Assessing the influence of FDM to the postoperative healing processes in distal fracture of the radius

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ABSTRACT

Introduction: Distal radius fractures are among the most common types of fractures. Irrespective of the choice of therapy (whether conservative or surgical), these fractures may entail negative consequences in the form of limited range of motion and diminished muscle strength. Such sequelae cause limited hand performance, which, considering the important function of the hand, may negatively affect the quality of life and impair patient's independence in performing everyday activities Despite a considerable progress in medicine and physical therapy over the last several years, distal radial fracture outcomes seem to be unsatisfactory. Conventional mobilization methods do not increase the number of very good and good outcomes. Nevertheless, the effects of a therapist's efforts concentrated on specific tissues of the musculoskeletal system, such as fasciae, seem to be an effective treatment method rapidly restoring the normal range of motion and muscle strength and consequently – full hand function.

Aims: To present the Fascial Distortion Model (FDM) as a potentially effective treatment of musculoskeletal dysfunctions after distal radius fractures.

Methods: A total of 65 patients (12 men, 53 women, 22 to 81 yerars of age) suffering a distal radial fracture were randomized into a study group (n = 33) and control group (n = 32). Apart from the standard recommendations and exercise instructions, the study group underwent three sessions with the use of FDM techniques. These therapeutic sessions were conducted once a month. The therapy was adjusted to individual limitations and patient feedback related to pain. The utilized therapeutic techniques included triggerbands, herniated triggerpoints, continuum distortion, folding distortion, cylinder distortions, and tectonic fixation.

An efficiacy analysis of the FDM techniques was done by pre- and posttherapeutic measurements of grip strength, the range of motion (extension, flexion, adduction and abduction) at the radiocarpal joint, of the ability to perform daily tasks (DASH 100 scale) and the level of pain (100 mm VAS).

Results: Single FDM therapy sessions conducted in the evaluation group resulted in immediate improvement in the range of motion and grip strength and a significant improvement in all studied parameters ($p < 0.005$). In comparison with the control group, patients treated with the use of the FDM techniques achieved better results in grip strength and range-of-motion assessment.The effects achieved after each session were maintained or improved in the period before the next session. No negative effects of therapy, such as a decrease in strength or limited range of motion, were observed in any patient.

Conclusion: The results indicate very high efficacy of the FDM as a therapeutic technique rapidly improving the muscle strength and the range of motion in the affected joint.

Acknowledgements (optional)

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Introduction and aim of the study

Distal radius fractures of the radius are among the most common types of fractures. In young people, these are usually direct-mechanism fractures or high-energy injuries. In the elderly, distal radial fractures are caused by a low-energy trauma such as a fall from the standing height [57, 61]. Irrespective of the choice of therapy (whether conservative or surgical), these fractures may entail negative consequences in the form of limited range of motion and diminished muscle strength. Such sequelae cause limited hand performance, which, considering the important function of the hand, may negatively affect the quality of life and impair patient's independence in performing everyday activities [12, 24, 26].

Despite a considerable progress in medicine and physical therapy over the last several years, distal radial fracture outcomes seem to be unsatisfactory. A number of patients, especially the elderly, still complain of limited function and performance in the injured hand. Conventional mobilization methods do not increase the number of very good and good outcomes [9, 30, 48]. Meanwhile, the number of publications on the use of novel therapies, and particularly the osteopathic methods, remains low. Nevertheless, the effects of a therapist's efforts concentrated on specific tissues of the musculoskeletal system, such as fasciae, seem to be an effective treatment method rapidly restoring the normal range of motion and muscle strength and consequently – full hand function [49, 75].

The aims of this study are:

- To present the problem of distal radial fractures as function-limiting injuries of the hand,
- To present the Fascial Distortion Model (FDM) as a potentially effective treatment of musculoskeletal dysfunctions,
- To present the results of our studies on the efficacy of FDM techniques in the treatment of radial fracture patients,
- To review the available literature concerning previous studies.

1. Background

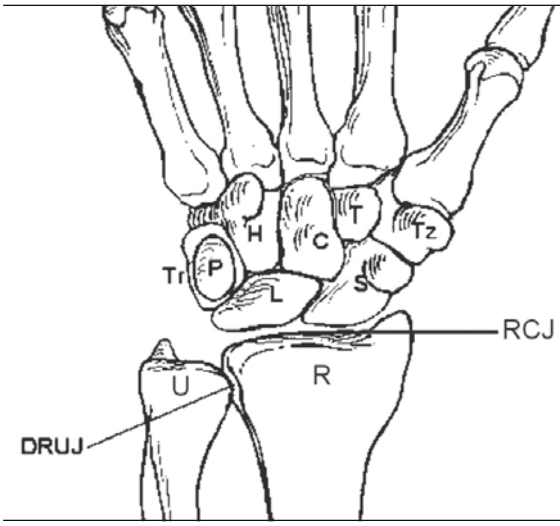
1.1. Anatomy of the distal radius area

1.1.1. Bones and joints

The articulations at the distal end of the radius include the radiocarpal joint and the distal radioulnar joint (DRUJ).

The DRUJ comprises the circumference of the head of the radius and the radial notch of the ulna serving as its socket. The articular capsule is loose yet strong.

The radiocarpal joint connects the radius with the proximal carpal bones, comprising the following bones: the scaphoid, lunate, triquetral, and pisiform (however, the pisiform bone is not part of the articular facet). The articular facet of the distal end of the radius constitutes 75% of the joint's socket and the remaining part of the socket is made up by the articular disc filling the space between the head of the ulna and the carpal bones. The articular socket is slightly inclined toward the ulna and tilted anteriorly, which results in an increased range of adduction and flexion. The head of the joint, comprising three carpal bones (the scaphoid, lunate, and triquetral), is ellipsoid in shape (Fig. 1) [5, 22].



S – scaphoid
L – lunate
P – pisiform
Tr – triquetral
H – hamate
C – capitate
T – trapezoid
Tz – trapezium
U – ulna
R – radius
RCJ – radiocarpal joint
DRUJ – distal radioulnar joint

Fig. 1. The bones forming the radiocarpal and the distal radioulnar joint.

The proximal carpal bones are connected via arthrodial joints of limited mobility held firmly together by ligaments, which facilitates synchronized movements of all three bones constituting the radiocarpal joint with respect to the radius. The articular capsule is loose. The radiocarpal ligaments, which strengthen the articular capsule and control the movements in the joint include:

- the radial collateral ligament – extends from the styloid process of the radius to the scaphoid bone, controls the adduction (ulnar abduction) of the hand and transfers the rotational movements of the forearm onto the hand,
- the ulnar collateral ligament – extends from the styloid process of the ulna to the triquetral bone and to the pisiform bone; it controls the abduction (radial abduction) of the hand and, together with the radial collateral ligament, transfers pronation and supination of the forearm onto the hand,
- the palmar radiocarpal ligament – extends from the styloid process and the palmar margin of the radius to all four bones of the proximal carpal row; it controls the extension and supination of the hand,
- the dorsal radiocarpal ligament – has its origin on the dorsal margin of the distal radius and its insertion on the dorsal surface of the proximal carpal bones, controls the palmar flexion and pronation, but is weaker than the one mentioned above,
- the palmar arcuate ligament of the wrist – combines fibers of the palmar radiocarpal ligament and ulnar collateral ligament; it controls the extension in the joint,
- the dorsal arcuate ligament of the wrist – connects only the scaphoid and triquetral bones; it controls the flexion and abduction (Fig. 2) [5, 22].

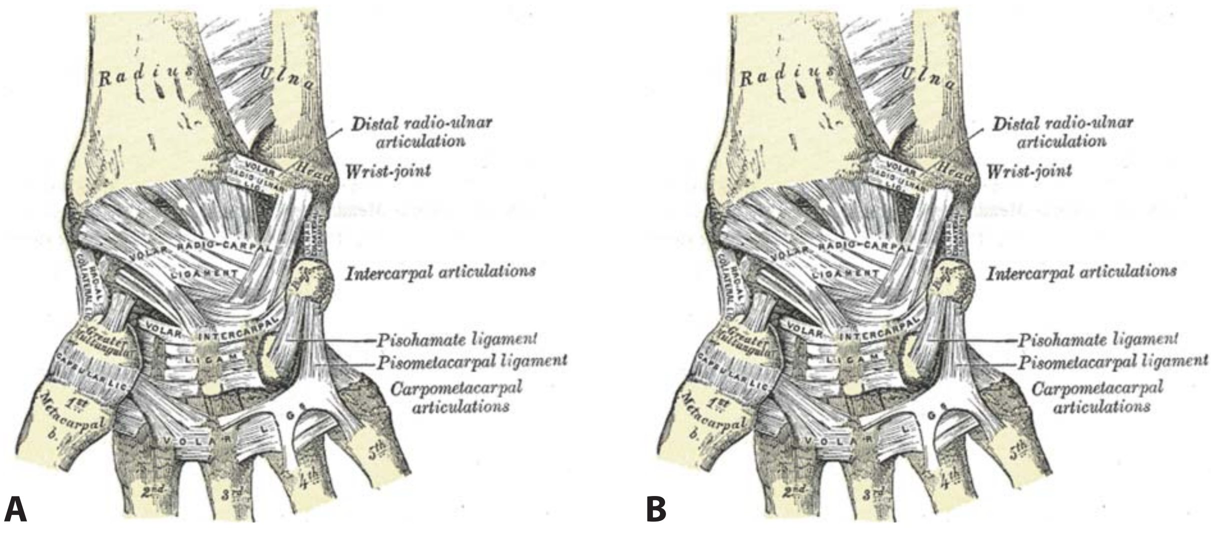


Fig. 2. Ligaments of the radiocarpal joint; palmar view (A) and dorsal view (B).

1.1.2. Muscles

The muscles mobilizing the joints at the distal end of the radius belong to a group of forearm muscles. They can be divided into three groups:

- the anterior (palmar) group – comprising eight muscles: the pronators teres and quadratus, the flexors carpi radialis and ulnaris, the flexors digitorum superficialis and profundus, the flexor pollicis longus, and the palmaris longus muscle; this group is responsible for the flexion of the radiocarpal joint and pronation of the forearm,
- the posterior (dorsal) group – comprising seven muscles responsible for the extension of the radiocarpal joint: the extensors digitorum, indicis, digiti minimi, pollicis longus and extensor brevis, as well as the extensor carpi ulnaris and the abductor pollicis longus,
- the lateral (radial) group – comprising four muscles: the brachioradialis (not involved in wrist movements), the extensors carpi radialis longus and brevis, and the supinator muscle. This group of muscles is responsible for the extension in the radiocarpal joint and supination in the radioulnar proximal and distal joints (Fig. 3) [5, 22].

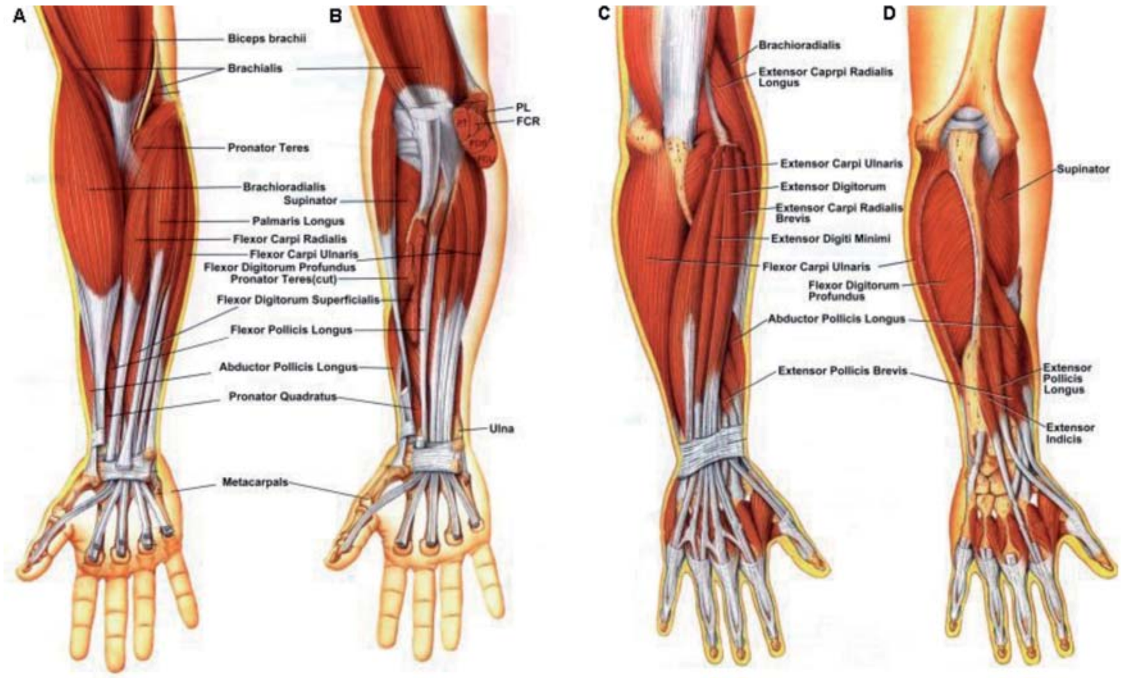


Fig. 3. Muscles of the forearm; anterior views (A and B) and posterior views (C and D).

1.1.3. Fasciae

The antebrachial fascia, which is a continuation of the brachial fascia, surrounds all the muscles of the forearm. From the anatomical point of view, it can be divided into the proximal part, the cubital fascia, surrounding the structures of the elbow joint and enclosing the cubital fossa, and the distal part continuing into the fascia of the hand at the wrist level.

Joined with the posterior margin of the ulna along its entire length, the antebrachial fascia forms intermuscular septa separating individual groups of antebrachial muscles. Moreover, the fascia forms multiple divisions separating individual muscles. Fibres of the antebrachial fascia run circularly and are particularly thick and strong where the fascia continues into the fascia of the hand.

The fascia of the hand is divided into four laminae. Two of them – the palmar deep fascia and the dorsal interosseous fascia – are the deep layers. More superficially, on the dorsal side, the superficial dorsal fascia of the hand can be found, beneath which lie the tendons of the extensors digitorum longus. On the palmar side, there is the superficial palmar fascia of the hand. In its middle part, it thickens markedly and forms the palmar aponeurosis, whose palmar fibers intertwine with the palmar longus muscle tendon, and the dorsal (deep) fibers interlace with the extensor retinaculum [5, 22, 27, 68].

1.2. Selected biomechanical aspects

1.2.1. The radiocarpal joint

The radiocarpal joint is ellipsoid, with the distal part of the radius and the articular disc forming the socket, and the proximal carpal bones forming the head. This is an articulation with two degrees of freedom. The possible movements occur in a sagittal plane around a transverse axis (flexion and extension) and in a frontal plane around a sagittal axis (adduction and abduction). These movements can be combined into circumduction around the long axis of the arm [6, 29, 32, 34].

All of the above movements involve both the radiocarpal and the midcarpal joints (the latter connecting the bones of the proximal and distal carpal rows) as well as the arthrodial joints between all the carpal bones. These articulations are conjoined, thus their combined mobility is being considered.

The range of movements in a frontal plane is extensive, as it is 85° for active flexion and active extension each. The passive range of these movements is even greater at 95° and 100°, respectively (Fig. 4, 5) [29]. During flexion, the radiocarpal joint is responsible for 50° of mobility, and the midcarpal joint for 30°. During the extension, the greater role can be attributed to the mobility in the midcarpal joint (45°), whereas the radiocarpal joint is responsible for only approximately 35° of the range of extension [6].

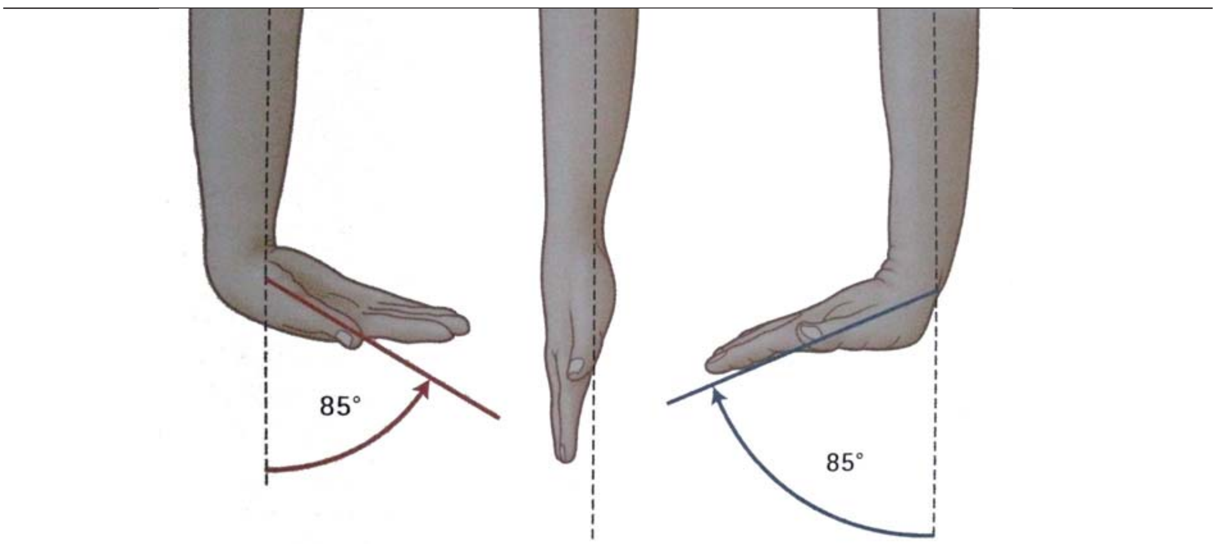


Fig. 4. The range of active flexion and extension in the wrist.

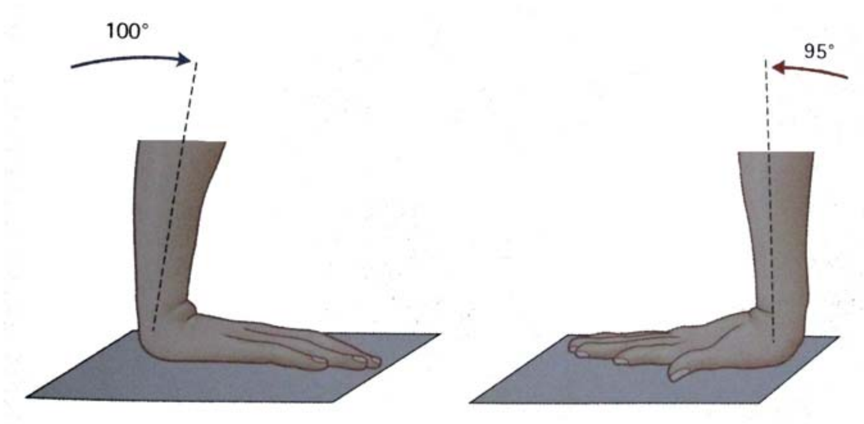


Fig. 5. The range of passive flexion and extension in the wrist.

Range of motion in a frontal plane is smaller at 15° of the active abduction (radial abduction) and 40–45° of the active adduction (ulnar abduction) (Fig. 6) [6, 29, 32, 34].

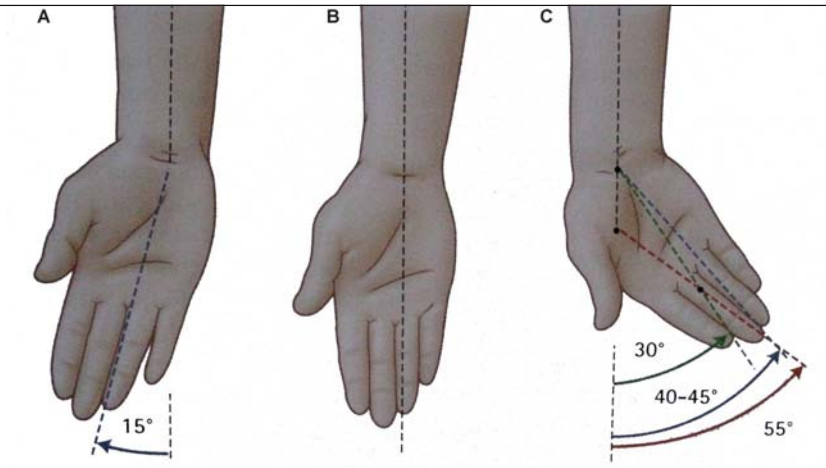


Fig. 6. The range of abduction (A) and adduction (C) of the wrist starting from the intermediate position (B).

1.2.2. The distal radioulnar joint

This articulation is a pivot joint with one degree of freedom. The movements of pronation and supination of the forearm occur in a horizontal plane around the long axis of the forearm. This articulation is functionally coupled with the proximal radioulnar joint, formed by the circumference of the head of the radius and the radial notch of the ulna. This coupling means that movement in both of these joints is necessary in order to achieve rotation of the forearm. Movement in these joints is controlled by the pronator and supinator muscle flexion and, in extreme positions, by the articular capsules. The interosseous membrane stabilizes the movements in those joints controlling the mobility of the ulna and the radius, relative to each other in the long axis of the forearm. The range of supination in the forearm is 90° and pronation – 85° (Fig. 7) [6, 29, 32, 34]].

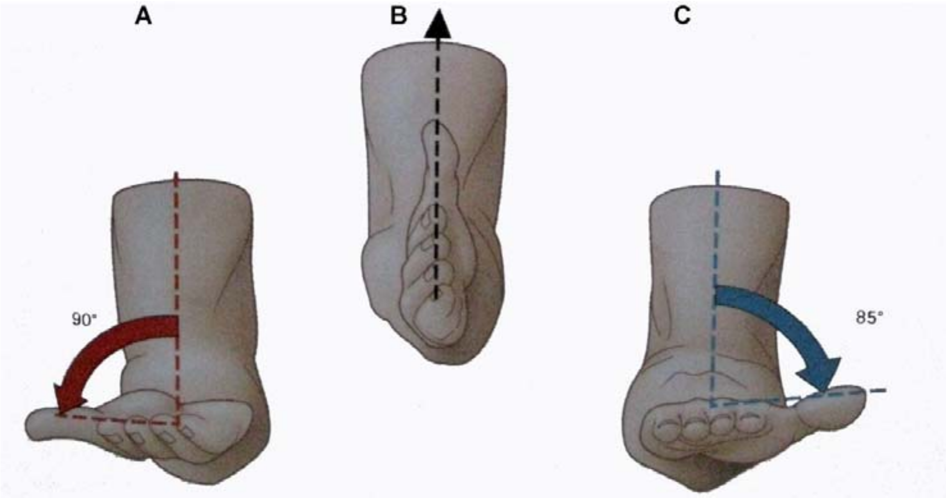


Fig. 7. The range of supination (A) and pronation (C) of the forearm from the intermediate position (B).

1.3. Distal radial fractures

Distal radial fractures are among the most common injuries reported in emergency departments and A&Es. Moreover, these are among the most common fractures in the elderly, although they are not uncommon in the young adult population or children and adolescents where they occur as a result of high-energy injuries [10, 20, 26].

1.3.1. Mechanisms of injury and fracture classifications

A distal radial fracture is most commonly a result of indirect force, i.e. fall on the hand. Direct fractures caused by an impact of a heavy object are rare. Depending on the mechanism of injury, fractures can be divided into fractures in extension mechanism (when the hand was extended during the fall) and, less common fractures in flexion mechanism (when the hand was flexed).

Usually, conventional names are used for the different types of distal radial fractures:

- Colles' fracture – a distal metaphyseal fracture of the radius, where the fracture slit may reach the articular surface; with angulation and radial shortening,
- Smith's fracture – also known as a reverse Colles' fracture, characterized by volar displacement of distal fracture fragments, it may be extra-articular or may involve the radiocarpal joint,
- Barton's fracture – involves the dorsal or palmar margin of the radial articular surface and is complicated by wrist subluxation,
- Chauffeur's fracture – an intra-articular fracture of the radial styloid process,
- Die-Punch fracture – involves a depression fracture of the lunate fossa or a depression of a central facet fragment.

There are also other classification systems intended to facilitate communication among the medical personnel and help the clinician to select the most effective treatment. Among the oldest, there is the Frykman's classification which divides fractures into intra-articular and extra-articular, and then according to the damage to the styloid process of the ulna; this classification comprises eight types of fractures (Fig. 8) [18].

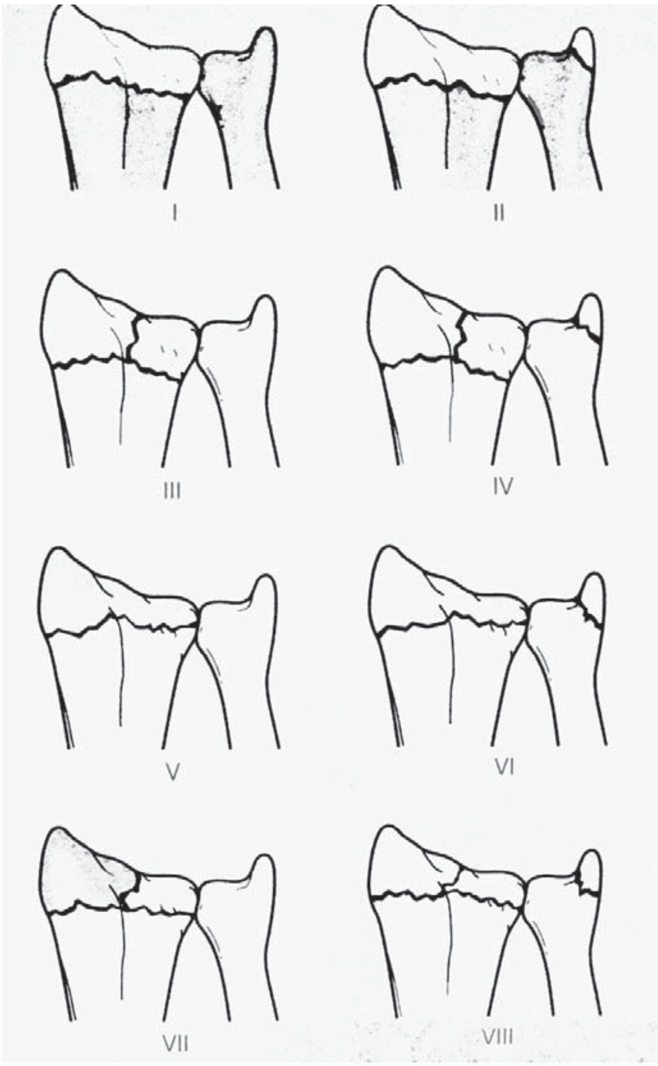


Fig. 8. The Frykman's classification of distal radial fractures.

The fracture classification most commonly found in literature is the AO classification, due to its simplicity on one hand and precise division of fractures into types and subtypes on the other. The AO classification divides fractures into three main categories:

A – extra-articular fractures,

B – partly intra-articular fractures,

C – fully intra-articular fractures.

Fracture subtypes can be classified based on the extent of injury to the joint and metaphyseal fragmentation (Fig. 9). This classification is of practical benefit, considering that assigning a given fracture to the right type has bearing on the selection of treatment approach.

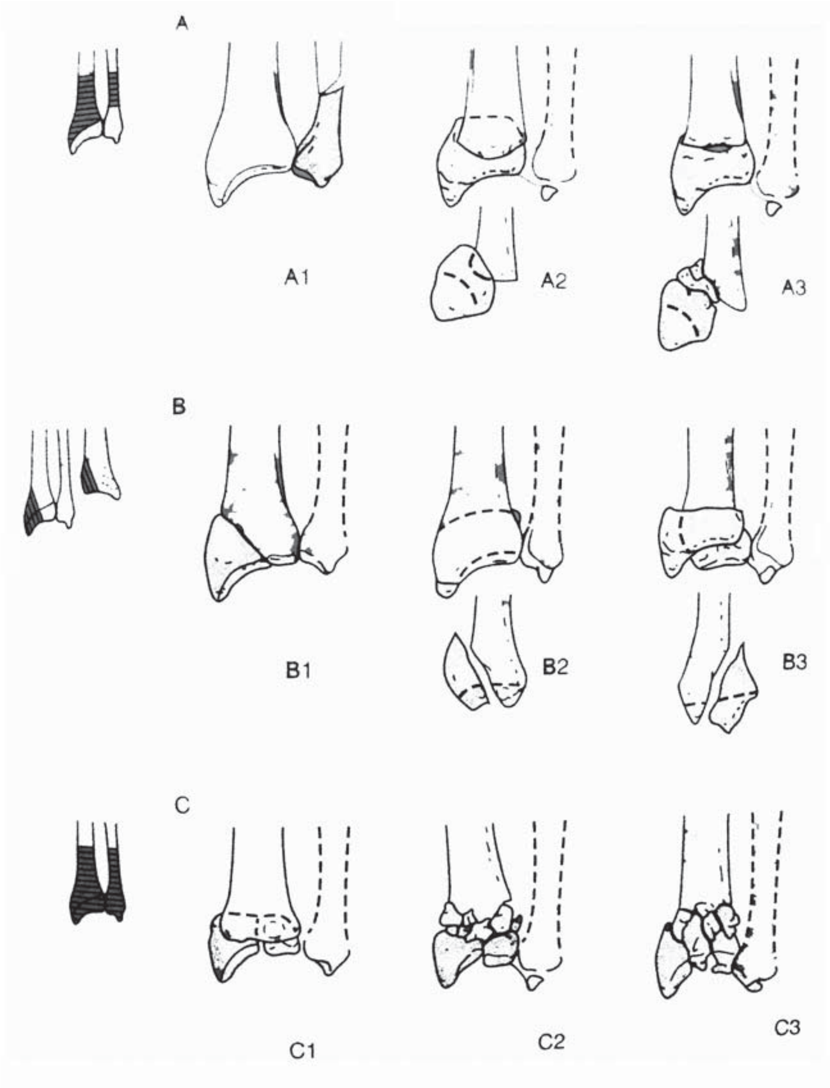


Fig. 9. The AO classification of distal radial fractures [Muller].

Similar principles are used in the so-called universal classification of fractures into four main types, as well as in the Medoff's classification based on radiographic findings and the selected treatment method. These classification systems, however, are less commonly applied.

Relatively frequently encountered is the Fernandez classification, which divides fractures according to the mechanism of injury and co-existing damage as well as the recommended treatment into:

Type I – bending fracture of the metaphysis,

Type II – shearing fracture of the joint surface,

Type III – compression fracture of the joint surface,

Type IV – avulsion fracture, radiocarpal fracture with dislocation,

Type V – complex fractures of types I-IV, high-energy fracture [Brown, Sanders].

Distal radial fractures can be divided into indirect (more common) and direct (less common) mechanism injuries. Based on the kind of trauma, there may be high-energy or low energy fractures. High-energy fractures occur usually in young people as a result of falls from a height, a forceful impact or a traffic accident. Low-energy fractures are caused by falls from the standing height and are typical for the elderly suffering from osteoporosis. As mentioned above, distal radius fractures may result from a fall on an extended hand (Colles' fracture), which is the most common fracture type or on a flexed hand (Smith's fracture) [15, 26, 79].

The following may be associated with distal metaphyseal fractures of the radius:

- fracture of the ulnar styloid process,
- fracture of the scaphoid bone and other carpal bones (particularly in children),
- periscaphoid dislocations,
- injury to the triangular fibrocartilage complex,
- ligament injuries (especially of the interosseous ligaments),
- injury to tendons, nerves, and other soft tissues surrounding the fracture.

Fracture-associated soft tissue injuries occur in about 70% fractures, which in the case of misdiagnosis may lead to carpal instability [15, 20, 26, 35].

1.3.2. Fracture epidemiology

Distal metaphyseal fractures of the radius constitute 12–15% of all fractures. A vast majority of distal radial fractures are osteoporotic. These are seven times more frequent in women over 60 than in men of the same age. Incidence of these fractures ranges from 0.5% to 2% annually, and the number of people suffering from this injury grows rapidly in the age group of 60 to 69. Risk factors for fractures in this population include mainly low bone mineral density (BMD) and a fracture in the family. This is often the first sign of osteoporosis, particularly in regions where early osteoporosis diagnostic tests are neglected. Poor mechanical strength of bones is another factor predisposing to fragment displacement during treatment, late instability, and deformities [21, 41, 57, 61, 62].

1.3.3. Diagnostics

Early assessment of the injury involves visual inspection and physical examination. The wrist is often deformed, immobilized in one position, and any attempt at movement causes severe pain. Before any further diagnostics or treatment is undertaken, the distal limb has to be assessed for pulse and superficial sensibility.

Radiographic imaging is the evaluation of choice in suspected distal radial fracture. Routine radiographic images are postero-anterior and lateral views showing the fracture line (Fig. 10).

Additionally, a lateral view may be obtained with the wrist positioned in a neutral position and elevated by 10º off the image plate. This projection more accurately shows the radiocarpal joint surface.

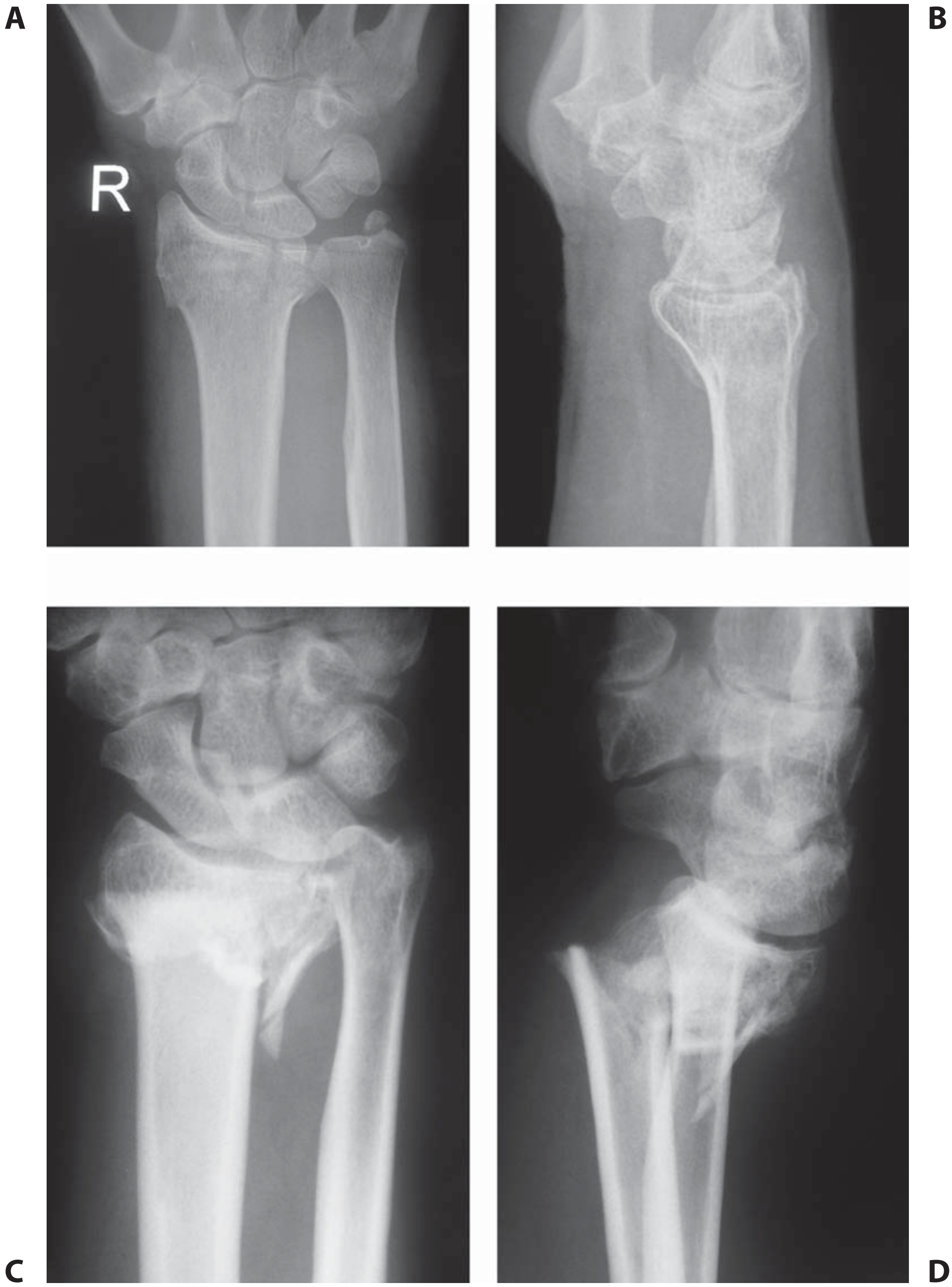


Fig. 10. A radiographic image of a radial fracture in antero-posterior (A) and lateral (B) views; C, D – distal radius fracture – type C3.

Computed tomography (CT) and magnetic resonance imaging (MRI) are among the additional examinations used in differential diagnosis assessing the associated injuries, such as ligament and tendon tears, as well as in assessing the joint surface fit in trans-articular fractures (Fig. 11) [26, 71].

A **B**

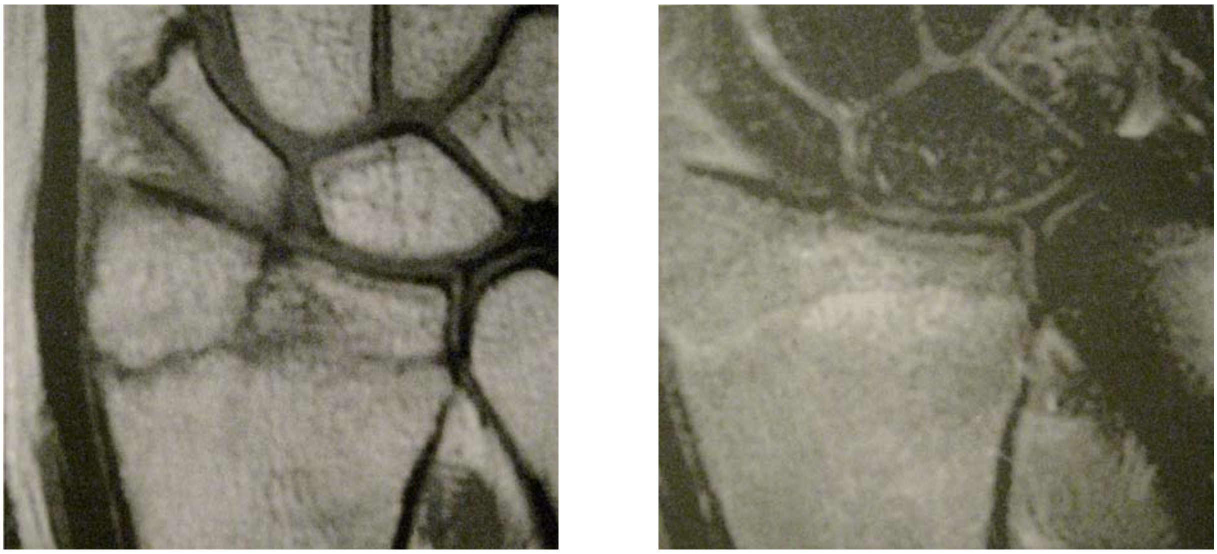


Fig. 11. An MRI scan of an intra-articular fracture of the radius: the fracture line in the T1-weighted sequence (A) and a hyperintense area of bone marrow edema in the FST2-FSE sequence (B).

1.3.4. Treatment of distal radial fractures

The treatment goals in fractures of the distal radius are reconstructing the anatomical angles of the radiocarpal joint surface, as well as maintaining the proper radial height and the stability of the distal radioulnar joint. The congruence of articular surfaces of the scaphoid and lunate fossas is of major importance, as it allows forces to be properly distributed across the wrist and ensures the execution of smooth movements in the radiocarpal joint. Important from the point of view of restoring the hand function is reconstruing the normal biomechanical parameters of the wrist, in particular:

- the radial inclination angle, normally between 22–23°, with an acceptable range of 13-10°,
- the palmar tilt of the distal radius (norm 11–12°, range 0–28°),
- the radial height in comparison with the ulna (norm 11–12 mm, acceptable range 8–18 mm) (Fig. 12).

The expected long-term treatment effects are the return of full range of flexion, extension, radial abduction and ulnar abduction of the wrist, as well as forearm rotation [12, 24, 26].

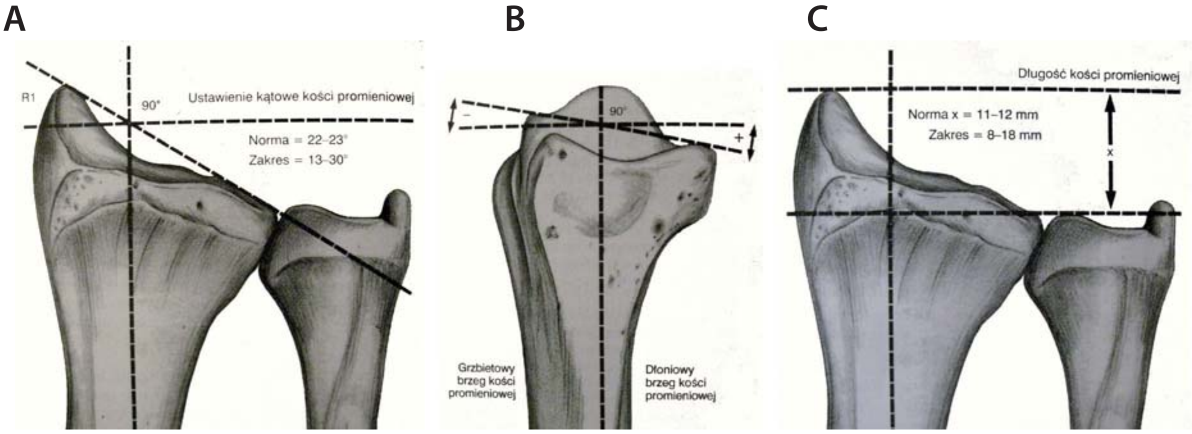


Fig. 12. Normal positioning of the distal end of the radius: radial inclination angle (A), radial tilt (B), and radial height (C).

1.3.4.1. Conservative management

Conservative management indications include:

- extra-articular fractures with or without displacement,
- intra-articular extension fractures without displacement,
- compression fractures with slight fragment displacement.

Moreover, conservative management is used in patients with contraindications to general anesthesia.

In fractures with displacement, reduction of fragments is required prior to fragment immobilization. This is most commonly done using closed methods under local anesthesia. During the reduction procedure, the fragments are pulled apart with the help of another person or using finger traction. Non-displaced and reduced fragments are stabilized with the use of an individually moulded sugar-tong splint. This splint remains in place for 2–3 weeks with a weekly inspection for the axial positioning of fragments. After splint removal, the forearm is placed in a cast for 3–5 weeks. After 6 weeks of immobilization, the cast is removed and passive wrist movements are introduced. Further rehabilitation is similar to that following surgical treatment and its purpose is to restore full joint mobility, muscle strength, and the ability to perform daily activities.

If any fracture displacement occurs within 2 weeks after the fracture reduction and immobilization, surgical stabilization should be considered [16, 24, 26, 40].

1.3.4.2. Surgical treatment

Surgical treatment indications are:

- intra-articular fractures with displacement,
- unstable fractures,
- fractures with significant initial fragmentation,
- fractures with a significant shortening of the radius, particularly compression fractures,
- fractures impossible to reduce using the closed methods.

The methods of choice in surgical treatment of distal radial fractures include: percutaneous Kirschner-wire stabilization, external fixation, external fixation with K-wireing or internal fixation, and internal fixation with the use of plates and pins. Fracture stabilization is preceded by closed, open or arthroscopic-assisted reduction [26, 40, 73].

Percutaneous wire stabilization is conducted after closed reduction of the fracture. Kirschner wires are introduced via small incisions in the skin through the styloid process of the radius and into the cortical layer of the proximal fragment of the ulna (Fig. 13). In the Kapandji method, the wires are utilized as levers for the entire fracture and help reduce the fracture as well as maintain the required shape of joint surfaces. After the wires are introduced, the wrist is immobilized in a splint or plaster cast for 4–5 weeks. This method is not recommended for treating fractures in the elderly; however, in younger patients, it leads to significantly better outcomes than conservative management [4, 24, 26, 65, 73].

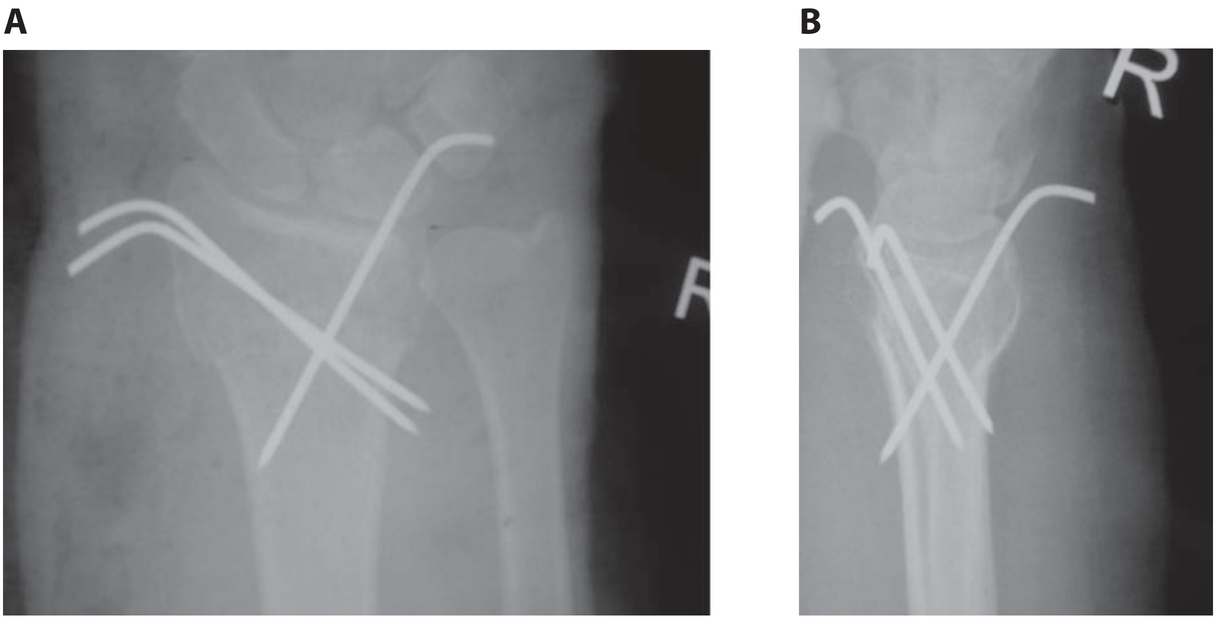


Fig. 13. Post-surgery radiographic images of a fracture treated with Kirschner wires – antero-posterior (A) and lateral (B) views.

Good long-term effects are also achieved with external fracture stabilization. This is performed with the use of an external fixation device, comprising pins introduced into the bone and external bars (Fig. 14). External stabilization is sometimes supported with the Kirschner-wire fixation or internal stabilization, a bone graft or arthroscopic-assisted fragment reduction. The use of external stabilization with the support of Kirschner wires is an effective means of fragment immobilization and it decreases the risk of repeated surgery. However, it may increase the incidence of infection [14, 21, 25, 26].

A **B**

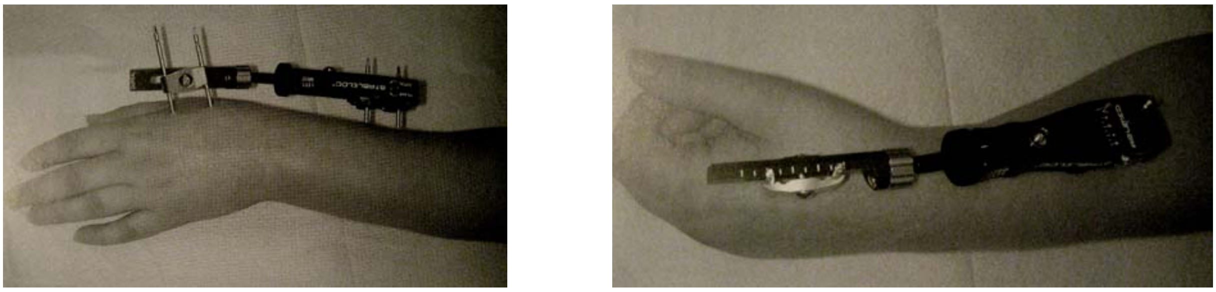


Fig. 14. The use of external fixation in radial fracture management.

Arthroscopic reduction of fragments is particularly useful in injuries with extensive fragmentation of the epiphysis and appears to be a more effective method of assessing the articular surface of the reduced fragments than fluoroscopy. Moreover, it facilitates the diagnosis of any co-existing damage to ligaments and the triangular cartilage [24, 26].

In the case of fractures impossible to reduce, open reduction and internal fixation are used. Internal fixation is also used in multiple-fragment and compression fractures, with a co-existing ulnar fracture, and in people with osteoporosis. In multiple-fragment fractures, stabilization can be achieved with the use of screws and Kirschner wires. With fewer fragments, a dorsal distraction plate or fixed-angle plates can be used dorsally or volarly. Distraction plates are utilised in high-energy fractures with considerable fragmentation of the distal radial epiphysis. Stabilization with the use of a dorsal plate is indicated in Barton's fracture (shear type) and in fractures with displacement of the dorsal margin of the articular surface. This technique, however, is less and less common, as it may result in irritation or damage to the extensor digitorum tendons. Stabilization with the use of palmar plate helps to restore the length of the radius and achieve appropriate ulnar inclination (Fig. 15). Some authors report clinically asymptomatic joint instability following this treatment. It is worth noticing that the use of internal stabilization contributes to a quicker restoration of full range of motion, whereas its long-term effects seem to be similar to those achieved with the use of external stabilization. Mechanical stabilization with a plate is equally effective to that with external fixators, although clinical studies show inconsistent results of comparative evaluation of these types of stabilization among different authors [8, 14, 17, 25, 26, 36, 52, 53, 55, 64, 72].

A B

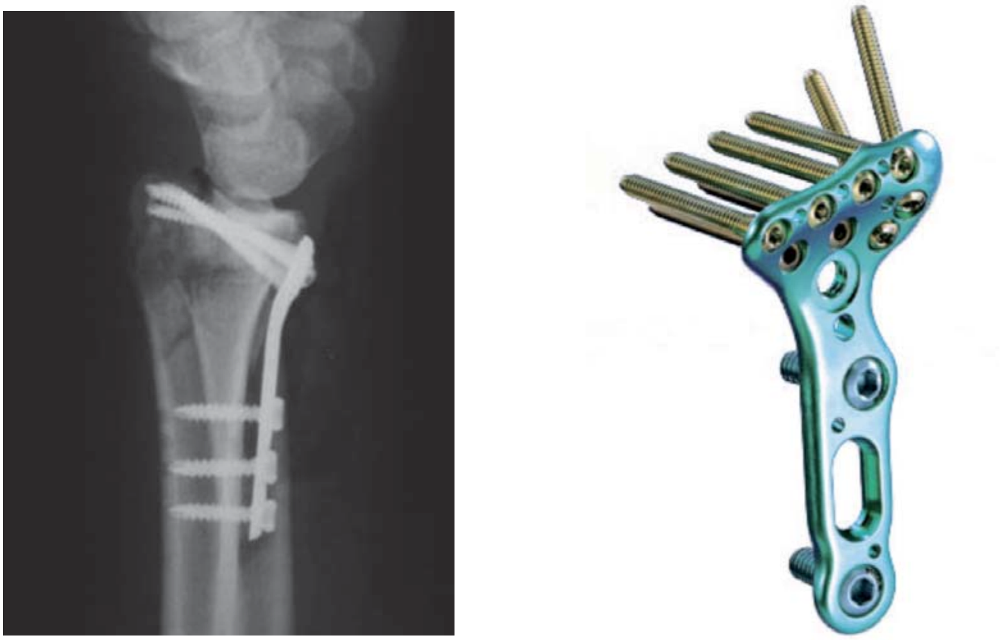


Fig. 15. A post-operative radiographic image of a fracture stabilized with a fixed-angle palmar plate (A) and an image of a palmar plate (B).

In the case of significant bone loss, which is most often due to fragment impaction, grafts of bone or bone replacement materials are implemented. Bone grafts are also utilized with the placement of stabilizing plates in order to replace any larger bone defects [26, 64].

The outcomes achieved one year after the injury seem to be similar irrespective of the treatment method, provided that it has been properly matched to the type of fracture and the patient's condition [14, 50].

1.3.4.3. Complications

Management of distal radial fractures is associated with a high rate of complications that eventually contribute to a significant number of unsatisfactory outcomes. Complications of both conservative and surgical management include:

- displacement resulting in incorrect bone union,
- delayed, or lack of, bone union,
- permanent nerve damage due to injury, surgical procedures or long-term pressure,
- inflammation of the joint and periarticular tissues (also as a result of infection), which may cause bone nonunion,
- tendon rupture,
- inadequate mobility or instability of the radiocarpal or distal radioulnar joint,

- Sudeck’s atrophy (reflex sympathetic dystrophy syndrome),
- Volkmann’s ischemic contracture,
- rarely: pressure sores caused by incorrectly applied plaster cast, carpal tunnel syndrome.

Incorrect union is one of the easily manageable sequelae causing most problems with restoring the hand function. Bone axis correction is achieved by intra-articular or extra articular osteotomy. An osteotomy procedure does not guarantee full joint function recovery, however, in most cases the results are satisfactory [26, 38, 43, 63, 78].

In the case of lack of union or delayed bone union, attempts are undertaken at conservative treatment with the use of physical therapy procedures (magnetotherapy with high-induction fields) as well as surgical treatment (resection of the fractured bone ends, re-fixation, cortico spongeous graft) or compression-distraction osteosynthesis (the Ilizarov technique), particularly with a co existing radial shortening and axis warping. If the treatment is ineffective, carpal arthrodesis can be performed, which improves the hand function with relatively few complications [39, 56, 60, 66].

Treatment of other complications is consistent with the generally accepted management procedures and will not be addressed in this article due to the detailed character of the subject.

1.3.4.4. Physical therapy

The objectives of physical therapy following the removal of an immobilization device or the union of surgically fixed fragments are:

- restoring the full range of motion at the radiocarpal and distal radioulnar joints,
- achieving the full muscle strength, particularly grip strength,
- full recovery of the affected hand in terms of daily functioning.

The rehabilitation period can be divided into three phases:

- the early phase, lasting from fracture immobilization to approximately week 6,
- the intermediate phase, lasting from week 6 to week 8 post injury,
- the late phase, beginning approximately in week 8 post injury and lasting until the full hand function is restored (approximately week 12).

Early phase (weeks 0–6)

The main purpose of this phase is to decrease the rigidity and edema of the hand. Effective means include hand elevation above the heart level, frequent movements of fingers, the use of hand and wrist compression supports (or appropriate adhesive tapes). Active and passive finger range-of-motion exercises are also recommended (Fig. 16). The patients should use the hand as much as they can in performing light daily tasks, especially in the case of stable or successfully surgically stabilized fractures. If there are no contraindications for forearm rotation, forearm supination exercises should begin already in the early phase of rehabilitation, as this is one movement that can quickly become limited. Other wrist movements can be also performed, provided there are no contraindications and wrist stability is maintained (e.g. with palmar plate fixation or non-bridging external fixation). Post operative management requires the gently massaging of the scar to prevent its hypertrophy. Additionally, active exercises of the elbow and shoulder joints are recommended in order to prevent limitation of the range of motion in these joints. Magnetotherapy, local cryotherapy and, in the case of conservative management, electrotherapy are used to minimize pain, as well as to accelerate bone union and normal remodeling of the existing union.

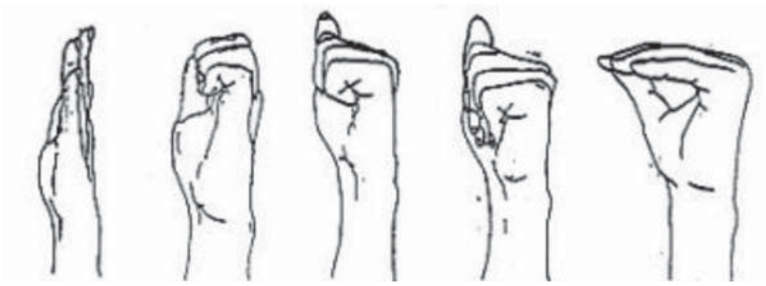


Fig. 16. Finger exercises for flexor tendon mobilization.

Intermediate phase (week 6–8)

After approximately 6 weeks, Kirschner-wire or external stabilization is removed. Also with other treatment methods, the patients should be encouraged to gradually give up external immobilization after 6 weeks. This phase focuses on increasing the limited range of motion of the wrist (flexion and extension, abduction and adduction) and forearm (supination and pronation). To this end, active-assistive and passive exercises are used, as well as supination splints or other dynamic splints, if required. Any physical therapy initiated to that point should be continued in this phase.

Late phase (weeks 8–12)

After about 8 weeks following the injury, complete bone union is achieved, allowing the patient to begin the strengthening exercises of the hand using soft balls of various types and rubber hand trainers, as well as small weights, dumbbells or specially constructed devices for strength training in various movements. Additionally, wrist, metacarpal, finger, and forearm range-of-motion exercises are continued (Fig. 17). An important element of the late phase of rehabilitation is restoring the normal hand function. This is achieved through exercises with the use of various common objects – mugs, balls, cylinders, knobs, door handles, dials and other elements used daily by the patient. If necessary, electrotherapy (to fight pain as well as in the form of electric muscle stimulation) and local cryotherapy are used to prevent development of post-exercise edema and pain.

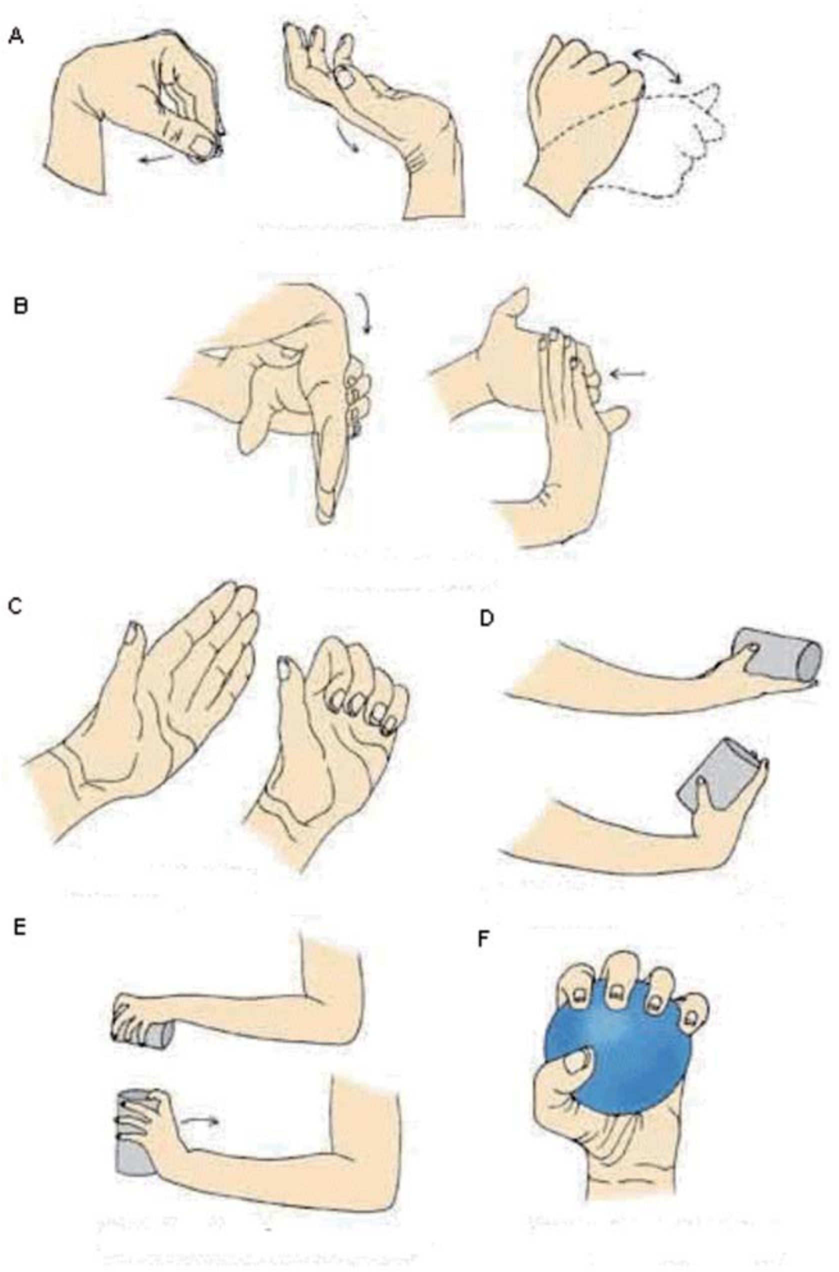


Fig. 17. Wrist exercises:

A – increasing the range of motion,

B – stretching the wrist into flexion and extension,

C – tendon mobilization exercises,

D – wrist flexion while holding a cylinder,

E – wrist extension while holding a cylinder,

F – increasing the grip strength.

Typically, a large proportion of patients receive instructions on how they should exercise and do the assigned exercises on their own at home. According to many authors, there is no significant benefit in conducting the rehabilitation program at the clinic, and that benefits, if any, are mainly due to greater patient satisfaction and decreased pain. Unfortunately, the role of physiotherapy in the treatment of distal epiphyseal fractures of the radius and in quick restoration of the hand function in these patients is still underestimated, which leads to not fully satisfactory outcomes or significant delays in achieving the full limb function [9, 30, 43, 44, 48, 66, 69].

1.4. The Fascial Distortion Model (FDM)

The Fascial Distortion Model (FDM) is a manual therapy method created and developed in the United States by Stephen Typaldos, an osteopath with many years' experience. This technique is also known as TMT (Typaldos Manual Therapy).

The tenets of this technique are based on the knowledge and diagnosis of the types of fascial structural, and consequently functional, abnormalities (distortions). Typaldos considers these distortions to be more significant as the causative factor of pain as well as muscle motor and function limitations than other injuries, such as sprains, luxations, fractures, mechanical muscle injuries. Thus, management of fascial distortions directly affects the other elements of the musculoskeletal system by alleviating pain, reducing movement limitations or edema. This gives the way to quicker and more effective treatment of injuries to other musculoskeletal system structures [75].

1.4.1. Fasciae

Fasciae are fibrous structures composed of connective tissue and located in all parts of the human body – they make up tendons, ligaments, superficial and deep fasciae, pericardium, and other structures the function of which is to join, protect, separate, isolate, and envelop internal organs, muscles and systems of the body.

As a result of their structure, fasciae have poor blood supply. A major portion of oxygen and nutrients as well as metabolites are transported via diffusion between cells and fascial perfusion fluid. This has important consequences in the case of fascial distortions described further in this chapter.

Due to their diverse functions and locations, fasciae differ in structure and mechanical properties. Fascial structures can be divided into the following types:

- fascial bands – including tendons, ligaments, and the iliotibial tract,
- spiral bands – surrounding parts of limbs, trunk, blood vessels, and internal organs,
- folded fasciae – including joint capsules, interosseous membranes and fascial septa,
- smooth fascial bands – lining joints, lining the abdominal cavity beneath other types of fasciae (except folded fasciae).

The function of all fascial types is the protection of various structures. Fascial bands protect joints, blood vessels, tissues, and some areas of the trunk and limbs against perpendicular external forces. Spiral bands of fascia protect extra-articular tissues against harmful effects of traction or compression forces. Bands of irregular, plicated structure are to protect the joints against longitudinal forces, i.e. traction and compression. Finally, smooth fascial bands maintain adequately low level of friction between the different structures, which allows them to easily shift against each other.

Apart from their protective function, fasciae also have a very important function as a structure able to receive mechanical signals. Parallel fibers of connective tissue forming fasciae are excellent transducers of mechanical forces, received by mechanoreceptors located in both the fasciae and adjoining tissues. Mechanoreceptors react both to stretching and compression that affects the pressure in surrounding tissues and in the receptor cell itself. Stimuli received by receptors are transferred to the central nervous system. It is vibration, sensed via single fascial fibers and proportional to the level of external stimulation, that plays a significant role in the reception of stimuli. Moreover, the vibration frequency of fascial fibers determines the characteristics of perceived discomfort: pulling, burning, numbness or pain. This fascial receptor function is used extensively by the central nervous system in controlling the muscle contraction and motion in the joint [75].

1.4.2. Fascial distortions

Fascial distortions can be divided into:

- triggerbands,
- herniated triggerpoints,
- continuum distortion,
- folding distortion,
- cylinder distortion,
- tectonic fixation.

The type of fascial functional abnormality is determined based on medical history. What calls for particular attention is the manner in which the patient shows the painful area and describes the nature of discomfort (burning, stabbing, pulling, etc.). In fascial distortions, it is significant that an injury not only limits the range of motion, diminishes proprioception, and impairs normal muscle function, but it also significantly disturbs fluid transport between fascial laminae, and thus unsettles the chemical balance of the fascia and connecting tissues [75].

Triggerbands

Triggerbands are fascial bands that have been twisted, separated, torn or wrinkled (Fig. 18). The patient reports burning or pulling sensation along the fascial band and shows the pain with a wide movement of his/her hand along the affected fibers. The wider the movement the larger fascial area has been damaged. The pressure of fingers against the skin will be grater with fascia located deeper than with superficial fascial injuries.

The aim of treatment in this type of injury is to break the existing fascial adhesions, which had formed after the injury and changed the band structure (in chronic conditions), and to restore the normal arrangement of fibers. If fascial bands have been twisted, the first action will be to rotate them back the other way. Secondly, the torn or separated fascial bands are approximated to allow for their heeling by restoring their normal anatomy.

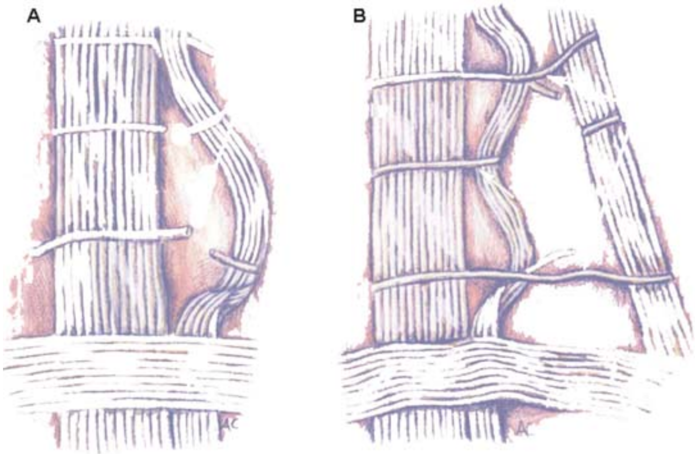


Fig. 18. Acute (A) and chronic (B) fascial band distortion.

Herniated triggerpoints

Herniation of fascial bands occurs when the underlying tissues protrude in an area of weakened connective tissue. This type of injury may cause a number of discomforts such as: pain in the cervical spine, shoulder, abdominal pain or the over-stretching of gluteal muscles. The patient indicates the painful area with one or several fingers pressing the injured site. The range of motion in neighboring joints is limited.

The treatment of herniated triggerpoints is to apply adequate perpendicular force to the injured site in order to "press" the herniated tissues back in and restore their normal anatomical relations.

Continuum distortion

This type of distortion is characterized by structural imbalance in the transition zone between the tendon, ligament or any other fascial structure and bone. As a result of this, the altered transition zone structure becomes more vulnerable to external forces. The structure alteration is mostly due to the growth of bone or tendon tissue that takes over the transition zone. This results in a loss of the transition zone or its significant shift (Fig. 19). Such injuries are mostly acute. These include tarsal joint sprains, over-stretching of neck muscles, and sacroiliac joint pain. In conditions of this type, the patient always indicates the painful site with a single finger. These injuries may be misdiagnosed as minor fascial band disturbances. Diagnosis should be based on the efficacy of a particular treatment technique.

Treatment aims to "shift" the overgrowing tissue (whether tendon or bone) back into place and to "expand" the transition zone to its normal size and position. A complementary treatment of continuum distortion is ice massage, which reduces the general discomfort around the joint.

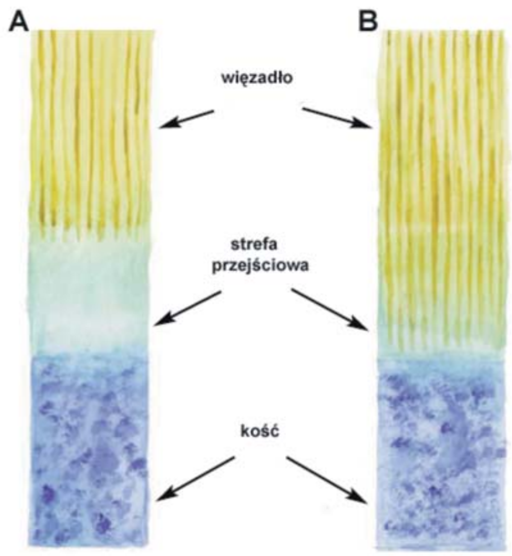


Fig. 19. Transition zone alterations – neutral state (A), ligamentous state (B), bony state (C) and "mixed-state" (continuum distortion) (D).

Folding distortion

Distortion in fascial folds is due to the traction or compression forces that exceed the mechanical resistance of periarticular fascia on which they are exerted. Based on their mechanism, folding distortions can be divided into traction distortions and compression distortions (Fig. 20). The resulting joint pain can easily be relieved by applying the forces in the same direction as those that caused the injury – traction is used in traction-related injuries, and compression is effective in compression injuries. These actions help the overly stretched or compressed tissues to return to their physiological state and the "organized" structure. Treatment also involves the often co-existing structure abnormalities caused by joint rotation at the time of injury.

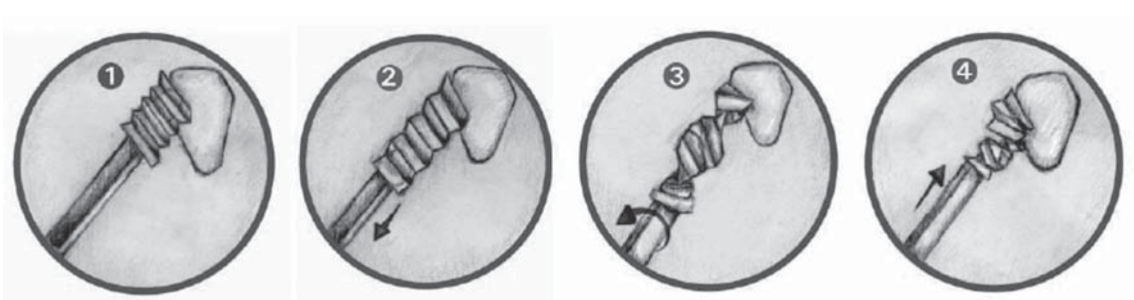


Fig. 20. Fascial distortion mechanism in a joint area following sudden traction and rotation.

Cylinder distortion

This type of distortion affects the fascia cylindrically encircling the individual segments of limbs (excluding the joints), the torso, and internal organs. As a result of compression or traction exceeding fascial resistance, the fibre arrangement shifts causing a disruption in the parallel, organized fascial structure (Fig. 21). Patients characterize their pain as situated deeply, despite the actual superficial location of its cause. More often than not, they are unable to determine the exact location of discomfort. This discomfort may sometimes seem to be neurological due to its character: tingling, numbness or reflex sympathetic dystrophy. While indicating the pain site, the majority of patients repeatedly squeeze the affected soft tissues. The pain may spontaneously relocate with time.

The treatment aims to restore the physiological arrangement of fascial fibers both with respect to each other and to the long axis of the limb. This is achieved by simultaneously twisting and pulling or compressing the damaged fascia. As with the already described treatment of periarticular fascial distortions, the direction of therapeutic force should be opposite to that which had led to the given fascial injury.

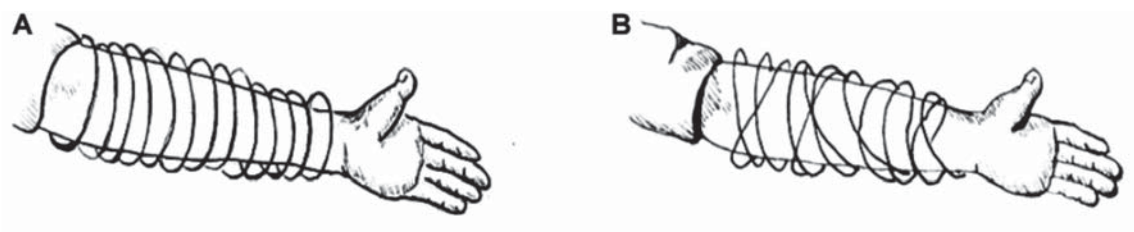


Fig. 21. Normal (A) and distorted (B) structure of spiral fascial fibres of the forearm.

Tectonic fixation

Tectonic fixation (fascial adhesion) occurs as a result of reduction in the amount of fluid produced by smooth fasciae. Adhesions cause limitations of fascial mobility in relation to itself and the surrounding tissues. There are also disturbances in the nourishment of cells incorporated in the fascial structure. Adhesions of the fasciae surrounding the shoulder, hip, and intervertebral joints are the most significant ones from the clinical point of view, as they produce the most severe symptoms.

The treatment of fascial adhesions should first address the other co-existing problems and then focus on increasing the tissue fluid perfusion. The final step of treatment is to restore the fascial mobility in relation to the adjoining tissues by severing the existing adhesions [75].

1.4.3. Treatment techniques

The FDM treatment techniques combine precision and relatively high force that needs to be applied to restore the fascial structure. These techniques can be divided into:

- manipulative techniques performed with the thumb – these include the treatment of triggerbands, herniated triggerpoints, continuum distortions, and some of the techniques used in cylinder distortions. Thumb techniques allow the application of significant force in a single site at a certain angle, which increases the precision of these procedures, however, the area of their application is limited,
- manipulative techniques performed with the whole hand – these are used in the treatment of folding distortions, tectonic fixation, and some cylinder distortions. These techniques are characterized by a smaller degree of precision, however, they allow the use of a greater force applied over a larger affected area; there is also a possibility of applying a traction or compression force to the joint or to extra-articular soft tissues [75].

1.4.4. Contraindications to FDM

The main contraindications to the use of FDM techniques are:

- venous thromboembolism,
- conditions involving bleeding,
- confirmed aneurysm,
- phlebitis,
- other peripheral vascular conditions,
- history of stroke,
- severe oedema,
- open cuts and wounds in the treated area,
- acute bacterial, viral, and fungal infections,
- osteitis,
- septic arthritis,
- fractures,
- connective tissue disorders,
- neoplasm,
- pregnancy (in therapies involving abdominal, pelvic, and lumbosacral spine areas).

Very frequently, these techniques are painful, thus relative contraindications should include low pain threshold or an existing psychiatric condition. In addition, caution should be exercised when applying these techniques in children.

Following the therapy, there may develop erythema, bruising, and other reflex skin reactions in the treated area. Sympathetic reactions such as nausea, vertigo, and vomiting are rare [75].

2. Materials and methods

2.1. Materials

A total of 65 patients (12 men, 53 women) at ages ranging from 22 to 81 were included in this study. Members of this group were randomized into the study group (n = 33) and control group (n = 32). Table 1 shows the detailed characteristics of groups.

Table. 1. Study and control groups broken down by gender and age.

	Gender		Age	
	Women	Men	Mean ± SD	Range
Study group	25	8	62 ± 14	22 – 81
Control group	28	4	61 ± 13	30 – 80

All study participants suffered a distal radial fracture in the period from February to July 2009. The fractures were more common in the left limb (22 patients from the study group and 22 from control group) than in the right (11 and 10 patients, respectively). Table 2 shows the types of fractures according to the AO classification. All patients underwent the treatment with Kirschner-wire stabilization and a 6-week cast immobilization.

Table. 2. Types of fractures in the study and control groups according to the AO classification.

Fracture type	A			B			C		
Subtype	A1	A2	A3	B1	B2	B3	C1	C2	C3
Number of fractures in the study group	3	2	2	0	1	1	7	13	4
Number of fractures in the control group	0	5	0	1	1	2	22	1	0

Apart from the standard recommendations and exercise instructions, the study group underwent 3 sessions with the use of FDM techniques mentioned above. These therapeutic sessions were conducted once a month. The therapy was adjusted to individual limitations and patient feedback related to pain. The utilized therapeutic techniques included:

- triggerbands,
- herniated triggerpoints,
- continuum distortion,
- folding distortion,
- cylinder distortions,
- tectonic fixation [27, 68, 75].

The selection of therapeutic techniques was based on detailed history and observation of the patient during history-taking. Particular attention was being paid to pain location and the patient's body language when indicating the painful area.

Twenty-four patients underwent three sessions each, 3 patients underwent two sessions each, and 6 patients one session each. The control group received only exercise instructions and recommendations about managing their hand injury.

2.2. Methods

In order to conduct an efficacy analysis of the study therapy, the following were assessed:

- grip strength,
- range of motion at the radiocarpal joint: extension, flexion, adduction and abduction,
- ability to perform daily tasks,
- level of pain.

2.2.1. Grip strength assessment

Grip strength was assessed with the use of the Biometrics Ltd. E-Link H500 dynamometer. Grip strength was defined as a mean of three consecutive measurements and expressed in kilograms approximated to one decimal place [3, 40] (Fig. 22).

Fig. 22. Muscle strength assessment with the H500 dynamometer.

2.2.2. Range-of-motion assessment in the radiocarpal joint

Range of motion in the radiocarpal joint was measured with a manual goniometer according to the established standards (Fig. 23, 24) [29, 67, 80].

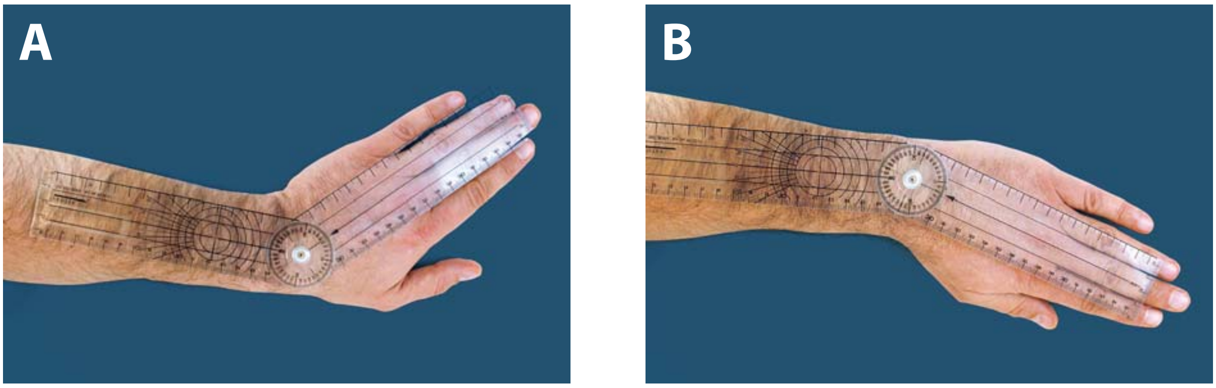


Fig. 23. Measurement of the range of flexion (A) and extension (B) in the radiocarpal joint.

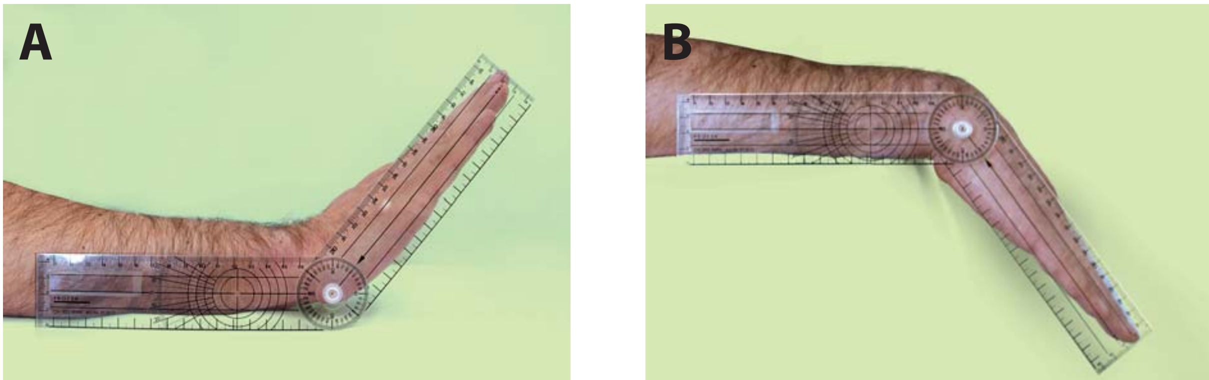


Fig. 24. Measurement of the range of abduction (A) and adduction (B) in the radiocarpal joint.

2.2.3. Assessment of patient's functional performance

A subjective hand function assessment was conducted with the DASH (Disabilities of the Arm, Shoulder and Hand) scale. This scale measures the patient's limitations in performing 23 everyday activities, such as housework, strength tasks, personal hygiene, social life and work, as well as 7 subjectively rated symptoms including pain, limb weakness, spasticity and the impact of these discomforts on sleep. Figure 25 presents the full version of the DASH scale. Each activity is scored from 1 (not at all difficult) to 5 points (unable to perform). The level of pain is rated in a similar manner from 1 (none) to 5 points (unbearable). In order to get the final result, the patient has to answer at least 27 out of 30 questions. The points from each answer are added and divided by the number of answers. For the result to be comparable with those achieved in other scales, the final score should be reduced by 1 and multiplied by 25. This way, the result falls within the 0-100-point range and is called the DASH 100 score. A higher score means greater limb disability [2, 33, 74].

The Disabilities of the Arm, Shoulder and Hand (DASH) Score

Date of completion...

Clinician's name (or ref).. Patient's name (or ref)..

		No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	Unable
1.	Open a tight or new jar	1	2	3	4	5
2.	Write	1	2	3	4	5
3.	Turn a key	1	2	3	4	5
4.	Prepare a meal	1	2	3	4	5
5.	Push open a heavy door	1	2	3	4	5
6.	Place an object on a shelf above your head	1	2	3	4	5
7.	Do heavy household chores (eg wash walls, wash floors)	1	2	3	4	5
8.	Garden or do yard work	1	2	3	4	5
9.	Make a bed	1	2	3	4	5
10.	Carry a shopping bag or briefcase	1	2	3	4	5
11.	Carry a heavy object (over 10 lbs)	1	2	3	4	5
12.	Change a lightbulb overhead	1	2	3	4	5
13.	Wash or blow dry your hair	1	2	3	4	5
14.	Wash your back	1	2	3	4	5
15.	Put on a pullover sweater	1	2	3	4	5
16.	Use a knife to cut food	1	2	3	4	5
17.	Recreational activities which require little effort (eg cardplaying, knitting, etc)	1	2	3	4	5
18.	Recreational activities in which you take some force or impact through your arm, shoulder or hand (eg golf, hammering, tennis, etc)	1	2	3	4	5
19.	Recreational activities in which you move your arm freely (eg playing risbee, badminton, etc)	1	2	3	4	5
20.	Manage transportation needs (getting from one place to another)	1	2	3	4	5
21.	Sexual activities	1	2	3	4	5
22.	During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups?	1	2	3	4	5
23.	During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem?	1	2	3	4	5
	Please rate the severity of the following symptoms in the last week	No difficulty difficulty	Mild difficulty	Moderate difficulty	Severe	Unable
24.	Arm, shoulder or hand pain	1	2	3	4	5
25.	Arm, shoulder or hand pain when you performed any specific activity	1	2	3	4	5
26.	Tingling (pins and needles) in your arm, shoulder or hand	1	2	3	4	5
27.	Weakness in your arm, shoulder or hand	1	2	3	4	5
28.	Stiffness in your arm, shoulder or hand	1	2	3	4	5
29.	During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand?	1	2	3	4	5
30.	I feel less capable, less confident or less useful because of my arm, shoulder or hand problem	1	2	3	4	5

number of responses: DASH total DASH 100:

Fig. 25. The DASH scale.

Moreover, the study group was additionally assessed in terms of pain intensity using the Visual Analog Scale (VAS) of 100 mm in length (with no calibration marks). The level of pain was expressed in millimetres, with 0 indicating no pain, and 100 – worst pain ever (Fig. 26) [13, 76].

Fig. 26. The 100-mm Visual Analog Scale, used for pain assessment.

Measurements were conducted by an independent person, blinded to the patient's group. The patients were not informed as to the expected assessment results. The study and control groups did not differ significantly in terms of baseline measurement results (range of motion, muscle strength), which was proved using Mann-Whitney U test (p>0,05). 24 patients from the study group completed all measurements and only these patients were finally included in the study.

Table 3. Initial measurement in the study and control group, expressed as percentage of values for the uninjured hand.

	STUDY GROUP (n=24)		CONTROL GROUP (n=32)	
	mean ± SD	range	mean ± SD	range
flexion	61,5 % ± 24,1 %	25 - 109 %	58,4 % ± 21,2 %	13 - 89 %
extension	56,3 % ± 22,8 %	24 - 107 %	61,1 % ± 23,8 %	37 - 120 %
adduction	65,4 % ± 33,7 %	20 - 160 %	59,9 % ± 27,6 %	25 - 115 %
abduction	61,6 % ± 32,8 %	14 - 133 %	73,2 % ± 30,0 %	10 - 157 %
grip strength	30,1 % ± 14,6 %	8 - 72 %	28,1 % ± 10,3 %	0 - 90 %

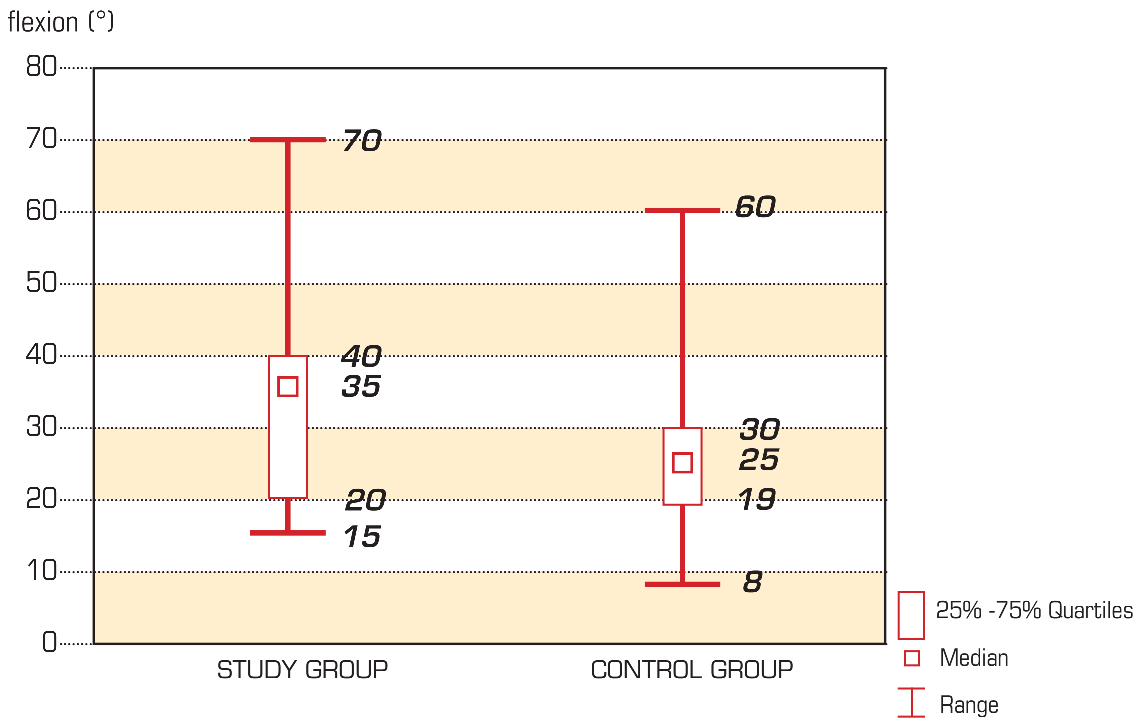


Fig. 27. Flexion range of motion in the study and control group (initial measurement).

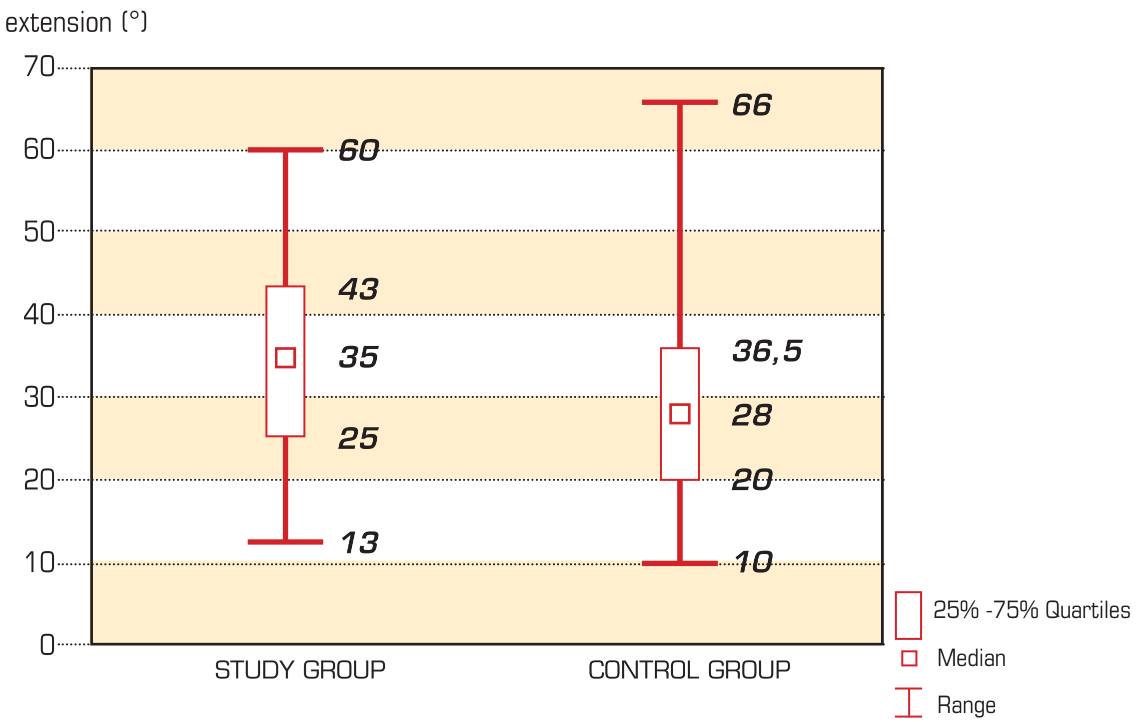


Fig. 28. Extension range of motion in the study and control group (initial measurement).

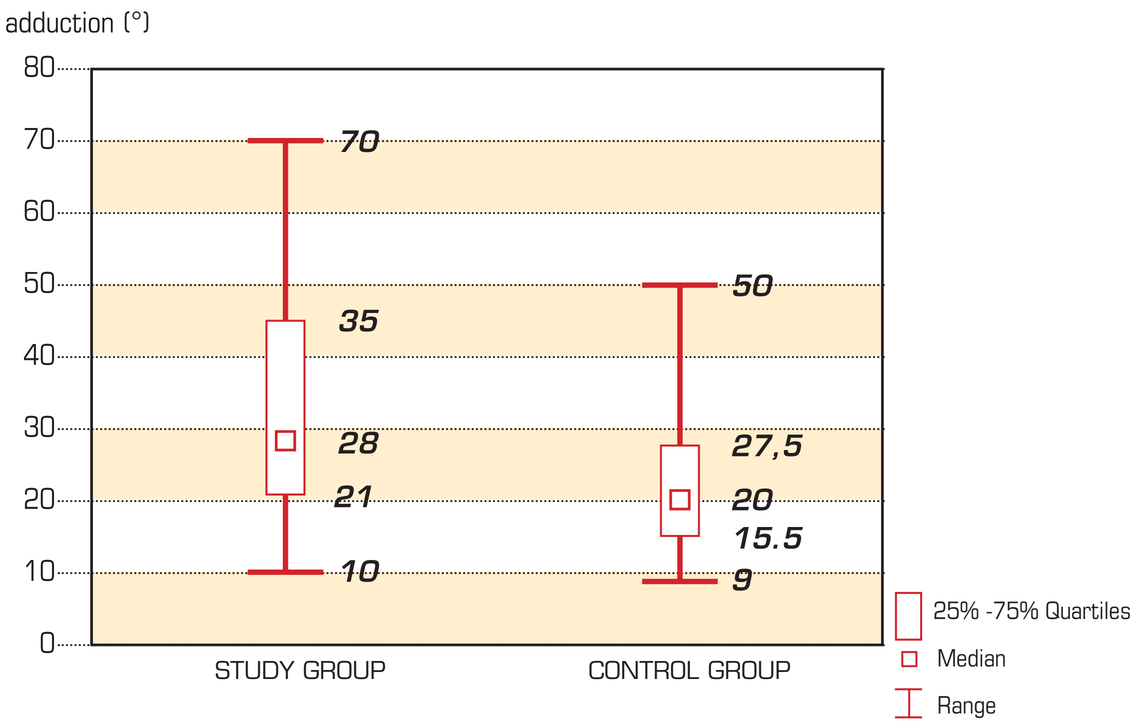


Fig. 29. Adduction range of motion in the study and control group (initial measurement).

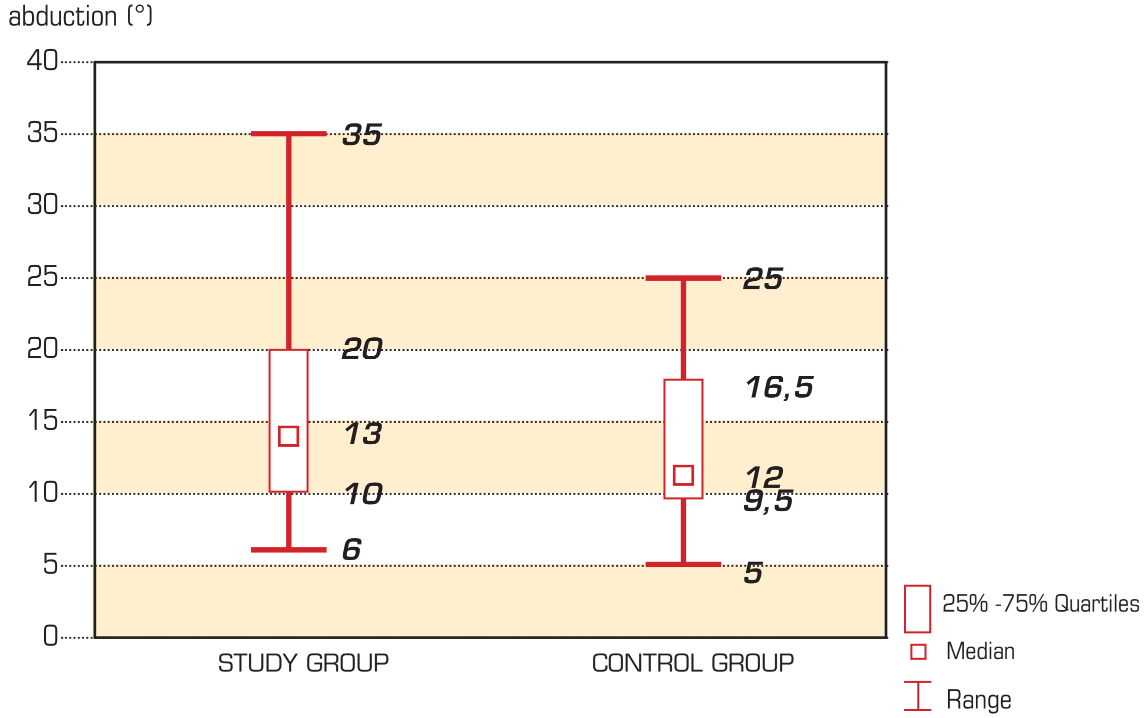


Fig. 30. Abduction range of motion in the study and control group (initial measurement).

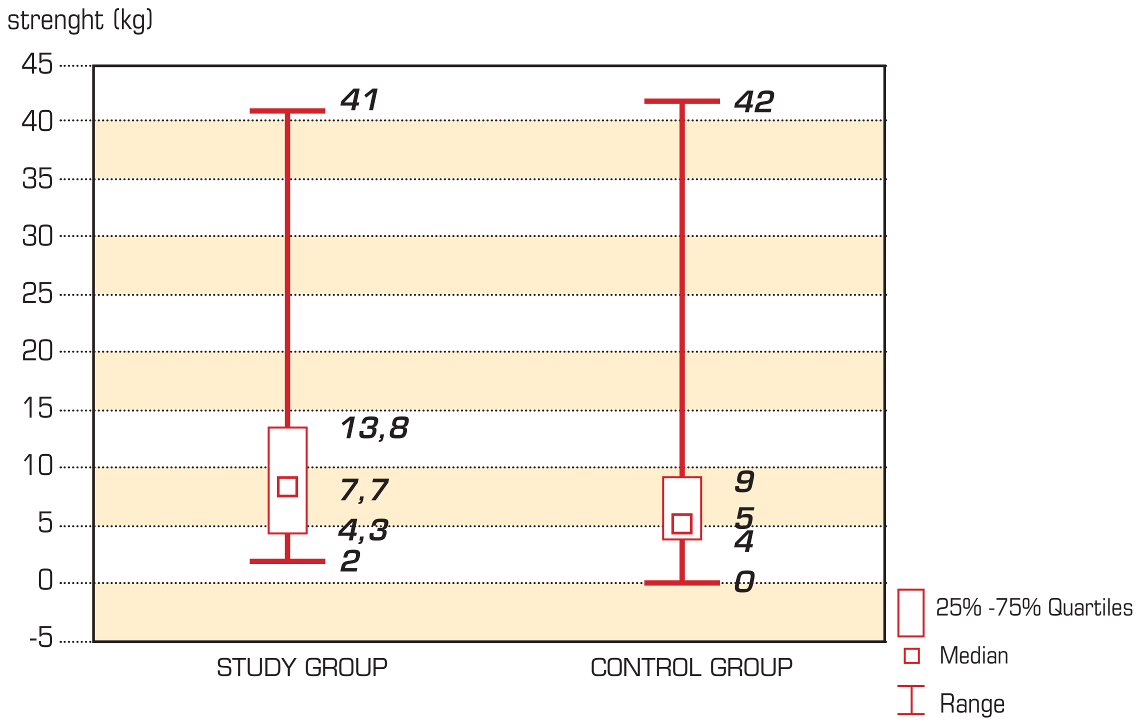


Fig. 31. Grip strength measurement in the study and control group (initial measurement).

2.3. Statistical analysis methods

The statistical analysis of study results was conducted with the use of Excel spreadsheet and Statistica 8.0 software. The basic statistics (mean, median, standard deviation, quartiles, range, frequency tables) and nonparametric tests were used. The differences between groups were analyzed with the Mann-Whitney U test, and the intra-group statistics were performed with the Wilcoxon matched-pairs test. Intra-group statistics in the evaluation group was additionally proved using Friedman's ANOVA test. Nonparametric tests were used due to the small sample size of study groups and results of test for normal distribution which was negative [70, 77]. Additionally range of motion and grip strength values were expressed as percentage of values for the uninjured hand of the same patient. Correlation analysis was performed using Spearman's Correlation Coefficient because of non-normal distribution of presented data.

3. Results

3.1. Grip strength and the wrist range of motion

As a result of therapeutic procedures, the evaluation group achieved a considerable increase in strength from 11.56 kg (1.8–41 kg) to 21.23 kg (8.6–53.3 kg) at three months following the removal of wires. These values correspond to an increase in hand strength from an average of 37% to 75% of that in a healthy hand. Five patients achieved strength values equal or greater than those in the uninjured limb.

The evaluation group achieved full range of abduction (mean 24,4°; 15°-36°) and flexion flexion (mean 61°; 46°-81°) in the radiocarpal joint three months after the removal of wires. Other ranges of motion - extension (mean 50,5°; 30°-67°) and adduction (mean 37,9°; 22°-51°) - and strength levels were, on average, still somewhat lower in the affected limb than in the uninjured one. Nonetheless, all the evaluated parameters improved significantly during the follow-up period ($p < 0.005$) and in selected patients they reached or exceeded those of the healthy hand. Table 4 presents detailed results expressed as percentage of healthy hand mobility.

Table. 4. Range of motion in the radiocarpal joint and grip strength in the evaluation group (n=33) at wire removal and 3 months later, expressed as percentage of values for the uninjured hand.

	at wire removal		3 months after wire removal		p value
	mean ± SD	range	mean ± SD	range	
flexion	61.5 % ± 24,1 %	25-109 %	112.7 % ± 23,4 %	75-157 %	0.00004
extension	56.3 % ± 22,8 %	24-107 %	77.1 % ± 17,0 %	47-115 %	0.00013
adduction	65.4 % ± 33,7 %	20-160 %	80.1 % ± 13,7 %	55-104 %	0.01577
abduction	61.6 % ± 32,8 %	14-133 %	103.2 % ± 39,7 %	51-220 %	0.00004
strength	30.1 % ± 14,6 %	8-72 %	75.2 % ± 26,2 %	29-149 %	0.00003

The control-group patients, who did not undergo controlled physical therapy procedures, achieved a statistically significant improvement in the range of motion and strength after 3 months following wire removal ($p < 0.005$) (table 5). However, these values were mostly still lower than those achieved in the evaluation group ($p < 0.005$), with the use of the therapeutic techniques presented above (table 4a).

Table. 4a. Comparison in range of motion and muscle strength between study (n=24) and control group (n=32).

	p value	
	At wire removal	3 months after wire removal
flexion	0,04019	0,00000
extension	0,06705	0,06705
adduction	0,49508	0,00044
abduction	0,00794	0,00031
strength	0,49508	0,00610

The control group achieved an increase in strength from 7,5kg (0-42kg) at baseline to 15,1kg (4-62kg) during the follow-up evaluation 3 months after the stabilization was removed. Range of flexion and extension achieved mean values of 37,9° and 44°. Adduction and abduction improved to mean 28,8° and 18,5° in 3 months after wire removal. Figure 32 shows detailed results.

Table 5. Range of motion of the radiocarpal joint and grip strength in the control group (n=32) after wire removing and 3 months later in percent of uninjured hand.

	initial measurement		control measurement		p value
	mean ± SD	range	mean	range	
flexion	58,4 % ± 21,2 %	13-89 %	78 % ± 28,0 %	29-101 %	0,00021
extension	61,1 % ± 23,8 %	37-120 %	71,1 % ± 25,1 %	58-125 %	0,00151
adduction	59,9 % ± 27,6 %	25-115 %	79,4 % ± 29,4 %	14-123 %	0,00284
abduction	73,2 % ± 30,0 %	10-157 %	87,5 % ± 30,9 %	14-128 %	0,00808
grip strength	28,1 % ± 10,3 %	0-90 %	57,1 % ± 15,3 %	15-122 %	0,00005

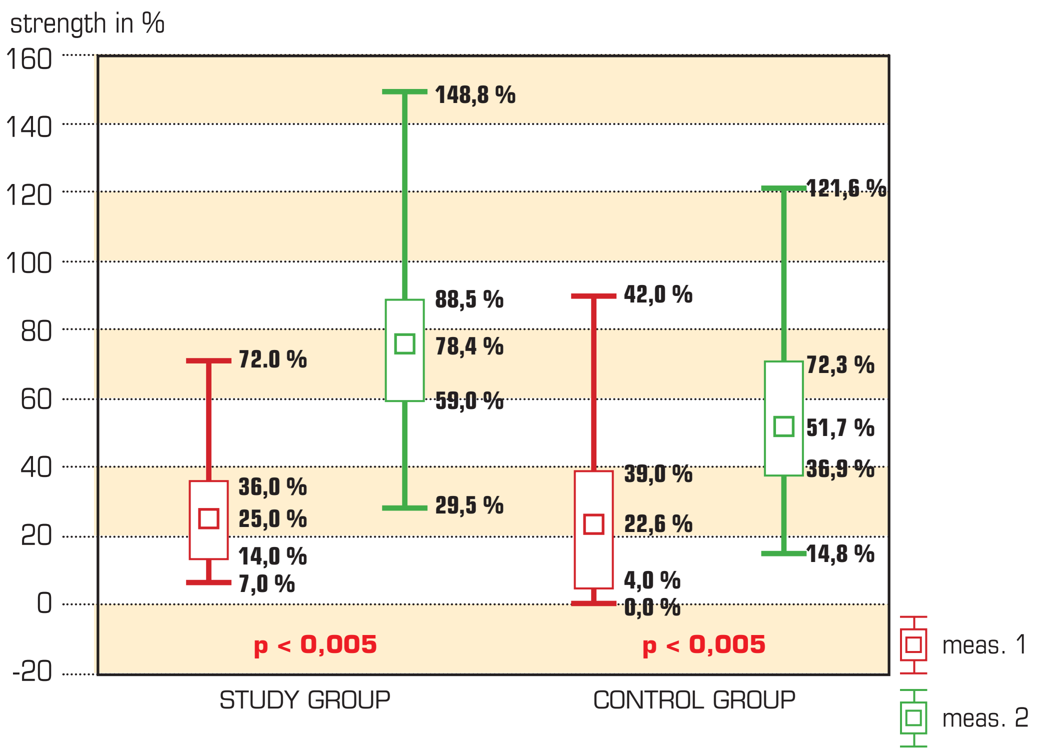


Fig. 32. Grip strength as percentage of strength in the healthy hand (mean, qartiles, minimum and maximum) in the evaluation and control groups at wire removal (1) and 3 months later (2).

3.2. Functional performance and the level of pain

The evaluation group achieved a significant improvement in the DASH score expressed as DASH 100 score ($p < 0.005$). The mean level of disability in everyday life improved from 39.6 points to 17.6 points (out of a 100). Figure 33 presents the distribution of scores at the first and last assessment in the evaluation group.

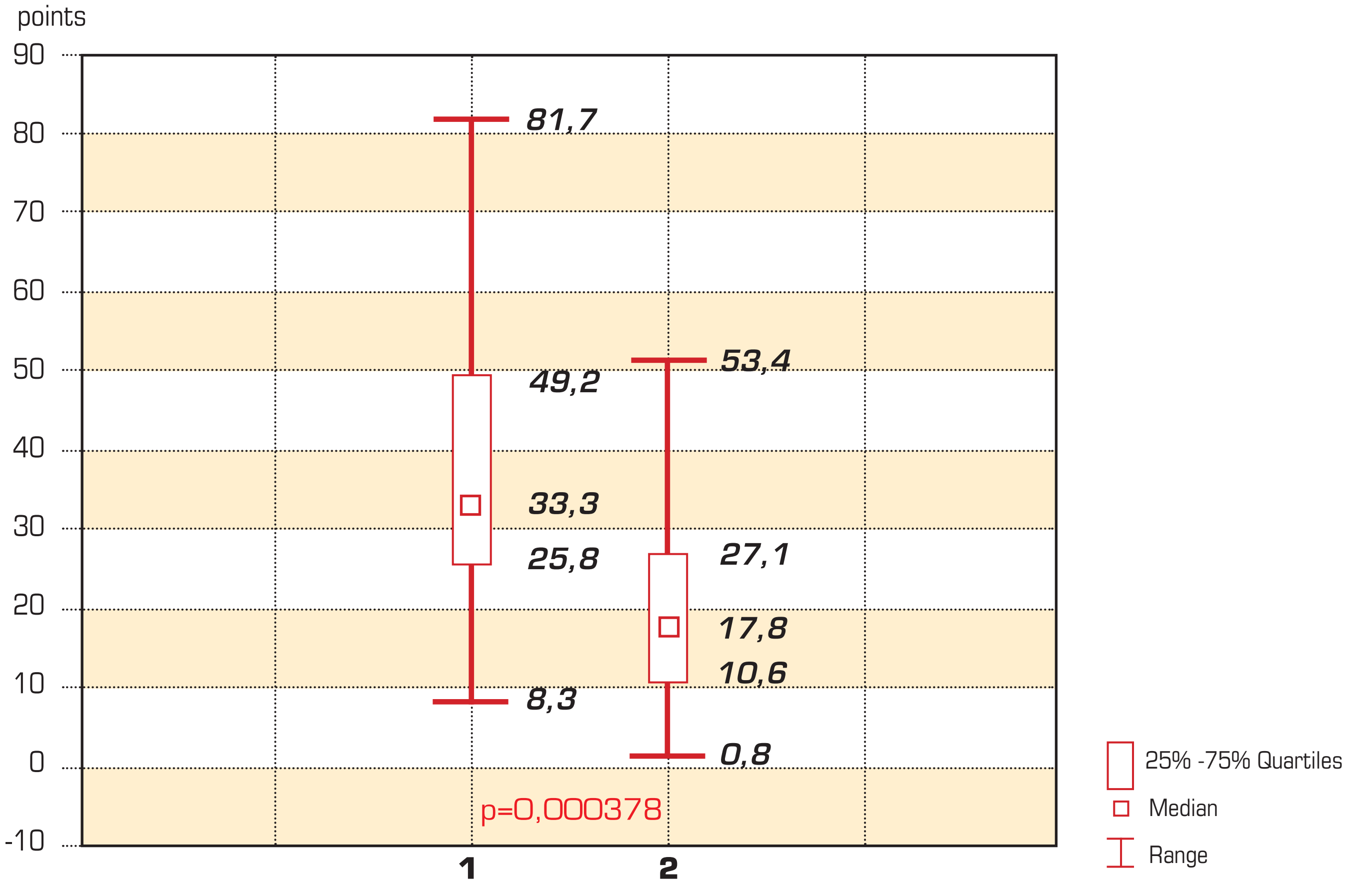


Fig. 33. Disability assessment in the affected hand immediately following wire removal (1) and 3 months later (2) in the study group (n=22); DASH 100 score.

There was a significant improvement in the subjectively assessed level of pain measured with the 100-point VAS scale from 40.7 points at the first assessment to 17.6 points at the last assessment ($p < 0.005$). It is worth noting that 4 patients achieved the level of no pain (0 points) and 5 others rated their pain below 10 points.

The control group achieved a significant improvement in the performance of the injured hand measured with the DASH scale ($p < 0.005$) with a mean of 50.9 points at the first assessment and 24.3 points at the follow-up assessment 3 months later. However, the increase in limb performance in the control group was not as considerable as that in the evaluation group. Fig. 34 summarizes the DASH scores achieved in the control group.

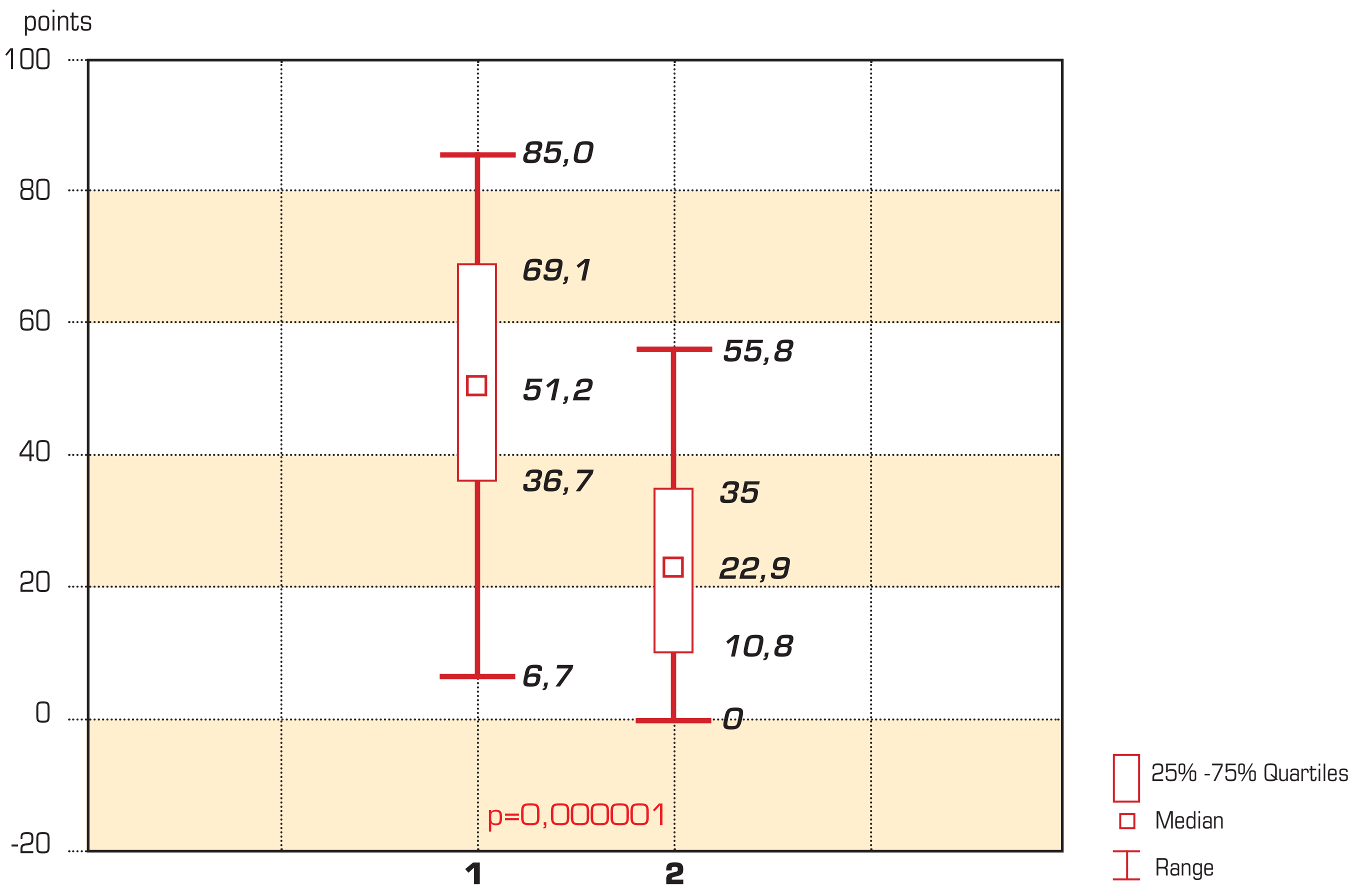


Fig. 34. The DASH 100 scores in the control group at wire removal (1) and at the follow-up assessment 3 months later (3).

3.3. Efficacy of FDM sessions

Single FDM therapy sessions conducted in the evaluation group resulted in a significant improvement in all studied parameters: range of motion in all directions and strength ($p < 0.005$). The third session (the last one) was an exception, as the improvement in strength parameters (the absolute strength expressed in kg and the percentage of strength in the healthy hand) was not statistically significant. The effects achieved after each session were maintained or improved in the period before the next session. No negative effects of therapy, such as a decrease in strength or limited range of motion, were observed in any patient. Global improvement in every measured parameter was confirmed by Friedman's ANOVA test ($p< 0.005$). Table 6 and figures 35-39 present the results in detail.

Table 6. Improvement in the parameters measured during the FDM therapy sessions in the evaluation group (mean values ± standard deviation). The values in red represent statistically significant improvement, $p < 0.005$.

	SESSION I		SESSION II		SESSION III	
	before	after	before	after	before	after
flexion [degrees]	46.6 ± 12,9	55.1 ± 11,2	56.8 ± 9.1	60.6 ± 9.6	58.6 ± 10.3	61.0 ± 9.2
extension [deg.]	37.2 ± 11,5	45.4 ± 10,3	43.1 ± 12.6	49.7 ± 12.5	44.9 ± 13.0	50.5 ± 12.4
adduction [deg.]	31.2 ± 7,8	34.3 ± 7.3	34.1 ± 8.9	37.7 ± 9.0	35.3 ± 8.0	37.9 ± 7.8
abduction [deg.]	16.4 ± 6,4	21.5 ± 6.3	23.8 ± 7.0	26.0 ± 5.5	22.0 ± 7.1	24.4 ± 6.4
strength [kg]	11.3 ± 9,5	13.6 ± 10.0	17.2 ± 9.4	18.7 ± 10.0	20.4 ± 10.8	21.2 ± 12.2

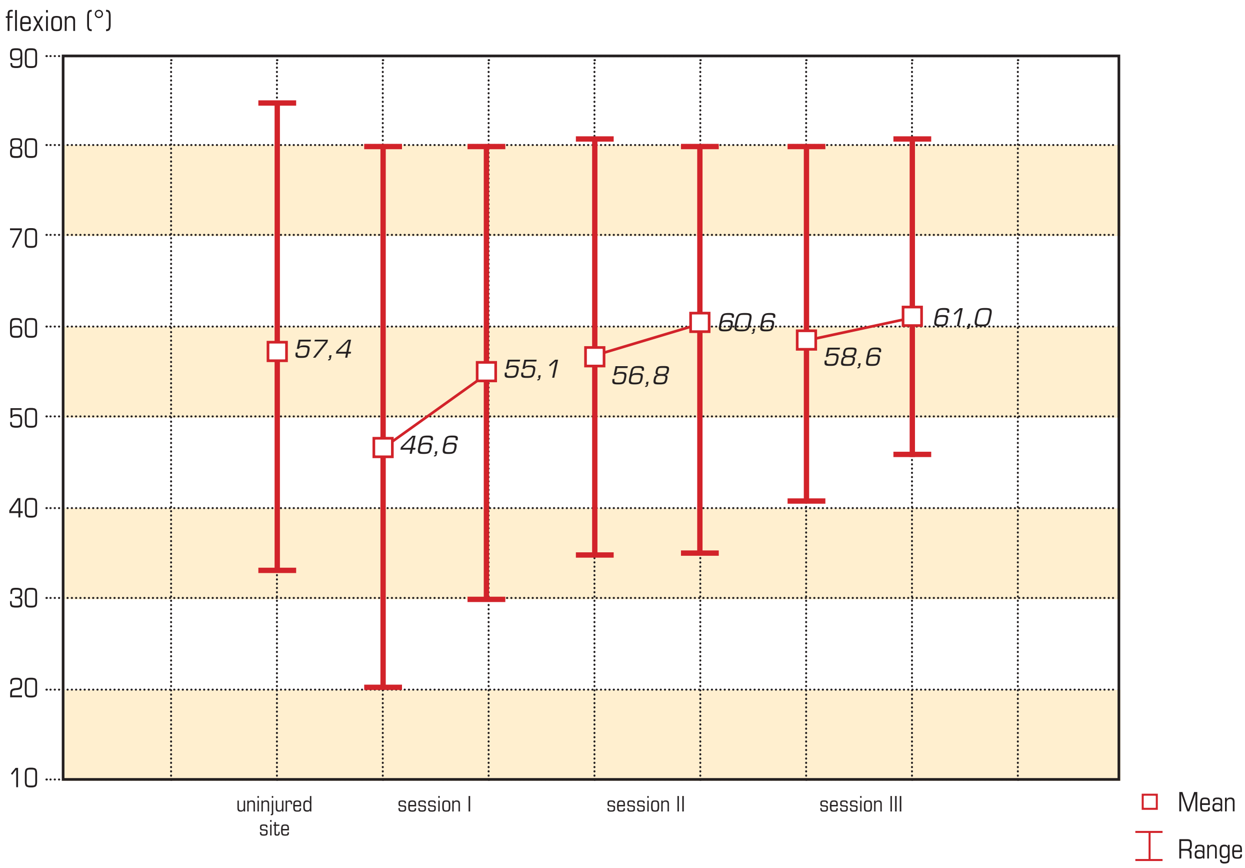


Fig. 35. Flexion range of motion of uninjured and injured hand before and after each treatment session.

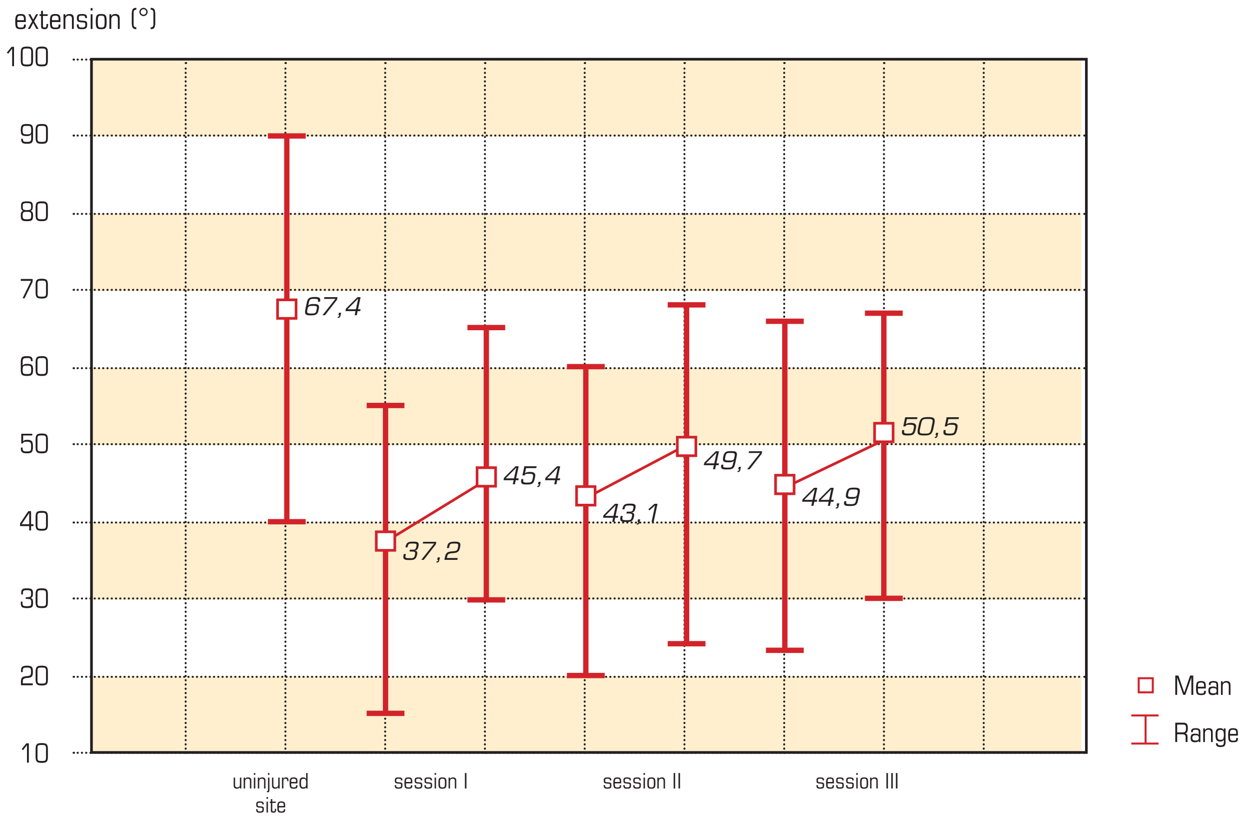


Fig. 36. Extension range of motion of uninjured and injured hand before and after each treatment session.

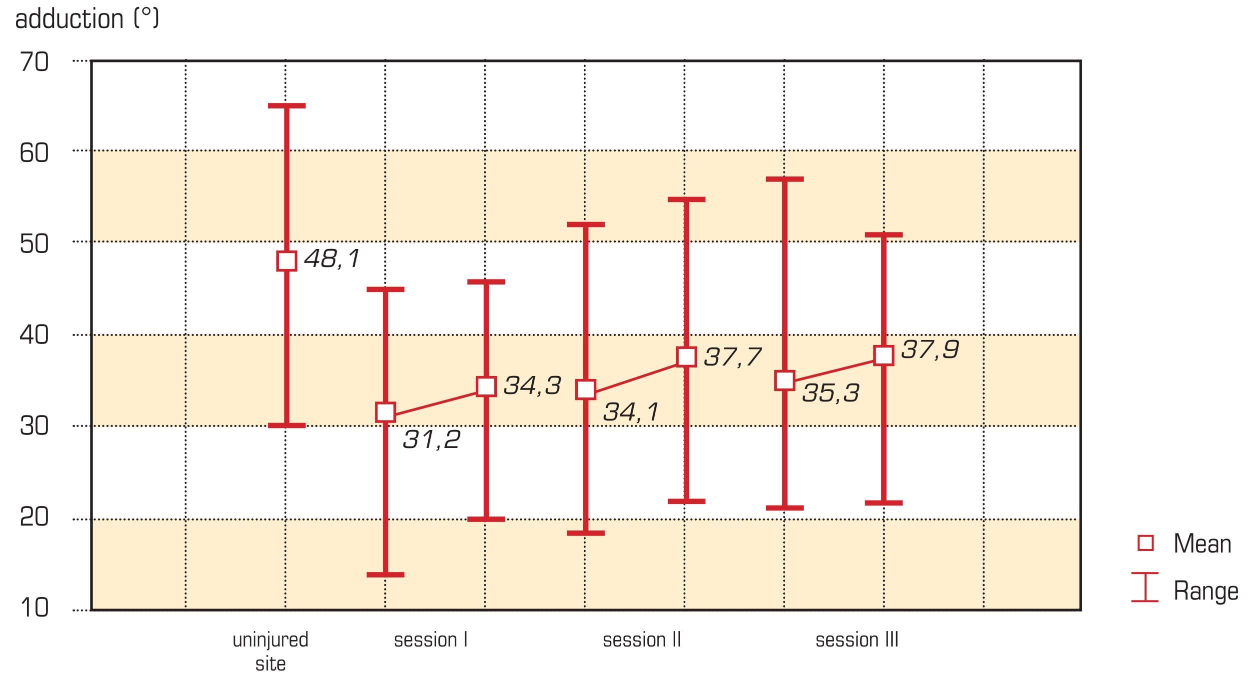


Fig. 37. Adduction range of motion of uninjured and injured hand before and after each treatment session.

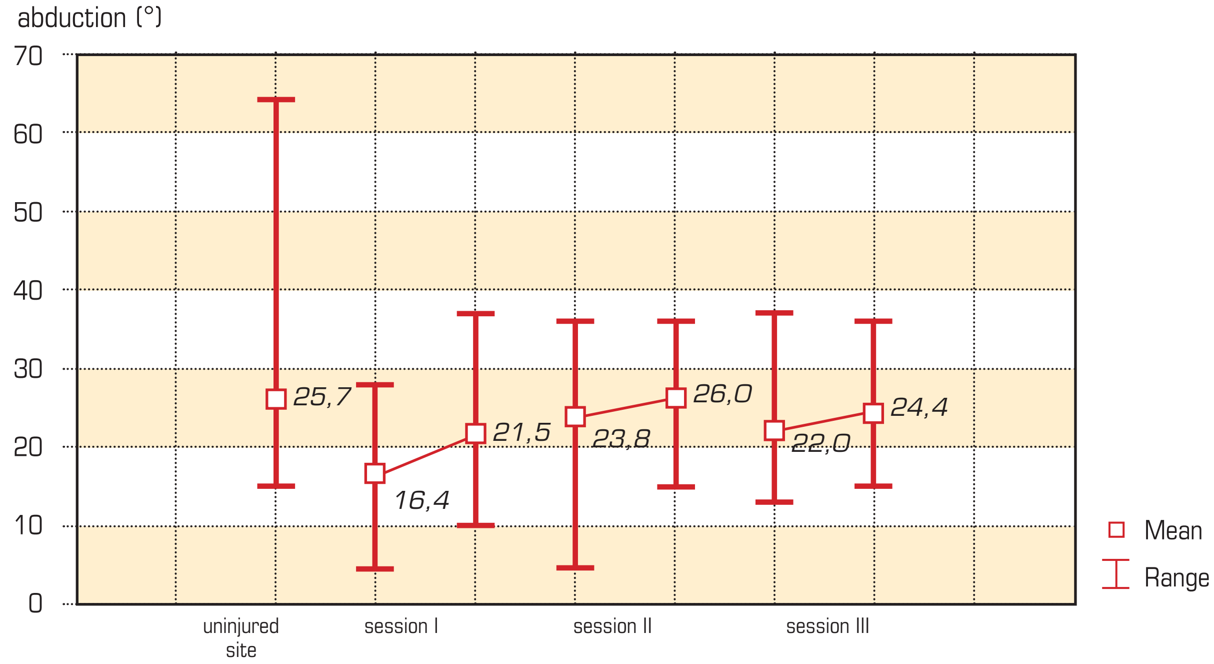


Fig. 38. Abduction range of motion of uninjured and injured hand before and after each treatment session.

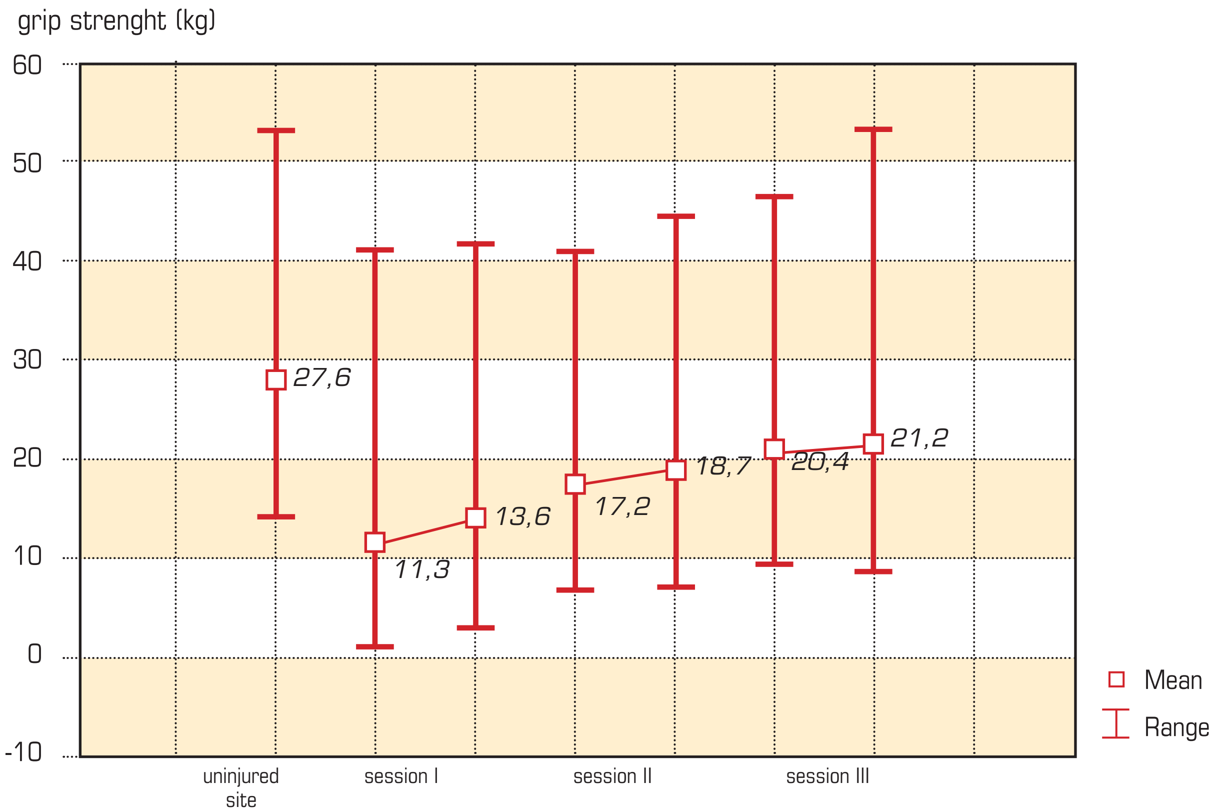


Fig. 39. Grip strength of uninjured and injured hand before and after each treatment session.

3.4. Correlation analysis

The data was also analyzed for correlation between the study parameters and the DASH score. The correlation between the range of motion expressed as percentage of that in the healthy limb with the DASH 100 score was moderate and ranged from –0.32 to –0.38 ($p < 0.05$). Similarly, the relationship between the functional performance assessment score and the level of pain assessed on the VAS scale was moderate and the Spearman's correlation coefficient was 0.48 ($p < 0.005$). A significant correlation was demonstrated between the injured hand strength (as percentage of the strength in the healthy hand) and the DASH 100 score, with correlation coefficient of –0.62 ($p < 0.005$). Figure 40 shows the plot of correlation between the DASH score and the level of pain and the strength.

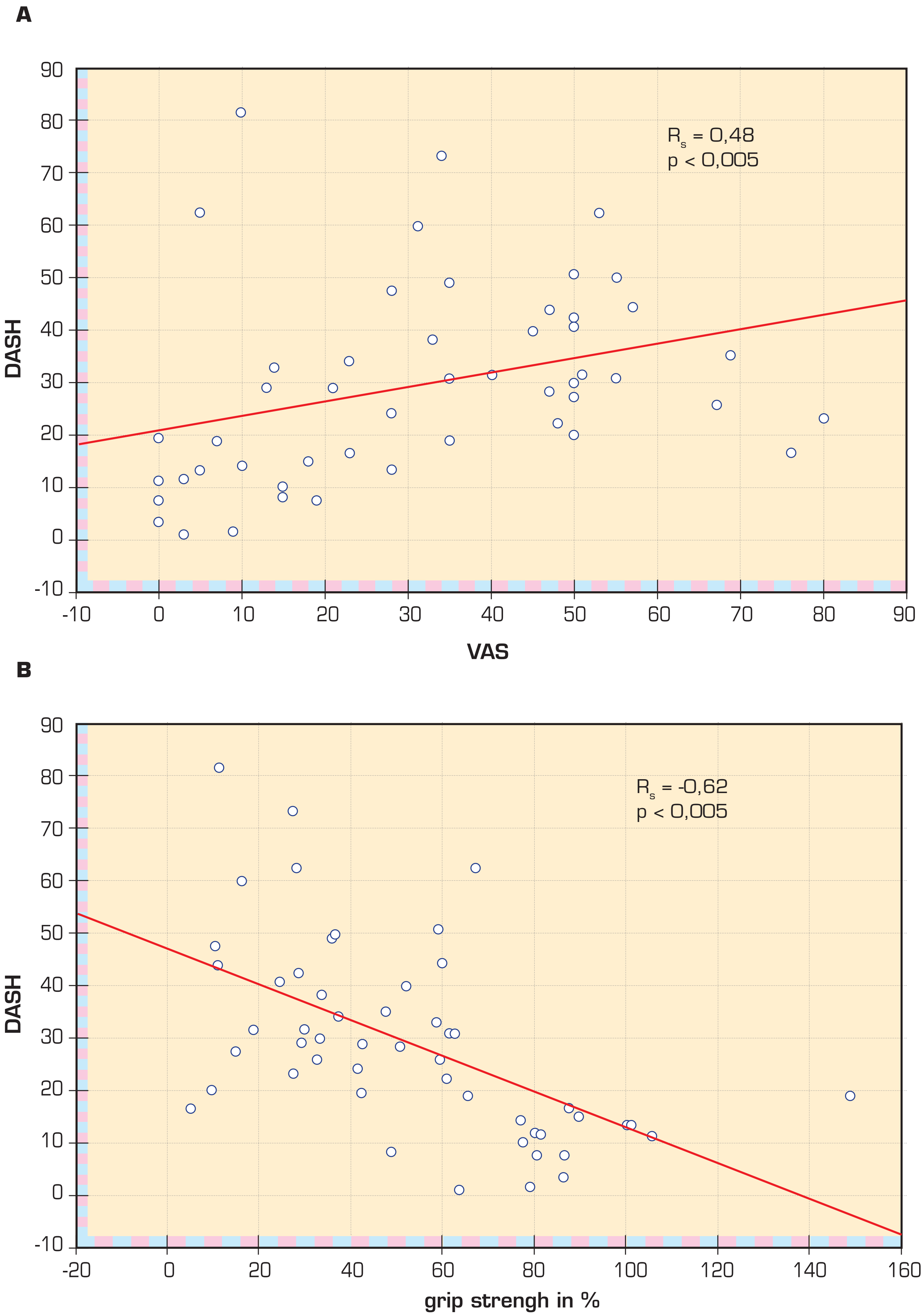


Fig. 40. Distribution and correlation plots of the DASH scores and the VAS pain scores (A) and the DASH scores and strength values as percentage of strength in the healthy limb (B).

4. Discussion

Distal radial fractures constitute approximately 14% of all fractures. In younger people, these fractures result from high-energy injuries, such as sports injuries, falls from a height and direct-mechanism injuries, such as a blow with a hard object. In the older population, over 60 years of age, the main cause of this typical forearm fracture is a low-energy injury, such as a fall from the standing height. [20, 26, 41, 57, 61, 62].

Fractures of the distal radius occur more frequently in women than men. This relationship is most pronounced in the older population, where these fractures are more common than in younger people. The incidence of fractures is also grater in the left upper limb than in the right [28, 42, 49]. A similar relationship was found in individuals qualified to participate in this study. Women constituted as much as 82% of the study group (75% of the evaluation group and 87.5% of the control group). The left limb was fractured in 66% patients from the evaluation group and in 69% of controls (overall, in 68% of all study participants).

The fact that there were no significant differences between the initial (baseline) measurements despite the existing differences in their mean values, justifies conducting a comparative analysis as well as discussion of the presented results.

4.1. Grip strength and the wrist range of motion

The level of grip strength achieved in the evaluation group was good or very good in a greater number of patients. The level of strength at 75% of that in the healthy hand is considered normal and this difference may be a result of differences between the dominant and the non-dominant limb, which can be considerable in the case of grip strength. It is worth noting that in some patients the grip strength in the injured hand was substantially greater (by nearly 50%) than that in the healthy hand. This suggests a high efficacy of FDM treatment. This greater strength may also be a result of pre-existing limitations in the healthy limb that might be reduced with the FDM technique (due to probably the same origin of limitations in both limbs).

In the control group, the mean grip strength was at a level of 57% of that in the healthy hand, which was significantly lower than in the evaluation group. However, studies by Krischak et al. confirm this result, as the authors reported a similar level of improvement in the group of patients exercising on their own at home [37].

The significant increase in strength in both the evaluation and control groups is doubtlessly a result of spontaneous healing following immobilization removal. This process is induced by everyday activities, where the patient, despite the limitations, uses his/her injured limb to perform tasks at home and at work or to exercise recreational activities. This is consistent with study results of various authors who have demonstrated that, irrespective of the type of treatment used following the removal of immobilization (giving instructions to exercise at home or providing active physiotherapy versus exercising under the supervision of a therapist or exercising alone), the return of grip strength occurs at a similar rate [30, 37, 48]. This rate may be slower in the elderly [31]. Thus, the use of FDM technique, which seems to accelerate this process, may be an effective way of achieving a quicker restoration of strength and, in correlation with an increase in the range of motion, the return of function in the injured hand.

The range of flexion and extension in the evaluation group was greater by over 12% and 3% than the respective ranges of motion in the opposite wrist. After the 3-month period following immobilization removal, there was also an improvement in the range of motion in the control group, however, this improvement was not as significant as that in the group receiving FDM treatment. This improvement was probably a result of the process described above, where spontaneous heeling and rehabilitation occur through exercising and performing everyday activities.

The evaluation group also achieved satisfactory results regarding the range of motion in a frontal plane (adduction and abduction), and the range-of-motion differences of about 20% between the healthy and the injured limb may be considered physiological (with the normal range of motion at 40° and 15° these differences are 8° and 3°, respectively). Again, the results of control group were somewhat worse in comparison to the results achieved in the group receiving FDM treatment.

A significantly greater range-of-motion improvement in the evaluation group may be a result of the specificity of Fascial Distortion Model technique, where range-of-motion limitations caused by fascial distortion are taken into account. Knowing the fascial structure and physiology, one is entitled to state that injuries presented in section 1 are very likely, with almost 100% certainty, to occur in patients with a distal radius fracture and limit the range of motion in these patients. Thus, treatment with the use of FDM techniques may, through correction of the normal fascial structure, effectively accelerate the return of the full range of motion.

4.2. Functional performance and the level of pain

Similarly to the objective measurements, the subjective functional assessment in both groups revealed a significant improvement after the 3-month period between the assessments. This improvement was reflected in the statistically significant decrease in the DASH score, down to 24.3 points (mean) in the control group and to 17.6 points (mean) in the evaluation group. The results achieved in the control group were higher than those reported by other authors (19 points in studies by Lucado et al. and 18.3 points in studies by Abramo et al.) [1, 46]. This might be due to a relatively lower rate of restoring the hand function that was caused by a lack of regular controlled physical therapy (the control group only received instructions but compliance was not verified). It is easy to see that at 3 months after the removal of immobilization and Kirschner wires, the evaluation group achieved a somewhat greater functional performance than patients in the mentioned studies [1, 46]. After 3 therapeutic sessions conducted over a period of 3 months, the results of FDM treatment were similar to those generally achieved at 12 and more months following an injury. According to different authors, these results are 13–14 points (DASH 100) [45, 46, 58]. In some studies, the results differ considerably – from 7.5 points in the Abramo study to 25 points in the study by Figl at 12 months after injury [1, 17].

According to various authors, functional assessments of the wrist with the use of DASH scale may be partly unreliable, due to the potential influence of other discomforts on the obtained result [19, 49]. However, there seams to be very little influence of the patient's psychological state on the results, as shown by slight or moderate correlation of the DASH score and the various psychological scales [54].

It should be borne in mind that achieving good and very good functional assessment score is a more important goal of conducted physical therapy than increasing the range of motion or muscle strength. Reducing the level of pain seems to be equally important, as it improves the patient's quality of life and the subjective assessment of patient's health. All these factors influence one another. However, functional assessment seems to be a reliable tool for measuring the efficacy of therapeutic method. The present study also shows that better results in the form of lower DASH 100 scores achieved with the use of Fascial Distortion Model treatment indicate that the complementation of conventional treatment with FDM therapeutic sessions may be the key to managing distal radial fractures and may contribute to a quicker restoration of hand function, and to increasing the proportion of patients satisfied with the treatment as well as with the state of their health. The partial and, in some patients, total alleviation of pain as shown by the lower DASH scores confirm the above notion.

4.3. Study result correlations

The present study showed the existence of correlations between the DASH score and the level of pain assessed with the VAS scale as well as the grip strength. Lower level of pain allows the patient to perform many everyday activities more easily. In addition, improved grip strength means that objects can be without a doubt handled with the use of the injured hand.

The study showed no relationship between the DASH 100 score and the wrist range of motion. Lucado et al. showed such correlations in studies evaluating the efficacy of dynamic railing in distal radial fracture patients [47], whereas Board et al. indicated a relationship between the functional assessment values and the surgically accomplished positioning of the radius: radial inclination, palmar tilt, and radial height in relation to the ulna [4]. Studies by Moore et al. including nearly 100 distal radial fracture patients indicate a significant relationship between the level of disability based on the DASH scale on one hand and the age of the patients as well as their fracture-related use of medications (usually analgesics) on the other [51]. The study presented here does not demonstrate any correlation between the DASH score and the patient age. However, this might be a result of a too small sample size and considerable diversity of ages within the study population. Another fact that is very likely to play a role here is that the studies by Moore et al. were conducted on the average 17 months after the injury and were retrospective in nature [51].

4.4. Efficacy of FDM

There are few literature reports about the efficacy of osteopathic procedures after distal radius fractures, and the available ones usually relate to short-term treatment outcomes [49]. We would like to emphasize that no report on the use of osteopathy or manual therapy in radial fractures or injures has been found in the Medline/PubMed database. The more abundant literature reports on the use of osteopathic procedures in the carpal tunnel syndrome indicate short-term efficacy of these procedures [11, 23, 59].

The results presented here indicate very high efficacy of the FDM as a therapeutic technique rapidly improving the muscle strength and the range of motion in the affected joint. It is worth noting that during each therapeutic session all patients achieved an improvement in the measured parameters. Better hand performance means a more extensive use of the limb in everyday activities, which may lead to quicker recovery and a full return of function. This is reflected in the results presented above, achieved after 3 months following the removal of immobilization.

During the present study or during the FDM therapeutic sessions, none of the patients developed complications following the surgery or the study therapy that negatively affected the final treatment outcome. Failure to complete the 3 therapeutic sessions by patients assigned to the evaluation group was caused by reasons other than a poor response to study treatment.

5. Conclusions

1. The Fascial Distortion Model (FDM) technique presented here has an impact on immediate improvement in the wrist range of motion and grip strength in patients treated for a distal radial fracture.
2. In comparison with the control group, patients treated with the use of the FDM techniques achieved better results in grip strength and range-of-motion assessment than patients who had not undergone these procedures.
3. A positive influence on the acceleration of the return of post-fracture hand function was observed in the evaluation group in comparison to the group of patients who had not undergone manual therapy procedures.
4. Our study results seem to indicate that the FDM technique is a beneficial alternative in treatment of patients with limited range of motion and diminished muscle strength.
5. For further studies, shorter intervals between the single FDM sessions might be adviceable.
6. Extended studies involving patients with other musculoskeletal disorders are needed in order to confirm the effectiveness of the FDM therapeutic techniques.

Summary

Functional performance of the hand is a crucial factor in the ability to carry out many everyday activities. The radiocarpal joint together with the midcarpal and both radioulnar joints allow movement in all three planes – sagittal, frontal and transverse. This means a great capacity in maneuvering objects, reaching, and performing complex manual tasks, which are indispensable for effective performance in today's world [22, 29].

Distal metaphyseal fractures of the radius may severely disrupt the patient's everyday functioning. Both the conservative and surgical treatments are usually associated with an approximately 6-week-long immobilization period of the injured limb [7]. A direct result of this local hypokinesis is limited range of motion due to the formation of tissue adhesions and tissue remodeling. This condition is exacerbated by the earlier injury of those structures and any surgical intervention. Immobilization is also the main reason behind diminished muscle strength and disuse atrophy. These effects of immobilization decrease functional motor performance. The patient is virtually unable to perform a number of activities [7, 43].

For many years now there has been a search for therapeutic methods that would quickly and permanently restore patient's performance, especially in everyday functioning. Previous attempts to compile different exercise and physiotherapy programs have been unsatisfactory, as their effectiveness did not differ from the effects of exercises performed by the patients on their own. There is still little knowledge about the effects, especially long-term effects, of manual therapy on the recovery process in post-immobilization patients [30, 44, 49].

The FDM technique presented in this article is based on the knowledge of fascial structure, function, and pathophysiology. According to this, fasciae can be divided into four categories, and their possible injuries as well as treatment methods into six types. Patient evaluation based on pain history as well as observation helps make a correct treatment-oriented diagnosis [75].

Patient evaluation results presented and discussed in this dissertation indicate an unquestionable effectiveness of the FDM technique, which brings an immediate improvement in the range of motion and grip strength. The results achieved between the sessions and after the mobilization period are promising – the patients undergoing FDM treatment are sooner able to return to normal everyday functioning.

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ANNEX 2 – A study assessment form for the control group

Schriftliche Einverständniserklärung zur Teilnahme an einem klinischen Studie

- Bitte lesen Sie dieses Formular sorgfältig durch.
- Bitte fragen Sie, wenn Sie etwas nicht verstehen oder wissen möchten.

Titel der Studie:
Patientin/Patient Name und Vorname:
Geburtsdatum:

☐ männlich ☐ weiblich

- Ich wurde vom unterzeichnenden mündlich und schriftlich über die Ziele, Ablauf der Studie mit dem und über die zu erwartenden eventuelle Risiken informiert.
- Ich habe die zur oben genannten Studie abgegebene schriftliche Patienteninformation vom [Datum] gelesen und verstanden. Meine Fragen im Zusammenhang mit der Teilnahme an dieser Studie sind mir zufriedenstellend beantwortet worden. Ich kann die schriftliche Patienteninformation behalten und erhalte eine Kopie meiner schriftlichen Einverständniserklärung.
- Ich wurde über mögliche andere Behandlungen und Behandlungsverfahren aufgeklärt
- Ich hatte genügend Zeit, um meine Entscheidung zu treffen.
- Ich bin darüber informiert, dass eine Versicherung Schäden deckt, falls solche im Rahmen der Studie auftreten.
- Ich weiss, dass meine persönlichen Daten nur in anonymisierter Form an aussenstehende Institutionen zu Forschungszwecken weitergegeben werden.
- Ich nehme an dieser Studie freiwillig teil. Ich kann jederzeit und ohne Angabe von Gründen meine Zustimmung zur Teilnahme widerrufen, ohne dass mir deswegen Nachteile bei der weiteren medizinischen Betreuung entstehen. In diesem Fall werde ich zu meiner Sicherheit abschliessend medizinisch untersucht.

Ort, Datum   Unterschrift der Patientin/des Patienten