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Original Article

Rehabilitation therapy for athletes after orthopedic surgery procedures on the forefoot

VOLODYMYR STAUDE[1], DMYTRO PROZOROVSKY[2], YEVHENIA RADZYSHEVSKA[3]
[1,2]State institute "Sytenko Institute of Spine and Joint Pathology of National Academy of Medical Sciences of Ukraine", Kharkiv, UKRAINE
[3]Kharkiv National Medical University, Kharkiv, UKRAINE

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Abstract:
Post-operative rehabilitation of patients is not less important, or even more important, than a technically perfect surgery procedure. A good functional result of treatment depends not only on surgery procedures, but also on an individually selected system of post-operative rehabilitation therapy, especially when it comes to athletes – patients with high functional requirements. **Purpose.** To improve the results of athletes' recovery after orthopedic surgery procedures on the forefoot, due to the restoration of a muscle function, responsible for the foot activity. **Material and methods.** We conducted prospective research on 36 patients engaged in different sports, with deformities and diseases of the forefoot, who had experienced surgery procedures aimed at repairing those deformities. All the patients were divided into 2 homogenous groups. The system of rehabilitation in the patients of the control group meant exercising in order to train a walking stereotype. The system of rehabilitation for the main group developed by us implied an effect of massage and special exercises on the following muscles and ligaments: m. tibialis anterior, m. fibularis longus, m. biceps femoris, lig. sacroischiadicus, tractus iliotibialis, m. tensor fascia latae, m. quadriceps femoris, m. adductor magnus, m. gluteus medius on both operated and healthy sides. The results of treatment were evaluated by the generally accepted assessment scale of AOFAS for the forefoot (module 2) 45, 60, 90 days after surgery procedures. The research data were statistically processed. **Results.** There was a statistically significant difference between the main and the control groups by the scale of AOFAS 60 days after a surgery procedure (MWUT, $p < .01$). The athletes of the main group were able to return to a training process 2 months after a surgery procedure on the forefoot, and those of the control group – 3 months after a surgery procedure. **Conclusions.** Massage and special exercises, aimed at restoring a stabilizing function of muscles and ligaments of stabilizers of not only the foot, but of the entire pelvic girdle and pelvis of both sides allowed reducing the dates of athletes' functional recovery by a month in comparison with the control group.
Key words: post-operative rehabilitation, deformity of hallux valgus, recovery of walking, myofascial chains, massage, gymnastics.

Introduction

Post-operative rehabilitation of patients is not less important, but even more important than a technically perfect surgery procedure. A good functional result of treatment depends not only on surgery procedures, but also on an individually selected system of post-operative rehabilitation therapy, especially when it comes to athletes – patients with high functional requirements. Recovery after a surgical injury is a precondition for a positive result of therapy. Rehabilitation measures are an indispensable part of a post-operative period which should be individual for each patient and depend on the volume and type of surgical treatment, a patient's age and a related pathology.

Treatment of patients with different deformities of the forefoot requires an individual approach in selection of a method of surgical correction and in further rehabilitation (Kardanov A. A., 2012).

Surgery procedures on the forefoot are usually performed when there are static deformities (Hallux valgus, hammer toes, arthrosis of foot ankles, osteochondropathy of metatarsal heads etc) (Roddy et.al., 2008). In order to repair deformities of the forefoot, in most cases different osteotomies with fixing bone fragments with wires, screws or plates, and also arthroplasty are used (Buckenberger & Goldman, 1995). Distal, diaphysial and proximal osteotomies of metatarsal bones are usually performed in order to repair available deformities, or to restore congruence of articular surfaces (Kroitoru et al., 2003; Khlopas & Fallat, 2020).

Modern standards of orthopedics mean using, on the one hand, minimally invasive instruments, on the other hand, stable fixation of bone fragments with early rehabilitation of a patient. Unfortunately, it is difficult to combine these parameters because of small-sized metal-fixers and significant loads on plantar surface of the foot. However, this problem in a post-surgery period can be solved using an individually selected plan of rehabilitation measures taking into consideration a bio-mechanical role of muscles of lower extremities.

Corresponding Author: VOLODYMYR STAUDE, E-mail: staudevl@gmail.com

Appropriate post-operative care for patients ensures a favorable long-term effect of the operation. Moreover, in order to encourage patients to accept recommendations, they should be informed of them before a surgery procedure.

Some authors believe that rehabilitation after such a surgery procedure must involve recovering tone and functions of such muscles as m. abductor hallucis, m. adductor hallucis, transverse head, oblique head, and also tendon m. flexor hallucis longus (Heineman et.al., 2020). Under longtime overstretching and overloading of these muscles, enthesopathies occur in the attachments, and myofascial trigger points appear in muscles (Korzh & Staude, 2021; Stecco, 2015; Bethers et. al., 2021). Such changes can be accompanied by pain, disorders of tone and balance of muscles and tendons (Dasi & Jhajharia, 2022; Wilke, 2018). Such musculoligamentous disorders are effectively treated by means of massage with a stretching effort along the axis of these muscles (Yuniana et. al., 2022).

Our system of rehabilitation combines the effect of massage and special exercises not only for muscles, stabilizing the great toe, but also for muscles, stabilizing and determining supportability of the foot and the entire pelvic girdle and pelvis. As T. Myers (2020) thinks, these are m. fibularis longus and m. tibialis anterior, which have a common attachment on the sole surface of the first metatarsal bone and stabilize the forefoot (Myers, 2020; Netter, 2019). The kinetic chain was described in our previous study (Staude et.al., 2023). Our system of rehabilitation involves exercises, recovering postural balance, which is necessary for performing simple everyday actions (Izzo et. al., 2022).

Some scientists think that combination of massage and further physical activities speeds up the recovery of muscle tone, a reduction in pain and restoration of the volume of motions in joints (Yuniana et. al., 2022).

Purpose. To improve the results of athletes' recovery after orthopedic surgery procedures on the forefoot due to the restoration of a muscle function, responsible for foot activity.

Material and methods

We conducted prospective research on 36 patients engaged in different sports, with deformities and diseases of the forefoot who had experienced surgery procedures aimed at repairing those deformations. There were 28 patients with hallux valgus, 12 of them had hammer toes. There were 8 patients with osteoarthrosis of the second metatarsophalangeal articulations caused by osteochondropathy of metatarsal heads (Kohler disease 2). All the patients were divided into 2 homogenous groups in terms of their age, gender and degree of static deformity of the forefoot, that further allowed performing appropriate comparison of treatment results applying different approaches in a post-operative period. The main group involved female patients of 18–46 years old, 14 patients – with static deformities of the forefoot and 4 patients with consequences of Kohler disease 2. The control group included female athletes of 19–45 years old, 14 patients with deformations of the forefoot and 4 patients with consequences of Kohler disease 2. All the patients with deformities of the forefoot experienced the following osteotomies on the first metatarsal bone: distal osteotomies (Chevron) in 4 cases, diaphyseal osteotomies (Scarf) in 16 patients and proximal osteotomies in 8 cases, osteotomy Weil on the second metatarsal bone was performed in 12 cases. 8 patients with osteoarthrosis of metatarsophalangeal articulation experienced arthroplasty.

Both in the main and the control groups, post-operative care started immediately after a surgical procedure through applying the adhesive elastic bandage "Coban", which allowed maintaining toes in an appropriate position and prevented from post-operative edema due to moderate compression of soft tissues (Fig. I).

Figure I. Soft bandage on the forefoot after a post-surgery period using the adhesive elastic bandage "Coban", after a surgery procedure on the forefoot

On the first day after a surgery procedure, cold therapy was used to provide additional homeostasis and prevention of post-operative edema.

On the second day after a surgery procedure patients were permitted to walk in Baruk shoes (Fig. II) that allowed loading the operated lower extremity, excluding loads on the forefoot and transferring them to the rearfoot. It was possible due to the constructive characteristics of the shoes. These shoes were used during 4-6 weeks after a surgery procedure on the first ray of the foot and up to 4 weeks after a surgery procedure on the second ray of the foot depending on X-ray control, i. e. the degree of the formation of a bone callus.

Figure II. Baruk shoes

At the same time, physiotherapeutic treatment was prescribed, that was aimed at preventing and reducing post-operative edema and decreasing risks of phlogistic complications (UHF, magnetotherapy). Moreover, patients were prescribed physiotherapy as active exercises in the ankle joint, which also contribute to minimization of edema. Movements in the operated foot joints were allowed to perform 4-5 days after a surgery procedure, but only passive ones. They were permitted to perform active movements from the 4th week after a surgery procedure.

After the period of wearing Baruk shoes, 4 weeks after a surgery procedure, all the patients had individual corrective insoles made with lining longitudinal and transverse arches and the period of active rehabilitation with dynamic exercises started, adding massage for the patients of the main group. The system of rehabilitation in the patients of the control group implied exercising aimed at training the stereotype of walking. The system of rehabilitation developed by us for the patients of the main group implied the effect of massage and special exercises on the following muscles and ligaments: m. abductor hallucis, m. adductor hallucis, tendon m. flexor hallucis longus, plantar aponeurosis, tendon m. extensor hallucis longus, m. extensor digitorum brevis, m. tibialis anterior, m. fibularis longus, m. biceps femoris, lig. sacroischiadicus, tractus iliotibialis, m. tensor fascia latae, m. quadriceps femoris, m. adductor magnus, m. gluteus medius on both operated and healthy sides. It corresponds the effect on spiral and lateral myofascial chains according to the theory of T. Myers (2020). The complex of rehabilitation for the main group of patients involved exercises not only for recovering balance of the above muscles on both sides, but also for recovering postural balance. The patients of the main group underwent massage once a day during 10 days. The complex of special gymnastics was done once a day during 10 days.

The research was discussed and approved at the meeting of the Bioethics Committee of the State Institution "Sytenko Institute of Spine and Joint Pathology" of the NAMS of Ukraine (Minutes № 220 dated 18 November, 2021). The results of treatment were evaluated by the generally accepted assessment scale of AOFAS for the forefoot (module 2) (Cook et.al., 2011) (Tabl.1).

Table 1. The scale of AOFAS for the forefoot (module 2)

Parameters	**Points**
Pain syndrome – 40 points	
No pain syndrome or mild episodic syndrome not affecting activeness	40
Moderate, episodic pain syndrome or mild, daily pain syndrome (after a long walk)	30
Moderate, daily pain syndrome	20
Intense, permanent pain syndrome	0
Function – 45 points	
Restriction of activeness	
No restriction of daily and sporting activeness	10
No restriction of daily activeness, but restriction of sporting activeness	7
Restriction of daily activeness and sporting activeness	4
Distinct restriction of daily activeness and sporting activeness	0
Requirements for shoes	
Possibility of wearing different, fashionable shoes (without restrictions) with no necessity to wear corrective insoles permanently	10
Wearing shoes with corrective insoles permanently	5
Necessity to wear special orthopedic shoes or foot orthoses	0
Range of motions in metatarsophalangeal joints of the operated toe (-s) in degrees (dorsiflexion and plantar flexion)	
Norm or low restriction (75° or more)	10
Moderate restriction (30° – 74°)	5
Severe restriction (less than 30°)	0
Range of motions in interphalangeal joints (plantar flexion)	
No restrictions	5
Moderate restriction (more than 10°)	3
Distinct restriction (less than 10°)	0
Stability of metatarsophalangeal and interphalangeal joints (in all directions)	
Stable	5
Obvious instability or inability to shift	0
Callus in the area of metatarsophalangeal and interphalangeal joints	

Unavailable or available, but without clinical manifestations	5
Callus with clinical manifestations.	0
Evaluation of adaptation of a segment to flat surface —15 points	
Supporting II – V toes, feet, well-adapted to surface	15
Maladaptation of II – V toes to surface, with no symptoms	8
Severe reduction in supporting ability, with available symptoms	0

The results of treatment were evaluated 45, 60, 90 days after surgery procedures.

Statistical processing of the research data was performed with the software package of general purpose STATISTICA (License Number: 139-956-866). Non-parametrical methods were applied – Mann–Whitney U Test (MWUT) for comparison of non-related groups and Friedman test (FT) for comparing the value of signs in different periods of time. Descriptive statistics are presented in the text as Me (LQ; UQ), where Me is the median, LQ – the lower quartile, UQ – the upper quartile.

Different abbreviations were used in graphical presentation of the index of AOFAS at different times: Bef – the value before treatment, Aft_45 – 45 days, Aft_60 and Aft_90 – 60 and 90 days after surgery procedures.

Results

We performed evaluation of the results of treatment of the patients with deformities of the forefoot who experienced identical surgery procedures with identical nosological forms. The differences consisted only in the tactics of post-operative care. There were no statistically significant age-related differences between the patients of the research groups. In the main and the control groups there was statistically significant positive dynamics of treatment by the scale of AOFAS (FT, $p < .01$) (Fig. III, Fig. IV).

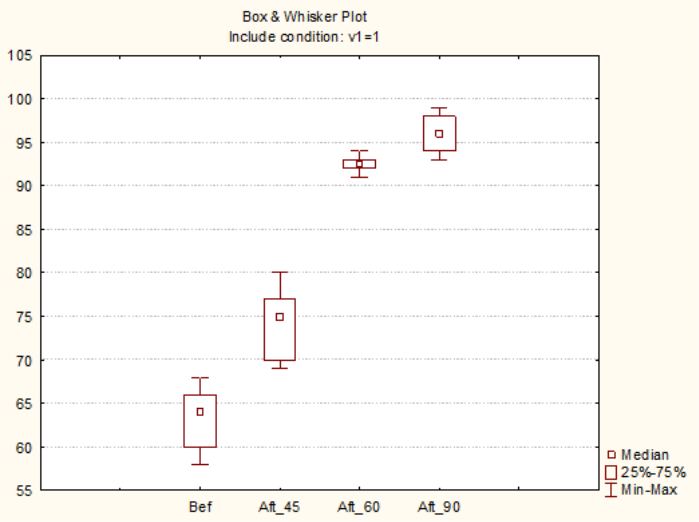

Figure II. Dynamics of the index of AOFAS in the main group before treatment and 45, 60 and 90 days after treatment

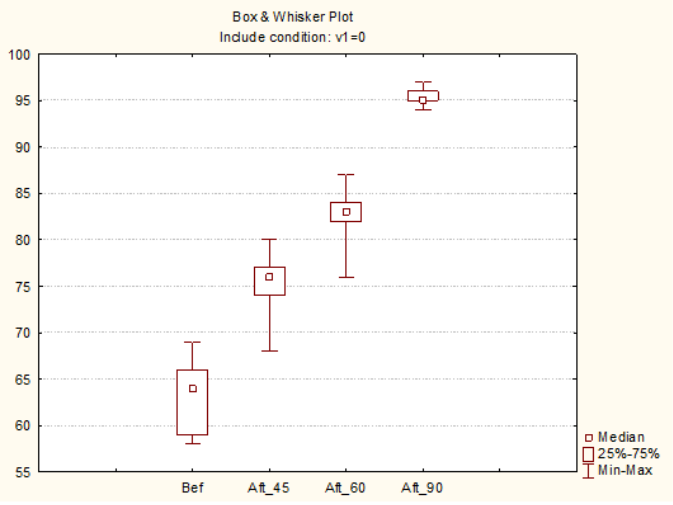

Figure IV. Dynamics of the index of AOFAS of the control group before treatment, 45, 60 and 90 days after treatment

Numerical characteristics of the index of AOFAS of both research groups in four points of observation are given in Tabl. 2.

Table 1. Descriptive statistics of the parameters of observation in the main and the control groups

Index	Mean	Medium	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
Main group							
Age	30.9	30.5	18	46	22	39	9.3
Bef	63.3	64.0	58	68	60	66	3.5
Aft_45	74.3	75.0	69	80	70	77	3.5
Aft_60	92.5	92.5	91	94	92	93	.9
Aft_90	95.9	96.0	93	99	94	98	2.0
Control group							
Age	31.1	30.0	19	45	24	38	8.5
Bef	63.6	64.0	58	69	59	66	3.6
Aft_45	74.8	76.0	68	80	74	77	3.7
Aft_60	82.1	83.0	76	87	82	84	2.9
Aft_90	95.3	95.0	94	97	95	96	.9

As it can be seen in the table, the score by the scale of AOFAS equaled 64 (70;77) and 64 (59;66) points in the main and the control groups, respectively. 45 days after a surgery procedure the values of the indexes equaled 75 (70;77) points and 76 (74;77) points, respectively. 60 days after a surgery procedure the scoring evaluation was the following: the index equaled 92.5 (92;93) points in the main group, it equaled 83.5 (82;84) points in the control group. 3 months (90 days) after surgery procedures, the indexes in both groups were almost identical and equaled 95 (95;99) points in the control group and 96 (94;98) points in the main group.

There were statistically significant differences between the main and the control groups by the scale of AOFAS 60 days after a surgery procedure (MWUT, $p < .01$) (Fig. V).

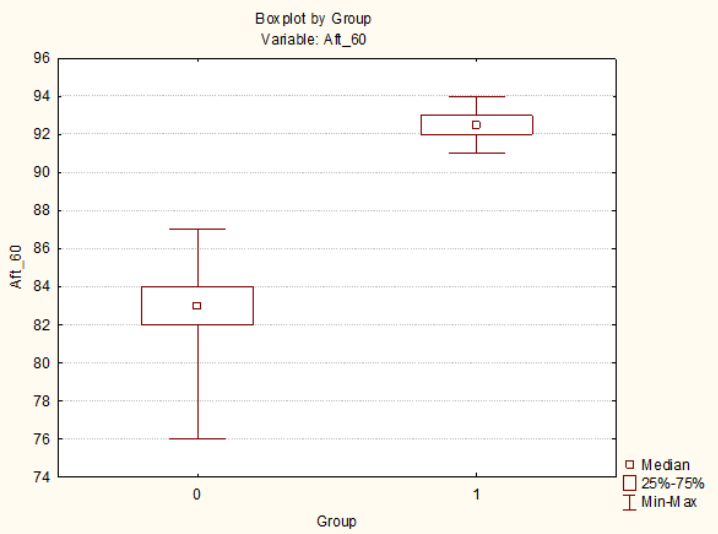

Figure V. The index of AOFAS 60 days after an orthopedic surgery procedure on the forefoot in the athletes of the main group (1) and the control group (0)

The athletes of the main group were able to return to a training process 2 months after a surgery procedure on the forefoot, and the athletes of the control group – 3 months after a surgery operation that allows inferring that there is a positive effect of the suggested methods of rehabilitation for faster functional recovery of athletes.

Discussion

It is necessary to highlight that all the athletes of the main and the control groups were female. It is determined by the fact that such deformities occur more frequently in females than in males. This correlation fluctuates between 15 to 1 or even more frequently (Kakwani & Kakwani, 2021).

We developed a system of rehabilitation therapy for such patients based on the hypothesis of T. Myers (2020) about kinematic myofascial chains.

Using anatomical products allowed proving that m. tibialis anterior has common points of attachment on the plantar surface of the first metatarsal bone with m. fibularis longus (Netter, 2019; Stecco, 2015; Steinke, 2018). These two muscles together with their tendons form the functional plantar loop which maintains foot stability (Myers, 2020). Imbalance of these muscles reduces foot stability and can cause pronation or supination of the

foot. The tendon m. fibularis longus, in its turn, on the head of the tibia, has a common point of attachment with the tendon m. biceps femoris, whose long head is attached to the ischial tuberosity of the pelvis and powerful sacrotuberal ligament with its tendon. Balance of the muscle tonus of m. quadriceps femoris, m. biceps femoris regulates the slope of the pelvis on the sagittal plane, that is shown in Fig. VI.

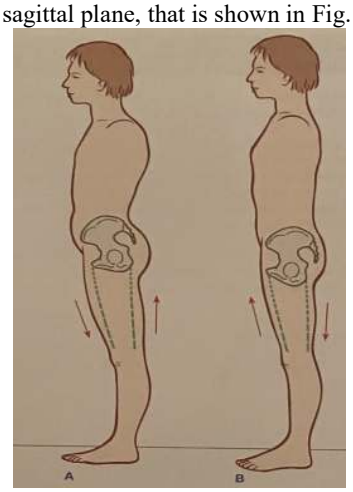

Figure VI. Stabilization of the pelvis due to the tonus balance m. quadriceps femoris, m. biceps femoris (Myers, 2020)

The study by V. Staude and Y. Radzishevska (2021) proves that massage and selective gymnastics targeted at certain muscles and joints can change the pelvic slope in the sagittal plane that is reflected in changes of the parameters of the spino-pelvic balance (Staude & Radzishevska, 2021).

In its turn, the second part of the plantar loop, m. tibialis anterior, is attached to the ectocondyle of the shinbone with its tendons and intertwines with tractus iliotibialis, which stretches m. tensor fascia latae. The short head of m. biceps femoris is attached to the thigh bone immediately affecting the tonus function of m. adductor magnus through it that has an effect on the pelvic slope in the coronal plane, that is shown in Fig. VII.

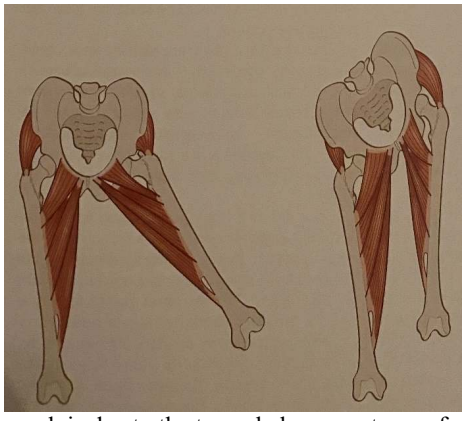

Figure VII. Stabilization of the pelvis due to the tonus balance m. tensor fascia latae, m. adductor magnus (Myers, 2020)

As a result of a surgery procedure, the location of the first metatarsal bone changes. This changes the conditions of functioning of m. abductor hallucis, m. adductor hallucis, tendon m. flexor hallucis longus, plantar aponeurosis, tendon m. extensor hallucis longus, m. tibialis anterior, m. fibularis longus, that affects the tonus of not only these muscles but also all the muscles biomechanically and anatomically connected with them. This allows speeding up the recovery of stability of not only the foot but also the entire pelvic girdle.

Unlike the standard rehabilitation of the control group of patients, the system of rehabilitation developed by us is aimed at the restoration of muscle balance of not only foot muscles, but also of all muscles of the kinematic chain determining the support ability of the lower extremities and the pelvis. Our system of rehabilitation mainly restores stabilizing properties of the plantar loop and all the muscles and ligaments biomechanically and anatomically connected with it. Massage and special exercises allow affecting the following muscles and ligaments: m. abductor hallucis, m. adductor hallucis, tendon m. flexor hallucis longus, plantar aponeurosis, tendon m. extensor hallucis longus, m. extensor digitorum brevis, m. tibialis anterior, m. fibularis longus, m. biceps femoris, lig. sacroischiadicus, tractus iliotibialis, m. tensor fascia latae, m. quadriceps femoris, m. adductor magnus, m. gluteus medius from both sides.

Our system of post-operative rehabilitation therapy is designed to affect both legs, the dominant and the non-dominant ones. The totality of all facts allowed speeding up the recovery of the main group of athletes. This fact coincides with the opinion of the authors who think that exercises for muscles, including those of the non-dominant legs of athletes, restore the balance between the muscles from both sides and increase functional capacities of muscles of both lower extremities (Ali Md Nadzalan et al., 2021).

That fact, that all the patients of the main and the control groups were athletes, is very important for the results obtained. It means that they had appropriate dispositional readiness for psycho-emotional and physical loads (Karpenko & Klympush, 2023; Popovych et. al., 2022a; 2022b; 2022c), preparation and a disposition to move towards a positive result (Plokhikh, 2023), psychological safety (Kalenchuk et al., 2023), overcome difficulties (Fomych, 2023) and, consequently, recover the stereotype of walking and moving.

Conclusions

Appropriate rehabilitation in a post-operative period is very important for earlier return of an athlete to a training process after an orthopedic surgery procedure on the forefoot.

Massage and special exercises aimed at recovering the function and stabilizing properties of the following muscles and ligaments: m. abductor hallucis, m. adductor hallucis, tendon m. flexor hallucis longus, plantar aponeurosis, tendon m. extensor hallucis longus, m. extensor digitorum brevis, m. tibialis anterior, m. fibularis longus, m. biceps femoris, lig. sacroischiadicus, tractus iliotibialis, m. tensor fascia latae, m. quadriceps femoris, m. adductor magnus, m. gluteus medius from both sides allowed obtaining not only a good functional result, but also reducing the dates of the athletes' functional recovery by a month in comparison with the control group.

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