ISSN 0030-5987. Orthopaedics, traumatology and prosthetics. 2021. № 3

УДК 616.728.9-001.6-089.8(048.8)

DOI: http://dx.doi.org/10.15674/0030-59872021373-84

Surgical treatment of valgus deformity of great toe (literature review)

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The most common manifestation of static deformity of the forefoot is hallux valgus. This symptom complex consists of valgus deviation of the first toe, varus deviation of the first metatarsal bone, and the presence of osteochondral exostosis along the medial surface of the head of the first metatarsal bone. The objective of the work was to determine the most common methods of treatment of hallux valgus and varus deformities of the first metatarsal bone on the basis of the analyzed published literature. Methods. We analyzed publications from the Google search engine, electronic databases PubMed, Google Scholar, archives of specialized journals and other relevant sources of scientific and medical information. Results. Based on the analysis of literary sources, the development of forefoot surgery from the 18th century to the present day was highlighted in the historical aspect. The greatest attention is paid to the use of various osteotomies of the first metatarsal bone for the correction of hallux valgus. In addition, special attention is paid to the development of various complications at osteotomies. Conclusions. The problem of surgical correction of hallux valgus is multifaceted and extremely interesting, containing a large number of nuances and hidden complexities. For quite a long time, there has been an improvement in various surgical techniques and methods of fixation. Considering the great variability of the clinical manifestations of hallux valgus, for many years no universal method of treating this pathology has been proposed. Therefore, in the future, most likely, individual and differentiated approaches to the choice of one or another method of surgical intervention will be considered, depending on what type of deformity of the forefoot the orthopedist-traumatologist has to meet in his practice. Key words. Hallux valgus, osteotomy of first metatarsal bone, osteosynthesis.

Вальгусна деформація I пальця стопи (hallux valgus) є найчастішим проявом статичної деформації її переднього відділу. Цей симптомокомплекс складається з вальгусного відхилення I пальця, варусної девіації I плеснової кістки та наявності випинання на медіальній поверхні стопи в проєкції головки I плеснової кістки. Мета. На підставі аналізу наукової літератури визначити найбільш застосовувані методики лікування вальгусної деформації I пальця стопи та варусної деформації I плеснової кістки. Методи. Проаналізовано публікації з пошукової системи Google, електронних баз PubMed, Google Scholar, архівів спеціалізованих журналів й інших релевантних джерел науково-медичної інформації. Результати. В історичному аспекті відображено розвиток хірургії переднього відділу стопи, починаючи з XVIII століття до сьогодення. Методики лікування hallux valgus умовно поділяють на три групи хірургічних втручань: на м'яких тканинах, кістках і суглобах, комбіновані. Нині обмежено показання до ізольованого застосування операцій на м'яких тканинах. Повноцінно скорегувати деформацію переднього відділу стопи можна лише за умов використання різних остеотомій першого променя стопи (I плеснова кістка й основна фаланга I пальця стопи). Приділено увагу різновидам коригувальних остеотомій, розвитку ускладнень та їхніх причин після виконання операцій. Висновки. Проблема хірургічної корекції вальгусної деформації I пальця стопи залишається невирішеною. Протягом століть фахівці розробляють і вдосконалюють хірургічні техніки та методи фіксації для корекції hallux valgus. Проте універсальний спосіб хірургічного лікування цієї патології натепер не створено. У подальшому вважаємо доцільним розглядати індивідуальні та диференційовані підходи до вибору певного способу хірургічного втручання (а іноді їхньої комбінації) залежно від виду деформації. Потребує розроблення універсальний алгоритм вибору оптимального способу хірургічної корекції за умов комбінованих деформацій, а також у випадках рецидиву після попередніх втручань.

Key words. *Hallux valgus*, osteotomy of first metatarsal bone, osteosynthesis

Introduction

The most common manifestation of static deformity of the anterior part of the foot is valgus deformity of the first toe (*hallux valgus*). These changes are manifested by valgus deviation of the first toe, varus deviation of the first metatarsal bone and a protrusion on the medial surface of the foot in the projection of the head of the first metatarsal bone [1].

The incidence of this disorder is not precisely established and differs significantly in different populations, ranging from 0.9 % [2], 2–4 [3] to 28.4 % [4]. According to the results of observations, factors that increase the probability of this static deformation include female sex [5, 6], and increased age [7].

The purpose of the study: based on the analysis of the published literature to determine the most widely used methods of treatment of valgus deformity of the first toe and varus deformity of the metatarsal bone.

Material and methods

The study involved review of publications from Google search engine, PubMed electronic databases, Google Scholar, archives of specialized journals and other relevant sources of scientific and medical information.

Results and their discussion

Valgus deviation of the first toe can be a source of suffering for the patient, accompanied by pain, causing difficulties in the selection and wearing of shoes [8].

The main method of treatment of valgus deformity of the first toe is surgery. The first reliable report of hallux valgus was found in the work of pedicure master Laforest at the court of Louis XIV after the publication of which in 1778 the author received the title of a «pedicure surgeon» (according to [9]).

In 1835, Liston (according to [10]) described a resection of the head of the first metatarsal bone. R. Volkmann [11] noted that such an intervention, although corrects the appearance of the foot, but makes walking more painful. In 1871, K. Hueter [12] performed a resection of the head of the first metatarsal bone. The same technique of operation was used by S. H. Mayo in 1908 [13], and in 1910 R. R. Vreden [14], therefore the technique of operation received the name Hueter-Mayo-Vreden. This surgery remained popular until the middle of the last century and has been repeatedly modified.

In general, many different methods have been proposed for surgical treatment of valgus deformity of the first toe with surgical correction of its components. In particular, if G.A. Albrecht [15] in 1911 described 11 operations, today there are more than 400. This number of different methods of surgical treatment proposed to correct the deformity, indicates that the problem remains relevant, and the «gold standard», the use of which would effectively treat patients, has not been developed [16]. It is possible that there is no ideal method of surgical correction of deformities caused by any abnormality of the anterior foot, due to their great variety.

The evolution of ideas about the role of certain anatomical structures in the pathogenesis of valgus deformity of the first toe has led to the development of many surgical techniques that have different points of application. They are conventionally divided into three groups of surgical interventions: on soft tissues, bones and joints, combined [17–23].

Among the operations performed on soft tissues in the area of the first metatarsophalangeal joint (MPJ) for the treatment of *hallux valgus*, the most common methods are by D. Silver [24], J. M. Hiss [25] and E. D. McBright [26–28].

D. Silver described the surgical technique in the amount of resection of the medial exostosis of the first metatarsal bone, lateral capsulotomy of the first MPJ, tenoadductorotomy and Y-shaped capsuloplasty after its V-shaped dissection. In Russian-language literature, this operation is called Schede. It can be used only in elderly patients or in conditions of initial degree of deformity.

Particular attention was paid to the capsule-ligament apparatus by E. D. McBright, whose findings were published in 1928 [26] and included resection of exostosis of the head and metatarsal bone, lateral release of the capsule of the first MPJ and transposition of the *m. adductor hallucis* tendon through the neck of the first metatarsal bone with subsequent removal (in advanced cases) of the lateral sesamoid bone. It should also be noted that the most common complication was iatrogenic varus deviation of the first toe.

Soft tissue surgeries are performed to correct tendon-muscle balance in the area of the first MPJ, and at the present stage their isolated use has limited indications [16, 28–30]. Recurrence of deformity is the most common complication of isolated operations on soft tissues due to the mismatch of the chosen intervention to the severity of the deformity. The second most common cause of recurrence is inadequate restoration of the medial part of the joint capsule.

Removal of the lateral sesamoid bone is also one of the consequences of varus deviation of the first toe. Excessive tension of the medial capsule after this

manipulation causes the development of *hallux varus* due to capsular-ligament imbalance.

It is possible to fully correct the deformation of the anterior part of the foot only using various osteotomies of the first toe (first metatarsal bone and the main phalanx of the first toe). However, it should be emphasized that each time during an osteotomy or other surgery for *hallux valgus*, it is necessary to apply the correction of pathologically altered tendon-muscle balance using the intervention on the soft tissues of the first MPJ area [31].

Operations on the skeletal system of the anterior foot can be divided into subgroups:

1. Osteotomy of the first metatarsal bone (at different levels) and the main phalanx of the first toe;

2. Arthrodesis of the first metatarsal-wedge-shaped joint (Lapidus operation);

3. Endoprosthesis of the first MPJ (hemi- / total);

Given the incurred combination of *hallux valgus* with medial deviation of the first metatarsal bone, the use of corrective osteotomy is appropriate for the correction of the structural element of this deformity.

Osteotomies of the first metatarsal bone are divided into distal, diaphyseal and proximal. Over the last century, there has been a debate about the most optimal level and operational techniques for their implementation. Minimal consensus among surgeons was reached provided that the larger the M1M2 angle (angle between axes of the first and second metatarsal bones) [16], the more proximal the osteotomy should be performed.

Distal osteotomy is used for mild to moderate deformities, but it is contraindicated in severe cases [32]. In 1881, Reverdin described a distal corrective wedge-shaped osteotomy of the first metatarsal with the wedge apex directed laterally, which was supplemented by resection of the osseous-cartilaginous exostosis of the head of the first metatarsal bone. The operation allowed to normalize the position of the first toe; however, it did not affect the M1M2 angle [33]. Subsequently, many of its modifications were proposed (Figure) [34].

In 1923, G. Hohmann described a technique for eliminating valgus deviation of the first toe [35]. The operation began with cutting off the *m. abductor hallucis* and *m. flexor hallucis brevis* tendons, separating them from the place of attachment to the base of the proximal phalanx and removing proximally. A wedge-shaped or trapezoidal osteotomy of the head was performed, the central fragment was removed, and then the distal part was excised in the direction of the head of the second metatarsal bone. Mobilized *m. abductor hallucis* tendon was fixed dorsally to the medial part of the main phalanx.

During 13 years (1945–1958) C. L. Mitchell and H.B. Hawkins [36] published a number of findings that reflected the results of their operation for the correction of primary varus deviation of the first metatarsal bone and valgus deviation of the first toe.

The authors performed a double osteotomy of the first metatarsal bone, namely incomplete section of the head in the perpendicular direction, followed by the second osteotomy a few millimeters proximal to the neck. The distance between the lines of osteotomies depended on the size of the required shortening of the bone.

After removal, a cortico-spongy fragment was formed, the head was displaced laterally and centrally, which allowed not only to reduce the intermetatarsal angle, but also to reduce the tension of the periarticular tissues. If it is necessary to change the angle of the articular surface of the head of the first metatarsal bone, distal osteotomy was performed at the desired angle.

However, this osteotomy is characterized by shortening of the first toe, which is formed after removal of the bone, as well as insufficient stability of the fragments. This can lead to dislocation of the distal fragment and fusion in the wrong

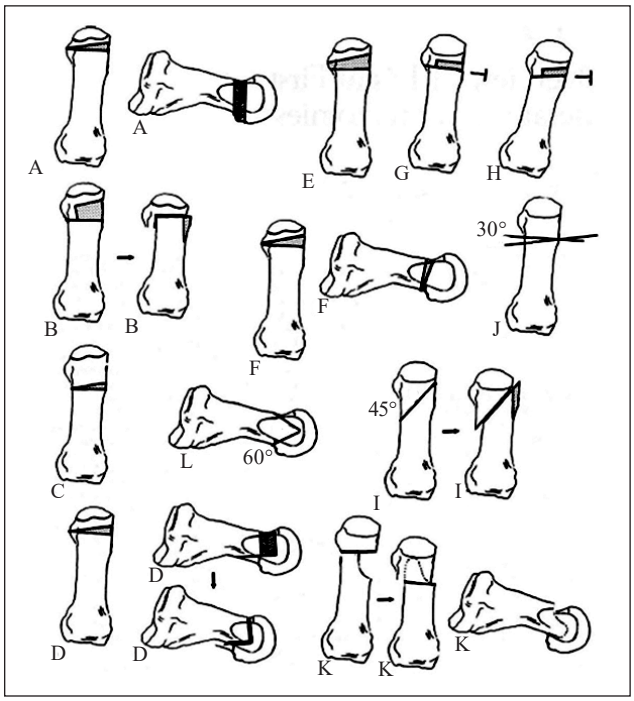

Figure. Schematic representation of different variants of distal osteotomies of the first metatarsal bone (A — Reverdin osteotomy, B — Roux osteotomy, C — Peabody osteotomy, D — Distal L osteotomy, E — Hohmann osteotomy, F — DRATO osteotomy, G — Mitchel osteotomy, H — Miller osteotomy, I — Wilson osteotomy, J — Lindbren and Turan osteotomy, K — Mygind osteotomy, L — Austin osteotomy) (за [34])

position with the development of subsequent metatarsalgia (10 to 30 % of cases) [37].

There may also be a loss of correction, which occurs much less frequently in the case of screws that increase the stability of fixation of bone fragments [38].

In 1974, J. W. Miller published the findings of Mitchell's modified operation. According to J. W. Miller, the axis of the foot was a more important reference point during osteotomy than the axis of the first metatarsal bone, so he recommended performing a proximal cut of the bone and subsequent displacement of the head perpendicular to the axis of the foot.

In 1963, J. N. Wilson described oblique osteotomy at the level of the distal third of the first metatarsal bone (inward, distally outward, and proximal) [40]. This technique allowed to adjust the M1M2 and M1P1 angles. The advantages of this operation determine the simplicity of performance, stability, which allows to avoid internal fixation, a wide contact area of osteotomized fragments of the metatarsal bone, reducing the likelihood of nonunion.

Evaluation of the results of this technique showed that in 90 % of patients [41] the operation was accompanied by shortening of the metatarsal bone, an average of 8.5 mm, in addition, in 24 % of cases described the formation of dorsal angulation at the level of osteotomy [42].

However, given that in the case of Wilson's osteotomy, a correlation was recorded between the shortening of the first metatarsal bone by more than 5 mm and the development of transient metatarsalgia [43], this technique is not recommended today for osteotomy of the first toe. But it can be successfully used in the treatment of Taylor's bursitis in zone of the fifth metatarsal bone.

In 1979, the findings of S. Miller and W. A. Croce [44] were published, which described distal osteotomy of the first metatarsal bone, which was substantiated by D. W. Austin. The author described in detail his technique and the first results of its application in 1981 [45]. This is a V-shaped osteotomy, which is performed at the level of the neck of the first metatarsal bone with subsequent lateral displacement of the distal fragment.

The peculiarity of the original technique was the formation of two sawings almost in the horizontal plane in such a way that their top is located at the level of the head of the first metatarsal bone, and the angle between the osteotomy lines was 60°. The operation was supplemented by capsule release and correction of tendon-muscle balance on both sides of the first MPJ [45]. The technique has become widespread, in the English-language literature it is called Austin osteotomy, in French — Chevron osteotomy.

Initially, the authors proposed not to fix bone fragments of the first metatarsal bone, believing that the shape of the osteotomy and the impact of the cancellous bone of the head segment on the fragment of the diaphyseal part of the bone should provide the necessary stability in the osteotomy area. However, the results published later showed a possible loss of the achieved correction in the long run — up to 12.5 % [46, 47].

Numerous variants of fragment stabilization have been described, namely with special plates, screw(s), Herbert screw, staples, needles, clamps made of biodegradable materials, etc. [48–51].

The use of Chevron osteotomy makes it possible to correct abnormal M1P1 (angle between the axes of the main phalanx of the first toe and diaphysis of the first metatarsal bone) [16] and M1M2 angles. Subsequent changes made it possible to correct all abnormal components of *hallux valgus* deformity in combination with *metatarsus primus valgus* [52]. They consist of a double osteotomy technique to change the angle of inclination of the articular surface of the first metatarsal bone (PASA) and vertical deformations of the head, allow shortening and lengthening of the first metatarsal bone, correction of dorsal and plantar flexion [53], including correction of *metatarsus primus elevatus*. The technique of double osteotomy is described by J. Gerbert et al. [54], it consists in performing an additional sawing of the metatarsal bone at the required angle to the first one, after which it is possible to turn the head and install it at the desired angle. H.F. Duke and E.M. Kaplan in 1984 [55] published information about their technique, according to which osteotomy lines are directed at an angle to the horizontal plane from the medial or lateral side, which allowed to move the head of the metatarsal not only laterally but also in the plantar, or dorsal direction. The combination of this technique with the technique of J. Gerbert proposed by S. F. Boc and colleagues [56, 57] in 1991, made it possible to eliminate the displacement in three planes.

Complications after Chevron osteotomy have been analyzed for a long time [54, 58]. Insufficient correction, recurrence of deformity, aseptic necrosis of the metatarsal head, metatarsalgia are recognized as the most common. It is believed that the main reason for the negative results of Chevron osteotomy is the wrong choice of type of surgery or inconsistency of presentation with the chosen technique.

The described distal osteotomies of the head of the first metatarsal bone should perform four main functions: reduction of the intermandibular angle, restoration of the axis of the first toe and the angle of rotation of the articular surface of the first metatarsal bone, shortening or maintaining the length of the metatarsal bone.

Reverden osteotomy involved mostly restoring the normal angle of the articular plane of the metatarsal bone, the same goal can be achieved with the operations according to Wilson, Mitchell and Austin with a simultaneous reduction of the intermetatarsal angle. A significant factor limiting the use of distal osteotomy is the impossibility of a significant shift of the head to the lateral side, so the intermetatarsal angle of 15°–16° is the limit in the case of choosing this manipulation. Its use can lead to a significant shortening of the metatarsal bone, which is a relative contraindication to use in the case of anatomically short metatarsal bones.

Despite the fact that technically correct distal osteotomies have good and excellent results in an average of 80 % of cases, 15–20 % of patients develop complications and unsatisfactory treatment results. The development of avascular necrosis of the head of the first metatarsal bone is observed from 0 to 20 % of cases [59–62]. Rare complications include nonunion, stress fractures in the area of transposition of the head, the development of varus deformity of the first toe.

Thus, distal osteotomies of the first metatarsal bone have favorable long-term results in patients with no or moderate degree of metatarsalgia secondary to clinically and radiologically insignificant deformity of the anterior foot.

In cases when valgus deviation of the first metatarsal is combined with the varus deviation of the first metatarsal bone, and the angle between the first and second metatarsal bones exceeds 15°–16°, the use of distal osteotomy does not allow to correct the existing deformation. The method of choice is osteotomy at the level of the diaphysis of the first metatarsal bone. To date, about 130 options for interventions at this level have been described. K. Ludloff and M. Meyer are considered to be the founders of diaphyseal osteotomies [63, 64]. Further modifications of classical concepts taking into account various abnormal links of deformations have been offered. In 1913, K. Ludloff performed an oblique osteotomy of the diaphysis, the plane of the cut of the first metatarsal bone was directed from the dorsal surface to the plantar in the proximal-distal direction. However, the possible secondary displacement of bone fragments did not allow this technique to become widespread, because prevention of these complications requires the use of external immobilization in the postoperative period.

Z-shaped osteotomy of the first metatarsal bone (Scarf) was first described by M. Meyer in 1926 [64]. C. J. Gudas in 1983 proposed to use AO screws to stabilize bone fragments [65]. Performed by C. J. Gudas, Scarf osteotomy involved horizontal sawing of the first metatarsal bone with subsequent fixation with two cortical screws. Subsequently, this operation has undergone many changes associated with additional opportunities to correct deformations, as well as methods of fixation [66–69].

L. S. Barouk (1992), publishing his own data on Scarf's operation, emphasized the importance of adequate lateral release and restoration of medial tissue tension [69].

Recently, Scarf osteotomy has become very popular. Excellent correction capabilities, relative convenience of implementation, preservation of blood supply to the head, a small number of complications, early rehabilitation — all this allows the use of this type of intervention in most cases of combination of valgus deformity of the first toe with varus deviation of the first metatarsal bone [70].

In severe (more than 30°) varus deviation of the first metatarsal bone, most orthopedists use proximal osteotomy, which was first proposed by J. Balasescu [71].

E. Juvara in 1920 [72] developed the technique of proximal oblique wedge-shaped osteotomy of the first metatarsal bone, its line was directed at an angle of about 40° to the axis of the bone. Initially, the original technique involved resection of a trapezius bone fragment, but later it changed and by 1970, Juvara osteotomy involved resection of the lateral wedge without intersecting the medial cortical plate. The main problem when using this method was the stability of bone fragments after osteotomy: in the case of insufficient fixation, secondary displacement and nonunion were often observed [73].

In 1923, J. Trethowan [74] first described a proximal wedge-shaped osteotomy with a wedge open inward. The author predicted displacement and immersion in the formed wedge-shaped defect, the base of the metatarsal bone of the resected medial exostosis of its head. The operation underwent changes in 1957, when the use of a graft from the resected base of the proximal phalanx of the first toe (according to Keller) was proposed [75]. The problems that arise when using this technique were associated with an artificial increase in the length of the first toe and in the case of its initial excess length, it causes deterioration, recurrence of deformation. In addition,

the preservation of the lateral cortical plate does not allow derotation of the metatarsal bone.

In 1948, D. Logroscino developed a method of double osteotomy of the first metatarsal bone, which resected wedge-shaped bone fragments from the head and base of the metatarsal bone. The main indications for surgery were significant deflection angles of M1M2. Logroscino surgery is a combination of methods proposed by Reverdin (1881), Balasescu (1902) and Trethowan (1923). There is still no unequivocal opinion among orthopedists about this technique, because most surgeons believe that the indications for performing this surgery should be carefully considered [54, 76].

The main complications of proximal osteotomy are related to the problems of repositioning and fixation of bone fragments. Hypercorrection most often occurs with a negative intermetatarsal angle, resulting in varus displacement of the first toe. Dorsiflexion of the metatarsal head is observed in the case of resection of a wedge with a larger base turned to the back of the foot. In addition, we must not forget about the excessive shortening of the first metatarsal bone, which leads to overload of the middle foot and, as a consequence, metatarsalgia. After the application of any osteosynthesis there are problems with consolidation due to insufficient stability of bone fragments.

As already mentioned, the most common diaphyseal osteotomy Scarf should be combined with osteotomy of the main phalanx of the first toe to correct its valgus deformity. In such cases, the operation of choice is a corrective osteotomy of the main phalanx of the first toe, described by O. F. Akin in 1925 [77]. It involves, after standard resection of the medial exostosis of the head of the first metatarsal bone to perform a wedge-shaped osteotomy of the proximal phalanx of the first toe. If necessary, derotation of the distal fragment of the phalanx was performed. Today, several main options for surgery are proposed: wedge-shaped distal and proximal cylindrical, less commonly used trapezoidal resection of the main phalanx of the first toe. Wedge-shaped osteotomy is performed for angular correction with simultaneous shortening of the toe, and cylindrical only to reduce the length of the toe, which is especially relevant for halomegaly. Resection of the trapezoidal fragment helps to achieve simultaneous shortening of the phalanx and angular correction. In all cases, derotation of the distal bone fragment is possible [78, 79].

Complications of Akin osteotomy include: prolonged pain, edema, delayed adhesion, nonunion, hypercorrection (*hallux varus*), as well as correction with displacement in the sagittal plane [80].

In addition to valgus deformity of the first toe, we should not forget about hypermobility in the first metatarsal-wedge joint, which may accompany *hallux valgus*. In fact, this hypermobility can be a problem when choosing a method of deformation correction. The difficulty lies in the complexity of maintaining the achieved correction after osteotomy at different levels of the metatarsal bone, some patients in the remote period after surgery developed *metatarsus elevatus* or metatarsalgia. Arthrodesis of the medial metatarsal-wedge-shaped joint proposed in 1934 by P. W. Lapidus allows to solve this problem [81]. The author also predicted arthrodesis between the bases of the first and second metatarsal bones with correction of the soft tissue complex.

In 1989, B. J. Sangeorzan and S. T. Hansen published a report on 40 operations for arthrodesis of the metatarsal-wedge joint, performed in the period from 1979 to 1984 [82]. The main indication for the use of this technique was a significant varus deviation of the first metatarsal bone secondary to hypermobility of the first toe. In 75 % of cases, excellent and good results were obtained, in 10 % arthrodesis did not occur, which led to repeated interventions using bone autoplasty. Additional indications for surgery are arthritic changes of the medial metatarsal-wedge-shaped joint, osteopenia, as well as central metatarsalgia (round foot).

In recent years, arthrodesis of the metatarsal-wedge joint has been used more often in the treatment of elderly patients with advanced stages of deformity. Complications after this technique are few and related to technical errors during joint resection or osteosynthesis. Strict adherence to the operation protocol allows to achieve favorable results in most cases [83–85].

In European countries there is an increasing interest to arthroplasty of the first MPJ [86–88]. However, they are most often used in conditions of deforming arthrosis of these joints, rigid joints, or repeated surgery for *hallux valgus*, when there are secondary iatrogenic complications in the form of aseptic necrosis of the head of the first metatarsal bone or fibrous ankylosis. It is especially important to take into account the functionality of the soft tissue complex (tendon-muscle balance) during the MPJ endoprosthesis operation. In cases with infectious complications after the initial correction of *hallux valgus*, it is recommended to perform arthrodesis of the first MPJ in a functionally advantageous position. The same operation is used when it is impossible to perform endoprosthesis replacement of this joint.

Conclusions

The problem of surgical correction of valgus deformity of the first toe is very multifaceted and extremely interesting, it contains a huge number of nuances and hidden difficulties. For several centuries, specialists have been developing and improving various surgical techniques and methods of fixation. Due to the large variability of clinical manifestations of valgus deformity of the first toe, no universal method of surgical treatment of this abnormality has been developed so far. It is logical to further consider individual and differentiated approaches to the choice of a particular method of surgery (and sometimes a combination thereof) depending on the type of deformity.

The development of a universal algorithm for selecting the optimal method of surgical correction in cases of combined deformities and recurrences after previous interventions needs further substantiation.

Analyzing the sources of the literature, we came to the conclusion that the issue of valgus deformity remains open today. Methods of treatment with the use of the latest technologies are widely discussed. The choice of surgical options is debatable. A more detailed study of this issue, in our opinion, is quite relevant and requires both the experience of the doctor and the consideration of new recommendations for approaches to treating patients.

Conflict of interest. The author declare the absence of conflict of interest.

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The article was received by the editors 03.08.2021

SURGICAL TREATMENT OF VALGUS DEFORMITY OF GREAT TOE (LITERATURE REVIEW)

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