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Research article

Recovery of post-arthrodesis hand function in the interphalangeal joint - Case presentation

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Abstract: Objectives. The paper highlights the importance of the kinetic recovery program used to regain post-arthrodesis hand function in the interphalangeal joint. Also, during the paper we will present both the techniques used and the methods applied in order to reduce pain and recover the remaining functional. **Materials and method.** During the study, a patient with open intra-articular communicative fractures AIFP D3, 4 in the right hand with bone-operated defect was analyzed. The patient was evaluated functionally postoperatively, during the recovery program and at the end of it. **Results.** During the recovery program, a progress and a good evolution of the hand functionality could be observed. Thus, the patient observed the kinetic program initially established by the physiotherapist and also it was possible to observe the increase of the mobility of the joints in the vicinity of the joints affected by the immobilization of the hand. During the recovery program, a decrease in edema was observed locally and an increase in the strength of the muscles of the hand. **Conclusions.** The physiotherapy program used to restore the functionality of the hand following arthrodesis at the level of the interphalangeal joints must be preceded by an appropriate evaluation and must include techniques adapted to the patient's abilities. An essential condition is a good collaboration between patient-physiotherapist-orthopedic surgeon, so that complications and recurrences can be avoided.

Keywords: hand, fracture, arthrodesis, recovery, gaming sistem

1. Introduction

Introduction

Hand injuries are very common and usually occur in young adults. In the United States, injuries to the hand and arm (28.3%) are the second most common after head and neck injuries (29.5%). They are characterized by a great variability in the extent and distribution of injury. Hand injuries have a significant impact on activities of daily life as well as physical function, which affect socioeconomic aspects of life [1].

Many patients with hand injuries experience limited motion, stiffness, and/or pain after their injury, especially during the initial stage of injury. Critical anatomic structures, which include tendons, nerves, and the vasculature located beneath the skin, make the nature of hand injuries complicated and clinical evaluations difficult. Therefore, functional outcomes after hand injury are measured with diverse tools, such as total active motion, [2] grip strength, Disability of Arm, Shoulder and Hand, Weinstein monofilament test, [3] global measures by a surgeon, Purdue pegboard test, pain, and return to work. Among functional measurements, TAM has been used as a good general metric for joint and tendon function. The factors associated with functional outcome after hand injuries are not well understood [4]. To our knowledge, a large number of damaged structures, hand injury severity score, level of injury, avulsion injury, and nerve injury are factors associated with functional outcome. Most of the previously described factors are related to the

characteristics of the initial injury [1].

Fractures that appear on the fingers are lesions that appear more and more frequently and include a wide aspect of severity. Surgical fixation is indicated in unstable fracture patterns to restore optimal finger function. In fractures associated with adjacent soft tissue damage, inadequate skin coverage, significant bone loss, and severe grinding of the joint surface, a satisfactory result with surgical fixation can be a challenge [5].

Arthrodesis of the distal interphalangeal joint of the finger or of an interphalangeal joint of the thumb is performed mainly for a painful joint. Pain can occur as a result of trauma, osteoarthritis or inflammatory arthropathy. Moberg and Henrickson stated that "the main conditions for a good digital arthrodesis are a painless and stable union in a proper position and within a reasonable time". Based on this consideration, several techniques have been described both for the restoration of the bone heads and for their stabilization [6].

Occupational therapy (OT) is an allied treatment planned to assure the maximum degree of autonomy to the patient. OT may be useful to enable patients to engage in meaningful roles and activities, adapt the living environment with all the necessary devices and precautions to decrease the risk of falls or accidents, and improve domestic life and functional mobility and mantainance of work abilities. OT therefore may give a significant contribute to the overall management of patients with PD and may have a significant impact on the quality of life of patients with PD [7].

The Rehabilitation Gaming System (RGS) is an effective rehabilitation tool that uses virtual games to address deficits resulting from brain lesions in patients who have suffered a stroke. The platform uses task-oriented game training, adjusts complexity levels to patients' abilities, and uses ENG sensing technology to record muscle contraction. The system is designed as a portable device which is a home-based rehabilitation platform that offers personalised functional rehabilitation. The system only requires a PC, EMG sensor, and a microcontroller. The Low-Cost Rehabilitation System combines deficit movement training with a variety of virtual reality-based video games tailored to individual patients. As patients perform different tasks, they are motivated to do more because game is based on high score winning. The training programs are optimised through analysis of the patient's performance and complexity can be adapted to the user. The data from each training session is sent to clinicians for analysis and can be used to optimise and adjust individual rehabilitation programs remotely [8].

In order to develop a kinetic program as efficient as possible, we must take into account both the patient's personal and heredocolaterale antecedents. Considering the pathology as well as the antecedents, the physiotherapist in collaboration with the orthopedic surgeon will design an individualized program adapted to the patient's needs in order to regain the functionality of his hand in the most efficient and safe way. Due to the current pandemic context, the patient's recovery program was visibly hampered, a large part of it taking place at the patient's home under the careful supervision of the physical therapist [9].

The paper highlights the adaptation of the kinetic program to the needs of the patient, the use of new therapeutic means and innovation but also the need for good cooperation between the patient, physiotherapist and orthopedic surgeon. In addition, the paper wants to highlight new methods that can be introduced and used successfully in the recovery of patients who have suffered this kind of fracture.

Matherial and Methods

The paper examines a case involving a 50-year-old patient who suffered a work accident. As a result of this accident, the patient suffered open intra-articular AIFP D3, 4 fractures in the right hand. The patient was also operated on in an emergency. The surgical treatment consisted of performing the arthrodesis of the two affected joints with 2 BK in X each, followed by the immobilization of the right hand in a cast. After 7 days, a first control radiograph was performed (Fig 1), and after 3 weeks another radiograph (Fig 2), after which the two BKs were removed, and after 4 weeks no immobilization was necessary. The patient was evaluated functionally postoperatively, during the recovery program and at the end of it.

Fig 1. X-ray hand, face and profile.

Fig 2. X-ray hand, face and profile, after 4 weeks.

After discharge, the patient was advised to:

- Maintaining the high operated segment;
- Avoiding physical exertion and local traumas;
- Sterile dressings with sanitary alcohol every 2 days;
- Returns on 30.12.2020 to CCPR with control radiography performed in advance for re-evaluation;
- Suppression of sutures at 14 days postoperatively;
- Maintains immobilization on the splint for 4-6 weeks. He will then resume his movements gradually, under the supervision of a physiotherapist.

The basis of the postoperative recovery program consists of physiotherapy procedures adapted to the patient's needs and an individualized physiotherapy recovery program, safe and adapted to the patient's needs.

The recovery plan was established from the first consultation and included: anamnesis, testing and clinical evaluation of the patient (joint and muscle testing), establishing the objectives of the recovery program, Minutes of recovery meetings, explaining the importance of performing complementary exercises at home, establishing a trusting relationship between the patient and the physiotherapist taking into account the

psychological aspect of the case.

At certain intervals, the physiotherapist evaluated the results of the program and according to them maintained or modified the parameters of the execution of the exercises and changed the approach of the applied techniques.

The following issues were considered:

• immobilization causes significant functional deficits for the joint;
• fingers that do not require immobilization will be mobilized continuously;
• edema is the most dangerous functional enemy and therefore must be combated early.

Objectives pursued in the kinetic recovery program:

The main objective of the recovery program was to regain the functionality of the hand following trauma and immobilization and aimed at:

- reduction of edema and pain;
- increasing the mobility of the joints adjacent to those affected;
- restoring joint strength and mobility;
- increase in muscle tone and strength;
- socio-professional reintegration of the patient;

Therapeutic means used: massage therapy, ultrasound, anti-slope postures, postures in rest and correction splints, passive and self-passive mobilizations, free active mobilizations, stretching exercises, occupational therapy, gaming system.

Kinetic program stages

Early recovery period (during immobilization)

Maintaining mobility at the level of neighboring joints (elbow, shoulder)-free active mobilizations, performed several times a day.

Muscle toning-isometric contractions under plaster, the contraction force gradually increases.

Recovery after suspension of immobilization

• Weeks 1-2

Immediately after the removal of the plaster splint, the recovery continued by preventing edema and combating pain, reducing the stiffness of the neighboring joints.

To reduce pain, we can use associated means such as heat, ice or electricity. They will help to manage the pain and to reduce any edema that is forming or already existing in the area where the surgery took place, anywhere along the arm or in the hand. Massage in these areas can also be done to improve circulation and help relieve any discomfort.

Thus, it was performed:

- Forearm and hand massage (the region near the fracture);
- Active-passive movements;
- Passive and self-passive mobilizations (8-10 minutes 4-5 times a day);
- The ability to move gradually increases. Mobilize each joint separately and start with the distal joints.
- Ultrasound (2-3 times a week) to combat pain / inflammation. One day of ultrasound, 1 day of massage.

Fig 3. Keeping the limb in an anti-decline posture.

Fig 4. Mobilization of adjacent free joints.\

Fig 5. Massage.

Fig 6. Passive mobilizations.

- Weeks 3-4

The next part of the treatment focused on regaining range of motion, strength, and dexterity in the joints on both sides of the fingers affected by arthrodesis, as well as the other fingers, wrist, hand, elbow, and even the shoulder. As the movement of the affected joints will be permanently lost, it is of paramount importance to maintain the range of motion, strength and dexterity in the joints surrounding the fusion so that the functional patient's hand can continue to be used.

In order to regain the functionality of the hand, it is necessary to consider the recovery of the muscular strength and the maintenance of the muscular tone. In order to increase the muscular strength, exercises were performed with different resistance, so the muscles were gradually strained. It is necessary to increase muscle strength to supplement the activity of the joints affected by immobilization.

- Active exercises - free exercises for each joint performed frequently (hour by hour);
- Active exercises with resistance and progressive loading;
  - ✓ Opposite resistance by physiotherapist
  - ✓ Resistance of a medicine ball
  - ✓ Resistance represented by the medicinal elastic (Fig 3);
  - ✓ Gravitational strength and weight of the mobilized segment
- Panel occupational therapy;
  - ✓ Exercises on pulleys with a small weight (0.5 kg);
  - ✓ Exercises with the help of the sailor's hand wheel;
  - ✓ Exercises with the flexor device for the forearm;

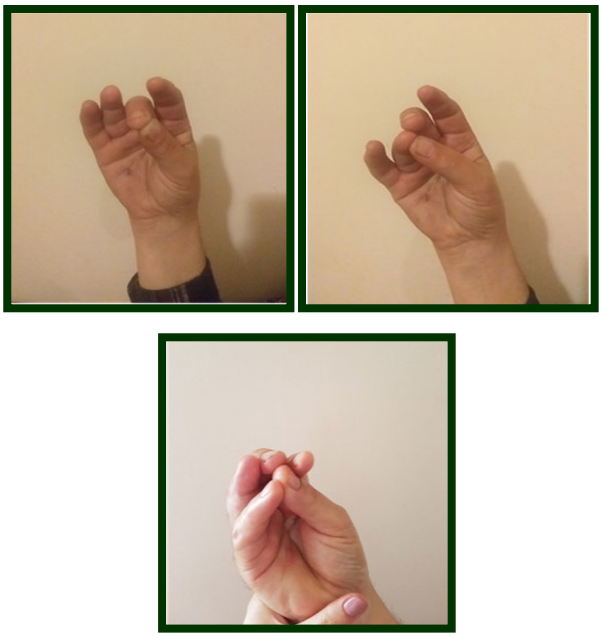

Fig 7. Opposability of the police to the affected phalanges.

In addition, in order to strengthen the grip, we will educate the patient on how to hold and support the objects to perform daily tasks, compensating for the affected fingers. Exercises for catching objects of different sizes (money, batteries, balls, etc.) will be performed for this purpose.

Functional use of the hand helps to restore mobility and reduces edema. An essential step in recovering as soon as possible is the reintegration of the patient into socio-professional activities. If in the previous weeks the strength was increased and the tone was

maintained, the edema was prevented, the mobility of the neighboring joints was increased and the pain was combated, in these weeks we will use all these improvements for the usual activities of the patient.

Maximizing dexterity can greatly improve the functional use of the patient's hand. For this reason, we will also incorporate functional activities, such as lifting items from a table or twisting items in place using the affected hand. These functional activities encourage the joints and muscles of the hand and arm to work in unison, which is essential to maximize the use of the general upper limb.

The degree of progressive loading of the previous exercises used has been increased and the emphasis has been on occupational therapy.

Occupational therapy aims to regain and develop the skills of daily life, to allow work to improve joint mobility and to assess the need for work facilities by adapting tools to the profession of the patient (carpenter).

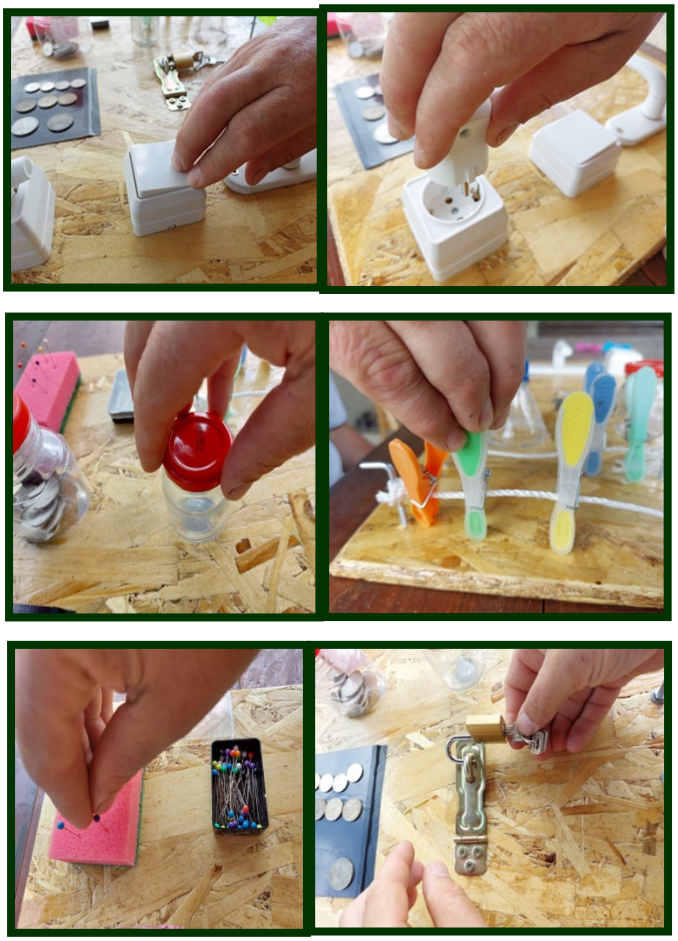

Fig 8. Occupational therapy board.

Thus, the following activities are recommended to the patient, taking into account his professional training and his passions:

- packaged;
- carpentry;

- handicraft;
- chess;

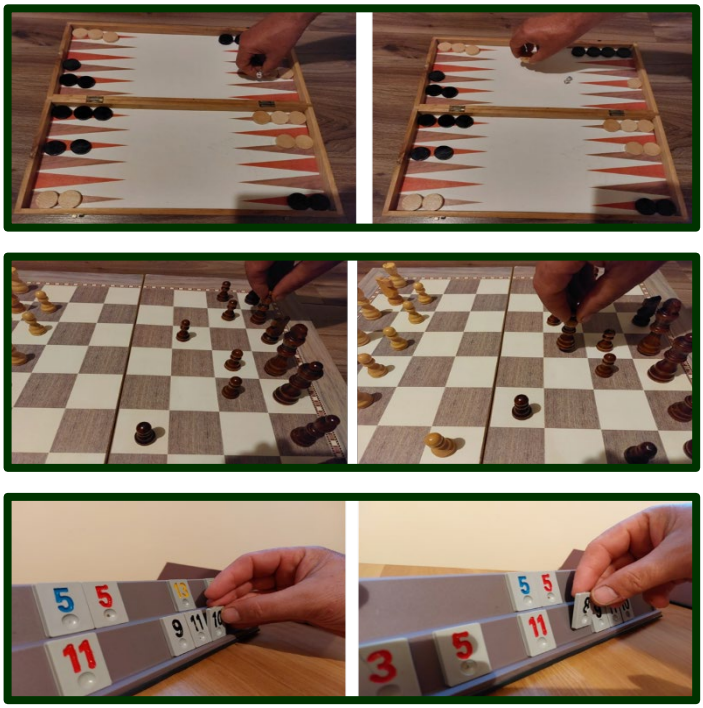

Fig 9. Rummy, chess, backgammon game.

Usual activities: pressing the doorknob, the switch, holding the cutlery, etc.

It is necessary to regain the ability to perform fine movements, such as tying laces or closing a button on the shirt, writing, etc.

The writing requires more attention, because the affected hand is the right one and the patient will have to adopt a new position of the fingers to perform the writing.

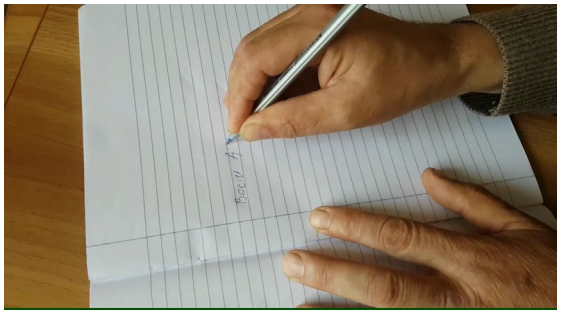

Fig 10. Writing.

The Gaming Rehabilitation System is based on human-computer interface system using Electromyography (EMG) . This game encompasses the rehabilitation of the muscle in itself by asking the user to move the muscle and measure the potential difference generated due to action potential using MyoWare muscle sensors kit. This newly generated raw

EMG signal is passed on to Arduino, which is interfaced with a computer through a Graphical User Interface (GUI) based computer game. An EMG sensor and computer interface allows the interaction with the computer without physically touching a keyboard, mouse or other input device [10].

The system can work with any game. For example, T-Rex dinosaur game can be played on any pc because doesn't require specific hardware requirements. It is a browser game-based game so it doesn't require high end pc performance or disk space. System is compatible to any pc with any operating system and its only requirement will be a computer with USB standard (Universal Serial Bus). The Arduino Due has the ability to act as a USB host for peripherals such as a keyboard connected to the SerialUSB port. For this propose it must be used Keyboard Controller library.

The figure bellow represents a screenshot of the game. Game is score based so the patient will be motivated to make higher and higher score.

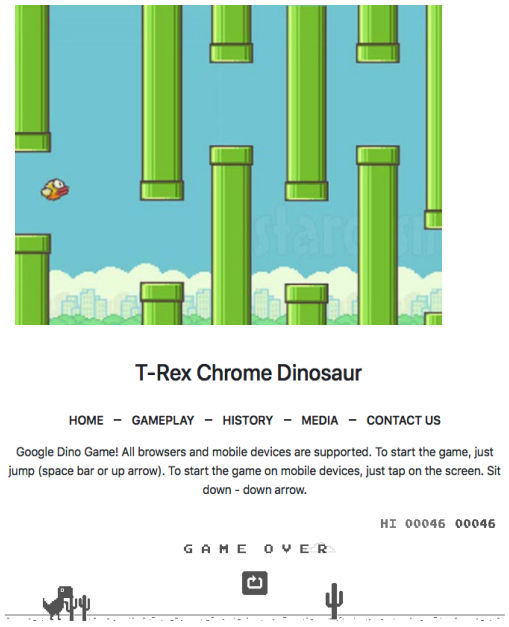

Fig 11. Game Screenshot.

The Arduino board contains 16 channels for analog inputs with 10-bit analog to digital converter. This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023. This yields a resolution between readings of: 5 volts / 1024 units or, .0049 volts (4.9 mV) per unit. It takes about 100 microseconds (0.0001 s) to read an analog input, so the maximum reading rate is about 10,000 times a second.

Placing EMG electrodes on muscle:

- Thoroughly clean the intended area with soap to remove dirt and oil;
- Snap electrodes to the sensor's snap connectors;
- Place the sensor on the desired muscle ;
- After determining which muscle group you want to target (e.g. bicep, forearm, calf), clean the skin thoroughly;

- Place the sensor so one of the connected electrodes is in the middle of the muscle body. The other electrode should line up in the direction of the muscle length;
- Peel off the backs of the electrodes to expose the adhesive and apply them to the skin;
- Place the reference electrode on a bony or nonadjacent muscular part of your body near the targeted muscle;
- Connect to PC via development board. Connecting Arduino Board to Pc. Arduino Board will be detected as an input device. Every muscle contraction will trigger a key pressed. Keys can be mapped custom to be compatible with most online games.

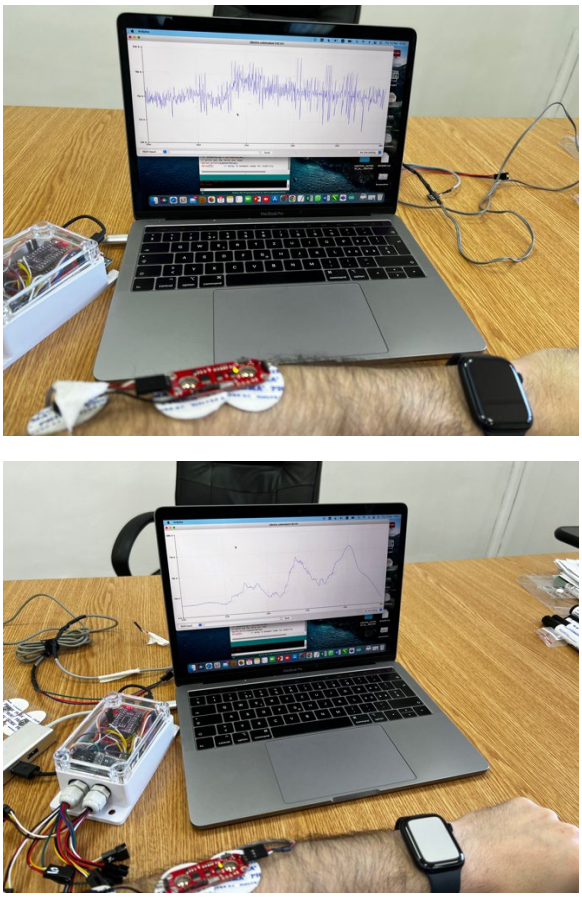

Fig 12. Signal acquisition (raw signal left and rectified).

Results and Discussion

To assess progress, joint and muscle testing was performed for the main joints affected in the immobilization, including: the hand joint (Table 1), the metacarpophalangeal joint

(Table 2).

Table 1. Functional parameters for the hand joint.

Test	Movement	Hand joint - normal amplitude		Hand joint - after immobilization		
Articular testing		Active	Passive	Weeks 1-2	Weeks 3-4	Weeks 5-6
	Flexion	90°	90°	70	75	80
	Extension	75°	85°	55	60	65
	Radial inclination	15°	20°	5	10	15
	Ulnar inclination	40°	45°	30	35	40
Muscular testing	Flexion	F5		F2+	F3-	F4-
	Extension	F5		F2+	F3-	F4-
	Radial inclination	F5		F2	F3-	F3+
	Ulnar inclination	F5		F2	F3-	F3+

Table 2. Functional parameters for the metacarpophalangeal joint.

Test	Mouvement	Metacarpophalangeal joint - normal amplitude		Metacarpophalangeal joint – after immobilization		
Articular testing		Active	Passive	Weeks 1-2	Weeks 3-4	Weeks 5-6
	Flexion	90°	100°	75	80	85
	Laterality (abduction and adduction)	15°-20°	20°	7	10	15
Muscular testing	Flexion	F5		F2+	F3-	F4-
	Extension	F5		F2+	F3-	F4-
	Laterality (abduction and adduction)	F5		F2	F3-	F3+

After following the kinetic program, the patient had a good evolution throughout its period. Recovery started early, even during immobilization, which was beneficial to recover as quickly as possible post-operatively and to prevent edema caused by immobilization.

Since the affected joints do not move and therefore do not need any therapy to gain range of motion, improvements were very quickly observed with the methods addressed in the ultization of the functional hand and in the socio-professional reintegration of the patient.

Conclusions

The patient-physiotherapist-orthopedic surgeon collaboration is essential for achieving the goals in post-operative recovery.

Home exercise programs are very important. Informing patients by the physiotherapist about the importance of regularly performing these exercises at home, as well as indicating how to perform them, is essential for obtaining the best possible functional recovery, as well as for maintaining post-operative joint mobility and stability and preventing functional sequelae and complications.

The kinetotherapeutic program used to recover the functionality of the hand following arthrodesis at the level of the interphalangeal joints must be preceded by an appropriate assessment and must include techniques adapted to the patient's capabilities. These techniques and methods must progressively require the patient, and finally reintegrate into his socio-professional activities and adapt to them.

Use of gaming in the rehabilitation of neurologically impaired patients now shows major scientific promise. Rehabilitation based on Gaming System is a highly effective tool that can be installed in hospitals and also can be used at patient home. Games can be run on any computers even on older ones and this gains great benefit for the patient because it doesn't require great computer performance.

Games are able to effectively increase patients' scores after a certain period of rehabilitation through them. Both patient classes have been shown to display slightly better improvements when using the gaming rehabilitation technics board than when engaging in regular therapeutic methodologies. Every day in rehabilitation process can be different because the patient can play other games so every day routine is not installed. Games in rehabilitation can hold a very important role in successful psychological and neuropsychological approaches. In short, rehabilitation performed using new software and virtual environments has been shown to be a valuable tool for recovery form stroke and other accidents.

Author contributions.

All the authors had the same contribution.

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