Acta Orthop. Belg., 2014, **80**, 190-195

ORIGINAL STUDY

Proximal interphalangeal Joint Replacement : Resurfacing Pyrocarbon versus Silicone Arthroplasty

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Prosthetic replacement of the proximal interphalangeal joints is an operative treatment for osteoarhtritis, to preserve the range of motion and the function of the hand.
The purpose of this study is to detect the differences regarding pain and function between a silicone implant using a volar approach and a resurfacing implant, placed through a dorsal approach.
Patients were reviewed clinically and scored. We found no significant differences in outcome between the two types of implants. However, the complication rate in the resurfacing group was significantly higher. Also, the economic cost of both implants was significantly different. The resurfacing implants were more expensive than the silicone implants.

Keywords : proximal interphalangeal joint ; osteoarthritis ; arthroplasty ; silicone ; resurfacing.

INTRODUCTION

The PIP joint is a hinged bicondylar synovial joint, moving in an uniaxial plane. It is part of a complex kinetic chain and plays an important role in both grasp and pinch.

Osteoarthritis of the proximal interphalangeal (PIP) joints can be a disabling and painful condition. Arthrodesis of the joint may be a valuable solution, but the subsequent rigidity of the finger is a major disadvantage, especially in the ring and small finger (*18-20*).

Arthroplasties without replacement of the joint, e.g. resection, palmar plate advancement, vascularized toe joint transfer, fibrous interposition or fibrous ingrowth have been abandoned over the years because of disappointing results. Prosthetic replacement was proposed as an alternative, which should preserve the range of motion, reduce the pain and improve the hand function (*5,9,14,16*).

Development of a prosthetic replacement of the PIP joint started already in 1940, when Burman developed a vitallium cap for the PIP and metacarpal-phalangeal joint (*4*). Swanson reported on silicone implants for PIP joints in 1969. (*17*) Although several adaptations have been made during the past decades, this type of implant still continues to be used (Fig. 1). Main complications of these types of implants are the lack in lateral stability, subsidence, heterotopic bone formation, poor long term range of motion and the risk of implant fracture (*2,15*).

Other types still in use, are unconstrained resurfacing prostheses, consisting of two articulating

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No benefits or funds were received in support of this study.

Fig. 1. — Image of a silicone type implant (a) and a resurfacing pyrocarbon type implant (b).

components, replacing the articular surfaces. They were first reported by Linscheid and Dobyns in 1979 (*12*). Several different constructs and materials have been used over the years, including stainless steel, titanium and polyethylene. In 2000, a semi-constrained pyrocarbon implant was introduced. The Ascension PIP (Ascension Orthopedics, Inc., Austin, Texas) implants are made of a graphite core coated with pyrocarbon. It is a press-fit implant without cement (Fig. 1b). Pyrocarbon has a very similar elastic modulus compared with cortical bone (creating a favorable environment for load transfer) and a very low wear rate (much less than titanium or zirconia) (*3,8*). However, studies have been published reporting a high complication rate in these types of implants (*11,13,21,22*).

The purpose of our study is to evaluate the differences in pain and function between patients with a silicone type joint replacement and those with a resurfacing type. The economic impact of both types of implants was also considered.

PATIENTS AND METHODS

The study was designed as a single centre retrospective cohort study. Between august 1998 and November 2011, 56 patients underwent an arthroplasty procedure of one or more PIP joints of the hand at our institution. A total of 64 arthroplasties were performed ; in 27 cases, a silicone prosthesis (Wright Medical Technology, Inc, Arlington, TN) was placed through a volar approach, in the other 37 cases, a resurfacing procedure with a pyrocarbon implant (Ascension Orthopedics, Inc, Austin, TX) was performed using a dorsal approach.

There were no clear criteria regarding when to perform which procedure. The choice was left to the discretion of one of the two surgeons (ID and LDS). Since the silicone type implants were available first, the patients operated early all received a silicone implant, even in the index finger.

Surgical techniqu

The silicone type prostheses were implanted through a volar approach. A volar Bruner ‘s incision centred over the PIP joint was made, carefully protecting the neurovascular bundles. The C1, A3 and C3 pulleys were divided at their insertion on one side and elevated to expose the flexor tendons, which were retracted to the side. The volar plate was detached proximally and the accessory collateral ligaments divided from their insertion. Then the joint was opened in a “shotgun” manner. The condyles of the proximal phalanx head were removed, staying perpendicular to the long axis of the bone. The base of the middle phalanx was prepared, taking care not to injure the central slip insertion or collateral ligament insertion. The medullary canals of both phalanges were prepared, a trial implant was inserted and range of motion was assessed. Satisfactory range of motion without buckling or displacement of the implant had to be achieved.

The surgical procedure for the pyrocarbon resurfacing implants was performed using the dorsal approach described by Chamay (*6*). A longitudinal inciscion was made over de the PIP joint through the skin and subcutaneous tissues, exposing the extensor mechanism. The

central slip was isolated proximally to the dorsal rim of the middle phalanx for approximately 1-2 cm and cut transversely and then reflected distally. The proximal phalanx head was resected by an osteotomy 90 degrees to the long axis of the phalanx, protecting the origins of the insertions of the collateral ligaments. While protecting the volar plate, a small back cut was met for the posterior aspect of the proximal phalangeal component and a perpendicular osteotomy at the base of the middle phalanx was made. Broaching of the medullary canals was done in the same way as in the silicone implants. Final components were inserted "press-fit", the extensor mechanism was repaired and skin was closed.

Postoperatively in both procedures, a bulky dressing was applied. After ten days, the dressing was removed and patients were allowed to move the finger without force for another 4 weeks. After that all activities were allowed. Routinely, no physiotherapy was given. Radiographies were only obtained in cases of suboptimal postoperative evolution.

Evaluation

All patients were contacted by mail and invited to return for clinical evaluation. Radio-ulnar stability was assessed, range of motion of the joint was measured, as well as grip strength using a dynamometer. The pain was scored on a visual analogue score with 0 meaning no pain, 10 severe pain. Furthermore a quick DASH score (Disability of arm, shoulder and hand) was completed and patients were asked if they were satisfied and would have the same operation again. Any history of additional surgical procedures or complications was recorded. The groups were compared with the Student's T-test ; $p < 0.05$ was considered significant.

Since our objective was to determine the clinical outcome, no additional radiographies were taken.

To evaluate the financial aspects of these two types of implants, the corresponding companies were contacted by telephone. Full prices as well as the amount paid by the patient after reimbursement by the health care system were recorded.

RESULTS

Thirty-two patients eventually agreed to return for clinical review, resulting in 41 reviewed PIP joints (a response rate of 64%). In the examined group, 17 PIP joints were replaced by a silicone prosthesis while 24 had a resurfacing procedure.

In the group of patients with a silicone implant, average age was 59,5 years (ranging from 39 to 80 years), male to female ratio was 5/12 and right/left ratio was 6/11. There were 2 index fingers operated, 4 middle fingers, 9 ring fingers and 2 little fingers. Indications for the operation was primary osteoarthrosis in 8 cases, posttraumatic arthrosis in 4, rheumatoid arthritis in 4 and psoriatic arthritis in 1.

In other the group, average age was 60 years (ranging from 45 to 71 years), male to female ratio was 3/21 and right/left ratio was 12/12. There were 8 index fingers operated, 6 middle fingers, 9 ring fingers and 6 little fingers. Indications for the operation were primary osteoarthrosis in 22 cases, posttraumatic arthrosis in 1 and psoriatic arthritis in 1. Patient characteristics were summarized in Table I.

In the silicone group, mean DASH score was 36,5/100 and VAS for pain was 0,2/10. 15 out of 17 patients declared they were satisfied. There were no recorded reinterventions, and only one superficial infection was recorded. This results in a complication rate of 5,9%. For the range of motion, a mean extension lag of 6,5° (standard deviation was 12,4°) and a mean flexion of 46° (standard deviation 29,2°) was found. Mean radio-ulnar movement was 4,7° (standard deviation 6,5°). The mean grip strength was 20 kilograms (standard deviation 7,4 kg).

In the resurfacing group, mean DASH score was 37/100 and VAS for pain was 1/10. 12 out of 24 patients declared they were satisfied. Two implants were revised to arthrodesis of the PIP joint and one implant was replaced by a silicone type. In 6 patients, a swan neck deformity had evolved over time, 3 had experienced a dislocation of the components and there were no recorded infections. This results in a complication rate of 37,5%. When examining the range of motion, we found a mean extension lag of 14° (standard deviation 18,3°) and a mean flexion of 48° (standard deviation 12,1°). Mean radio-ulnar movement was 4,7° (standard deviation 5,9°). The mean grip strength was 15 kilograms (standard deviation 6,9 kg).

For the silicone implant, the price is € 272,66 including taxes. Of this amount, € 227,22 is reimbursed by the health insurance, leaving a cost of € 45,44 for the patient. The resurfacing type of

Table I. — Patient characteristics

Implant type	Silicone	Resurfacing
Number of patients	17	24
Right/left hand	6/11	12/12
Index/middle/ring/little finger	2/4/9/2	8/6/9/6
Mean age (range)	59,5 years (39-80)	60 years (45-71)
Indications	Arthrosis 8 Posttraumatic 4 Reumatoid arthritis 4 Psoriatic arthritis 1	Arthrosis 22 Posttraumatic 1 Psoriatic arthritis 1

implant consists of two separate components, with a price tag of € 584,62 each, excluding taxes. This means a total cost of € 1239 including taxes, with a reimbursement up to € 1032,83, leaving a total cost of € 206,56 for the patient.

Using the Student's t-test, we calculated a p-value for quick Dash of 0,9 ; for the extension lag p-value was 0,16 ; for the flexion 0,7 and for axial deviation it was 0,5. Only for the number of complications and the price difference, it reached statistical significance ($p < 0,05$), both for the total cost and the amount paid by the patient (Table 2).

DISCUSSION

In this study, we found no significant differences in clinical outcome between the two types of implants. However, the complication rate in the resurfacing group was significantly higher. Also, the economic cost of both implants is significantly different. Because the operation time and post-operative protocol are generally the same in both procedures, the cost of the implant is the single most important factor influencing the total cost of this procedure. We realize that the obtained price information is only valid in Belgium but believe that similar price differences exist in other countries. We were unable to identify any other studies that performed an economic analysis of silicone or pyrocarbon arthroplasty.

Several reviews have been published on the outcome of different types of implants for the PIP joint. Foliart and Moraga (*10*) described long-term complications of the Swanson silicone implants in 1995. After reviewing 70 articles concerning silicone replacement of MCP, PIP and DIP joints, a total of 2463 PIP implants were discussed. Of these, 52 implants were removed because of fracture of the implant in 21 cases, continous pain in 9, infection in 5, synovitis in 4, loosening in 4 and 9 were removed because of miscellaneous cases.

This results in a complication rate of 2%.

In 2008, Squitieri and Chung (*16*) published a systematic review on the outcomes and complications of vascularized toe joint transfer, silicone arthroplasty and pyrocarbon arthroplasty for post-traumatic joint reconstruction of the finger. They reviewed 21 studies and found a comparable active ROM in the PIP joint between silicone and pyrocarbon implants (44+/-11° vs 43+/-11°, respectively). Surgical revision was indicated in 18% of the cases of silicone arthroplasty, compared to 33% in the pyrocarbon group. Overall, silicone implant arthroplasty had the lowest complication rate, both surgical and overall, despite having the most available data and the longest follow-up (17 months).

Adams *et al* performed a meta-analysis on PIP joint replacement in patients with arthritis of the hand. They found 5 prospective studies, accounting for 101 implants, 81 pyrocarbon implants and 20 ceramic. Ninety-two were implanted through a dorsal approach, the other 9 through a palmar approach. They found a substantial improvement in self-reported hand pain. Grip strength improved 60%, key pinch strength improved to a greater degree than power grip force. The largest effect size for improvement of grip was reported for implants where the central slip was not detached at surgery. The overall increase in ROM was small and data within studies also indicate that ROM may be lost following surgery. The difference between the two populations was not reported. Overall complication

Table 2. — Results. DASH : Disability of arm, shoulder and hand ; VAS : visual analogue score ; ROM : range of motion

Implant type	Silicone	Resurfacing
Mean DASH score	36,5/100	37/100
VAS for pain	0,2/10	1/10
Patient satisfied	15/17	12/24
ROM		
mean extension lag	6,5° (SD 12,4°)	14° (SD 18,3°)
mean flexion	46° (SD 29,2°)	48° (SD 12,1°)
Radio-ulnar deviation	4,7° (SD 6,5°)	3,5° (SD 5,9°)
Grip strength		
Mean (kg)	20 (SD 7,4)	15 (SD 6,9)
Complications		
Swan neck deformity	None	6
Dislocation	None	3
Infection	1	None
Total (complication rate)	1/17 (5,9%)	9/24 (37,5%)
Reinterventions	none	2x arthrodesis 1x revision with silicone implant
Total price (including taxes)	€ 272,66	€ 1239
Reimbursement	€ 227,22	€ 1032,83
Amount paid by patient	€ 45,44	€ 206,56

rate ranged from 10 to 72%. Post-operative complications included amputation of a finger, revision, migration and loosening. Loosening occurred in 12.5% of pyrocarbon replacements and 10% of ceramic replacements. Of these loosened joints, eight (9%) occurred following a dorsal approach and three (33%) following a palmar approach. Migration occurred in 12% (n = 10) of pyrocarbon replacements, constituting 11% of all replacements introduced through a dorsal approach. There was no report of migration with ceramic replacements (*1*).

In 2013, Chan *et al* (*7*) published a systematic review concerning pyrocarbon versus silicone PIP joint arthroplasty. 35 studies were selected for review, describing a total of 1882 PIP joints. In the majority of cases, a silicone implant was used (1430) whereas in the other 452 cases, a pyrocarbon implant was used. There were significant differences between the two populations. Among the available data in the silicone group, 11 studies reported the number of joints that were pain-free after the operation. This represented 549 of a total of 718 joints (76%). In the pyrocarbon group, most authors reported pain data using visual analogue scales, three studies reported the number of joints that were pain-free after surgery : 32 of 50 joints (64%).

In the silicone group, overall range of motion increased from 29.2 + 16.0 degrees preoperatively to 37.4 + 13.6 degrees postoperatively, ($p < 0.001$). In the pyrocarbon group, 13 studies reported preoperative range of motion, and all 14 articles on pyrocarbon implants reported postoperative range of motion. Overall, the arc of motion was 36.8 + 13.4 degrees preoperatively and 44.8 + 16.8 degrees postoperatively ($p < 0.001$).

In the silicone group three studies found an improvement in grip strength after silicone arthroplasty. In the pyrocarbon arthroplasty group, eight studies found that surgery offered improved grip strength. Relative grip strength, which compares the affected hand to the unaffected hand, was reported in two studies and the results showed an improvement from 62 percent to 75 percent and 53 percent to 66.3 percent after surgery. Functional outcome parameters were variable. Some authors found an improvement, whereas others found that operated hands scored lower than uninvolved hands.

The rates of revision and salvage operations were nearly four times as high in the pyrocarbon group compared with silicone. In the silicone group, 19 joint complications were reported (2 percent) that were treated nonoperatively, 33 joints (4 percent) required revision surgery, and 19 joints (2 percent) underwent salvage procedures. In the pyrocarbon group 35 joints (8 percent) were treated nonoperatively, 59 joints (14 percent) required revision surgery, and 34 joints (8 percent) underwent salvage procedures. There were some complications that tended to be implant specific, in casu silicone arthroplasty was associated with problems such as host-bone subsidence.

Most of these reviews provide results comparable to our findings, which seems to favour the silastic type of implants. The influence of the approach however, remains to be clarified. The damage done to the dorsal slip of the extensor tendon may be responsible for the development of swan neck deformity, one of the most reported complications in the resurfacing group. Of course this will never have any influence on the immense price difference, an aspect that will become more and more important in the future. In view of these findings, we consider silicone arthroplasty the preferred procedure over resurfacing arthroplasty, both in posttraumatic and rheumatoid arthritis.

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