Peg-in-socket arthrodesis of the interphalangeal joints of the toes

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Abstract

Background: Toe deformations are not uncommon, particularly among female patients. They can be operated on as an isolated or a combined procedure. There are various IP joint arthrodesis techniques. We present our experience with the "peg-in-socket" technique.

Methods: The rates of complications in the group treated with arthrodesis fixed with Kirschner pin (KI group – 20 patients, 26 toes) and in the group treated with peg-in-socket technique (PEG group - 50 patients, 61 toes) were compared and evaluated with Chi-square test.

In the PEG group, the pain and activity improvement were evaluated with Z-test. Footwear limitations, success of bone arthrodesis, pain or callus relapse, toe form, position and orientation before and after the procedure are described.

Results: Early complications were more frequent in the KI group ($p < 0.05$).

In the PEG group, pain evaluation improved from 15.6 to 31.2 points ($p < 0.01$), activity limitations from 3.7 to 5.9 ($p < 0.01$). All patients continued to wear orthopaedic or comfortable shoes. Five of 50 patients had unsuccessful arthrodesis (1 pseudoarthrosis, 2 nonunions, 2 malunions). All patients had painful calluses before the procedure. Afterwards 9 were pain- and callus-free, the rest reported occasional minor residual pain. All patients had deformed toes preoperatively. After the peg-in-socket arthrodesis, 9 toes outlooks were graded as excellent, 50 as good and 2 as bad.

Conclusion: The "peg-in-socket" arthrodesis is not the simplest technique. Jet it is a reliable, repeatable and inexpensive ambulatory procedure which uses patient's structures without foreign materials.

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1 Introduction

Toe deformations are an issue faced mainly by women in midlife and beyond. They are treated operationally only after an unsuccessful conservative therapy. Arthrodesis of small, interphalangeal (IP) joints on toes are conducted with deformations of proximal (PIP) or distal (DIP) joints with painful calluses. They can be performed as an independent procedure, as part of more extensive combined procedure or as a temporary measure while waiting for a combined procedure. The most pervasive technique of arthrodesis of IP joints is arthrodesis

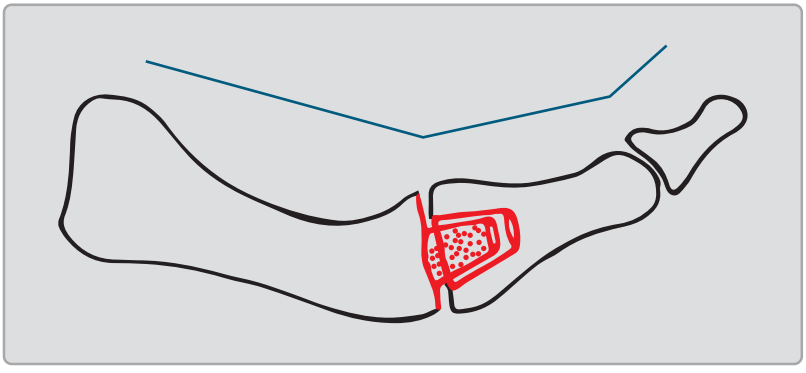

Figure 1: Scheme of the peg-in-socket arthrodesis.

with the Kirschner wire (KW). Surgeons know this technique very well, it is a routine procedure as it is also used, for example, in the therapy for some fractures (12) or osteotomies (10). In recent years several arthrodesis techniques that use bone implants have become popular on the market. There is also a technique that uses no implants and no KW. This is the peg-in-socket arthrodesis that this article is focused on.

The peg-in-socket arthrodesis of IP joints was first described by Soule in 1910, however, then still using KW stabilization (in Wolke and Sparman (25)). Alvin and Garvin (1) were the first to promote this technique without KW in 1980. Schlefman, Felton and McGlamry (23) were the first to describe a major series of 125 successful peg-in-socket arthrodesis without using KW.

In Slovenia this technique was already used, however, it is practically unknown today.

2 Methods

The Jesenice General Hospital has been performing most arthrodesis procedures using KW. This is a generally well-known and broadly used, relatively simple and low-priced technique that is also suitable for inexperienced surgeons. In the past decade we have also been practising peg-in-socket arthrodesis, however, this is not the simplest of techniques, and is more suitable for experienced surgeons who are more focused on foot pathology.

2.1 Description of techniques

2.1.1 The surgical technique of peg-in-socket arthrodesis

By making an elliptical cut above the IP joint and a vertical tenotomy of the tendons of toe extensors we uncover the joint. We make sure to protect the venal and nerve branches of the toe. Using a scalpel and a raspatory we release soft tissue surrounding the head of the proximal phalanx, as this technique can also be used on the second joint, where the medium phalanx becomes "more proximal". Using a bone clamp we form the peg into the taper-shaped form for improved contact in the socket at the final fixation (Figure 1 and Figure 2). At the time of the procedure, most patients have had partially fixed and curled toes, so we generally focus the peg in the plantar direction in order to coordinate the shape of the operated toe with the others. We require about 5–7 mm in length and width. Using a narrow raspatory we form a channel through the base of the distal phalanx. It should be focused to run from the plantar towards the dorsal side, which is, however, often not possible, especially with the distal phalanx, because the bones are too small. Then we move the peg into the socket (Note: more than two attempts to plug it in mean the loss of the "intrinsic" stability of the arthrodesis!). We secure the bone arthrodesis with two stitches of the ten-

Figure 2: Operative picture of the peg-in-socket arthrodesis.

don. Using one or two stitches on the skin, we cover the area.

We connect the toes in an "eight". After the wounds heal, toes can also be protected using buddy taping. Patients should be notified before the surgery that after the procedure the toe will be shorter, thicker and blueish (livid).

When changing binds and exercising we should be careful not to be too rough, so that the arthrodesis is not loosened, or that the peg is not dislocated or even broken. Stretching helps stop a decline of the dorsiflex contractions in the metatarsophalangeal (MTP) joints. The patient must be taught how to stretch correctly: they should use their middle finger to fix the head of the metatarsus (MT) from below, while pressing with their thumb on the proximal phalanx from the inside towards the plantar side.

Until the arthrodesis is clinically proven with a radiograph, the patient should not actively push it over the finger. They can begin gradually and with increasing strength to apply pressure and pus over the fingers 6 to 8 weeks after the procedure. After the operation the patient needs a shoe with a wide toe box, or even better an open one. If further procedures are planned, a temporary post-operative shoe should be prescribed. In spite of the satisfaction with the procedure, most patients continue to use softer orthopaedic footwear even after the surgery.

It is desired that a surgeon operator conducts the first check-up and binder. Further routine binders and stitch removals can be performed by the personal doctor. After 6–8 weeks it is time for a clinical and radiography control examination with an operator who also provides the instructions on further recovery and check-ups.

2.1.2 Surgical arthrodesis technique for IP joints using KW

Using an elliptical cut we uncover the IP joint. After cleaning the joint we select the girth of the KW. We first insert the wire through the bone towards the distal part, towards the outside and then, while keeping a close eye on it, retrogradely towards the proximal part. We squeeze the area of arthrodesis with hand and verify the orientation with an radiography imaging device. We stitch up the wound in one or two layers. The external part of the needle that is located before the toe is protected by dressing it. The patient is given instruction regarding the strain, footwear and foot protection. Control examinations and dressing are performed at the outpatient clinic, and the control examination with the operating surgeon after 6 weeks. KW is removed, the bone fusion is checked with radiography, and the patient receives instructions regarding further dressing the wound, control examinations, stress and footwear.

Because of frequent movements of the pins and poor cooperation of some, especially older patients, we began looking into other options.

2.1.3 Other techniques

Today there is a range of techniques for arthrodesis with bone implants, however our institution does not perform them because of cost-cutting measures.

2.2 Description of groups

2.2.1 The KW group

A total of 10 men and 10 women, aged 36 to 97, with a median age of 66 were operated. In 15 operations 1 toe was operated on, in 4 cases 2, and in 1 case 3 toes. Most frequently arthrodesis was performed on the second toe (13 times) and in 3 cases the little toe. Among these, the KW fell out in 1 case, it sunk in 1 case and in 1 case (fixation with 2 wires) the procedure went well. All patients were operated on under local anaesthesia, at the outpatient clinic or at the so-called day hospital. After the discharge the personal doctor dressed the wound. The first control check-up with the operating surgeon was generally one week after the procedure, the second after 6 weeks (X-Ray and removal of KW), and the final one 2-3 months after surgery.

2.2.2 The PEG group

The first 50 patients (46 women and 4 men, 61 toes) were operated using the peg-in-socket arthrodesis of IP joints by the end of 2014. They were 43 to 89 years of age, with the average age of nearly 62 years. One patient had a deformed PIP 2nd toe on the right foot after an injury. With one patient the deformation developed after an infection following attempted arthrodesis of PIP with KW. The other patients (2 men and 46 women) had degenerately deformed toes. Most often we performed arthrodesis of only 1 toe (with 39 patients the PIP joint of the 2nd toe, with 2 patient the PIP joint of the 3rd toe). With 4 patients we operated 1 toe on both feet (all of them the 2nd toe). With three patients we performed arthrodesis of 2 toes (the 2nd and the 3rd toe) and with two of them 3 toes (the 2nd, 3rd and 4th toe) of the same foot. In combination with other procedures on the front of the toe we used peg-in-hole arthrodesis with 7 patients (always the 2nd toe). In this series none had a correction of the same bases at the height of the MTP joint at the same time (e.g. osteotomy according to Weil). Arthrodesis was performed on the DIP joint 5 times. It should be clear from the above that the PIP joint of the 2nd toe is most often affected (43 of 50 patients). Preliminary therapy of toes with the hallux valgus and rigidus diagnosis and was held on 6 patients, 2 of which had preliminary therapy on the same toe (1 patient: pseudarthrosis after fixation with KW). All patients were operated on in the scope of a day hospital, except for 6 of them, and with them peg-in-socket arthrodesis was used in combination with other, more extensive procedures. Routine control check-ups, dressings and stitch removal was performed by the personal physician, while the operating surgeon performed clinical and x-ray controls after 6–8 weeks, 6 months and 1 and 2 years.

2.3 Statistics

The Jesenice General Hospital began performing arthrodesis of IP joints in 2008. Until 2011 we carefully performed 20 such operations. We compared the early complications with the share of 20 patients from the same period who were operated using KW. We failed to prove the apparently obvious difference in the

frequency of post-operational complications, most likely due to the small sample. We only managed to do this when the PEG group reached 50 patients in 2014.

In the PEG group we used the AOFAS Lesser toe Metatarsophalangeal – Interphalangeal Scale (14) for monitoring the success rate of the technique regarding lowering pain, limitation of activities, footwear issues, success rate of the arthrodesis, repeated calluses on operated toes and the shape and orientation of toes. By using the test of difference between two arithmetic medians we calculated improvements regarding pain and function. The assessments of other factors were descriptive, however, for the purpose of clarity we simplified them and assigned them scores.

Categories:

- **pain:** no pain: 40 points; mild, occasional pain: 30 points; moderate pain only during the day: 20 points; severe, lasting pain: 0 points.
- **limited activities:** no limits: 10 points; unlimited daily, limited sports activities: 7 points; limited daily and sports activities: 4 points; severe limitations to daily and sports activities.
- **adjustment to footwear, 2 categories:** no limits (fashionable footwear); with limitations (orthopaedic footwear, insoles, soft footwear.
- **success of IP arthrodesis, 2 categories:** successful (clinically and radiograph fused arthrodesis), unsuccessful (nonunion or clinical irregularities; non-, malunion, pseudarthrosis).
- **callus, 2 categories:** no callus at the point of correction; callus present.
- **orientation and shape of the toe:** good (focus, position and shape of toes is the same as its neighbours); acceptable (smaller derogations compared to neighbouring toes); poor (clinically evident derogation in any direction).

The study was approved by the Committee for Medical Ethics of the Jesenice General Hospital on 14. June 2017 (decision no. 0307-270/2017:2).

3 Results

3.1 Comparison of early complications between KW and PEG groups

3.1.1 Early complications in the KW group:

- 3 cases of KW falling out
- 4 cases of KW moving (shortened 3 times, removed once)
- 1 case of KW sinking (removal under local anaesthesia)
- 1 case of inflammation at KW
- 1 case of infection of the toe (treatment with an antibiotic)

Total early complications: 10 from a total of 20 patients.

In spite of early complications all therapies concluded within 2 to 3 months with the instruction "control if needed". Only 2 returned: 1 male patient, operated on primarily because of trauma, for semi-amputation because of issues with blood supply to the toes, and 1 female patient because of a major correction at a later time. We assume that the other treatments were successful.

3.1.2 Early complications in the PEG group:

- 4 suspicions of infection, which were eliminated after clinical and lab tests
- 1 case of wound opening and an infection, treated with an antibiotic and dressings

- 1 case of peg breaking during surgery (with tenodesis and buddy taping the end result was good)
- 1 case of peg breaking during dressing at the healthcare centre (successfully treated with buddy taping)
- 1 case of dislocation during dressing (operation on multiple toes); reposition at the outpatient clinic; radiograph showed nonunion, with minimum flexibility at this point, form acceptable, toe not hurting when touched
- 1 case of radiograph-visible nonunion, clinically clean and not painful at the touch
- 1 case of pseudarthrosis, mild pain, acceptable form, no need for review
- 1 case of medial malunion: after an unknown sprain, most likely during dressing, the middle phalanx fused with the medialised orientation with perspective to the axis of the proximal phalanx, and as a result the toe is thickened; however, it as long as its neighbour, and the patient suffers from only mild pain, finds the form acceptable and is satisfied walking around in soft footwear
- 1 case of malunion in hyperextensions without the active dorsiflexion of the toe due to fused toe extenders after numerous operations at the height of the MTP joint.

Total early complications: 8 from a total of 50 patients.

One patient died 4 years after peg-in-hole arthrodesis, but did not have any issues with the toe during this time.

3.1.3 Conclusion of comparison

The impression of fewer early complications in the PEG 50 group compared to the KW group was proven with the share test. The calculated value of the Chi-squared test (5.54) is above the critical value (3.84), level 1 of freedom and $p < 0.05$.

3.2 The success rate of peg-in-socket arthrodesis in the PEG group

All operated toes were shorter and thicker than before surgery, and the share of arthrodesis was high (with 47 of 50 patients or 3 of 61 toes). There were 2 malunions and 1 true pseudarthrosis. In spite of significantly reduced pain all continued using customized footwear, just like before the surgery. 48 patients were satisfied with the procedure, and would recommend it to a friend, while 2 would recommend caution when deciding for the procedure, and none were expressly dissatisfied.

The improvements regarding the estimated pain and the limitations to activities were assessed using the test of difference between two arithmetic medians.

The pain estimate for 50 patient improved after peg-in-socket arthrodesis from an average of 15.6 points (0 to 20 points, $s = 84$) before surgery to 31.2 points (20 to 40 points, $s = 4.8$) after surgery. The calculated value of $Z = -11.4$ is smaller than $Z_{\alpha 0.005} = 2.58$ at $p < 0.01$.

With limitations to activities the estimate improved from 3.7 points (0 to 4, $s = 1.7$) before surgery to 5.9 points (0–10, $s = 2.7$) after the procedure ($Z = -6.6 < Z_{\alpha 0.005} = 2.58$, $p < 0.01$).

In spite of the satisfaction with the procedure, the patients continued using customized or orthopaedic footwear (7).

With 5 patients we assessed the attempted peg-in-socket arthrodesis as unsuccessful. With 2 patients the radiograph did not show that bone fused (clinically without any issues or apparent deformations). With 1 patient there was a sprain, most likely during dressing, of the peg from the socket, and fusion in

the lateral side (the patient is satisfied, almost with no pain, and she finds the orientation and shape of her toe to be acceptable. With 1 patient the toe fused already in hyperextension, and without any active dorsiflexion already from before due to calluses after numerous procedures. We saw once the connections of pseudarthrosis with symptoms.

With 2 patients the peg did break (1 during surgery, 1 during dressing at the community health centre), however, with both of these patients bone fused with no clinical issues, and were therefore classified as successful.

Before surgery all patients had at least one toe that was fixed deformed and had a callus. After the procedure 9 patients had toes with no calluses. A total of 39 patients, including the patient with the final pseudarthrosis, had no local calluses after the surgery, but suffered from some occasional pain t the point of arthrodesis, however, it was far less intense than before the surgery. The shape and orientation of toes of 2 patients were very bad (1 medial malunion and 1 malunion in hyperextension).

4 Discussion

Toe deformations are generally an issue for women in midlife and elderly women. Most often the issue is on the second toe in the form of a hammer toe deformation (6).

The most frequent technique for arthrodesis of IP toe joints is using KW. The technique is relatively simple, however, its weaknesses are poor rotational stability and compression between the two bone parts, the possibility of infection along the pin, running the pin through an unaffected DIP joint, and a toe that is straightened along its length (8,11). Fixation most often lasts 6 weeks. Compared to the 3-week fixation, the longer period had fewer relapsing deformations and undesirable movements to the transfixed joined, though there were differences in the number of complications (16). There can be many complications. Authors report on infections along the wire and in the wound, loosening, movements, dislocation, curving and breaking pins (8,11,3,4), about pain at the location where the wire exits the toe, and the pain at removal, about damage to the cartilage and even unplanned arthrodesis of neighbouring joints (3), about hyperextension and the deformations to DIP joints after PIP arthrodesis (4). Satisfaction with the KW technique is approximately 85% (6). The rate of reviews is at 2.5% (Zingasa et al. v Cantena et al. (3)) and up to about 10% (15). Kramer et al. (17) found in a series of 1,115 arthrodesis with KW on 876 patients, all conducted by a single surgeon, that pins moved 94 times, 2 pins broke, 9 infections along the pin, 150 relapsed deformations, and the so-called malalignment on 55 toes. They had to re-operate on 94 toes. There were 18 disruptions to blood supply, and 10 toes had to be amputated.

Because of frequent early complications and not a completely predictable result there is a search on for techniques that can provide good stability at the point of arthrodesis, a high rate of fusion in a favourable orientation and fewer complications.

Konkel et al. (16) report on fixation using an absorbable pin. The rate of bone fusion was 73%, fibrosis arthrodesis was at 19%, with 2 cases of arthrodesis of DIP joints, 11 floating toes of a total of 48, 7 medial and 1 lateral angulations, 3 mallet deformations (after PIP correction). A total of 91% of patients were still satisfied with the result.

Kane and Klimarting (13) describe the results after tenodesis of PIP joints

resulting from hammertoe deformations without fixation. They strived to avoid looseness, but still had 18 of 100 toes (80 patients) with floating toes, 4 relapses of deformation, 3 infections to soft tissue and 1 case of a rotation problem, lateral toe deviation, a swollen toe and hyperextension at the location of the desis. They had 2 revisions, but none of the patients was completely dissatisfied.

In recent years several arthrodesis techniques are available on the market that use bone implants.

Fazal, Lawrence and Williams (8) used the 2-part implant StayFuse on 140 patients and noted that with 95% of the toes there were clinically no issues, even though only 73% of bone fusion was visible on a radiograph. They did not 8 complications related to the implant: 1 case of punctured cortical bone, 6 cases of moved components (4 of which required revision), 1 broken implant. The revision rate in their series was 3.3%. 61.1% were very satisfied with their treatment, 33.5% were satisfied and 5% were not satisfied.

Ellington, Andreson, Davis, Cohen and Jones (7) achieved a 60.5% bone fuse with a StayFuse implant with primary operations and a 53.8% in review operations. With 13.2% the shape of the toe was not ideal in the coronary plane and in 5% in the sagittal plane. The occurrence of nonunion is described in 55.3% of cases, however, 3 patients were operated on again: 1 because of loosed implant in the bone canal, 1 because the implant broke, and 1 needed a correction at the level of the MTP joint.

When using the Smart Toe® implant all 29 patients (53 toes) in the Catena, Doty, Jastifer, Coughlin and Stevens (3) series were satisfied. They only noted 1 minor rotation deformity, with 81% noting a bone fusion visible in radiography, and 87% of the patients able to return to pre-operation activities with no problems. They additionally fixed the area for 3–4 weeks with KW. The authors found that the level of bone fusion is similar to the one in their previous study (3) on stabilisation of IP arthrodesis with KW and emphasize that connective fusion is not necessarily linked to poorer results.

Coillard, Petri, Damme, Deprez and Laffenetre (4) achieved 83.8% bone fusion using the Smart Toe implant, along with 98% patient satisfaction. They managed to decrease the angulation rate in PIP joints from an average of 40.3% to 13.5%. However, they noticed the so-called mallet deformations of DIP joints in 23% of patients, most likely because of stabilization at the PIP.

With older patients the problematic toe can also be amputated, especially as the recovery is fast. Galletine and DeOrio (9) report on success in easing pain, improving the function, and fewer issues with footwear after amputations with older patients who had a severely painful hammertoe deformity of the second toe (average age 78, range of 72 to 86). In their series there was no decrease of derogations of the big toe.

Mittag and Wulker (1), Arnold (2), Coughlin (5), and Shirzada, Kiesaua and DeOrio (24) emphasize that the likelihood of an unfavourable result of therapy is significantly lowered if the selection of the surgical therapy is based on the mechanism of the occurrence of the deformity or recidivism. An example of the technique that is more focused on the mechanism of the deformity than the consequences is transferring the deep flexor tendon to the extensor (Myerson and Jung (20)).

One of the worst complications with IP arthrodesis is a floating toe. Resolving this issue is complex and unpredictable. Myerson in Filippi (17) used implanting a spongiotic implant and stabilizing it with KW, achieving bone fusion in 75%

of cases. 11 of 12 patients were satisfied, while 4 infections were treated orally with antibiotics, and two had issues with the blood supply to the tip of the operated toe, which took care of itself.

In our series we had no cases of floating toe at the point of arthrodesis or at the level of MTP joints. It is true that in this series we did not have extensive corrections of full individual columns in the sense of concurrent corrections with e.g. the Weil osteotomy, relaxations or tendon movements.

This article also shows our complications in the stabilisation of arthrodesis of deformed toes with KW, however, mainly as the reason for finding other techniques. The descriptions of our complications and those of other authors (3,4,8,11,16,17) are meant to encourage interested readers into reviewing their own results and potentially considering other methods of arthrodesis.

As the techniques using implants are relatively expensive, especially when correction of several toes is required, and the procedure is not highly valued in the scope of public healthcare, we opted to test the peg-in-socket arthrodesis technique.

Using the peg-in-socket technique we achieved a high rate of bone arthrodesis (58/61 toes with 47 of 50 patients), satisfaction with the procedure (48 of 50), few unfavourable final toe shapes (2 malunions and 1 hyperextension), with very few complications. It is true that practically all the corrections were performed by the same surgeon, or was at least present when others operated. We believe that the results would have been different if this method was used by inexperienced surgeons or those who only seldom perform arthrodesis of IP joints.

We see that none of the current techniques is perfect, however, the satisfaction rate with this procedure is high. The advantage of the KW technique is simplicity, however, it has numerous potential complications. The same applies to absorbable pins. Tenodesis is not firm enough without stabilisation. Implants carry all the potential pros and cons of foreign bodies in the bone. They are also generally expensive, which is an important factor in Slovenia. That is the reason we present the peg-in-socket arthrodesis of IP joints technique, which was used in Slovenia in the past, but is fairly unknown today.

5 Conclusion

At the Jesenice General Hospital we began performing arthrodesis of IP joints in 2008, and so far the experience is not bad. There were relatively few complications in our series, with a high rate of fusion. It is true that the technique is more demanding and not recommendable for occasional use or for inexperienced surgeons.

Advantages There are no foreign materials, migrations or expulsions of KW, no additional worries regarding KW during dressing, or removals of the fixating medium. No non-standard surgical instruments are needed. The shape of the toe can be adjusted to the neighbouring toes. The technique is predictable, repeatable, reliable and inexpensive, and the procedure can be done with local anaesthesia. In case of technical issues during surgery or at a later point, it is still possible to switch to other fixation techniques, e.g. using KW.

Disadvantages The technique itself is more demanding than using arthrodesis with KW and is more suitable for more experienced surgeons. There is a danger of the peg breaking, the bone being punctured when making a channel during the operation, as well as the

possibility of peg weakening, dislocating or breaking during dressing or with incorrect exercises.

Conclusion Peg-in-socket arthrodesis of IP toe joints is a reliable and repeatable option that should not be disregarded by surgeons who focus on foot surgery.

6 List of abbreviations

- DIP – distal interphalangeal joint
- KW – Kirschner wire
- MTP – metatarsophalangeal joint
- PIP – proximal interphalangeal joint
- IP – interphalangeal joint

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