

PRESENT STATE-OF-THE-ART IN ELBOW ARTHROPLASTY

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Prosthetic joint replacement of the elbow is, with some delay in comparison with the shoulder, the finger joints and especially the hip and knee joint, becoming a routine operation at least in more specialised orthopedic and trauma centers. In the seventies and eighties, more than 80% of the indications were in patients affected by rheumatoid arthritis, in which both sides were typically affected, seriously jeopardising their independence in activities of daily living. In the last decade an increasing number of posttraumatic osteoarthritic cases were included in the indications. Among the numerous prosthetic devices, only a few have stood the test of time (> 10 years); a meta-analysis of the world literature shows an average follow-up of less than 5 years. Two main types of prostheses must be distinguished, linked and non-linked. The linked prostheses are, with few exceptions, so-called sloppy hinges with a clearance between both components, permitting movement in the sagittal plane and in the frontal plane and also some rotation. Using the normal anatomical stabilising structures, the stresses on the interface are reduced. This type of linked prostheses has a wider range of possible indications than the non-linked resurfacing prostheses, which require a largely preserved bone stock and intact ligaments in order to avoid instability with subluxations or even dislocations. Resurfacing prostheses can be more or less constrained according to the degree to which they mimic normal elbow anatomy. In order to reduce the stresses on the interface, the more constrained resurfacing prostheses make additional use of an intramedullary stem. The fixation of the device in the bone is achieved with bone cement in nearly all the linked and non-linked prostheses. Sloppy hinges with condylar configurations (as the GSB III elbow prosthesis) or an anterior flange (Coonrad-Morrey) further reduce the stresses on the interface and have

better long-term results. Special instruments help to place the prosthesis in correspondence to the normal center of rotation and to minimise the bone resection needed and the risk of intra-operative complications (condyle fractures, shaft perforation).

The results concerning pain relief and mobility are, for all properly placed prostheses, very satisfactory in the first years. A reliable account of long-term results (> 10 years of non-interrupted series of elbow prostheses) has so far been given only by a few authors. In cases with rheumatoid arthritis the survival rate at 10 years reaches 90%; the complication rate however is still definitely larger than with hip, knee and shoulder prostheses. This is particularly true for posttraumatic OA cases. Aseptic loosening, infection, instability and ulnar nerve lesions are at the fore and about twice as frequent as in RA, especially in patients below 60 years of age. In order to keep a safe retreat possibility open, we insist on the best possible preservation or reconstruction of normal anatomy (e.g. condyle reconstruction) when implanting an elbow prosthesis.

Keywords : elbow arthroplasty ; prostheses.

Mots-clés : arthroplastie du coude ; prothèses.

INTRODUCTION

While hip and knee arthroplasty and even shoulder arthroplasty have become routine operations in modern orthopedic centers of the western hemisphere, elbow arthroplasty still remains a rather

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seldom performed operation. The following reasons are at the fore :

1. A unilateral destruction of hip or knee joints cannot, in contrast to joints of the upper extremity, be functionally compensated by the opposite side.
2. The shoulder joint is much more frequently affected by degenerative and posttraumatic lesions than the elbow joint and hence jeopardises the ADL functions to a higher percentage.
3. Even in far advanced destruction of the elbow by rheumatoid arthritis (RA), more than 80% of the patients still maintain a flexion of 110° or more, which enables them to perform most self care activities (4).

However, to complete the majority of ADL activities with ease, we need a flexion/extension range of motion of about 100° (140-30-0°) (13) and a range of pronation/supination of 100° (50-0-50°). A reduction of elbow mobility by 50% reduces the functional value of the upper extremity by 80% (15).

Indications

No other disease has stimulated artificial joint replacement in the upper extremity more than rheumatoid arthritis (RA) with its relatively high (1-2%) incidence, frequency in still young patients and its characteristic bilateral involvement. The mostly successful operations in RA have stimulated the interest in using the same methods even for unilaterally destroyed elbow joints, especially in posttraumatic osteoarthritis.

Elbow arthroplasty must be considered in cases

1. Where there is irreparable incongruity of the joint surfaces after intra-articular fractures or fracture-dislocations or in stages 4 and 5 of RA according to the classification of Larsen-Dahle-Eek (10) .
2. When pain can no longer be controlled by drug administration.
3. When elbow function is severely limited by reduced flexion (< 100°) or extension (> -80°) and severe instability. Age, job, dominant or adominant arm, uni- or bilateral involvement

have an impact on the final decision, according to the varying individual demands.

The **contra-indications** are :

1. Still active infection and a relative contra-indication, post-infectious conditions
2. Poor skin condition with multiple scars, or skin adhering to the bone
3. Palsy of flexor or extensor muscles
4. Poor motivation of the patient
5. It goes without saying that all generally accepted contra-indications for surgical procedures, such as poor general health, preclude the performance of an elbow arthroplasty. Advanced age, however, with a good general condition is not, *per se*, a contra-indication. The same holds true for young patients, if other successful alternatives are not available.

Alternative procedures to artificial joint replacement

Reasons to be cautious with artificial joint replacement – as in all other joints – are young age and heavy physical demands (profession, sports, hobbies).

In RA, pain and swelling may prevail in the earlier stages (Larsen 1-3) where an *arthroscopic* or *open synovectomy* can give good results for a long period of time (> 10 y) in 2/3 of the cases (18).

Arthrodesis of the elbow is not a real alternative, but rather a salvage procedure e.g. in chronic infections, severe instability (flail elbow) and poor soft tissue conditions (extensive scar formation after burns, paralysis).

Resection arthroplasty may give remarkable results, but as there always exists a reverse relationship between stability and mobility, an increasing number (in our experience 1/3 after 5 years), of non-satisfactory results (e.g. painful instability) are to be expected. The same is true for *arthrolysis* and *distraction arthroplasty* in cases where joint surfaces remain incongruent. *Open* or *arthroscopic arthrolysis* give good results in cases where a well-defined intra-articular obstacle can be removed. An *open arthrolysis* can be successfully used, particularly for extra-articular stiffness.

Distraction arthroplasty (9), combined with remodelling of the joint surfaces, is a still relatively rarely performed alternative to artificial joint replacement in young and physically active patients. Its advantage : it leaves open the possibility of a later joint replacement, should the function deteriorate. However, in young RA patients with reduced physical demands, we prefer artificial joint replacement using our GSB III prosthesis with strict conservation (or reconstruction) of the condyles. This allows a retreat to a relatively stable “resection arthroplasty” should we be forced to remove the prosthesis (e.g. in case of severe infection).

Types of elbow prostheses

Hemi-arthroplasties with a metallic surface covering the lower end of the humerus have been used in rare instances in the sixties (16). The results were rather disappointing, not least because early aseptic loosening inevitably had to be expected in the great majority of cases where advanced bony destruction did not permit a good adaptation of the implant. Fully constrained metal-to-metal hinges were used in the early seventies with amazingly good early results concerning pain relief and mobility, but they had a high rate of loosening after a few years due to high stresses at the bone-implant interface. Prostheses which deliberately resected both condyles created insurmountable difficulties for the surgeon when trying to salvage these elbows (10, 11) (fig. 1). Fully constrained metal-to-metal hinges are therefore rarely used any more today (mostly after resection of malignant tumours). The rate of aseptic loosening according to the literature, reached 26-68% after only 3 years (6).

The question as to whether the use of a hinge might be justified at the elbow, was answered by London (11) and others, who showed that even though the elbow is not a true hinge joint, movements take place around one single axis except at the extremes of the range of motion.

Generally, we distinguish two groups of artificial elbow joints : linked and non-linked.

Linked prostheses are based on the hinge principle and can be fully constrained or semi-con-

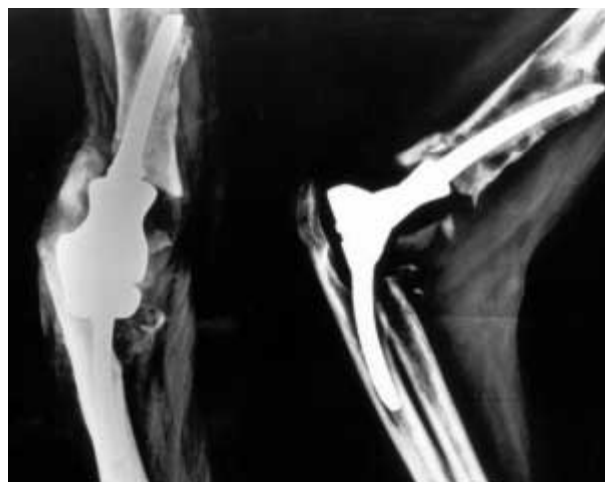


Fig. 1. — The Dee prosthesis, a fully constrained metal-to-metal hinge has become loose after a few years, with severe damage (spontaneous fractures, bone resorption) to the surrounding bone. Resection of the condyles makes a functionally efficient salvage extremely difficult.

strained according to whether motion is only possible in the sagittal plane (flexion-extension) or whether a clearance between both components (= *sloppy hinges*) allows for some degree of lateral movement (ab-/adduction), or even rotation. Intramedullary stems and cement fixation try to cope with the enormous forces acting on the implant. Swanson's constrained hinge (17) is one of the few remaining fully constrained hinges. Of many sloppy hinges which have been used in the eighties (fig. 2) we do not know whether they are still in use and what are the long-term results. The best known sloppy hinges from the USA are the Coonrad-Morrey and the HSS (Hospital for Special Surgery) prosthesis and in Europe the GSB III prosthesis. The HSS (fig. 2b) sloppy hinge is centrally loaded with some loading on the two condyles, at the extremes of varus and valgus. It has an axle which is only loaded at the extremes of tensile forces. The earlier snap-fit mechanism has been abandoned because of potential severe polyethylene wear and implant failure. The Coonrad-Morrey sloppy hinge (fig. 2a) is manufactured from titanium alloy Ti-6Al-4V with a cobalt chrome pin which passes through the ultra high molecular weight polyethylene bushing, to secure the ulnar component. The metallic pin is secured with a split

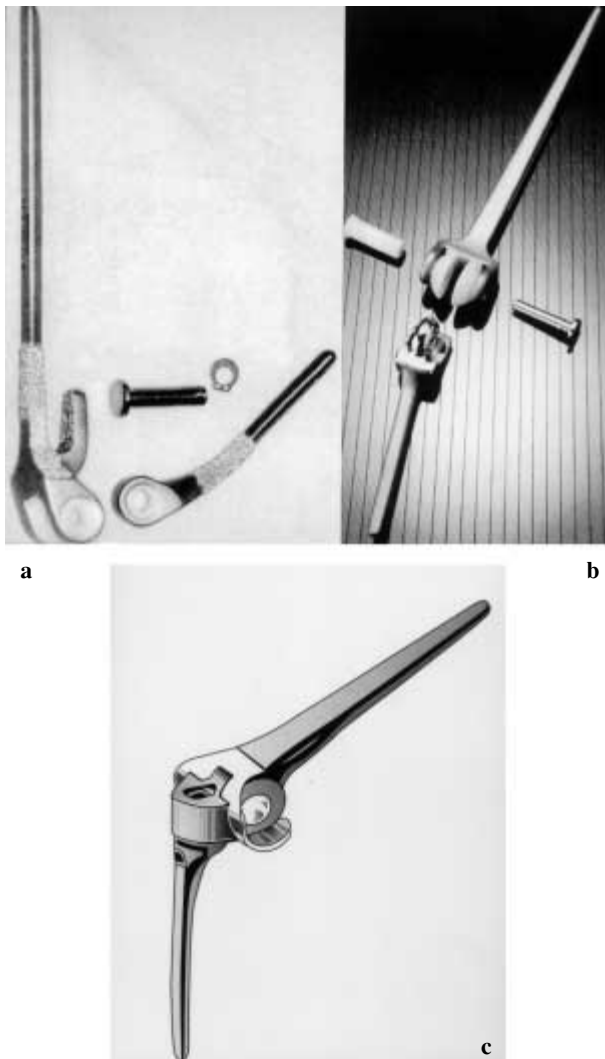


Fig. 2. — *a.* The Coonrad-Morrey prosthesis, a sloppy hinge prosthesis ; *b.* The HSS (Hospital for Special Surgery) sloppy hinge ; *c.* The GSB III sloppy hinge.

locking ring to avoid uncoupling. There is a 7°-to-10° hinge laxity or toggle, consistent with the average laxity of the normal elbow (13). In 1981 an anterior flange was added to the lower humeral stem, permitting the insertion of a bone graft, to enhance fixation at a point where maximum stress has been found to occur.

Non-linked prostheses only replace the joint surfaces. This can be done by means of a non-anatomical cylindrical humeral component rolling in the polyethylene of the ulnar component, (e.g. Roper-

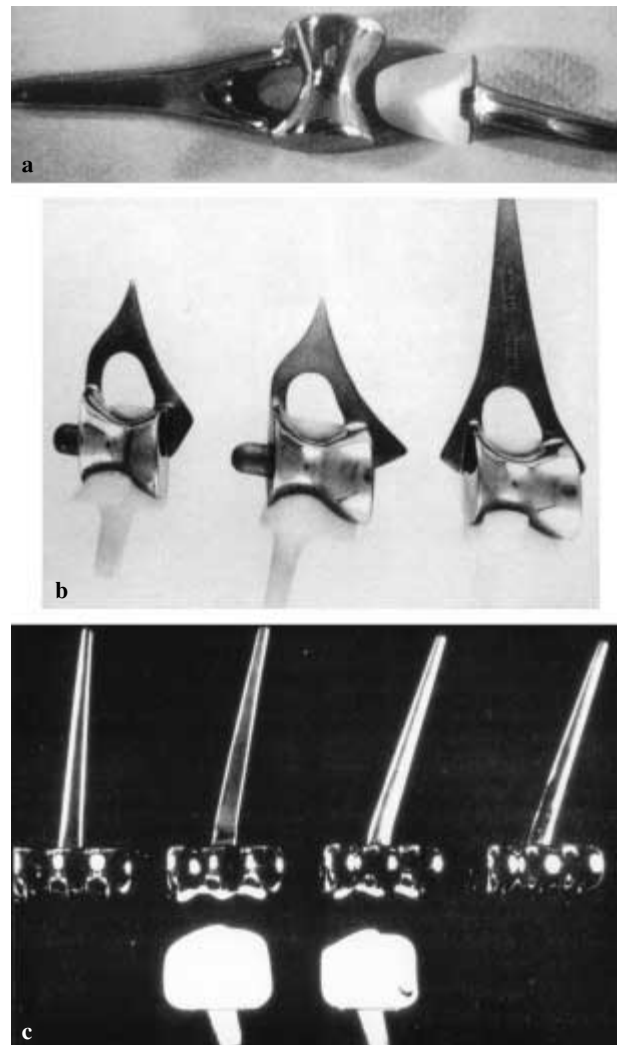


Fig. 3. — *a.* The Guepar elbow prosthesis, an "anatomical" resurfacing prosthesis ; *b.* The Souter-Strathclyde prosthesis, a more constrained anatomical resurfacing prosthesis ; *c.* The Capitello-Condylar prosthesis (Ewald), a more constrained "anatomical" resurfacing prosthesis.

Tuke, Kudo). These prostheses are called non-constrained resurfacing prostheses, in spite of the fact that there are only prostheses with more or less constraint, but none without. Resurfacing prostheses mimicking normal anatomy are called semi-constrained (Ewald, Souter-Strathclyde, Guepar) (fig. 3). An intermediate position between the non-anatomical and the anatomical resurfacing prosthesis is taken by the Norway, Wadsworth and Liverpool prostheses.

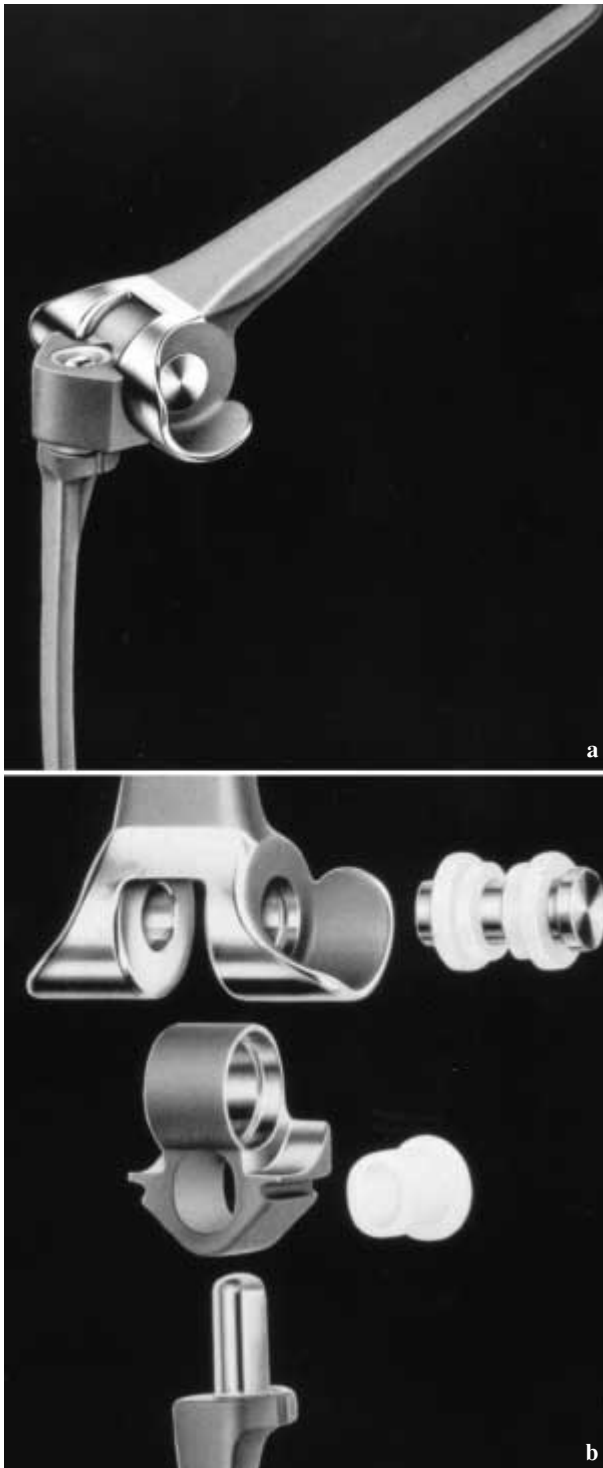


Fig. 4a+b. — The GSB III elbow prosthesis, a sloppy hinge with condylar support and HDP bushes for low friction.

All non-linked resurfacing prostheses have to rely upon intact ligaments and bony surfaces which remain fairly good.

The high rate of aseptic loosening in many non-linked prostheses, which were used in the beginning without stems, led to modifications using an intramedullary stem. Most of these prostheses are also fixed with bone cement. There are at least two reasons :

In rheumatoid arthritis the indication for replacement of the elbow joint with an artificial joint is frequently postponed until severe destruction is present and the original anatomical shape has been lost. There is no possibility of satisfactorily adapting the prosthesis to the remaining joint surface, not to mention the severe osteoporosis which is frequently present.

In posttraumatic OA, the surgeon not only encounters severely destroyed joint surfaces, but also cases with malunion. In such situations it is rather difficult to get enough bony ingrowth with a non-cemented prosthesis, owing to the limited possibilities of reducing the “jumping distance” to less than 1 mm. The medullary cavity of the humerus being quite variable in shape, rather ellipsoid distally and round proximally, the conditions for obtaining an optimal primary stability are rather poor. An exception is the Kudo prosthesis which has mostly been used for cases with RA and preserved anatomy.

The question as to whether the radial head should be retained, resected or replaced has been answered by most elbow surgeons resecting it. The few surgeons who initially replaced the radial head have given up doing so years ago and have shifted the ulnar joint part more to the center of the elbow, thus reducing the valgus stresses which may be increased by the radial head resection. To my knowledge only the Guepar prosthesis in its more recent model replaces the radial compartment.

In the last few years some other resurfacing prostheses have been presented on the market, but do not yet have a sufficient follow-up.

Long-term results (> 10 years) of larger series with non-linked prostheses have been published by only a few authors (Ewald, Souter). The complication and revision rate is for most non-linked resur-

facing prostheses definitely higher than with shoulder prostheses and far greater than with hip and knee prostheses.

A larger spectrum of possible indications is the characteristic of the *sloppy hinges*. The most frequently used prostheses of this type are the Coonrad-Morrey, the HSS (Hospital for Special Surgery) and the GSB III prosthesis.

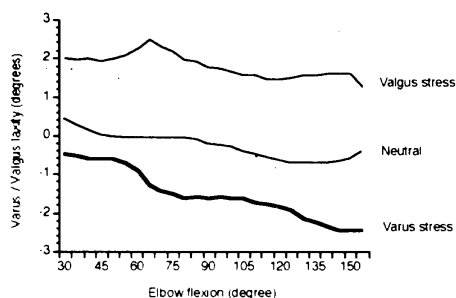
The GSB III prosthesis (fig. 4)

The GSB III prosthesis has been in use since 1978 without essential modifications. It is the result of a careful analysis of the pitfalls seen with the first generation, namely the GSB I prosthesis (1971) a fully constrained metal-metal hinge and the GSB II prosthesis (1976) which already used epicondylar flanges, but did not yet have the characteristics of a sloppy hinge and the low friction principle.

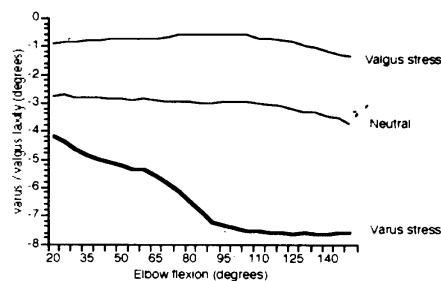
The GSB III prosthesis was constructed in 1978 and has been used since then in over 350 cases without major modifications. It is one of the sloppy hinges and works on the principle of low friction arthroplasty at the hinge mechanism as well as in the connecting piece between the humeral and ulnar components. The humeral component has large supporting surfaces on the medial and lateral condyles. Furthermore, its stem is wide for the transfer of rotational stresses and is easy to introduce in the oval-shaped entrance of the medullary cavity. On the hinge part of the humeral component, an oval connecting piece is fixed in which the

ulnar component fits. There is a clearance between both, allowing lateral movement in the varus or valgus direction as well as some rotation. There is also, to a certain degree, a piston movement. The GSB III prosthesis permits a hyperextension of approximately 10° and has a range of motion of 180° . A study (Herren *et al.*) (8) using an electromagnetic tracking device, monitored the three-dimensional orientation of the ulna, relative to the humerus in neutral, valgus and varus positions during simulated active motion. The same protocol was used for the intact elbow before and after the implantation of a GSB III prosthesis, according to the usual surgical techniques, with only partial detachment of the collateral ligaments and after complete cut of both collateral ligaments. Herren *et al.* were able to prove that the GSB III elbow prosthesis functions as a true semiconstrained device with an overall pattern of motion comparable to the normal elbow. This motion pattern is potentially greater than allowed by the ligaments, indicating that the ligaments do absorb some of the forces during function (fig. 5).

Another specific feature of the GSB III prosthesis is the flanges of the humeral component which rest on the medial and lateral condyles and cover them anteriorly and distally. They help to significantly reduce the stresses on the interface, especially during normal daily activity, which is mostly done with the elbow flexed and a more or less important degree of shoulder flexion-abduction. The stress on the interface depends largely on the amount of torque, which depends on the relation-



Intact elbow



GSB III elbow prosthesis

Fig. 5. — Elbow laxity in the normal elbow compared to GSB III elbow

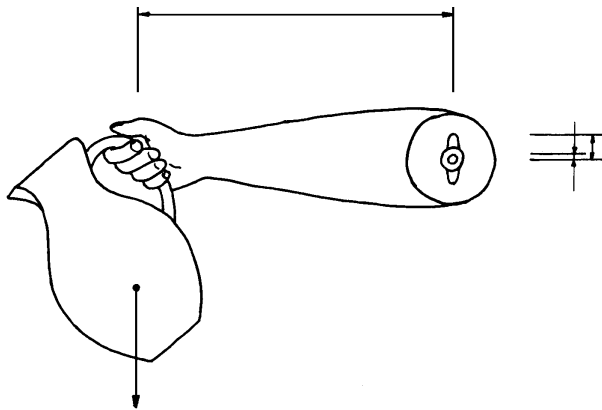


Fig. 6. — The stress on the interface largely depends on the amount of torque, which depends on the relationship of the lever arm and the radius of the implant fixation device (cemented stem of the humeral component with or without epicondylar flanges).

ship of the moment arm (length of the forearm plus weight) and the radius of the implant fixation device (the cemented stem of the humeral component with or without epicondylar flanges) (fig. 6).

The ratio of the lever arms in cases of purely intramedullary and epicondylar fixation (as for the GSB III prosthesis) is 4.7 (4.2-5.0). Due to the different lever arm of the forearm in a short person compared with a tall person, the torque varies (tabl. I). Comparing the torque acting on the interface in prostheses with only an intramedullary fixation, or with an epicondylar fixation, we find a remarkable difference of torque in favour of our epicondylar fixation. As expected, this difference increases with the weight carried in the hand (tabl. II).

These specific features may account for the high percentage of survival after more than 10 years (see below). On the other hand it demands a minimal intracondylar bone resection for implantation and, in cases of fracture of the epicondyles, stable fixation, or where the condyles are missing, their reconstruction by means of autologous bone grafts (figs. 7, 8). This keeps a safe retreat possibility open in cases where the prosthesis has to be removed (e.g. in a recurrent deep infection) and guarantees fairly good stability.



Fig. 7. — Only reconstruction of the condyles by means of a full-thickness autologous graft from the pelvis (5) combined with implantation of a sloppy hinge with condylar support (e.g. GSB III prosthesis) has a chance to restore a well moving and stable elbow (Fig. 10). **a.** From the mid part of the pelvis, a full thickness graft measuring 2.5/8 cm or 5/8 cm if both condyles have to be replaced ; **b.** The deficit is covered with bone from the bone bank.

The **material** used in the GSB III prosthesis :

The component exposed to torsion and flexion is made out of the clinically tested and fatigue-fracture resistant Protasul-10 alloy. The components exposed to motion fatigue are made from wear-resistant, cast alloy Protasul-2. Both components are safely connected by a special welding procedure. The synthetic cases are made from Sulene-PE.

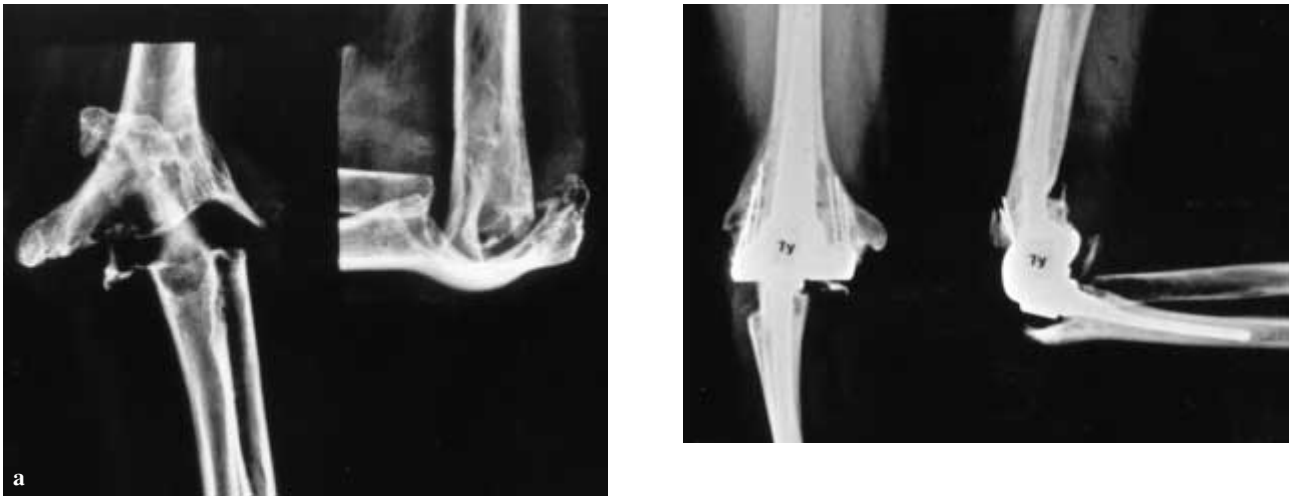


Fig. 8. — Elbow in severe RA with extensive bone resorption at the condyles. Reconstruction of the condyles by means of autologous bone implants taken from the resected bone while implanting the GSB III prosthesis. Seven years after surgery, excellent interface and well-healed grafts.

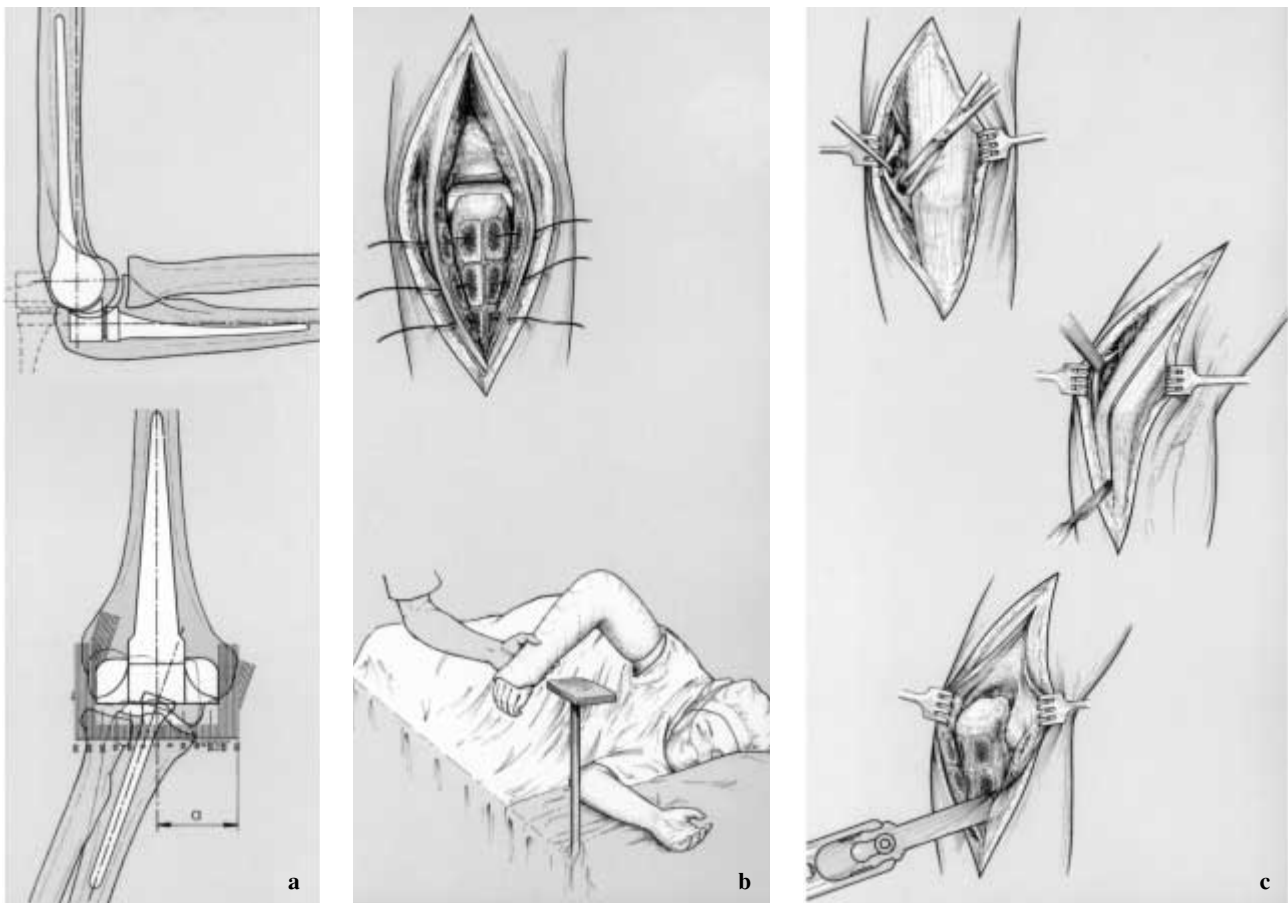
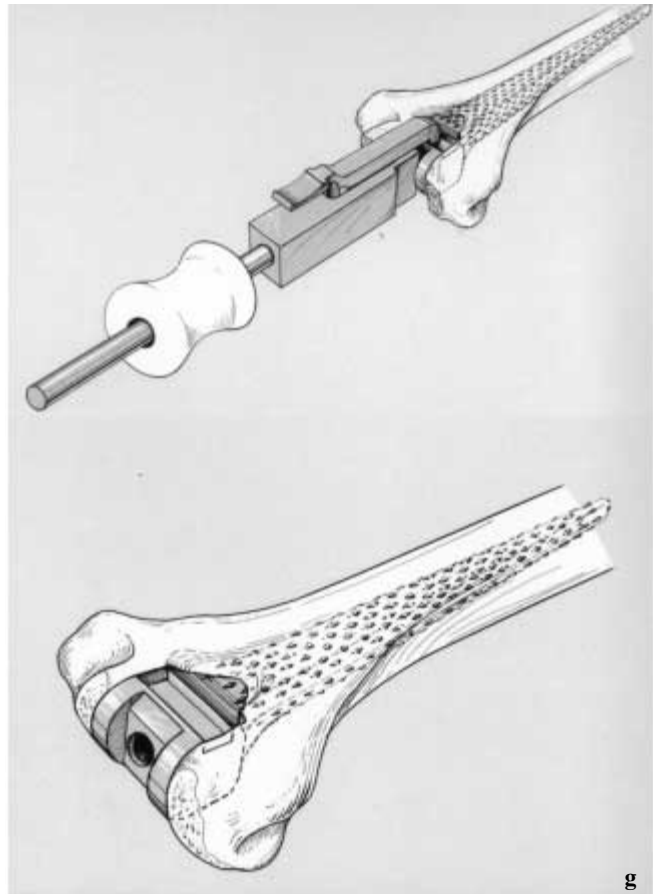
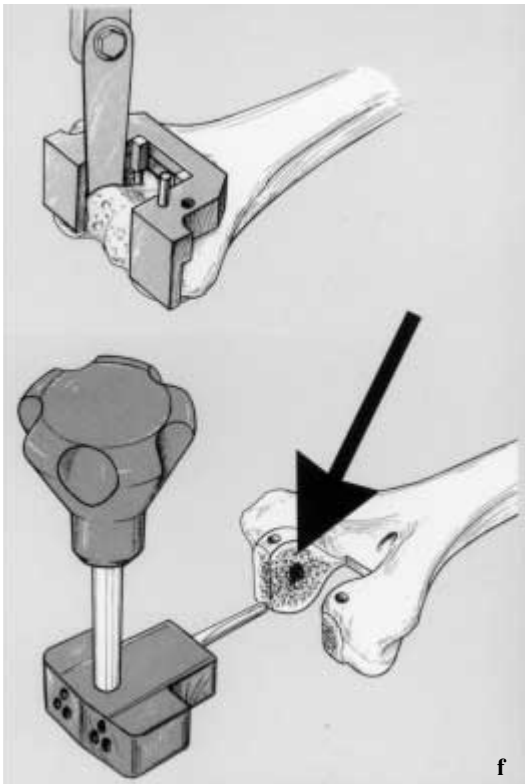
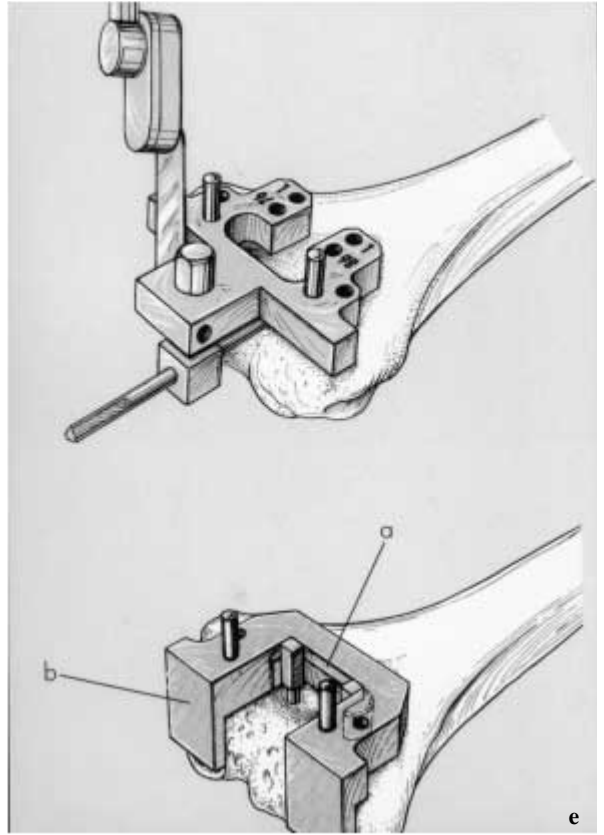
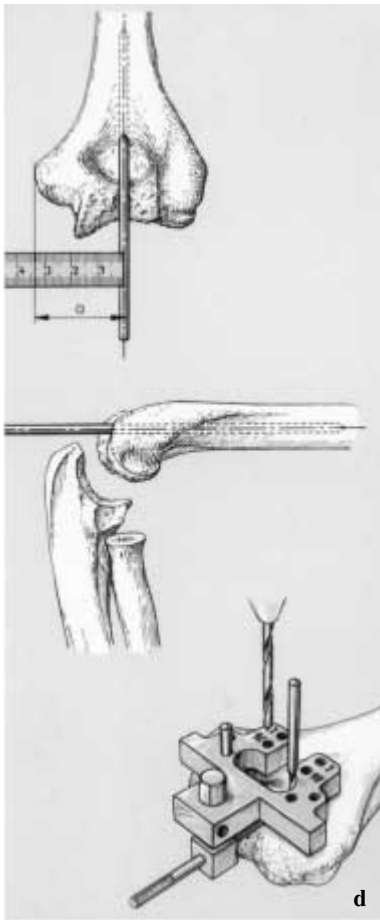


Fig. 9. — Technique for implantation of the GSB III elbow prosthesis operative.



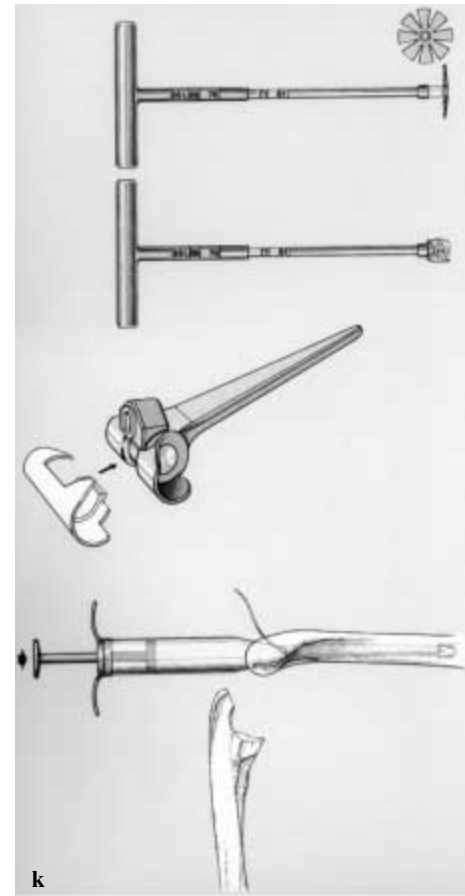
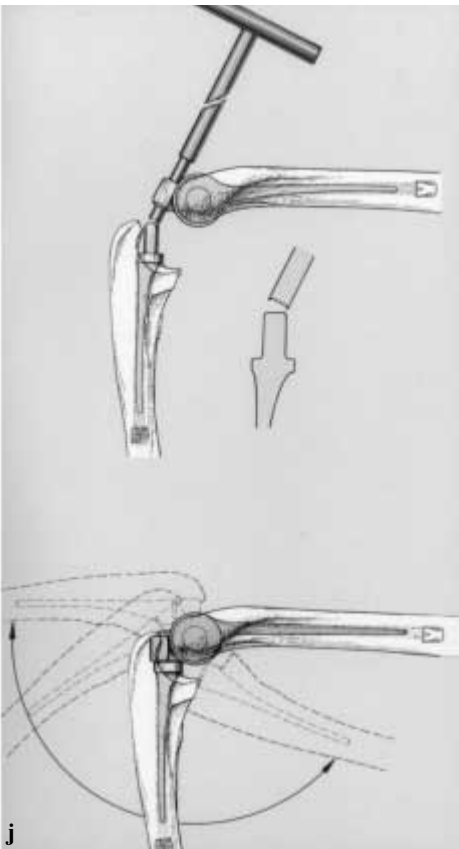
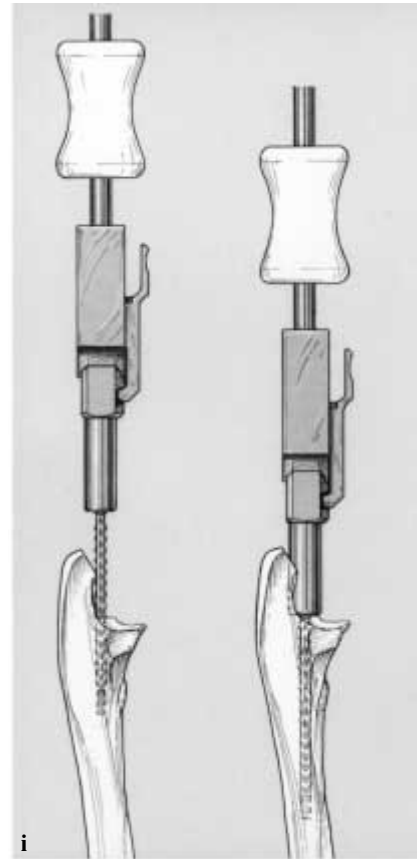
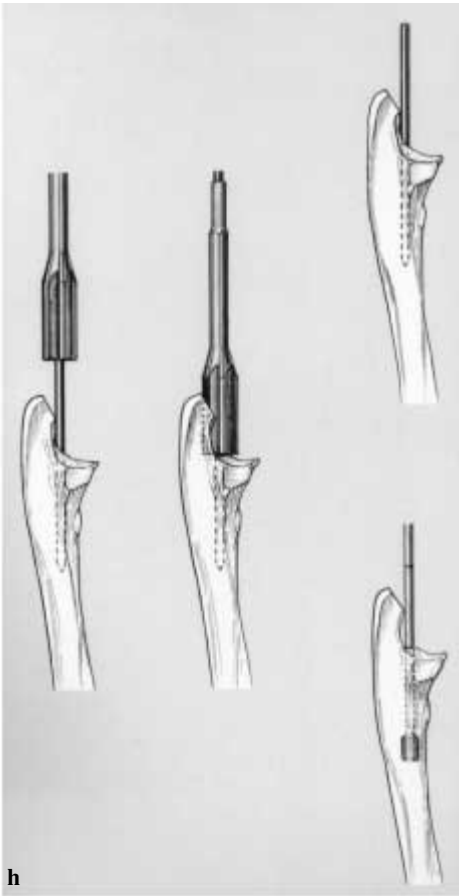


Fig. 9. — Operative technique

Table I. — Torque in intramedullary fixation of elbow prostheses

Small person :	30-35 cm : 0.4 cm = 75-88
Average person :	35 cm : 0.5 cm = 70
Tall person :	35-40 cm : 0.6 cm = 58-67
Average :	70 (58-88)
Torque in epicondylar fixation	
Small person :	30-35 cm : 2 cm = 15-17
Tall person :	35-40 cm : 2 cm = 14-16
Average	15 (14-17)

Produce range : The GSB III elbow prosthesis comes in three humeral sizes and four different ulnar components. All components can be freely combined with each other.

SURGICAL TECHNIQUE (fig. 9)

Careful pre-operative planning is essential where the size of both components is determined by means of a template on an AP xray of the extended elbow and a lateral view at 90° of flexion (fig. 9a). Moreover, we can define the entry point of the Steinman pin into the humerus with a mm-scale. In cases of severe destruction of the distal humerus we use the xray from the opposite elbow to determine the approximate level of the center of rotation in relation to the proximal border of the olecranon fossa, which is preserved even in severe bone loss. The patient is positioned on his lateral side and the arm placed at right angles on a padded support. A sterile tourniquet is placed over the proximal part of the humerus (fig. 9b).

A dorsal incision starting on the midline about 10 cm proximal to the tip of the olecranon is slightly curved to the radial side around the olecranon and ends again in the midline over the dorsal crest of the ulna, 8-10 cm distal to the olecranon tip. Where there have been previous operations the scar closest to our usual incision is chosen, provided there is a distance of at least 3-4 cm from other scars and freely movable skin without adhesions to the underlying bone (fig. 9c).

The ulnar nerve is routinely exposed and mobilised as far as the origin of the first motor

Table II. — Stresses on interface

	Intramedullary fixation	Epicondylar fixation
Forearm		
No weight	70 kg (58-88)	15 kg (14-17)
1 kg	150 kg (116-176)	30 kg (28-34)
4 kg	350 kg (290-440)	75 kg (70-85)
9 kg	700 kg (580-880)	150 kg (140-170)

branch distal to the sulcus. The accompanying vessels should be carefully protected. The triceps tendon is split in its middle part 6 cm proximal to the olecranon-tip. The triceps is detached with thin bone slivers from the ulna using a sharp chisel. The tip of the olecranon is resected as well as any sharp bony spicule from the distal edge of the trochlear notch that may jeopardise the ulnar nerve during the necessary manipulations while preparing the bone for implantation. Particular care is necessary in a very thin shell-like olecranon where we always meticulously preserve the longitudinal median crest. Resection of the head of the radius is routinely done, protecting the radial nerve with a subperiosteal retractor. The collateral ligament should not be detached, or only left attached with a thin bone sliver in ankylosed cases, in order to improve mobility if other soft tissue releases (anterior capsule) or the removal of bony prominences do not suffice. A guiding Steinmann pin is inserted at the spot determined by the template preoperatively (fig. 9d). On this Steinmann we position the condyle resection guide which is anchored with two pins on which the condyle protection guide can be placed, together with the humerus box guide after resection of the condylar extensions (fig. 9e). The intercondylar block is resected without risk concerning bony lesions or even fracture of the condyles (fig.9f). These precision cuts, similar to those obtained in modern knee arthroplasty, allow for reliable localisation of the center of elbow rotation and, after preparation of the medullary cavity by means of the humerus drilling guide reamers and the use of the special rasp, the implantation of



Fig. 10a+b. — Severe RA, with the ulnar condyle completely missing. The thin shell of the broken olecranon can be seen. Reconstruction of the missing condyle with a full-thickness graft 2.5/8 cm, taken from the mid part of the pelvis (fig. 7). The graft is fixed between an AO reconstruction plate and the ulnar flange of the GSB III elbow. Seven years after surgery : well healed, solid graft, excellent interface.

the GSB III prosthesis at the corresponding level of both the natural and the prosthetic center of rotation. The condyles are prepared with an oscillating saw, so that they end flush to the rounding of the rasp that corresponds to the inner side of the condylar support of the prosthesis (fig. 9g). The position is then checked with a trial prosthesis. For the preparation of the ulna a Steinmann pin is carefully inserted into the medullary canal which is situated

quite dorsal and bends radially. A large and a small reamer prepare the bed for the ulnar component after having enlarged the medullary canal with various reamers and the rasp (fig. 9h). The trial prosthesis is inserted and assembled with the humeral component and the range of motion is tested (fig 9i, j). Full extension and unobstructed flexion should be achieved. Should the tension after coupling be insufficient, tension can be increased by moving the ulnar component more proximally by means of a PE washer.

With the aid of a special uncoupling instrument, the trial prosthesis is removed, the medullary cavity sealed at the precise level with a HDP plug for the humerus and a bone plug for the ulna (fig. 9k). A drain is inserted, the medullary cavity is dried and low viscosity bone cement is injected retrograde with a syringe. With a cement protector the humeral component is first inserted and carefully adapted to the humeral condyles. In cases of bone loss, we add to the defective condyle an autologous bone graft which is fixed by means of 3 or 4 1-mm K-wires which are bent backwards at their ends. Only for completely missing condyles do we use full-thickness grafts from the midpart of the iliac crest and fix them with a reconstruction plate and screws in intimate contact with the lateral side of the humeral shaft and the condylar flange of the prosthesis (fig. 10). All cement escaping from the medullary cavity anteriorly is removed as well as that eventually entering the hinge mechanism of the prosthesis. After temporary uncoupling of the components, the Esmarch band is opened for haemostasis and reapplied. The triceps is fixed to the olecranon with 3 transosseous sutures, which were placed before inserting and cementing the ulnar component. We practically never translocate the ulnar nerve, but document preoperative lesions and deficits of nerve function.

Aftercare

A prepared dorsal plastic elbow splint in 40° flexion is placed on the well padded-elbow in neutral pronation and supination including the wrist. Five to 7 days after surgery, we start assisted active flexion (never beyond 90° in the first 2-3 weeks or

before safe wound healing) and purely passive extension. After 3 weeks, flexion is increased and assisted active extension allowed. This treatment is done 2-3 times daily, after wound healing. Continuous passive motion can be used. Physiotherapy continues on an outpatient basis with the purpose of increasing the strength and range of extension. The goal is to achieve an active extension equalling the passive extension after 4 weeks. Otherwise, the stronger flexors will gradually take over the active extension deficit. Occupational therapy should start after 2 weeks as an important complement to physiotherapy in order to reach independence in the activities of daily living as soon as possible.

RESULTS

Numerous problems arise if we try to compare the results published for different elbow prostheses. The great majority of studies do not present a **complete serie of patients** that include the results and particularly the complications in those patients who have died in the meantime. Moreover, different, more or less experienced, individuals are frequently made responsible for the examination of patients living far away from the hospital where they were operated on or these patients were contacted only by phone.

The greatest problem, however, concerns the **short-term follow-up**. A meta-analysis of 31 relevant publications in the world literature from 1987 till 1997 gave an average follow-up of only 4.89 years (2.3-9.6 years) which is obviously not enough if we consider, for instance, that in a very reliable publication (12), the authors using the Pritchard Mark II prosthesis found a survival rate of 92% at 5 years which dropped to 43% at 8 years. We hardly have any reasons to trust the great number of optimistic reports on results with a mean follow-up below 5 years.

Varying indications : The great majority of reports on results with elbow prostheses concern RA patients. If the operation is not postponed to a stage of irreparable bone loss, good and even excellent results are much easier to obtain in comparison

to posttraumatic osteo-arthritis. In the latter cases the great majority had undergone previous surgery, sometimes several operations (osteosynthesis, surgery for delayed union, malunion or nonunion) using screws or plates which are still in place. The risk of complications (delayed wound healing, infection, nerve damage, adhesions etc.) is considerably increased. From the technical point of view prosthetic replacement of posttraumatic elbows is more demanding, because bone loss, deformity and instability due to damage to the ligaments are by far more frequent than with RA.

All these differences concerning the results of elbow arthroplasty according to the underlying pathology make the comparison of different methods difficult. In a disease such as RA, the ADL function, as one of the possible criteria, depends only partly on elbow function, but additionally also on the function of the shoulder, wrist and finger joints. Demands on an operated elbow vary greatly according to the condition of the opposite arm and whether the dominant or adominant elbow has been operated, whether crutches are needed because of damage to the joints of the lower extremity, etc.

Not only the quality of bone, but sometimes even more importantly the condition of the soft tissues (ligaments, nerves etc.) may have a considerable impact on the outcome, with special regard to complications and revisions.

A meta-analysis of the results reported in the world literature from 1986 to 1992 (22 relevant publications with a total of 838 elbow arthroplasties) with an average follow-up of less than 5 years, gave mostly positive figures concerning pain relief (85-95%) and gain in range of motion (20°-40°), which amounted to 120-140° for flexion and -20°-50° for the extension deficit.

The complication rate however was high : 357/828 corresponding to 43% ; the revision rate was 18% (151/828). The percentage of permanent complications amounted to 15% (124/828).

The main complications concerned aseptic loosening (17.2% radiological, 6.4% clinical loosening), infections (8.1%), ulnar nerve lesions (10.4%), instability (7% to 19%), dislocations (4.3%), subluxation (2.2%-6.5%) and intraoperative fractures (3.2%).

In the more recent literature the number of complications has decreased, at least when considering publications written by very experienced authors (Ewald, Inglis, Morrey, Souter). Moreover, the number of studies with a longer follow-up (> 10 years) is increasing (Ewald, Morrey, Gschwend). This may improve our judgement as to which prostheses are likely to give long standing results for the various conditions of elbow destruction.

Results with the GSB III elbow joint.

From 1978 till 1997, 288 GSB elbow prostheses were implanted at the Schulthess Clinic in Zurich, 186 for RA and 102 for OA, mostly posttraumatic. A survey has been done on the first 197 elbow prostheses of which 155 were for RA and 42 for OA (35 with posttraumatic OA). The pre-operative mean value for pain on a visual analogue scale from 0-10 was 7.67 for RA and for posttraumatic OA 6.10. The corresponding postoperative values were 0.25 and 1.02 respectively. The flexion/extension range for RA increased from 119°-37°-0 to 139°-27°-0 and for posttraumatic OA from 96°-44°-0 to 128°-32°-0 representing a gain of 30° for RA cases and 44° for OA cases. The pro/supination values increased for the RA cases from 54°-0-50° pre-operatively to 73°-0-67° postoperatively and for the OA cases from 57°-0-49° to 76°-0-72°. The results in ankylosed and stiff elbows showed only a minor difference of about 5° between the stiff elbows and the general group concerning flexion, and a more important difference concerning the extension deficit for the stiff elbows: -35° for OA and -29.1° for RA compared to -27° for the whole group.

We compared our complication rate with the meta-analysis of the world literature 1986-92 and found in our cohort an infection rate of 1.7% for the RA cases and 3.8% for the OA cases, compared to 7.1% (3.5% superficial and 4.6% deep infections) in the world literature. Disassembly of both components was relatively high in our survey with 4.2% compared to 4.3% dislocations and 2.2% subluxations in the meta-analysis study. Ulnar nerve lesions were rare in our cohort with 2% compared to 10.5% in the meta-analysis of the world literature.

Long-term results

The value of any type of artificial joint replacement can best be estimated if we have reliable clinical and radiological data on a significant number of joints replaced more than 10 years ago. The reliability also depends however on the competence of the examiner and the quality of xrays taken, as well as on a careful analysis of the results with special regard to complications and revisions in those patients who died before 10 years had elapsed since surgery. For obvious reasons such surveys are rare in the world literature and with regard to elbow prostheses only 3 relevant studies (including our own on the long-term results of the GSB III elbow prosthesis) were found. Ewald's long-term follow-up with the Capitello-condylar elbow prosthesis (2) and Morrey's publication on the Coonrad-Morrey elbow prosthesis (3) found a survival rate at 10 years of over 90% for RA elbows. In Morrey's series we may wonder what will happen in the near future to those elbows which had complete (7%) or partial (8%) wear of the polyethylene bushings as well as to those which had radiological signs of circumferential or partial (>50%) radiolucencies either at the humeral or ulnar or both components. These cases, even if they had no relevant pain or functional impairment at the last follow-up, might soon need revision surgery. The mean duration of radiographic follow-up in Morrey's series was slightly less than 10 years, i.e. 115 months for those patients still alive. In Ewald's series with an average follow-up of 16 years (10-23 y) 9% of 153 surviving patients had their elbow exchanged, 3% for infection, 3% for dislocation and only 1.4% for loosening. Incomplete and less than one-millimetre wide radiolucent lines were found in 4% of humeral and 9% of ulnar components. Forty four percent had other orthopedic complications, among which ulnar nerve palsy was the most frequent (18%). However, only 5% had permanent deficits. Eleven percent had dislocation or subluxation and were treated conservatively. It is not stated whether full and permanent stability was achieved. The author however expresses his concern about an increased loosening rate due to polyethylene wear debris with subsequent osteolysis in a longer-term analysis.



Fig. 11a+b. — Severe mutilating rheumatoid arthritis in an elderly lady. 14 years after GSB III arthroplasty there is no trace of radiolucency at the interface in spite of a severe osteoporosis (cortisone medication) and excellent mobility.

Our own long-term analysis (7) concerns the first series of GSB III elbow arthroplasties performed between 1978 and 1986. Fifty-one of the 59 patients suffered from RA, 8 from posttraumatic OA. From the total of 59 patients with 65 elbow prostheses, 24 patients with 28 elbow prostheses died in the meantime, although two of them – both operated bilaterally – had carried their elbow prostheses for more than 10 years and had already been

assessed for inclusion in the long-term follow-up. Two patients, each with one elbow prosthesis, were lost to follow-up, they had left Switzerland for Mexico and Italy without providing a new address. Three male patients still living (2 suffering from posttraumatic arthritis, 1 from juvenile arthritis) had had their prosthesis removed before 10 years had elapsed. They figure among the complications. The remaining 32 patients (28 RA, 4 posttraumatic



Fig. 12a+b. — Pseudarthrosis after 4 failed attempts to reconstruct a C3 fracture of the distal humerus. The elbow joint itself was ankylosed (fibrous ankylosis), the mobility took place only in the pseudarthrosis (flail elbow). The patient was sent to us several years after the original fracture. The reconstruction of the condyles with bone from the remaining fragments and fixation with K-wires and a screw, led to a pain-free and stable elbow with 140° of flexion, but an important extension deficit due to damage to the triceps (4 previous operations). Excellent interface.

OA) with 36 GSB III elbows, were clinically and radiologically examined on average 13.5 years post-operatively. Pain was absent, or only slight and occasionally present, in 91.6% of the cases. Mobility (flexion/extension) increased by 37° for the RA cases (flex/ext. postop. 144.2°/-27.8°) and 67° for the posttraumatic OA cases (flex/ext postop. 141°/-44°). Aseptic loosening and deep infection were each observed at a frequency of 4.6% (3/65). The most frequent complication (9/65 = 13.8%) was disassembly of the prosthetic components, although 2 of the 3 infections mentioned, 2 postoperative fractures unrelated to the operative technique and one case of syringomyelia, are included in this group. Disassembly as a complication had to do with the learning curve, specifically with inadequate placing of the centre of rotation of the prosthesis in relation to the natural centre of rotation in the normal elbow. The introduction of precision instruments with special guides and the prolongation of the connecting ulnar component allow the elimination of this type of complication. Ulnar nerve lesions with permanent hypesthesia or

paresthesia were found in 2 cases (3%). With 87.9% of the 65 GSB III prostheses remaining *in situ* after more than 10 years, our results approach those reported for hip and knee prostheses.

Two examples, one representing the 14 years result in an elderly lady (fig.11a+b) suffering from mutilating RA, the other the 15 year result in a posttraumatic osteoarthritis (fig.12a+b) may show the efficacy of the GSB III elbow arthroplasty.

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SAMENVATTING

N. GSCHWEND. Elleboog protheses : huidige stand van zaken.

Totale elleboog vervanging wordt stilaan, al zij met vertraging ten opzichte van de heup, de knie, de schouder en de vingers, ook routine heelkunde in gespecialiseerde trauma- en orthopediecentra. Aanvankelijk ging het in meer dan 80% van de indicaties om ellebogen aangetast

door reumatoïde artritis. Dikwijls waren beide ellebogen ernstig aangetast en waren de patiënten hierdoor sterk functioneel gehandicapt en afhankelijk. In de laatste 10 jaar nam de indicatie "posttraumatische arthrosis" aanzienlijk toe. Van de vele ontwerpen hebben slechts enkelen 10 jaar overleving gehaald ; in een meta-analyse van de wereldliteratuur blijkt de gemiddelde overleving lager dan 5 jaar. Fundamenteel bestaan er twee types van prothese : namelijk de scharnier protheses en de geleidingsprotheses. De meeste scharnier ontwerpen hebben geen rigide onderlinge verankering, zodat naast bewegingen in het sagitale en frontale vlak ook nog enige rotatiemogelijkheid bestaat. De stabiliteit wordt verzekerd door de anatomische structuren, zodat de weerslag op de botfixatie van de prothese wordt beperkt. Het indicatiedomein van dit type prothese is breder dan dat van de geleidingsprothese, waarbij enkel de gewrichtsvlakken worden vervangen, en dus de botstructuur van het gewricht en de stabiliserende ligamenten grotendeels intact moeten zijn, wil men subluxatie of luxatie mijden. Er bestaan geleidingsprotheses met zeer conforme en met weinig conforme contactvlakken, afhankelijk van hoe nauw ze de normale elleboog-anatomie volgen. De zeer conforme protheses vereisen een intramedullaire stem om de krachten op de prothesen-bot overgang te verminderen. Praktisch alle protheses worden gecementeerd. Bij de "losse" scharnierprotheses met een condylair element (GSB III) of met een anterieure plaat (Coonrad-Morrey) is het krachtkoppel werkzaam op de botfixatie nog minder sterk en derhalve het lange termijn resultaat beter. Precisie instrumentarium verzekert minimale botresectie, helpt bij de juiste centrering van het implantaat en vermindert sterk het risico op peroperatoire complicaties (zoals condylaire fractuur en diaphyseperforatie).

Het resultaat op korte termijn, wat pijn en beweeglijkheid aangaat, is gunstig, als de prothese correct geplaatst is. Er zijn slechts enkele studies voorhanden waar de resultaten op lange termijn degelijk worden besproken (follow-up van 10 jaar). Het overlevingscijfer na 10 jaar bij reumatoïde artritis bereikt 90% ; maar het aantal complicaties ligt veel hoger dan bij de heup, de knie en de schouder. In geval van posttraumatische arthrosis en zeker bij patiënten onder de 60 jaar, ligt de kans op loslating, infectie, instabiliteitsproblemen en N. Ulnaris aantasting tweemaal hoger dan bij reumatoïde artritis. Zeker moet zo goed mogelijk de normale anatomie (bijvoorbeeld de condylaire configuratie) worden bewaard bij het plaatsen van een elleboogprothese, omdat men bedacht moet zijn op een mogelijke revisie.

RÉSUMÉ

N. GSCHWEND. État actuel de l'arthroplastie du coude.

Le remplacement prothétique de l'articulation du coude est en train de devenir une opération de routine, du moins dans des centres d'orthopédie-traumatologie spécialisés ; cette évolution s'est faite avec un certain retard par rapport à d'autres articulations comme l'épaule, les articulations des doigts et surtout la hanche et le genou. Dans les années 1980 et 1990, les indications d'arthroplastie du coude concernaient dans plus de 80% des cas des patients atteints d'arthrite rhumatoïde, présentant habituellement une atteinte bilatérale qui interférait gravement avec leur indépendance dans la vie de tous les jours. Un nombre croissant d'arthroses posttraumatiques du coude sont venues s'ajouter aux indications, au cours de la dernière décennie. Parmi les nombreuses prothèses qui ont vu le jour, seules quelques unes ont résisté à l'épreuve du temps (> 10 ans) ; une méta-analyse de la littérature montre un suivi moyen inférieur à 5 ans. Il faut distinguer deux types principaux de prothèses : les prothèses contraintes et les non-contraintes. Les prothèses contraintes sont, à de rares exceptions près, ce que l'on a appelé des «charnières molles», avec un jeu entre les deux composants permettant des mouvements dans le plan sagittal et dans le plan frontal, et un peu de rotation. Ces prothèses utilisent pour leur stabilité des structures anatomiques normales, ce qui réduit les contraintes aux interfaces. Ce type de prothèse contrainte peut trouver des indications plus étendues que les prothèses de resurfaçage non contraintes, qui exigent un capital osseux bien conservé et des ligaments intacts pour éviter une instabilité génératrice de subluxation, voire de luxation. Les prothèses de resurfaçage peuvent

être plus ou moins contraintes, en fonction de la façon dont elles reproduisent l'anatomie normale du coude. Dans le but de réduire les contraintes aux interfaces, les prothèses de resurfaçage les plus contraintes recourent en outre à une tige intra-médullaire. La fixation osseuse se fait au ciment, pratiquement pour toutes les prothèses contraintes et non-contraintes. Les «charnières molles» qui comportent un élément condylien (comme la GSB III) ou une plaque antérieure (Coonrad-Morrey) ont de ce fait des contraintes encore plus faibles sur les interfaces et elles donnent de meilleurs résultats à long terme. Des instrumentations précises aident à placer la prothèse à l'emplacement exact du centre de rotation et à minimiser la résection osseuse et les risques de complication peropératoire (fracture condylienne, perforation diaphysaire).

Les résultats sur la douleur et la mobilité sont satisfaisants à court terme pour toutes les prothèses correctement implantées. Quelques auteurs seulement ont fourni une description fiable de leurs résultats à long terme (séries continues de prothèses de coude avec recul de plus de 10 ans). Dans l'arthrite rhumatoïde, la survie à 10 ans atteint 90% ; cependant, le taux de complications reste largement supérieur à ce qu'il est pour les prothèses de hanche, de genou et d'épaule. Ceci est particulièrement vrai pour les cas d'arthrose post-traumatique, dans lesquels le descellement aseptique, l'infection, l'instabilité et les lésions du nerf cubital sont environ deux fois plus fréquents que dans l'arthrite rhumatoïde, en particulier chez les patients de moins de 60 ans. Nous insistons sur la conservation ou la reconstruction aussi poussée que possible de l'anatomie normale (par exemple la reconstruction condylienne) lors de l'implantation d'une prothèse de coude, car il est nécessaire de se réserver une position de repli.