Review article
https://doi.org/10.18019/1028-4427-2024-30-5-743-752

Arthroplasty of the proximal interphalangeal joint of the hand: the current state of the problem

P.V. Fedotov✉, **D.V. Kovalev, A.S. Mikhailov**

Federal Center for Traumatology, Orthopedics and Arthroplasty, Cheboksary, Russian Federation

Corresponding author: Pavel V. Fedotov, mr_vulfgar@mail.ru

Abstract

Introduction The proximal interphalangeal joint (PIP joint) plays an important role in ensuring optimal finger dexterity, grip strength and overall hand functionality. Arthroplasty is a promising direction in the surgical treatment of arthritis of the PIP joint of the hand, however, the inconsistency of the results encourages the world scientific community to be restrained and further investigate the problems associated with PIP joint arthroplasty.

The **purpose** of the work was to identify the main problems of PIP joint arthroplasty based on the analysis of foreign and domestic medical literature.

Materials and methods In this literature review, an analysis of foreign and domestic scientific publications devoted to the treatment of diseases and injuries of PIP joint was carried out. The purpose of the study was to provide a brief historical background and identify the main problems of PIP joint arthroplasty based on the analysis of foreign and domestic medical literature.

Results and discussion The choice of the implant and the surgical aproach used are the two most frequently discussed issues in PIP joint arthroplasty; dorsal, palmar and lateral surgical approaches are described, each with its own advantages and disadvantages. Dorsal approaches are used most often because they are easier to perform; however, the fragile extensor apparatus is damaged with the subsequent development of extensor lag. A number of authors concluded that stiffness and extensor lag were the most common postoperative complications. Several combinations of materials are available: from classic chrome-cobalt/polyethylene to ceramic/ceramic and pyrocarbon/pyrocarbon. Most of them have not stood the test of time yet, and for most implants there is still a lack of real long-term monitoring series for survival of the design.

Conclusion The morphology of joints, small bone sizes, complex biomechanics and the load on the hand are a special problem in PIP joint arthroplasty. It is still not possible to restore the full range of motion in this joint, despite the success of colleagues in arthroplasty of large joints.

Keywords: proximal interphalangeal joint; arthroplasty, hand joints; arthroplasty of the proximal interphalangeal joint, biomechanics of the fingers of the hand

For citation: Fedotov PV, Kovalev DV, Mikhailov AS. Arthroplasty of the proximal interphalangeal joint of the hand: the current state of the problem. *Genij Ortopedii*. 2024;30(5):743-752. doi: 10.18019/1028-4427-2024-30-5-743-752

INTRODUCTION

The problem of treating osteoarthritis of the proximal interphalangeal joint (PIPJ) is caused by the low incidence of the disease along with its high medical and social important (significant limitation of motor functions of the fingers, leading to a decrease in the quality of life); insufficient coverage of the problem due to insufficient clinical experience and a shortage of highly qualified specialists in this field; continuous change of PIPJ implant lines on the medical market. All this limits the possibilities for comparing the clinical effectiveness of PIPJ arthroplasty, conducting multicenter studies of its results, including long-term follow-ups.

The proximal interphalangeal joint (PIPJ) plays an important role in maintaining optimal finger dexterity, grip strength, and overall hand function [1]. PIPJ osteoarthritis is relatively common, with a radiographic prevalence of 18 % [2], and affects primarily women aged 60 to 79 years, although both men and women are affected equally between the ages of 80 and 89 years. Based on radiographs (R) and photographs (P), the prevalence of osteoarthritis in the PIP joint of the hand (R, 18 %; P, 6 %) is lower than that in the distal interphalangeal (DIP) joint (R, 35 %; P, 24 %) or the carpometacarpal (CMC) joint (R, 21 %; P, 8 %) [2, 3]. Foreign colleagues report that the interphalangeal joints of the dominant hand demonstrate a higher prevalence of osteoarthritis than in the non-dominant hand [4]. Degenerative changes in this joint are most often a consequence of idiopathic osteoarthritis (up to 60 %), post-traumatic arthritis (consequences of intra-articular fractures, ligament damage) (up to 25 %), systemic inflammatory diseases (most often rheumatoid arthritis — up to 15 %), and are also observed in tumor lesions (enchondroma, chondrosarcoma) [5]. Osteoarthritis of the proximal interphalangeal joint of the finger (both primary and secondary) causes pain with concomitant limitation of range of motion, which often leads to global deterioration of hand function [6]. The PIPJ accounts for approximately 85 % of the movements required for a functional grip [7].

It is still not possible to restore the full range of motion in this joint, in contrast to the success of colleagues in large joint arthroplasty. Conservative treatment of osteoarthritis of the PIPJ may reduce symptoms such as pain, swelling, stiffness, and decreased grip strength in the early stages. However, if the symptoms of the disease progress, surgical intervention is indicated [8].

Secondary osteoarthritis is most often caused by post-traumatic changes, followed by chronic unstable inflammatory diseases. Being a hinge joint, it is extremely stable in the sagittal plane, but has limited tolerance to angular, axial and rotational loads. Thus, the PIPJ is one of the most injury-prone joints. The vulnerability of the PIPJ is due to its unprotected position in the finger and long moment arm. Among potential hand injuries, PIP joint injuries are quite common in the general population and are especially pronounced in athletes [9, 10].

According to the scientific literature, the main surgical methods for treating patients with stage III osteoarthritis of the PIP joint are arthrodesis and total joint replacement. The ideal treatment goal for end-stage PIP joint osteoarthritis is painless restoration of adequate mobility and stability. The index and middle fingers are the pinch partners of the thumb, while the fourth finger and little finger require mobility to grasp larger objects. The severity of instability and deformity must be considered for choosing the correct treatment method for PIP joint problems [11, 12]. The goal of all these treatments is to reduce pain, which leads to improved overall hand function. Arthrodesis remains the main salvage method for end-stage PIP joint arthritis and is especially useful in cases of instability, deformity, or bone insufficiency of the joints that are not typically amenable to arthroplasty. Although arthrodesis sacrifices joint mobility for stability, it is often a necessary compromise to optimize hand function [1].

The **purpose** of the work was to identify the main problems of PIP joint arthroplasty based on the analysis of foreign and domestic medical literature.

MATERIAL AND METHODS

This literature review analyzes foreign and domestic scientific publications devoted to the treatment of diseases and injuries of the PIP joint. The search was conducted in the electronic databases Google Scholar, PubMed, e-LIBRARY in Russian and English using the search phrases: arthroplasty of the proximal interphalangeal joint, arthrodesis of the proximal interphalangeal joint, osteoarthritis of the proximal interphalangeal joint. The depth of the study was 37 years.

The review is based on scientific publications on arthroplasty, functional anatomy and biomechanics of the proximal interphalangeal joint from 1988 to 2024 inclusive. Conference abstracts and case reports were excluded.

RESULTS AND DISCUSSION

The conducted analysis of medical literature on PIPJ arthroplasty as one of the surgical methods of treating patients with terminal stages of deforming arthrosis showed that from the moment of its introduction to the present day, many options and methods of its implementation have been proposed.

Many criteria play a role in determining surgical tactics: compliance, type of activity and functional needs of the patient, anatomical features of the structure of the PIP joint and the unique function of each finger of the hand. Thus, painless stability for effective opposition to the thumb is more important for the 2nd and 3rd fingers, while the maximum possible range of flexion is more important for the 4th and 5th fingers, since they are responsible for the grip strength of the hand. It follows that arthrodesis operations are preferable for the 2nd and 3rd fingers, and arthroplasty for the 4th and 5th fingers. However, there is currently insufficient reliable and complete research data to confirm or reject this thesis. Compared to arthroplasty, the undeniable advantages of arthrodesis are a significant reduction in pain, up to its complete absence, as well as the ability to achieve a satisfactory cylindrical grip of the hand with adequate fixation of the PIP joint in physiological positions (20–30° flexion for the 2nd and 3rd and 40–50° for the 4th and 5th fingers). However, this will significantly affect precision grip types, precise movements and fine motor skills, which may be important for some professions [13, 14].

Understanding the anatomical and physiological features of the PIP joint is of particular importance for restoring its function. The different morphology of the PIP joints of the 2nd to 5th fingers, small bone sizes, complex biomechanics and high load on the hand create a number of problems in their arthroplasty.

Features of anatomy and biomechanics of the proximal interphalangeal joint of the hand

The PIP joint is formed by the head of the proximal phalanx and the base of the middle phalanx of the finger. The head of the proximal phalanx has the shape of a trapezoidal ridge with condyles of radial and ulnar asymmetrical shapes and an intercondylar flat groove. The condyles differ from the 2nd to the 5th finger. In the frontal plane, the ulnar condyle of the index and middle fingers is more pronounced, and on the ring and little fingers, the radial condyle (Fig. 1).

Fig. 1 Dorsal-palmar radiograph of four fingers of the left hand in the direct view. On the index and middle fingers, the ulnar condyle of the head of the proximal phalanx is more pronounced, on the ring and little fingers, the radial condyle of the head of the proximal phalanx is more pronounced (white wedges illustrate the angle of inclination) [18]

The corresponding articular socket of the base of the middle phalanx has two flat concave protrusions, between which a saddle-shaped ridge passes in the dorsal-palmar direction. The base of the middle phalanx is somewhat wider than the head of the basal phalanx in both the frontal and sagittal planes [15].

The range of motion in the PIP joint is 0–0–100° according to the neutral-zero method. This joint provides 85 % of the flexion arc of the fingers; the remaining 15 % is taken by the distal interphalangeal joint [16]. For a long time, the PIP joint was considered a "simple" block-shaped joint with only one center of rotation in the head of the base link. However, more precise anatomical studies showed that the joint partners, the head of the basal phalanx and the base of the middle phalanx, are not absolutely congruent [16, 17]. In the frontal plane, the condyles of the head of the proximal phalanx articulate with the corresponding concave protrusions of the joint cavity of the base of the middle phalanx through relatively small contact surfaces located not on the tops of the condyles, but closer to the center [18].

The radius of the arc of the articular surface of the base of the middle phalanx is approximately 30 % greater than the radius of the arc of the condyle of the head of the proximal phalanx. The difference in size and the discrepancy in the shape of the partner joints provide the possibility of rolling-gliding movements during flexion and extension, as well as lateral flexion and slight rotational movements. When clenching a fist, the shape of the finger joints leads to complex movements of separate phalanges: the middle and distal phalanges of the index and middle fingers, as well as the middle phalanx of the little finger are supinated, the middle and distal phalanges of the ring finger and the distal phalanx of the little finger are pronated [19, 20]. The choice of implant and the surgical approach used are the two most frequently discussed issues in arthroplasty of the PIP joint.

Surgical approaches for performing arthroplasty of the proximal interphalangeal joint depend on the clinical situation, or the choice is guided by the personal experience of the surgeon.

Surgical approaches to the proximal interphalangeal joint

Dorsal, palmar, and lateral approaches were described for PIP joint arthroplasty. Each has its own advantages and disadvantages. Dorsal approaches are the most commonly used because they are easier to perform, but they also involve damage to the fragile extensor apparatus, that further results in extensor lag [19].

The most common reason for reoperations in PIP joint arthroplasty is dysfunction of the extensor apparatus [21]. This has prompted surgeons to explore alternative palmar and lateral approaches to this finger joint. The palmar and lateral approaches offer several theoretical advantages over the dorsal approach. Both approaches allow surgeons to avoid incisions on the extensor apparatus and, therefore, do not require prolonged postoperative immobilization, which eliminates the possibility of postoperative adhesions and allows for immediate rehabilitation [22].

Dorsal surgical approach is the most widely used and technically the least demanding compared to the palmar and lateral approaches. It is also good when it is necessary to simultaneously correct certain soft tissue conditions, such as mild "swan neck" or "boutonniere" deformities. A straight or slightly curved longitudinal incision is made. Several methods of access to the joint were described. Swanson et al. advocated a midline split of the central glide of the extensor tendon [23]. An alternative is the approach described by Chamay, which uses a V-shaped extensor flap, which provides a good view of the joint and allows for the creation of a long, stable suture for tendon closure [24].

In their study, Bodmer et al. concluded that the tendon splitting approach generally yields better results and is associated with fewer complications compared to the approach described by A. Chamay [24, 25].

Bone canals are created and filed according to the requirements of the selected implant. For silicone implants, the resection line is planned according to the size of the implant, with care to preserve as much of the collateral ligament as possible. Tension should be chosen so that full flexion and extension are possible. If there is a delay in extension, either a smaller implant or a larger bone resection is necessary. In case of significant joint deformity or collateral ligament insufficiency, a reinforcing suture of the ligaments and/or a stepwise release on the contracted side is necessary. The joint should be well balanced and at the same time allow a full passive range of motion. It is almost impossible to correct the deformity that was not corrected on the operating table, even with a proper rehabilitation program.

The dorsal approach compromises the extensor mechanism, requiring immobilization. This exposes the patient to a high risk of loss of extension due to tendon elongation if mobilization is too early or joint stiffness if mobilization is prolonged [26, 27].

The *palmar surgical approach* has, at least theoretically, several advantages over other approaches. If this method is used, the tendons are not damaged directly and, in particular, the delicate extensor mechanism remains intact. However, the palmar approach is technically more challenging and offers limited space for implantation of the artificial joint. Moreover, a pre-existing tendon imbalance is more difficult to correct. The technique described by Herren et al. provides good access to the joint [28]. A skin flap is created on a radial basis, the flexor tendon is exposed and opened transversely; then the incision is continued on the ulnar and radial sides with release of additional collateral ligaments. Approach to the joint is achieved by hyperextension. Some relaxation of the ulnar collateral ligament may be necessary if the joint is not elastic enough for good exposure. Osteophytes are carefully removed, as this may be a potential site for entrapment of the bending implant. The head of the proximal phalanx is then resected, taking care to identify the neurovascular bundle and protect it with retractors. Bone preparation and implantation are performed in the same way as with the dorsal approach. In cases with pre-existing deviation of the flexor tendon due to lateral deformity, the tendon can be re-centered. It is important to re-check the passive range of motion before final closure. At the end of the procedure, the lateral edge of the palmar plate is sutured to the accessory ligament. The rehabilitation program follows the principles outlined for the dorsal approach, but does not require any special protection of the extensor tendons and even allows passive motion [29, 30].

It is difficult to conclude how good the palmar approach is. However, the dorsal approach requires immobilization to allow the tendon to heal. The palmar plate and flexor tendon sheath are compromised by the palmar or anterior approach. The palmar approach is less commonly used because it is more difficult to perform. Its advantage is maintaining the continuity of the extensor and flexor mechanisms and symmetrical stretching of the collateral ligaments [30–33].

The *lateral surgical approach* is the least common approach used for PIP joint arthroplasty. The incision is made in the midline on the ulnar side of the finger and curves dorsally over the middle phalanx. After releasing the oblique and transverse fibers of the reticular ligaments, the extensor apparatus is elevated and can be mobilized laterally while leaving the insertion of the central pad intact. The ulnar neurovascular bundle remains on the volar side of the joint. In the classic lateral approach, the ulnar collateral ligament must be completely separated so that the joint can be exposed on the radial side. This is best accomplished with a triangular flap that can be reflected proximally. The implant can be placed as described previously. For closure, the ulnar collateral ligament must be reattached so that active rehabilitation is possible. The ulnar side should be protected with a splint for up to six weeks. Bain et al. described a modified lateral approach in which the collateral ligament is split to accommodate the implant and reconstructed from side to side [34]. At least theoretically, the risk of instability is decreased and early, unrestricted active mobilization is possible.

The lateral approach is used rarely, since it provides limited impact on the joints. Its main disadvantage is the transection of the transverse reticular ligament and one of the collateral ligaments with the risk of lateral instability. Some authors have performed ligament reconstruction using transosseous sutures or anchors to solve this problem [35–36].

It should be noted that the advantage of the dorsal approach to the PIP joint is improved visualization of the articular surface, while the disadvantage can be considered a violation of the central sliding and extensor mechanism, which requires mandatory restoration of the extensor apparatus with a subsequent delay in the range of motor exercises. The palmar approach to the PIP joint can preserve the integrity of the extensor tendon, which allows for an early range of motion in the postoperative period.

There is no consensus on which approach provides better treatment results. Tranchida et al. in a study on 66 adult patients (88 fingers) who underwent PIP joint replacement compared the mean change in the range of motion, postoperative range of motion, and postoperative complication rates, and also examined the relationship between the duration of immobilization and time to rehabilitation with postoperative range of motion. This study found no statistical differences in mean postoperative range of motion, complication rates, or revision surgeries between the palmar and dorsal approaches in PIP joint replacement [37].

Moreover, it should not be forgotten that the palmar approach is more traumatic and difficult to use and requires more knowledge and time from the surgeon to perform.

Therefore, the dorsal approach is optimal, since it is the easiest to perform, but requires adequate restoration of the finger extensor apparatus, strong fixation and early rehabilitation. This is why this approach is more frequently used.

Choice of an implant

Due to the anatomical features of the PIP joint and the difficulties in choosing a surgical approach caused by them, an important problem remains the choice of an implant, which should have an identical morphology of the articular surfaces to a healthy joint, maximum mobility, identical stability and resistance, along with a little loss of bone mass during implantation. Moreover, stable and reliable fixation and a sliding pair without abrasion are properties that an ideal artificial joint should also have. The ways to implement all these requirements to the implant have not yet been fully found, and not only for the finger joint. With regard to the anatomy described above, the following observations can be made regarding the currently available implants for finger joints. None of the currently existing implant modifications corresponds to the morphology of the anatomical finger joint. However, by analyzing the literature, a certain tendency towards modular components and less connected structures can be traced. Despite the further development of materials and design, the silicone prosthesis developed by Swanson in the early 1960s remains the most frequently implanted artificial joint in the PIP joint of the fingers [23]. It is not a true prosthesis but rather a flexible filler that is encapsulated by connective tissue and slides back and forth along the medullary canal. Swanson (1994) was of the opinion that free sliding of the silicone filler is necessary for good joint mobility and has a positive effect on its durability. The ability to slide helps to reduce the forces acting on the bone. The author described this sliding: when the finger is flexed, the silicone filler in the medullary canal slides distally and when extended, proximally, as a “piston effect” [23, 38]. Lateral stability remains a problem, especially for the index and middle fingers, where stability is important for pinch [39, 40, 41]. Therefore, some authors still recommend arthrodesis of the index finger [42]. Compared with metal, ceramic or pyrocarbon prostheses, silicone filler implants are significantly less expensive. Despite good long-term results, their disadvantages include lack of stability, implant fractures and silicone fragmentation, which are repeatedly observed over time. According to current literature, silicone implants are not inferior to newer implants, and complications are well known. Therefore, to improve the results, the emphasis should be shifted to the surgical approach [31, 43]. The newest generation of PIP joint implants is based on the principles of surface replacement using a two-component concept [44–49].

The proximal component replaces the bicondylar head of the proximal phalanx, and the distal component has a kind of cup that articulates with the head. Most of these implants do not represent a true resurfacing concept, as a significant amount of bone must be resected, and long stems are needed for both components to ensure adequate fixation. Several material combinations are available, from the classic chrome-cobalt-polyethylene to ceramic-ceramic and pyrocarbon-pyrocarbon.

Pyrolytic carbon implants have been used as an alternative to silicone arthroplasty with minimal limitations. Tuttle et al. reported a total of 15 postoperative complications, the most common of which was noticeable joint creaking [50]. Incomplete pain relief was observed in 50 % of patients in that series. Only two joints showed radiographic signs of loosening. Nunley et al. showed insufficient pain relief and no improvement in the range of motion in patients after placement of pyrolytic carbon implants for posttraumatic arthritis of the PIP joint [51]. Although pyrolytic carbon has excellent biocompatibility and ideal sliding characteristics, problems with osseointegration difficulties and joint creaking have been reported. The survival rate of pyrolytic carbon implants was 85 % (83 of 97) at five years of follow-up, with high patient satisfaction. Patients should be informed that the procedure provides good pain relief but does not increase range of motion [52].

Notermans et al. concluded in their study that stiffness and extensor lag were the most common postoperative complications [53]. Also, many authors call stiffness the most common complication [52, 54, 55]. In a review of 76 revision arthroplasties of the PIP joint, Pritsch et al. found that extensor dysfunction was the most common (67 %) indication for reoperation [56].

Overall, the new generation of PIP joint implants based on the resurfacing concept seemed to be a logical progression of PIP joint arthroplasty, but most of them have not yet stood the test of time, and most implants lack real long-term survival series [11].

The tremendous success of ceramic-ceramic friction pairs in large joint surgery has encouraged clinicians to more widely use this friction pair in small joint surgery [3, 57–59]. The use of ceramics in hip arthroplasty was highly appreciated by researchers good competitive qualities of this material: wear resistance, bioinertness, and biocompatibility. Hydroxyapatite-coated ceramic implants have shown an encouraging combination of an optimal tribological pair and osseointegration at the same time, which significantly stimulates interest in studying this material [60].

Certain advances in PIP joint arthroplasty were presented in the independent study of Muradova et al. and Fedotova et al. using the analysis of arthroplasty results. The authors note a stable increase in the range of motion and a high rate of patient satisfaction (82 %) [3, 61].

Although the results regarding implant loosening and pain have improved in recent years, some problems remain unresolved. The morphology of the joints, small bone sizes, complex biomechanics and load on the hand are a special problem in the PIP joint arthroplasty. It has not yet been possible to restore the full range of motion in this joint, despite the successes of colleagues in large joint arthroplasty.

CONCLUSION

This literature review shows that the choice of implant and surgical tactics are the most common problems in PIP joint arthroplasty, requiring solution and further study. A proper understanding of the various surgical approaches, their indications, techniques and shortcomings will help to optimize treatment results. The convenience of each approach helps the surgeon to minimize complications, improve function and individualize the treatment of primary or secondary arthritis of the PIP joint.

The use of different implants for PIP joint arthroplasty, which are available in various designs, enables to reliably eliminate pain while maintaining a definite mobility. However, the patient should be informed about the limited mechanical strength and service life of the implants. It is necessary to establish a feedback with the patient, since it is impossible to achieve a good result, without patient's adequate compliance and work despite excellent surgical techniques and the choice of the optimal implant.

Conflict of interest *Not declared.*

Funding *Not declared.*

REFERENCES

1. Faulkner H, An V, Lawson RD, Graham DJ, Sivakumar BS. Proximal Interphalangeal Joint Arthrodesis Techniques: A Systematic Review. *Hand* (N Y). 2023;18(1):74-79. doi: 10.1177/1558944721998019
2. Wilder FV, Barrett JP, Farina EJ. Joint-specific prevalence of osteoarthritis of the hand. *Osteoarthritis Cartilage*. 2006;14(9):953-7. doi: 10.1016/j.joca.2006.04.013
3. Muradov MI, Baitinger VF, Kamolov FF, ey al. Assessment of the remote results of endoprosthesis replacement of joints of fingers of the hand. *Issues of reconstructive and plastic surgery*. 2016;(1):33-41. (In Russ.) doi: 10.17223/1814147/56/5
4. Jonsson H. Age related prevalence of hand osteoarthritis diagnosed by photography (HOASCORE). *BMC Musculoskelet Disord*. 2017;18(1):508. doi: 10.1186/s12891-017-1870-0
5. Nikolaenko A., Ivanov V., Zgirsky D., et al. Arthroplasty of the proximal interphalangeal joint (literature review). *Medline.ru*. 2022;23:748-766. (In Russ.)
6. Srnec JJ, Wagner ER, Rizzo M. Implant Arthroplasty for Proximal Interphalangeal, Metacarpophalangeal, and Trapeziometacarpal Joint Degeneration. *J Hand Surg Am*. 2017;42(10):817-825. doi: 10.1016/j.jhsa.2017.07.030
7. Forte A, Murray P. Osteoarthritis and prosthetic joints in the hand.. In: Farhadieh RD, Bulstrode NW, Mehrara BJ, Cugno S. (eds). *Plastic Surgery - Principles and Practice*. Elsevier Publ.; 2022:896-905. doi: 10.1016/B978-0-323-65381-7.00057-5
8. Yamamoto M, Malay S, Fujihara Y, et al. A Systematic Review of Different Implants and Approaches for Proximal Interphalangeal Joint Arthroplasty. *Plast Reconstr Surg*. 2017;139(5):1139e-1151e. doi: 10.1097/PRS.0000000000003260
9. Kamnerdnakta S, Huetteman HE, Chung KC. Complications of Proximal Interphalangeal Joint Injuries: Prevention and Treatment. *Hand Clin*. 2018;34(2):267-288. doi: 10.1016/j.hcl.2017.12.014
10. Hensler S, Behm P, Wehrli M, et al. Lateral stability in healthy proximal interphalangeal joints versus surface replacement and silicone arthroplasty: Results of a three-dimensional motion analysis study. *Hand Surg Rehabil*. 2020;39(4):296-301. doi: 10.1016/j.hansur.2020.02.013
11. Herren D. The proximal interphalangeal joint: arthritis and deformity. *EFORT Open Rev*. 2019;4(6):254-262. doi: 10.1302/2058-5241.4.180042
12. Mercer D, Imada AO. Arthrodesis and arthroplasty of the small joints. *Oper Tech Orthop*. 2020;30(4):100832. doi: 10.1016/j.oto.2020.100832
13. Vitale MA, Fruth KM, Rizzo M, et al. Prosthetic Arthroplasty Versus Arthrodesis for Osteoarthritis and Posttraumatic Arthritis of the Index Finger Proximal Interphalangeal Joint. *J Hand Surg Am*. 2015;40(10):1937-1948. doi: 10.1016/j.jhsa.2015.05.021
14. Richards T, Ingham L, Russell I, Newington D. The Long-term Results of Proximal Interphalangeal Joint Arthroplasty of the Osteoarthritic Index Finger. *Hand* (N Y). 2022;17(2):266-270. doi: 10.1177/1558944720921468
15. Pang EQ, Yao J. Anatomy and Biomechanics of the Finger Proximal Interphalangeal Joint. *Hand Clin*. 2018;34(2):121-126. doi: 10.1016/j.hcl.2017.12.002
16. Leibovic SJ, Bowers WH. Anatomy of the proximal interphalangeal joint. *Hand Clin*. 1994;10(2):169-178.
17. Millrose M, Vonderlind HC, Thannheimer A. et al. Arthrodesis of the Proximal Interphalangeal Joint of the Finger-A Biomechanical Study of Primary Stability. *J Pers Med*. 2023;13(3):465. doi: 10.3390/jpm13030465
18. Hohendorff B, Spies CK, Unglaub F, et al. Anatomy of the metacarpophalangeal and proximal interphalangeal finger joint with respect to arthroplasty. *Orthopade*. 2019;48(5):368-377. (In German) doi: 10.1007/s00132-019-03716-7
19. Le Glédic B, Hidalgo Diaz JJ, Vernet P, et al. Comparison of proximal interphalangeal arthroplasty outcomes with Swanson implant performed by volar versus dorsal approach. *Hand Surg Rehabil*. 2018;37(2):104-109. doi: 10.1016/j.hansur.2017.11.008
20. Zhu AF, Rahgozar P, Chung KC. Advances in Proximal Interphalangeal Joint Arthroplasty: Biomechanics and Biomaterials. *Hand Clin*. 2018;34(2):185-194. doi: 10.1016/j.hcl.2017.12.008
21. Natera L, Moya-Gómez E, Lamas-Gómez C, et al. Proximal interphalangeal joint replacement: A comparison between the volar and dorsal approach. *Rev Esp Cir Ortop Traumatol*. 2014;58(5):303-8. (Im Span) doi: 10.1016/j.recot.2014.04.003
22. Renfree KJ. Surgical approaches for proximal interphalangeal joint arthroplasty. *Bone Joint J*. 2022;104-B(12):1329-1333. https://doi.org/10.1302/0301-620X.104B12.BJJ-2022-0946.
23. Swanson AB, de Groot Swanson G. Flexible implant resection arthroplasty of the proximal interphalangeal joint. *Hand Clin*. 1994;10(2):261-266.
24. Chamay A. A distally based dorsal and triangular tendinous flap for direct access to the proximal interphalangeal joint. *Ann Chir Main*. 1988;7(2):179-183. doi: 10.1016/s0753-9053(88)80061-9
25. Bodmer E, Marks M, Hensler S, et al. Comparison of outcomes of three surgical approaches for proximal interphalangeal joint arthroplasty using a surface-replacing implant. *J Hand Surg Eur Vol*. 2020;45(6):608-614. doi: 10.1177/1753193419891382. Epub 2019 Dec 9
26. Wei DH, Strauch RJ. Dorsal surgical approaches to the proximal interphalangeal joint: a comparative anatomic study. *J Hand Surg Am*. 2014;39(6):1082-1087. doi: 10.1016/j.jhsa.2014.02.004

27. Bickel KD. The dorsal approach to silicone implant arthroplasty of the proximal interphalangeal joint. *J Hand Surg Am*. 2007;32(6):909-913. doi: 10.1016/j.jhsa.2007.04.013
28. Herren DB, Simmen BR. Palmar approach in flexible implant arthroplasty of the proximal interphalangeal joint. *Clin Orthop Relat Res*. 2000;(371):131-135. doi: 10.1097/00003086-200002000-00016
29. Shirakawa K, Shirota M. Surface replacement arthroplasty using a volar approach for osteoarthritis of proximal interphalangeal joint: results after a minimum 5-year follow-up. *Hand* (N Y). 2020;15(1):81-86. doi: 10.1177/1558944718787332
30. Bouacida S, Lazerges C, Coulet B, Chammas M. Proximal interphalangeal joint arthroplasty with Neuflex® implants: relevance of the volar approach and early rehabilitation. *Chir Main*. 2014;33(5):350-355. doi: 10.1016/j.main.2014.07.004
31. Lautenbach M, Kim S, Berndsen M, Eisenschenk A. The palmar approach for PIP-arthroplasty according to Simmen: results after 8 years follow-up. *J Orthop Sci*. 2014;19(5):722-728. doi: 10.1007/s00776-014-0605-4
32. Stoecklein HH, Garg R, Wolfe SW. Surface replacement arthroplasty of the proximal interphalangeal joint using a volar approach: case series. *J Hand Surg Am*. 2011;36(6):1015-1021. doi: 10.1016/j.jhsa.2011.03.003
33. Proubasta IR, Lamas CG, Natera L, Millan A. Silicone proximal interphalangeal joint arthroplasty for primary osteoarthritis using a volar approach. *J Hand Surg Am*. 2014;39(6):1075-1081. doi: 10.1016/j.jhsa.2014.03.033
34. Bain GI, McGuire DT, McGrath AM. A Simplified Lateral Hinge Approach to the Proximal Interphalangeal Joint. *Tech Hand Up Extrem Surg*. 2015;19(3):129-132. doi: 10.1097/BTH.0000000000000094
35. Merle M, Villani F, Lallemand B, et al. Proximal interphalangeal joint arthroplasty with silicone implants (NeuFlex) by a lateral approach: a series of 51 cases. *J Hand Surg Eur Vol*. 2012;37(1):50-55. doi: 10.1177/1753193411413851
36. Segalman KA. Lateral approach to proximal interphalangeal joint implant arthroplasty. *J Hand Surg Am*. 2007;32(6):905-908. doi: 10.1016/j.jhsa.2007.04.011
37. Tranchida GV, Allen ST, Moen SM, et al. Comparison of volar and dorsal approach for PIP arthroplasty. *Hand* (N Y). 2021;16(3):348-353. doi: 10.1177/1558944719861718
38. Srnec JJ, Wagner ER, Rizzo M. Implant Arthroplasty for Proximal Interphalangeal, Metacarpophalangeal, and Trapeziometacarpal Joint Degeneration. *J Hand Surg Am*. 2017;42(10):817-825. doi: 10.1016/j.jhsa.2017.07.030
39. Amirtharajah M, Fufa D, Lightdale N, Weiland A. Conical, radiographic, and patient-reported results of surface replacing proximal interphalangeal joint arthroplasty of the hand. *Iowa Orthop J*. 2011;31:140-144.
40. Helder O, Marks M, Schweizer A, et al. Complications after surface replacing and silicone PIP arthroplasty: an analysis of 703 implants. *Arch Orthop Trauma Surg*. 2021;141(1):173-181. doi: 10.1007/s00402-020-03663-5
41. Weistra K, Kan HJ, van Alebeek VAHJ, Ritt MJPF. Proximal Interphalangeal Joint Arthroplasty Using a Silicone Implant: A Comparison Between Integra and NeuFlex in 72 Cases. *Hand* (N Y). 2024;19(2):236-240. doi: 10.1177/15589447221122829
42. Sweets TM, Stern PJ. Proximal interphalangeal joint prosthetic arthroplasty. *J Hand Surg Am*. 2010;35(7):1190-1193. doi: 10.1016/j.jhsa.2010.04.005
43. Forster N, Schindele S, Audigé L, Marks M. Complications, reoperations and revisions after proximal interphalangeal joint arthroplasty: a systematic review and meta-analysis. *J Hand Surg Eur Vol*. 2018;43(10):1066-1075. doi: 10.1177/1753193418770606
44. Schindele SF, Hensler S, Audigé L, et al. A modular surface gliding implant (CapFlex-PIP) for proximal interphalangeal joint osteoarthritis: a prospective case series. *J Hand Surg Am*. 2015;40(2):334-340. doi: 10.1016/j.jhsa.2014.10.047
45. Athlani L, Gaisne E, Bellemère P. Arthroplasty of the proximal interphalangeal joint with the TACTYS® prosthesis: Preliminary results after a minimum follow-up of 2 years. *Hand Surg Rehabil*. 2016;35(3):168-178. doi: 10.1016/j.hansur.2015.12.013
46. Jennings CD, Livingstone DP. Surface replacement arthroplasty of the proximal interphalangeal joint using the SR PIP implant: long-term results. *J Hand Surg Am*. 2015;40(3):469-473.e6. https://doi.org/10.1016/j.jhsa.2014.11.015.
47. Griffart A, Agneray H, Loubersac T, et al. Arthroplasty of the proximal interphalangeal joint with the Tactys® modular prosthesis: Results in case of index finger and clinodactyly. *Hand Surg Rehabil*. 2019;38(3):179-185. doi: 10.1016/j.hansur.2019.03.001
48. Regas I, Pluvy I, Leroy M, et al. Arthroplasty for destroyed proximal interphalangeal joint in hand trauma surgery: Silicone hinged NeuFlex® or gliding Tactys®? *Hand Surg Rehabil*. 2022;41(6):681-687. doi: 10.1016/j.hansur.2022.09.006
49. Wagner ER, Weston JT, Houdek MT, et al. Medium-Term Outcomes With Pyrocarbon Proximal Interphalangeal Arthroplasty: A Study of 170 Consecutive Arthroplasties. *J Hand Surg Am*. 2018;43(9):797-805. doi: 10.1016/j.jhsa.2018.06.020
50. Tuttle HG, Stern PJ. Pyrolytic carbon proximal interphalangeal joint resurfacing arthroplasty. *J Hand Surg Am*. 2006;31(6):930-939. doi: 10.1016/j.jhsa.2006.02.018
51. Nunley RM, Boyer MI, Goldfarb CA. Pyrolytic carbon arthroplasty for posttraumatic arthritis of the proximal interphalangeal joint. *J Hand Surg Am*. 2006;31(9):1468-1474. doi: 10.1016/j.jhsa.2006.07.017
52. Watts AC, Hearnden AJ, Trail IA, et al. Pyrocarbon proximal interphalangeal joint arthroplasty: minimum two-year follow-up. *J Hand Surg Am*. 2012;37(5):882-888. doi: 10.1016/j.jhsa.2012.02.012
53. Notermans BJW, Lans J, Ponton RP, et al. Factors Associated with Reoperation after Pyrocarbon Proximal Interphalangeal Joint Arthroplasty for the Arthritic Joint: A Retrospective Cohort Study. *J Hand Microsurg*. 2021;13(3):132-137. doi: 10.1055/s-0040-1709088
54. Dickson DR, Nuttall D, Watts AC, et al. Pyrocarbon Proximal Interphalangeal Joint Arthroplasty: Minimum Five-Year Follow-Up. *J Hand Surg Am*. 2015;40(11):2142-2148.e4. doi: 10.1016/j.jhsa.2015.08.009
55. Desai A, Gould FJ, Mackay DC. Outcome of pyrocarbon proximal interphalangeal joint replacement. *Hand Surg*. 2014;19(1):77-83. doi: 10.1142/S0218810414500130
56. Pritsch T, Rizzo M. Reoperations following proximal interphalangeal joint nonconstrained arthroplasties. *J Hand Surg Am*. 2011;36(9):1460-1466. doi: 10.1016/j.jhsa.2011.06.002
57. Fedotov PV, Kovalev DV, Mihajlov AS. Hemiendoprosthetics of the metatarsophalangeal joints in osteochondropathy of the metatarsal head (Freiberg-Keller II disease). *Department of Traumatology and Orthopedics*. 2022;4(41):52-56. 2022;(4):52-56. (In Russ) doi: 10.17238/2226-2016-2022-4-52-56. EDN LTRSGH

58. Frolenkov AV, Ul'janov VJu, Gorjakin MV. Case study of the first metatarsophalangeal joint total replacement. *Saratov Journal of Medical Science*. 2019;15(3):633-636. (In Russ)
59. Aleksandrov TI, Prohorenko VM, Chornij SI. Endoprosthetics of the wrist joint: a review of the literature and an analysis of their own observations. *Modern problems of science and education. Surgery*. 2017;4:28. (In Russ) URL: https://science-education.ru/ru/article/view?id=26607.
60. Volokitina EA, Antropova IP, Timofeev KA, Trufanenko RA. Current state and perspectives on the use of zirconium ceramic implants in traumatology and orthopaedics. *Genij Ortopedii*. 2024;30(1):114-123. doi: 10.18019/1028-4427-2024-30-1-114-123
61. Fedotov PV, Kovalev DV, Rybakov SN. The long-term results of proximal interphalangeal joint arthroplasty of the hand. *Genij Ortopedii*. 2024;30(2):191-199. doi: 10.18019/1028-4427-2024-30-2-191-199

The article was submitted 27.04.2024; approved after reviewing 20.06.2024; accepted for publication 01.08.2024.

Information about the authors:

Pavel V. Fedotov — orthopaedic surgeon, mr_vulfgar@mail.ru, https://orcid.org/0000-0003-2833-235X;

Dmitry V. Kovalev — Head of the Department, orthopaedic surgeon, kovalev@orthoscheb.ru, https://orcid.org/0000-0002-4011-6409;

Anatoly S. Mikhailov — orthopaedic surgeon, polik_travm@orthoscheb.ru, https://orcid.org/0000-0003-0533-0570.