Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713691514

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Online Publication Date: 01 January 2007

To cite this Article Lundborg, Göran, Besjakov, Jack and Brånemark, Per-Ingvar(2007)'Osseointegrated wrist-joint prostheses: A 15-year follow-up with focus on bony fixation',Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery,41:3,130 — 137

To link to this Article: DOI: 10.1080/02844310701318346

URL: http://dx.doi.org/10.1080/02844310701318346

Scand J Plast Reconstr Surg Hand Surg, 2007; 41: 130–137

informa
healthcare

ORIGINAL ARTICLE

Osseointegrated wrist-joint prostheses: A 15-year follow-up with focus on bony fixation

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Abstract

Five patients with rheumatoid arthritis or osteoarthrosis of the wrist joint were followed up for 15 (14–17) years after wrist-joint arthroplasty with semiconstrained artificial joint mechanisms that had been anchored to bone using the osseointegration principle. They were fixed by one titanium screw introduced into the radius, and two or more titanium screws introduced distally into the metacarpal bones. In four cases a screw was also introduced into the ulna thereby constituting one component in a distal radio-ulnar (DRU) joint mechanism. The titanium screw introduced into the radius and the distal metacarpal screws osseointegrated in all cases. In three cases the mechanism of the wrist joint or parts of it were replaced with new components that could be attached to the screws that were already osseointegrated. We conclude that wrist joint prostheses can be anchored to the surrounding bone using osseointegration and that they remain fixed for at least 15 years. The principle allows replacement of the joint mechanism, if needed, with maintenance of the osseointegrated anchoring elements.

Key Words: *Wrist joint, arthroplasty, artificial joint, rheumatoid arthritis, osseointegration, hand surgery*

Introduction

Arthroplasty of a rheumatoid wrist joint is still a challenging problem and a final solution has not yet been found [1]. Although the constrained Swanson silicone rubber implant may give good relief of pain [2,3], this type of prosthesis is usually no longer recommended because of complications resulting from breakage of the implants, wear, subsidence and increasing stiffness of the joint. Various types of semi-constrained or non-constrained mechanisms have been developed instead, which are anchored to bone either with or without cement [1,4–11].

Although good functional results have been achieved, problems have been reported in terms of imbalance and loosening, sometimes that require revision [1]. Evolving concepts have been aiming at an imitation of normal wrist joint anatomy with as little bone resection as possible [6,8–11]. Rahimtoola and Hubach [10] have recently presented a total modular wrist prosthesis that could be uncemented or not, and which is available in an unconstrained or constrained version. Although pain and range of movement improved, in several cases there were signs of possible loosening [11]. A wrist prosthesis including a distal radioulnar (DRU) joint component has been described by Lundborg and Brånemark [12] and Rahimtoola and Hubach [10], and a separate radioulnar DRU joint mechanism has been described by Scheker and Von Schroeder [13].

Controversies exist about the best way to anchor a wrist joint prosthesis to bone. In many cases the proximal component is press-fitted with no cement, while the distal component is cemented in place [6,8]. However, long-term follow-up is still lacking. We have previously described how wrist joint prostheses can be fixed to bone by the osseointegration principle as described by Brånemark et al. [14,15]. In a preliminary report, based on a small series of patients, we reported on the results from a 4–6.5 year follow-up with emphasis on the fixation of the

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(Accepted 8 February 2007)

ISSN 0284-4311 print/ISSN 1651-2073 online © 2007 Taylor & Francis
DOI: 10.1080/02844310701318346

prosthesis to bone [12]. No bony resorption or loosening of screws occurred.

The purpose of the present study was long-term follow-up of the same series of patients. Firm osseointegration of the wrist prosthesis also remained after long-term follow-up, extending for at least 15 years. We also showed that the joint mechanism can be exchanged, if needed, and replaced with a new mechanism that can be attached to the osseointegrated, anchoring titanium screws.

Patients and methods

Design of the joint mechanism

The joint mechanism was a semiconstrained type, individually designed in each case and produced in a limited number by the Brånemark construction team. It was based on a semiconstrained "ball-and-socket" principle with a distal ovoid-shaped ball made of titanium metal snapped into a socket made of high density polyethylene as previously described [12]. The two components extended from transverse titanium plates that were fixed to appropriately-sized titanium screws that were introduced proximally into the radius and distally into the second and third metacarpals. If needed, an additional metacarpal screw was extended into the carpus or the fourth metacarpal bone. The whole procedure was done in one stage. In four cases the construction also included a distal radioulnar joint (DRU) mechanism to stabilise the distal end of the ulna. In those cases, the proximal titanium plate, fixed to the radius, was extended in an ulnar direction into a semicircular structure that enclosed a polyethylene plate 2 mm thick with an oval-shaped slot. After bone grafting, a titanium screw was introduced into the distal end of the ulna. Another smaller titanium screw was then introduced in a distal-proximal direction through the slot into an approximately sized central channel in the ulnar screw, the head of the smaller screw still being kept distal to the slot in the polyethylene plate. The ulna was thereby effectively stabilised, with the possibility of rotation of the forearm.

Surgical technique

Through a slightly curved dorsal skin incision the extensor retinaculum was raised as a radially based flap. After synovectomy the joint capsule was incised and raised as a proximally and distally based flap. The ulnar head was excised and the distal part of the ulna stabilised either by a local fascioperiosteal flap or by the titanium construction already described. Transverse osteotomies were made distally in the radius and through the carpal region, resecting at least the proximal row and the proximal pole of the capitate bone. In all cases the bone was grafted so that the medullary cavities of the radius and metacarpal bones were firmly packed with cancellous bone graft from the iliac crest. A titanium screw of appropriate size was introduced centrally to the radius, taking care not to induce heat in the surrounding tissue. A second, shorter screw was usually used more radially in the radius to stabilise it. Titanium screws of smaller dimensions were introduced into the second and third metacarpal bones, sometimes also into the carpus or the fourth metacarpal bone. The joint mechanism was then fixed to the screws with a specially-designed locking system.

After closure of the joint capsule and suture of the retinaculum superficial to the extensor tendons, the skin was sutured and a bandage applied. The wrist was fixed in plaster and kept immobilised for three weeks before initiation of controlled active mobilisation.

Patients

Details of the patients are shown in Table I. There were five patients (one man and four women aged 35 (23–46) years at operation). Four patients had advanced rheumatoid arthritis and one osteoarthritis. The follow-up time was 15 (14–17) years.

Results

The functional outcome and radiological appearances are summarised in Table I.

The patients had little or no mild activity-related pain. Rotation of the forearm was good, in two cases 90° in both pronation and supination. Active extension varied from 15° to 35°, active flexion varied from 0 to 25°.

In all five cases the anchoring osseointegrated screws in the radius, carpus, and metacarpals remained firmly osseointegrated at follow-up with no signs of loosening. The remaining screws in the ulna were well osseointegrated into the bone, but there was regular bony resorption distally around the screw, leaving its most distal part exposed to the two surrounding soft tissues.

In two patients (cases 1 and 2) the joint mechanism remained intact over the whole observation period (Figures 1 and 2). However, an important concept in this construction is that the joint mechanism can, if needed, be removed and replaced with a new mechanism that could be attached to the already osseointegrated screws. In one patient (case 3) the joint mechanism including the distal carpal components was replaced after 11 years, and a new

Table I. Follow-up of osseointegrated wrist-joint prostheses.

Case No.	Sex	Age at operation	Follow-up (years)	ROM wrist extension/ flexion	Forearm rotation pronation/ supination	Pain	Comments
1	Female	37	14.5	15/25	90/90	None	Distal radioulnar (DRU) component intact at follow-up.
2	Female	46	15	25/20	90/90	Mild, activity-related; none at rest	DRU component, including ulnar screw, removed after one year.
3	Male	23	17	15/20	70/50	None	Replacement of wrist joint mechanism and carpal components after 11 years, new joint mechanism attached to the proximal osseointegrated screw. DRU component removed. Active golfer.
4	Female	28	16	20/25	70/60	Mild, activity-related; none at rest	Silicone joint mechanism replaced after one year, new semiconstrained mechanism attached to osseointegrated screws. DRU component removed. Fracture of one metacarpal screw. Active fly fisher, enjoys salmon fishing.
5	Female	44	14.5	35/0	70/50	None	Joint mechanism replaced after 8 years, a new mechanism attached to the osseointegrated screws. No DRU component.

All patients had rheumatoid arthritis except case 2, who had osteoarthrosis.

Figure 1. Case 1. Radiological appearance preoperatively (*a*), one year postoperatively (*b*), and 14.5 years postoperatively (*c*). All screws are firmly osseointegrated with no resorption zones. There is bony resorption around the distal 15 mm of the ulnar screw in the form of cortical tapering. The distal radioulnar joint mechanism is well maintained.

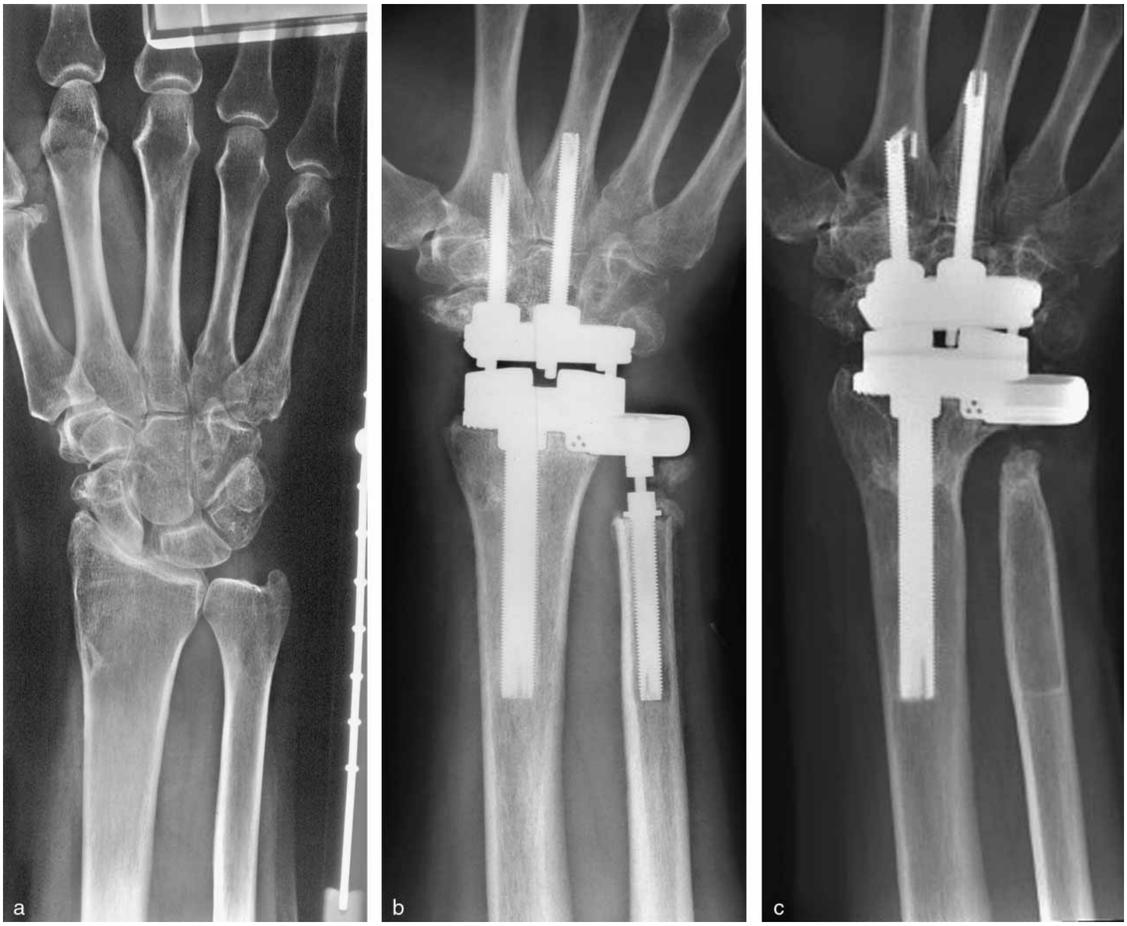

Figure 2. Case 2. Radiological appearance preoperatively (*a*), one year postoperatively (*b*), and 14 years postoperatively (*c*). The ulnar screw has been removed because of early loosening. Screws in radius and metacarpals are firmly osseointegrated, but fractures of the titanium material can be seen at the tips of both metacarpal screws.

mechanism was attached to the osseointegrated screw in the radius (Figure 3). In another patient (case 4) the first joint mechanism was a simple silicone design. Because the silicone material broke it was replaced early, and a new mechanism of the semiconstrained design was attached to the osseointegrated screws (Figure 4). In another patient (case 5) the whole joint mechanism had to be replaced after eight years, the new mechanism being attached to the osseointegrated screws (Figure 5).

In one patient (case 1) the DRU component was still functioning perfectly and was associated with 90° pronation and 90° supination (Figure 1). In the three remaining cases with DRU components the component was removed because of fracture of the material or early loosening of the screw. The screw in the ulna, however, was left in two patients.

Discussion

Pain and instability of the wrist joint are the most disabling problems for rheumatoid patients. Although fusion of the wrist can offer stability and reduce pain the sacrifice – to lose wrist movement – is substantial, particularly if both wrists are affected. Wrist arthroplasty can provide the patient with a functional range of movement, stability, and less pain [1]. Wrist arthroplasty improves the performance of daily activities and patients prefer it to arthrodesis [1]. Even a limited range of movement is important and sufficient for most daily activities [16].

Movement of the wrist is biomechanically complex, and many attempts have been made to develop a wrist prosthesis that will imitate normal wrist anatomy and function. A major issue is fixation of the prosthesis to bone, and – regardless of the technique used – loosening is a common long-term problem [1].

The purpose of this study was not to focus on the construction of a joint mechanism, but rather to evaluate the possibilities for long-term fixation of a wrist joint mechanism to bone by the osseointegration principle. This was originally proposed by

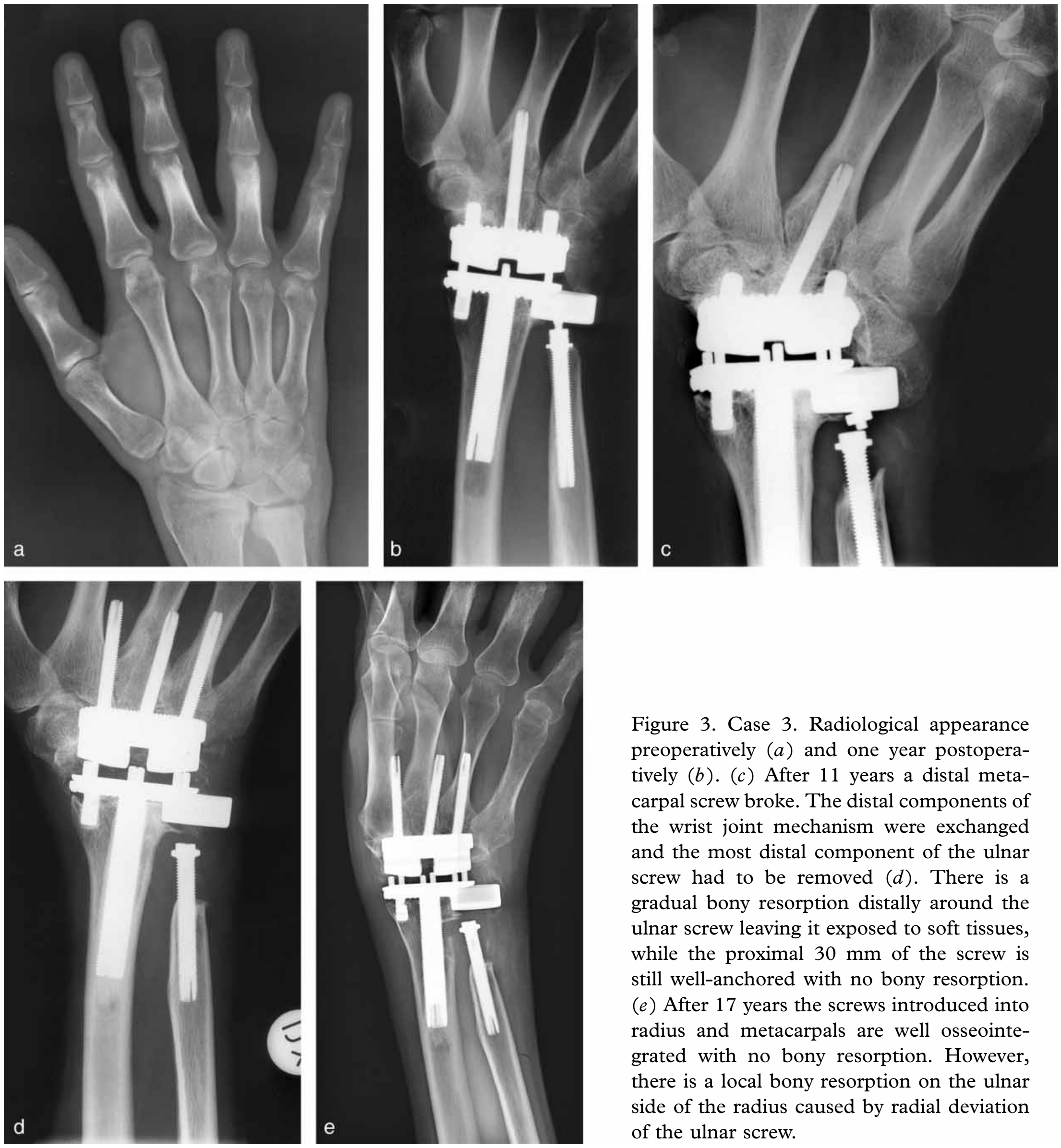

Figure 3. Case 3. Radiological appearance preoperatively (*a*) and one year postoperatively (*b*). (*c*) After 11 years a distal metacarpal screw broke. The distal components of the wrist joint mechanism were exchanged and the most distal component of the ulnar screw had to be removed (*d*). There is a gradual bony resorption distally around the ulnar screw leaving it exposed to soft tissues, while the proximal 30 mm of the screw is still well-anchored with no bony resorption. (*e*) After 17 years the screws introduced into radius and metacarpals are well osseointegrated with no bony resorption. However, there is a local bony resorption on the ulnar side of the radius caused by radial deviation of the ulnar screw.

Brånemark et al. 40 years ago [14,15], and can be defined as direct anchorage of an implant by the formation of bony tissue around the implant without the growth of fibrous tissue at the bone-implant interface [17]. Successful long-term fixation of a joint mechanism to bone with osseointegrated titanium screws has previously been reported for both metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joint implants [18–23]. It has been used for anchorage of dental prostheses in edentulous patients for more than 30 years [14,24]. It has been shown clearly that with a carefully controlled surgical and healing protocol, titanium screws will integrate into bone without any interposing layer of connective tissue at the interfaces between the titanium and the bone [25]. The advantages of this principle as an alternative to cement are obvious: tissue damage induced by heat and chemicals is avoided. In an analysis of 239 titanium implants (27 PIP joints and 212 MCP joints) in 86 patients, complete osseointegration was found in 94% 42 months after implantation, an observation that was also valid in cases followed up for more than five years [23].

An essential factor in the design of our prosthetic wrist joint was that the joint mechanism should be replaceable, and that a new mechanism could – if necessary – be implanted and attached to the already osseointegrated anchoring elements. In three of our cases the wrist joint mechanism was replaced because of material problems after one, eight, and 11 years, respectively. A new mechanism was placed on the well-integrated proximal and distal titanium screws, thereby replacing one component of the

Figure 4. Case 4. (*a*) Radiological appearance preoperatively. After one year an original silicone joint mechanism failed (*b*), and was replaced with a new semiconstrained joint mechanism that was attached to the osseointegrated screws. (*c*) Appearance after five years showing good osseointegration but proximal fracture of the screw in the third metacarpal. (*d*) Radiological appearance after 16 years. Bony resorption can be seen around the distal part of the titanium screw. Otherwise there is no bony resorption around the anchoring screws, which are well osseointegrated. The third metacarpal phalangeal joint has been replaced with an osseointegrated joint implant.

Figure 5. Case 5. Radiological appearance one year postoperatively (*a*). After eight years there was a fracture of the components of the proximal joint mechanism, and a new joint mechanism was attached to the already osseointegrated screws (*b*, *c*). (*d*) Radiological appearance after 14 years showing well osseointegrated screws.

wrist prosthesis; the osseointegrated screw elements were well-integrated and a new mechanism could easily be attached to the osseointegrated screws. This is an important part of our approach to arthroplasties, as no joint mechanisms can be expected to last for life. Our observation that the titanium screws remain integrated after at least 15 years, indicate clearly that the osseointegration of the titanium screws is permanent.

In summary, we have shown that osseointegration is a valid method of permanent fixation of a wrist joint prosthesis, and we have come one step closer towards the ultimate prosthesis with lifelong bony fixation, and with the possibility of replacement of the joint mechanism, although an ideal joint mechanism has yet to be developed.

References

[1] Anderson MC, Adams BD. Total wrist arthroplasty. Hand Clin 2005;21:621–30.

[2] Swanson AB, de Groot Swanson G, Maupin BK. Flexible implant arthroplasty of the radiocarpal joint. Surgical technique and long-term study. Clin Orthop Relat Res 1984;187:94–106.

[3] Kistler U, Weiss AP, Simmen BR, Herren DB. Long-term results of silicone wrist arthroplasty in patients with rheumatoid arthritis. J Hand Surg 2005;30A:1282–7.

[4] Meuli HC, Fernandez DL. Uncemented total wrist arthroplasty. J Hand Surg 1995;20A:115–22.

[5] Cobb TK, Beckenbaugh RD. Biaxial long-stemmed multipronged distal components for revision/bone deficit total-wrist arthroplasty. J Hand Surg 1996;21A:764–70.

[6] Menon J. Universal total wrist implant: experience with a carpal component fixed with three screws. J Arthroplasty 1998;13:515–23.

[7] Stegeman M, Rijnberg WJ, van Loon CJ. Biaxial total wrist arthroplasty in rheumatoid arthritis. Satisfactory functional results. Rheumatol Int 2005;25:191–4.

[8] Divelbiss BJ, Sollerman C, Adams BD. Early results of the Universal total wrist arthroplasty in rheumatoid arthritis. J Hand Surg 2002;27A:195–204.

[9] Radmer S, Andresen R, Sparmann M. Total wrist arthroplasty in patients with rheumatoid arthritis. J Hand Surg 2003;28A:789–94.

[10] Rahimtoola ZO, Hubach P. Total modular wrist prosthesis: a new design. Scand J Plast Reconstr Surg Hand Surg 2004; 38:160–5.

[11] Rahimtoola ZO, Rozing PM. Preliminary results of total wrist arthroplasty using the RWS prosthesis. J Hand Surg 2003;28B:54–60.

[12] Lundborg G, Brånemark PI. Anchorage of wrist joint prostheses to bone using the osseointegration principle. J Hand Surg 1997;22B:84–9.

[13] Scheker LR, Von Schroeder H. Dorsal stabilization of the distal radioulnar joint. Tech Hand Up Extrem Surg 1998;2: 234–41.

[14] Brånemark PI, Breine U, Lindström J, Adell R, Hansson BO, Ohlsson Å. Intraosseous anchorage of dental prosthesis. I. Experimental studies. Scand J Plast Reconstr Surg 1969;3: 81–100.

[15] Brånemark P-I. The osseointegration book – from calvarium to calcaneus. Berlin: Quintessenz Verlags-GmbH; 2005.

[16] Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. J Hand Surg 1985;10A: 39–43.

[17] Dorland's illustrated medical dictionary. 28th ed. Philadelphia: WB Saunders; 1994.

[18] Lundborg G, Brånemark PI, Carlsson I. Metacarpophalangeal joint arthroplasty based on the osseointegration concept. J Hand Surg 1993;18B:693–703.

[19] Möller K, Sollerman C, Geijer M, Brånemark PI. Osseointegrated silicone implants. 18 patients with 57 MCP joints followed for 2 years. Acta Orthop Scand 1999;70: 109–15.

[20] Möller K, Sollerman C, Geijer M, Brånemark PI. Early results with osseointegrated proximal interphalangeal joint prostheses. J Hand Surg 1999;24A:267–74.

[21] Lundborg G, Brånemark PI. Osseointegrated proximal interphalangeal joint prostheses with a replaceable flexible joint spacer – long-term results. Scand J Plast Reconstr Surg Hand Surg 2000;34:345–53.

[22] Lundborg G, Brånemark PI. Osseointegrated silicone implants for joint reconstruction after septic arthritis of the metacarpophalangeal joint: a 10-year follow-up. Scand J Plast Reconstr Surg Hand Surg 2001;35:311–5.

[23] Möller K, Geijer M, Sollerman C, Lundborg G. Radiographic evaluation of osseointegration and loosening of titanium implants in the MCP and PIP joints. J Hand Surg 2004;29A:32–8.

[24] Brånemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977; 16(suppl):1–132.

[25] Albrektson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants: requirements for ensuring a long-lasting direct bone-to-implant anchorage in man. Acta Orthop Scand 1981;52:155–70.