeks. In all cases using our apparatus, functional treatment began within the first days after surgery, which allowed the vast majority of patients to preserve or promptly restore range of motion in the joints of the injured limb.

Satisfactory results were observed in 27 (27.84%) and 8 (25%) patients in the control group, treated conservatively and with distraction devices, respectively. Development of joint motion in the injured limb began only after consolidation of the fragments (5-6 weeks after the injury) and was accompanied by significant difficulties. After the end of immobilization and the beginning of rehabilitation, pain syndrome accompanied by soft tissue swelling persisted, which complicated restorative treatment and required additional measures. The rehabilitation period for these patients was 4-5 weeks longer than that of patients in the main group. Moreover, despite the use of a full range of restorative treatment, full range of motion was not achieved in 12 (12.37%) patients treated conservatively. However, limb function was sufficient for self-care and professional requirements.

4. Conclusion

Unsatisfactory results were observed in 16 (16.49%) patients in the control group treated conservatively and in 3 (9.38%) patients after fixation with a distraction apparatus. Of these, 7 elderly patients experienced persistent pain, swelling, and stiffness, primarily due to secondary displacement of fragments and the development of neurodystrophic changes (CRPS). Satisfactory range of motion in the wrist joint was not achieved in these patients. In the remaining 12 victims with type C comminuted fractures, shortening of the radial epiphysis with disruption of the congruence of the articular ends occurred during conservative treatment, making it impossible to restore full hand function without additional surgical intervention.

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