Acta Orthop. Belg., 2008, **74**, 753-760

ORIGINAL STUDY

Metallosis in revision total elbow arthroplasty. Complications and staging method

Ilse DEGREEF, Raf SCIOT, Luc DE SMET

From Leuven University Hospitals, Leuven, Belgium

Although total elbow arthroplasty is a reliable treatment method for the arthritic joint, revision is necessary if loosening, instability, wear, fracture or infection occurs. We report 12 patients with 19 months (10-29) follow-up after revision arthroplasty for painful loosening in six cases, periprosthetic fracture in three, gross instability in one and skin perforation with possible infection in two. All cases presented with severe metallosis. Fractures were seen in four, triceps insufficiency in three and skin perforation in two. All patients were treated with exchange arthroplasty using the Coonrad-Morrey prosthesis. Three patients had in addition strut-allografting. The two patients with skin perforation and possible infection had a staged procedure. Mayo Elbow Performance Score improved from 24 to 87 with uneventful healing, fracture consolidation and allograft incorporation. At follow-up, triceps insufficiency persisted in all three cases. Transient neuropathy was present in five patients (4 ulnar, 1 radial). Metallosis in total elbow arthroplasty may be associated with severe tissue damage. A staging method is presented.

Keywords : metallosis ; total elbow arthroplasty ; revision ; loosening ; osteolysis.

INTRODUCTION

Representing the link in upper limb kinematics, a mobile and stable elbow joint is a key-factor in maintaining the patient's autonomy and functional status. Nowadays, total elbow arthroplasty (TEA) is an efficient surgical procedure in the treatment of a disabling, painful, stiff or unstable elbow joint in rheumatoid arthritis, osteoarthritis and post-traumatic arthritis (*5,16,21*). TEA provides good outcome with reliable medium to long-term results, approaching total knee arthroplasty results (*4,8,14, 16,24*). Although challenging, revision surgery can also provide reasonably good results in cases of loosening, instability, wear or infection (*5,9,17,22*). However, free metallic particles originating from any arthroplasty can impregnate and affect the surrounding tissues, resulting in metallosis (*2,11,13,18, 20*). Devastating bony and soft tissue damage can be seen, or even skin perforation and infection (*3,25*). Here, we report 12 cases with severe complicated metallosis, associated with important bony and soft tissue damage, which were treated by revision surgery and implant exchange within a time period of two years.

■ Ilse Degreef, MD, Orthopaedic surgeon.
■ Luc De Smet, MD, PhD, Orthopaedic Surgeon.
Department of Orthopaedic Surgery, Leuven University Hospitals, Belgium.
■ Raf Sciot, MD, PhD, Pathologist.
Department of Pathology, Leuven University Hospitals, Belgium.
Correspondence : Ilse Degreef, University Hospitals Leuven, Orthopaedic Surgery Department, Pellenberg Campus, Weligerveld 1, B-3212 Pellenberg, Belgium.
E-mail : ilse.degreef@uz.kuleuven.ac.be

No benefits or funds were received in support of this study

Table I. — Pre- and postoperative findings in all 12 patients with metallosis after total elbow arthroplasty who underwent revision arthroplasty. The radiological and clinical staging was added preoperatively and at follow-up. (y = years, FU = follow-up, m = months, DASH = Disabilities of Arm, Shoulder and Hand score, MEPS = Mayo elbow performance score, pre = preoperative, post = postoperative, F = female, M = male, RA = rheumatoid arthritis, # = fractured bone, H = humerus, U = ulna, Degen = degenerative, WL = Waldemar Link Elbow Arthroplasty)

Nr	Gender	Age (y)	Side	Diagnosis	Type 1	Indication for revision	Staging	Time interval (ym)	FU (m)	Complications	Allograft	MEPS pre	MEPS Post	DASH
1	F	69	L	#	Souter	Loosening	IIb	3y7m	29	Temporary Radial nerve	–	25	50	79
2	F	71	R	RA	Kudo	#	Vb	7y7m	26	Ulnar nerve	H + U	5	95	45
3	M	60	L	Degenerative Arthritis	IBP	fistula	IVd	2y9m	26	–	H + U	50	100	31
4	F	73	R	RA	WL	#	Vb	21y9m	27	Triceps weak	H + U	5	80	88
5	F	70	R	#	Kudo	Loosening	IIb	5y7m	15	–	–	35	good	Good
6	M	57	R	Hemophilia	Kudo	#	IIc	11y2m	10	Ulnar nerve	U + H	25	65	51
7	F	80	R	RA	Kudo	Loosening	IIIb	7y3m	15	–	–	10	80	50
8	F	76	R	RA	Kudo	Loosening	Ib	5y9m	11	–	–	40	100	85
9	F	64	L	RA	Kudo	fistula	Id	7y3m	16	Triceps, ulnar nerve	–	30	85	40
10	F	79	R	RA	Kudo	loosening	IIIb	11y8m	16	–	–	30	100	53
11	F	73	R	RA	Kudo	Instability	Ic	7y9m	16	Triceps, ulnar nerve	–	5	100	70
12	F	41	L	RA	Kudo	loosening	IIb	7y7m	15	–	–	30	100	38

MATERIAL AND METHODS

We studied patients who underwent elbow revision arthroplasty with severe metallosis in our institution between July 2004 and February 2006 ; all operations were performed by the first author. There were 12 patients and all were included (table I). The group consisted of 2 men and 10 women with 4 left and 8 right sided unilateral elbow revisions. The mean age at the time of revision surgery was 68 years (41-80). Primary indications for TEA were symptomatic rheumatoid arthritis of the elbow joint in 8, elbow fracture in 2, haemophiliac arthropathy in 1 and degenerative arthritis in 1 patient. All except two patients (nr. 1 and 4) had their primary elbow arthroplasty at our institution. The average time interval between primary and secondary elbow replacement was 8 years and 4 months (range, 2y9m to 21y9m). The original implants were 11 unconstrained elbows and 1 fully constrained linked TEA that had been placed 21 years earlier. As shown in table I, the indication for revision surgery was painful loosening in 6 cases, periprosthetic fracture in 3 cases, gross instability in 1 and skin perforation with possible infection in 2. All patients presented with a painful unstable elbow joint. A semi-constrained hinged TEA (Coonrad-Morrey, Zimmer©) was implanted in exchange using a posterior Vangorder triceps reflecting approach (*22*). In 8 patients synovial tissue was sent for pathological examination. A two-stage revision procedure was done in two patients who had a draining sinus over the proximal ulna with possible infection ; the time interval between the two stages was 6 weeks, during which theese two patients received intravenous antibiotics (fig 1). Three patients (cases 2, 4, 6) presented with periprosthetic fractures of the humeral and ulnar shaft due to cortical thinning after a ballooning phenomenon with metallic debris and concurrent inflammatory response ; two fractures occurred spontaneously and one after a fall on the elbow (fig 2). One patient presented with progressive instability of her right elbow since the primary bilateral TEA 12 years earlier. A collateral ligament reconstruction 7 years after the primary arthroplasty did not durably stabilise the joint, and gross instability recurred within two years. Complete triceps insufficiency was present at the time of revision surgery in three patients. The average preoperative Mayo Elbow Performance Score (MEPS) was 24 out of 100.

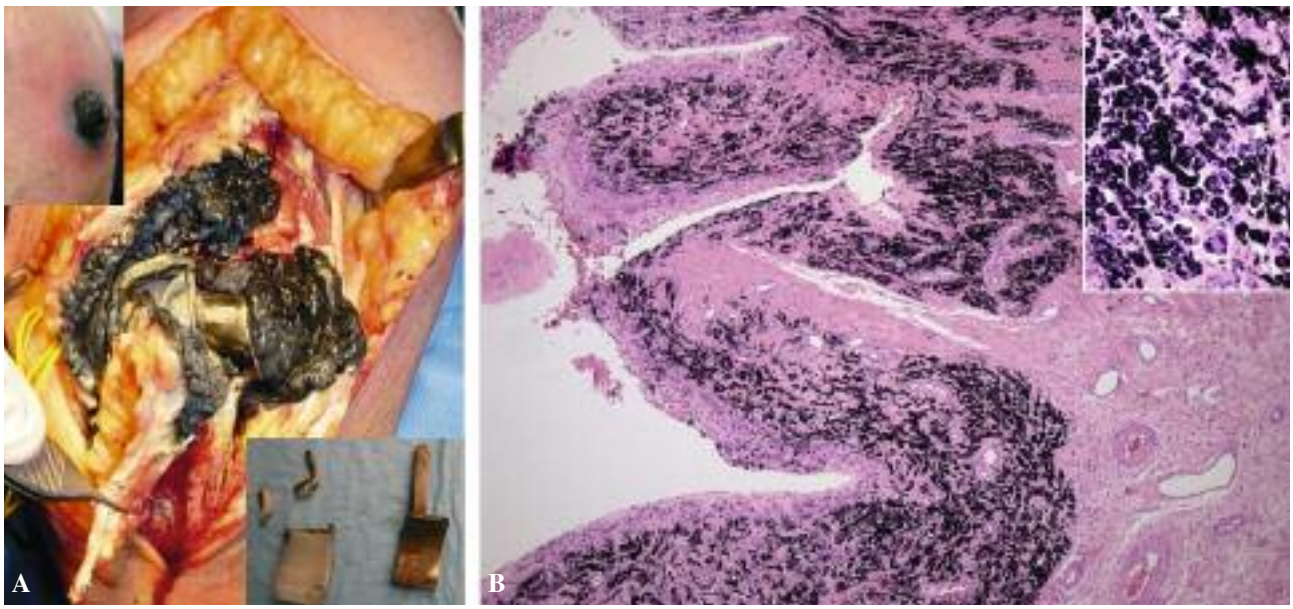

Fig. 1. — A : Skin perforation in case 9 (upper inset) with the intraoperative view. Removed implant demonstrating the metallic wear after polyethylene destruction (lower inset). B : Microscopic confirmation of the metallic deposits in synovial tissue : low power view showing the black pigment in the villous projections. The inset highlights the presence of particles in macrophages. Haematoxylin & eosin stain, × 100, × 400 (inset).

Fig. 2. — Preoperative (A) images with fractured ulna and humerus in case 2 and the radiological result after 2.5 years (B). The allografts show a bony bridge on ulna and humerus.

All patients were invited for clinical and radiological evaluation. One patient could not come to the clinic due to social problems and was contacted by phone and through her general practitioner. A new clinical and radiological evaluation was scheduled with a mean follow-up period after revision surgery of 19 months (range, 10-29). At the time of evaluation a standard radiograph, a Disabilities of Arm, Shoulder and Hand score (DASH) and new MEPS were taken.

To categorise the severity of bony and soft tissue destruction in TEA with metallosis, we developed a new radiological and clinical staging method which is presented in table II and fig 3. Bony destruction is categorized based on radiographic findings with spotting (I),

loosening (II), ballooning with cortical thinning (III), bony perforation (IV) and fractures in the final stage (V). In addition, a clinically based staging method further categorizes associated soft tissue damage from normal (a) to obvious synovial swelling (b), skin involvement with redness, thinning and black staining (c) and skin perforation and fistula in the worst stage (d).

The patients data and individual staging are included in table I.

RESULTS

In all patients severe metallosis was present with black impregnation of the synovium and surrounding soft tissue. All eight microscopically examined tissues showed remarkable black metallic deposits surrounded by inflammatory cells, confirming metallosis (fig 2). The affected soft tissue was debrided as much as possible but complete removal was never achieved due to the extent and the diffuse character of the metallosis. In the two patients (table I, cases 3 and 9) with a percutaneous fistula the revision arthroplasty was done as a staged procedure with a 6-week interval during which gentamicin-impregnated cement beads were left in the joint space and antibiotics (gentamicin and flucloxacillin) were administered intravenously. In one of these cases (case 3), *Corynebacterium* species was cultured in the fistula, but intraoperative tissue cultures remained negative in both. Although the humeral components were well fixed in both cases, they had to be removed because of the infection risk and of the instability due to severe soft tissue impairment requiring a linked type of TEA. In both cases the humeral shaft fractured at the time of removal of the components. In one case (case 3), strut allografting of the humerus with a tibia allograft was performed during the second stage. In the other patient (case 9), the humeral fracture had healed at the time of re-implantation and did not need fixation.

In 3 patients (cases 4,9,11), triceps insufficiency was present. In case 9 treated with a staged revision due to the fistula, a massive distal triceps defect was present and the ends of the tendon were approximated as much as possible. A 4th operation was scheduled 4 months after the second stage revision because of persisting functional deficit. A triceps reconstruction was easily achieved with a V-Y technique. Progressive rehabilitation with a hinged brace over a 3-month period yielded a very good result with satisfying active triceps function. However, 6 months later, the triceps again became weaker and after one year radiographs showed a recurrent loosening of the humeral component. In the second patient (case 11), presenting with a long standing gross instability, a massive triceps defect was not primarily closed. As expected she had no triceps function, but she was used to this and felt satisfied with the mobile and stable joint without the desire for further reconstructive surgery. The third patient (case 4) had a weakened but functional triceps and denied further treatment.

Strut allografting by means of a customised tibia allograft was done in 3 patients (cases 2,4,6) with insufficiency fractures of the humerus and ulna. After a 3-week period of collar and cuff immobilisation, progressive active motion was allowed. One of these patients had haemophilia and continued to show minor diffuse swelling and complained of vague pain afterwards.

In 7 patients (cases 1,5,7,8,10,11,12), simple exchange TEA with debridement of the metal impregnated synovial tissue was done, followed by almost immediate active rehabilitation.

Temporary ulnar nerve paraesthesia was present in 4 patients (cases 2,6,9,11). In one patient (case 1) a temporary radial nerve paralysis was present, probably due to intraoperative perforation of the proximal posterior cortex of the humerus with the 8-inch humeral arthroplasty component teasing the visualised nerve. The nerve palsy recovered within 3 months and the patient recovered uneventfully. Wound healing was uneventful in all patients.

At follow-up evaluation 19 months (10-29) after the revision surgery, MEPS was 87 (50-100) and average DASH score was 57 (31-88). No correlation between DASH and MEPS was seen (correlation coefficient $p < 0.37$). The MEPS improved significantly ($p < 0.001$) with an average of 63 points (24 to 87). The patient (case 5) who could not come to the clinic was satisfied, lived independently and her general practitioner reported she had a good function of her elbow with no pain.

At the last follow-up, no loosening was seen on radiographs, except for the above mentioned case 9. Osseous bridging was noted in cases with a fracture, and good allograft incorporation was evident (fig 2).

DISCUSSION

Due to the increasing incidence of primary TEA, the indications for revision surgery are rising (*9*). Improvements of the arthroplasty design have led to better survival rates (*14*). Attention for severe and recurrent complications is needed to improve long-time outcome.

Metallosis is defined as the infiltration of metallic wear debris in the periprosthetic soft tissues, caused by free metallic particles originating from the arthroplasty stem coating or friction of articular metal surfaces (*7,11*). In total hip arthroplasty, hard-on-hard articulations are used for their low wear and friction and good clinical results are obtained with smooth surface and perfect clearance (*11*). However, in case of incongruent metal-on-metal contact high friction moments arise leading to increased wear and rapid loosening as was seen here, in the non-weight bearing elbow joint (*11,13*). Depending on the design of the arthroplasty, particles of titanium, vanadium, chrome, cobalt and aluminium disperse in the surrounding serum and soft tissues. The systemic effects of particle release are yet unknown, but with cobalt, patients with limited renal function could be at risk (*1*). However, the local effects of these metal particles are feared due to the risk of devastating necrobiosis and necrosis (*18*). An inflammatory macrophage response (fig 1) with direct endocytosis of metallic debris with the release of osteolytic cytokines and suppression of collagen production, possibly associated with hypersensitivity to metallic debris, are contributing factors to this soft tissue destruction (*10,12,18,19*).

Significant polyethylene wear can lead to direct metal-on-metal contact as occurred in the cases presented here (fig 1). Although clinical and radiological data in this study show no obvious indication of inaccurate primary implantation, a total elbow arthroplasty imbalance or instability may speed up progressive polyethylene wear, resulting in metal-on-metal contact with a dramatic evolution of metallosis as was seen here (*14,24,26*).

The devastating soft tissue damage associated with an inflammatory metallosis process can interfere with reconstruction. In this study loosening, osteolysis, periprosthetic fractures, skin perforation with possible infection and triceps insufficiency were seen.

In case of loosening, cortical thinning and a ballooning process can weaken the bone with a risk for subsequent insufficiency fractures. These fractures are a surgical challenge, often requiring allograft reconstruction as was performed in 4 cases in this series (*9,15,17,22*). Clinical experience with hip arthroplasty and *in vitro* cytologic studies have demonstrated the inflammatory process in response to arthroplasty wear and particle debris (most importantly to metallic debris and to a lesser extent to polyethylene) causing osteolysis and ballooning by pressure remodeling (*6,10*). Similar mechanisms are likely to take part in the total elbow arthroplasty loosening process.

In metallosis, soft tissue erosion may be devastating. In the two cases with skin perforation and massive amounts of black metallic debris draining from a percutaneous fistula, there were no convincing arguments suggesting a primary infection, with negative history, normal blood lab investigations and negative preoperative cultures. Obviously, when skin perforation occurs, infection is suspected and staged revision is preferable, making the rehabilitation for the patient harder and longer. Due to diffuse bony and soft tissue infiltration, complete surgical elimination of all metallic debris is often impossible and should not be a prerequisite (*2*).

As observed in this series, revision surgery can relieve pain and restore function even in severe cases. The MEPS score improved significantly in all cases with an average of 63 points. To some degree, this is related with low preoperative scores because of important functional loss, particularly in the fracture cases. However, longer follow-up is needed although these patients had no other acceptable alternative than revision arthroplasty at the time of presentation. The DASH score is not correlated to the MEPS score at follow-up. This may be ascribed to the high co-morbidity in some of the

Table II. — Radiological and clinical staging method for metallosis after total elbow arthroplasty. Radiological illustrations are visible in figure 3

Staging	Radiograph	Clinical Presentation			
		Negative	Swelling	Skin thinning	Fistula
I	Spotting	Ia	Ib	Ic	Id
II	Loosening	IIa	IIb	IIc	IId
III	Ballooning	IIIa	IIIb	IIIc	IIId
IV	Perforation	IVa	IVb	IVc	IVd
V	Fracture	Va	Vb	Vc	Vd

Fig. 3. — Radiological illustration of the proposed staging method (table II) for metallosis after total elbow arthroplasty. Stage I : *spotting* without further signs of loosening, stage II : periprosthetic radiolucency as signs of *loosening*, stage III : *ballooning* with cortical thinning of humerus and ulna, stage IV : ulnar cortical *perforation* of the component, stage V : periprosthetic *fracture* of ulna and humerus.

patients with even wheel chair dependence, although good elbow function was achieved.

A standardised yearly radiological follow-up after any TEA may help for early detection of loosening and associated metallosis (*14,24,26*). Soft tissue and bone destruction can be devastating and in hip surgery, early revision is advised (*2*). This should also be considered in TEA.

In an attempt to standardise the evaluation of metallosis in the TEA patient with respect to the degree of technical difficulty in surgical revision related to the soft and bony tissue damage, we introduced a clinical-radiological staging method as illustrated in table II and fig 3 (*2,23*).

The design of the staging method was based on three types of data. Firstly, the classification of metallosis in hip arthroplasty literature was used as a basis for radiological features. Next, radiological and clinical data of TEA patients with metallosis seen in our series and other not (yet) operated patients were studied to categorise the different features. Finally, increasing soft and bony tissue damage resulting in increasing surgical challenge were categorised, and their evaluation was based on clinical and radiological signs. The staging method presented does not necessarily imply a predictable evolution from stages I to V (nor even from a to d) and is certainly not validated by this small retrospective study. However, it may provide a sound basis for future studies comparing treatment strategies and results.

Limitations of this study are its retrospective nature and the relatively small number of patients. A larger multicenter prospective study is needed for validation of the suggested staging method and the possible benefit of early revision surgery.

REFERENCES

1. **Brodner W, Bitzau P, Meisinger V, Kaider A, Gottsaumer-Wolf F, Kotz R.** Serum cobalt levels after metal-on-metal total hip arthroplasty. *J Bone Joint Surg* 2003 ; 85-A : 2168-2173.
2. **Chang JD, Lee SS, Hur M, Seo EM, Chung YK, Lee CJ.** Revision total hip arthroplasty in hip joints with metallosis. A single-center experience with 31 cases., *J Arthroplasty* 2005 ; 20 : 568-573.
3. **Dos Remedios C, Chantelot C, Giraud F, Migaud H, Fontaine C.** Results with Kudo elbow prosthesis in non-traumatic indications : a study of 36 cases. *Acta Orthop Belg* 2005 ; 71 : 273-288.
4. **Geschwend N, Simmen BR, Matejovsky Z.** Late complications in elbow arthroplasty. *J Shoulder Elbow Surg* 1996 ; 5 : 86-96.
5. **Gill DRJ, Morrey BF.** The Coonrad-Morrey total elbow arthroplasty in patients who have rheumatoid arthritis. A ten to fifteen-year follow-up study. *J Bone Joint Surg* 1998 ; 80-A : 1327-1335.
6. **Gonzalez Della Valle A, Rana A, Nestor B, Bostrom M, Westrich G, Salvati EA.** Metallic shedding, surface finish changes, and extensive femoral osteolysis in the loose Spectron EF stem. *Clin Orthop* 2006 ; 442 : 165-170.
7. **Grose A, Gonzalez Della Valle A, Bullough P, Lyman S, Tomek I, Pellicci P.** High failure rate of a modern, proximally roughened, cemented stem for total hip arthroplasty. *Int Orthop* 2006 ; 30 : 243-247.
8. **Hildebrand KA, Patterson SD, Regan WD, MacDermid JC, King GJW.** Functional outcome of semi-constrained total elbow arthroplasty. *J Bone Joint Surg* 2000 ; 82-A : 1379-1386.
9. **Kamineni S, Morrey BF.** Proximal ulnar reconstruction with strut allograft in revision total elbow arthroplasty. *J Bone Joint Surg* 2004 ; 64-A : 1223-1229.
10. **Kaufman AM, Alabre CI, Rubash HE, Shanbhag AS.** Human macrophage response to UHMWPE, TiAIV, CoCr, and alumina particles : analysis of multiple cytokines using protein arrays. *J Biomed Master Res A* 2007 ; 84 : 464-474.
11. **Keel JB, Kuster MS.** Massive wear of an incompatible metal-on-metal articulation in total hip arthroplasty. *J Arthroplasty* 2004 ; 33 : 632-640.
12. **Korovessis P, Petsinis G, Repanti M, Repantis T.** Metallosis after contemporary metal-on-metal total hip replacement. *J Bone Joint Surg* 2006 ; 88-A : 1183-1191.
13. **Kudo H, Iwano K, Nishino J.** Cementless or hybrid total elbow arthroplasty with titanium-alloy implants. A study of interim clinical results and specific complications. *J Arthroplasty* 1994 ; 9 : 269-278.
14. **Little CP, Graham AJ, Karatzas G, Woods DA, Carr AJ.** Outcomes of total elbow arthroplasty for rheumatoid arthritis : a comparative study of three implants. *J Bone Joint Surg* 2005 ; 87-A : 2439-2448.
15. **Loebenberg MI, Adams R, O'Driscoll SW, Morrey BF.** Impaction grafting in revision total elbow arthroplasty. *J Bone Joint Surg* 2005 ; 87-A : 99-106.
16. **Malone AA, Taylor AJN, Fyfe IS.** Succesful outcome of the Souter-Strathclyde elbow arthroplasty. *J Shoulder Elbow Surg* 2004 ; 13 : 548-554.
17. **Mansat P, Adams RA, Morrey BF.** Allograft-prosthesis composite for revision of catastrophic failure of total elbow arthroplasty. *J Bone Joint Surg* 2004 ; 86-A : 724-735.
18. **Milosev L, Antolic V, Minovic A *et al.*** Extensive metallosis and necrosis in failed prosthesis with cemented titanium-alloy stems and ceramic heads. *J Bone Joint Surg* 2000 ; 82-A : 352-357.

19. Okafor CC, Haleem-Smith H, Laqueriere P, Manner PA, Tuan RS. Particulate endocytosis mediates biological responses of human mesenchymal stem cells to titanium wear debris. *J Orthop Res* 2006 ; 24 : 461-173.

20. Radmer S, Andresen R, Sparmann M. Total wrist arthroplasty in patients with rheumatoid arthtritis. *J Hand Surg* 2003 ; 28-A : 789-794.

21. Ramsey ML, Adams RA, Morrey BF. Instability of the elbow treated with semiconstrained total elbow arthroplasty. *J Bone Joint Surg* 1999 ; 81-A : 38-47.

22. Sanchez-Sotelo J, O'Driscoll S, Morrey BF. Periprosthetic humeral fractures after total elbow arthroplasty : treatment with implant revision and strut allograft augmentation. *J Bone Joint Surg* 2002 ; 84-A : 1642-1650.

23. Su EP, Callander PW, Salvati EA. The bubble-sign : a new radiographic sign in total hip arthroplasty. *J Arthroplasty* 2003 ; 18 : 110-112.

24. Thillemann TM, Olsen BS, Johannsen HV, Sojbjerg JO. Long-term results with the Kudo type 3 total elbow arthroplasty. *J Shoulder Elbow Surg 2006 ;* 15 : 495-499.

25. Wilkinson LM, Stanley D. Posterior surgical approaches to the elbow : a comparative anatomic study. *J Shoulder Elbow Surg* 2001 ; 10 : 380-382.

26. Willems K, De Smet L. The Kudo total elbow arthroplasty in patients with rheumatoid arthritis. *J Shoulder Elbow Surg* 2004 ; 13 : 542-547.