



MIKKO IKÄVALKO

# Rheumatoid Elbow Destruction and its Treatment with Souter-Strathclyde Arthroplasty



ACADEMIC DISSERTATION

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the Faculty of Medicine of the University of Tampere,  
for public discussion in the auditorium of Finn-Medi 1,  
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Heinola, 4. May 2004 Mikko Ikävalko



## ABSTRACT

Elbow involvement is very rarely seen in the early years of rheumatoid arthritis, but 15 years after onset of disease approximately two thirds of patients have symptoms or/and radiological changes in their elbows. The severity of elbow deformity depends on the activity of synovitis, which may cause destruction of the cartilage, the bones and the ligaments. Surgical treatment of the rheumatoid elbow is not very common; approximately one hundred elbow replacements are performed in Finland annually and apparently, the number of synovectomies is even smaller.

In Study I the incidence of involvement and nature of destruction of humeroulnar and humeroradial joints were evaluated in a prospectively followed cohort of 74 patients with seropositive and erosive rheumatoid arthritis. At the 15-year follow-up standard anteroposterior and lateral radiographs were taken of 148 elbow joints and the grade of destruction assessed by the Larsen method. Erosive involvement ( $\geq$  Larsen grade 2) was observed in 75 (51%) of the 148 joints in 45 (61%) patients out of 74. Thirty patients had bilateral and 15 unilateral affection. Erosions were most often found on the capitellum (43%) and the lateral epicondyle (39%) of the humerus or on the olecranon of the ulna (35%).

Studies II-VI were based on a follow-up of 525 consecutive Souter-Strathclyde elbow replacements undertaken during the years 1982-1997. There were 372 female and 34 male patients with a mean age of 57 years. A total of 119 patients underwent a bilateral procedure. The indication for operation in 522 cases was rheumatoid arthritis or other chronic inflammatory joint disease. The mean duration of the disease at time of operation was 25 years (2-70). By reason of complications there were 108 reoperations in 82 patients up to the end of 1998. During the early years of this study the relative number of primary complications

was essentially higher. The cumulative success rates without aseptic loosening five and ten years after surgery were according to survival analysis 96 and 85 per cent, respectively.

One hundred and fifty-eight primary elbow arthroplasties (out of 525) were undertaken in 134 patients with severe joint destruction (Larsen Grade 5) or large bone defects or both. Major complications led to 5 early and 16 late reoperations in 19 patients. In survival analysis, the cumulative success rate without revision for aseptic loosening at 5-year follow-up was 97%. There were 26 rheumatoid patients who had 32 preoperative fractures treated with Souter elbow arthroplasty. Twenty of the fractures united and 12 did not.

Prosthesis survival was assessed in the 7 most commonly used component types among the 522 primary Souter elbow replacements. One operation for osteoarthritis and two operations for posttraumatic arthrosis were excluded from this study. Forty-seven patients underwent 51 operations for aseptic loosening up to the end of the year 2000. In survival analysis the general cumulative success rates for the whole study cohort without revision for aseptic loosening 5 and 10 years after surgery were 96 and 84%, respectively. The highest 5-year survival rates were 100%, the lowest 93%, and the 10-year survival rates 91% and 76% respectively. Judging from this study there would appear to be marked differences in the survival of various types of Souter components in elbow arthroplasty.

The appearance of radiolucent lines in radiographs of the 522 primary Souter-Strathclyde elbow arthroplasties was evaluated. The elbow region was divided into ten zones. Our purpose was to find areas, which can be easily distinguished, and secondly the significance of which is different for fixation due to anatomical factors and structures of components. At 1-year follow-up, translucencies in two of the zones had prognostic value for aseptic loosening.

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## **ABBREVIATIONS**

ACR = American College of Rheumatology

CI = confidence interval

CT = computerized tomography

DMARD = disease-modifying anti-rheumatic drug

EULAR = European League Against Rheumatism

FU = follow-up

HU = humeroulnar

HR = humeroradial

JCA = juvenile chronic arthritis

MRI = magnetic resonance imaging

NSAID = non-steroidal anti-inflammatory drug

OA = osteoarthritis (arthrosis)

p = probability

PE= polyethylene

RA = rheumatoid arthritis

RF= rheumatoid factor

RFH = Rheumatism Foundation Hospital

ROM = range of movement (motion)

TEA = total elbow arthroplasty

US = ultrasonography

## LIST OF ORIGINAL PUBLICATIONS

1. Lehtinen JT, Kaarela K, Ikävalko M, Kauppi MJ, Belt EA, Kuusela PP, Kautiainen HJ, Lehto MUK: Incidence of elbow involvement in rheumatoid arthritis: A 15 year endpoint study. *J Rheumatol* 28:70-74, 2001.
2. Ikävalko M, Lehto MUK, Repo A, Kautiainen H, Hämäläinen M: Souter-Strathclyde elbow arthroplasty: A clinical and radiological study of 525 consecutive cases. *J Bone Joint Surg (Br)* 84-B:77-82, 2002.
3. Ikävalko M, Belt EA, Kautiainen H, Lehto MUK: Souter Arthroplasty for Elbows with Severe Destruction. *Clin Orthop* 421:126-133, 2004.
4. Ikävalko M, Lehto MUK: Fractured rheumatoid elbow - treatment with Souter elbow arthroplasty. A clinical and radiological mid-term follow-up study. *J Shoulder Elbow Surg* 10:256-259, 2001.
5. Ikävalko M, Belt EA, Kautiainen H, Lehto MUK: Revisions for aseptic loosening in Souter-Strathclyde elbow arthroplasty. Incidence of revisions of different components used in 522 consecutive cases. *Acta Orthop Scand* 73 (3):257-263, 2002.
6. Ikävalko M, Belt EA, Kautiainen HJ, Lehto MUK: Early radiographic signs predicting aseptic loosening in Souter-Strathclyde elbow arthroplasties. A radiological analysis of 522 consecutive elbow replacements. (submitted)



## 1. INTRODUCTION

In everyday life the importance of hand function is usually hardly often to question, whereas the role of the elbow joint is easily forgotten. Elbow function is nonetheless indispensable in that the hand must be directed to seize an object. Stretching and bending of the elbow joint brings the hand holding an article to some intended point, naturally in conjunction with the function of the humeroscapular and the wrist joints. The rotational movement of the lower arm is of importance in positioning the hand. The pronation and supination of the lower arm are dependent on the elbow and the wrist. The upper extremity also assists the motion of the body: by grasping something with the hand the body can be pushed away, pulled upwards or closer. In these functions the elbow is irreplaceable.

Biomechanical studies have shown surprisingly high compressive forces transmitted across the elbow in normal life; even in activities such as dressing and eating they may amount to half of the body weight. Walking with crutches may cause compressive forces 3 to 4 times the body's weight (Souter 1981, Morrey et al. 1981a).

Rheumatoid arthritis (RA) is a chronic inflammatory disease of unknown etiology. Rheumatoid factor (RF) -positive RA is erosive in 99% of patients (Kaarela et al. 1993). RA and other related inflammatory diseases involve the elbow joint in two thirds of patients, but often as late as 10-15 years after the onset of the disease (Fleming et al. 1976, Ljung et al. 1995). Due to destruction of cartilage, bone and ligaments pain, instability and restriction of movement develop. Restriction of extension is one of the earliest symptoms. Subsequently, restriction of flexion or severe instability may prevent the patient from reaching his or her

mouth with the hand. Severe loss of function in the elbow is unfortunately also often related to damage of the shoulder and wrist.

The conservative treatment of RA consists in medical and physical treatments and patient education. Orthoses are not often used in the treatment of the elbow joint.

The first reported surgical treatment was resection arthroplasty for ankylosis of the elbow, introduced by Ollier in 1882 (Ollier 1882). In RA patients, synovectomy with or without resection of the proximal radial head has been a relatively common procedure during recent decades (Laine and Vainio 1967, Copeland and Taylor 1979). The need for synovectomy has generally decreased, obviously due to the active use of disease-modifying antirheumatic drugs (DMARDs). Resection-interposition arthroplasty been undertaken in advanced cases, especially during the 1960s - 80s (Hurri et al. 1964). However, in long-term follow-up this was often complicated by progressive bony erosiveness and instability and the need came to be recognized for management of elbow destruction by endoprosthesis, especially in view of encouraging results of hip and knee replacements with endoprosthesis. Early results with elbow hinge prosthesis designs were not satisfactory (Dee 1973, Morrey and Bryan 1982). In the 1980s the frequency of complications was still high, and there were only a few good long-term results. Since that new designs and alternative models have been developed. Operative techniques have improved, not only in total elbow arthroplasties (TEAs), but also in much more common hip and knee arthroplasties. Obviously, the long-term results of TEA have also gradually become more satisfying (Gill and Morrey 1998, Gschwend et al.1999). However, the significance of total elbow replacement remains to some extent controversial. The right timing of the procedure and correct patient selection - as well as skilful performance of the operation itself - are still a challenging task.

## **2. REVIEW OF THE LITERATURE**

### **2.1. Anatomy of the elbow**

#### 2.1.1. Bones

The elbow joint is formed by the joint surfaces of three bones, the humerus, the ulna and the radius, three articulations constituting the humero-ulnar, the humero-radial and the proximal radio-ulnar joint. Humero-ulnar articulation permits flexion-extension movements. Pronation, supination and axial rotation of the forearm occur mainly in the humero-radial and proximal radio-ulnar joints.

The distal humerus has a bicondylar joint surface consisting of the trochlea and the capitellum. The trochlea is inclined in the valgus direction on the average  $8^\circ$  from the longitudinal axis of the humerus and with  $5-7^\circ$  internal rotation with respect to the axis through the epicondyles. The distal humerus has an antecurvature of  $30^\circ$ . The joint surface of the proximal ulna is called the incisura trochlearis or trochlear notch. The opening of the trochlear notch has a retrocurvature of  $30^\circ$ , which with the antecurvature of the humerus makes stable full extension and flexion of approximately  $150^\circ$  possible.

The angle between the forearm and the upper arm is called the carrying angle. In full extension it is on the average  $11^\circ$  valgus (range  $0-22^\circ$ ). In full flexion the angle is on the average  $6^\circ$  of varus. This change from valgus to varus makes place by reason of the shapes of the joint surfaces.

The joint surface of the radial head is concave, forming articulation with the capitulum of the humerus. The articular rim of the radial head is covered with cartilage along  $280^\circ$  of its

circumference. The parallel concave joint surface in the ulna is called the incisura radialis. The proximal radio-ulnar joint allows a rotation of 160-170°. This, with the distal radio-ulnar joint in the wrist, permits pronation and supination of the forearm.

**Figure1.** Anteroposterior (AP) and lateral view of the right elbow in a 42-year-old female patient with RA (no rheumatoid changes visible)



### 2.1.2. Ligaments

The ligament complex in the elbow is divided into medial and lateral components. The medial collateral ligament comprises three parts: the pars anterior, the pars posterior and the pars transversa. The pars anterior is the most significant structure stabilizing against valgus-inducing forces.

The lateral ligament complex consists of the lateral collateral and the annular ligaments. The annular ligament encircles the radial head. The lateral collateral ligament extends from the annular ligament to the lateral epicondyle of the humerus.

### 2.1.3. Nerves around the elbow

The ulnar nerve passes the elbow very close to the joint cavity. Proximally to the joint it is on the medial side of the triceps muscle. At the level of the joint it lies next to the pars posterior of the medial collateral ligament in a groove near the medial epicondyle of the humerus. The nerve runs under the tendon arch, which is the origin of the ulnar flexor muscle of the wrist.

The radial nerve branches proximal to the elbow joint into the sensory superficial branch and the deep motor branch. The ramus interosseus posterior from the deep branch runs close to the radial head.

The median nerve is located on the anterior side and care must be taken in anterior approaches to the elbow joint.

#### 2.1.4. Muscles around the elbow

The flexors of the elbow are the biceps, the brachial and the brachioradial muscles, the biceps muscle being the most important. In the pronated forearm it functions as a powerful supinator.

The extensors of the elbow are the triceps and the anconeus muscles. The long head of the triceps muscle also contributes to extension and adduction of the humerus, since it originates at the scapula. The medial and the lateral head have their origin at the humerus. The anconeus muscle is a weak extensor and functions as a stabilizer of the elbow joint.

The supinators of the elbow are the supinator and the biceps muscles. In flexion the biceps muscle is even a stronger supinator than the supinator. The brachioradial muscle also contributes in some measure to the supination force.

The forearm extensors - the ulnar extensor of the wrist, the extensors of the fingers and the radial extensors of the wrist originate at the lateral humeral epicondyle. The long and short radial extensors of the wrist support the flexors of the elbow. The long radial extensor of the wrist also contributes somewhat to the pronation force.

The forearm flexor-pronator group consists of the muscle pronator teres, the radial and ulnar flexors of the wrist, the long palmar muscle and the deep and superficial flexors of the fingers. They are inserted at the medial epicondyle of the humerus and the medial proximal part of the ulna. The pronator teres muscle is a strong pronator of the lower arm and a weak flexor of the elbow. The radial flexor of the wrist and the long palmar muscle also support

pronation of the lower arm. The ulnar flexor of the wrist also functions as a weak extensor of the elbow by reason of its posterior origin (von Lanz and Wachsmuth 1959, Pöll 1994).

## **2.2. Rheumatoid arthritis**

RA is a chronic systemic inflammatory autoimmune disease. Genetic and environmental factors are involved in its pathogenesis, but the initiating agent remains unknown. After T-cell activation, many immunological systems lead to chronic inflammation. Typical symptoms are pain, swelling and stiffness of the joint. Hypertrophy of the synovium causes the formation of granulation tissue (pannus) on the surface of the cartilage. Leakage of proteolytic enzymes causes erosions in cartilage and bone. Rheumatoid factor (RF) is a macroglobulin which acts as an antibody against the patient's own serum gamma globulins (Harris et al. 1969, Leirisalo-Repo et al. 1993).

Continuous inflammation leads to progressive erosion and finally to destruction of the joint. The rheumatoid process may also damage joint capsules, ligaments and tendons (Scott et al. 1986) The course of arthritis is variable, but in RF-positive cases the disease is erosive in 99% of patients (Kaarela et al. 1993).

Although diagnosis of the disease is made on clinical grounds, the 1987 revised classification criteria of the American College of Rheumatology may be helpful (ACR; Arnett et al. 1988) There are no specific diagnostic tests. Some 70-80% of the patients are RF-positive. The prevalence of RA is in Finland according to a study by Hakala 0.8% (Hakala et al. 1993). In a study by Kaipiainen-Seppänen the prevalence is approximately 0.9% in Finland and the annual incidence 39/100 000 of the adult population (Kaipiainen-Seppänen et al. 1996).

## **2.3. Rheumatoid changes in the elbow**

### **2.3.1. Incidence of elbow involvement in rheumatoid arthritis**

Elbow affection has occurred as the first joint involvement in only 3% of patients with RA (Fleming et al. 1976). In long-term RA, the elbows are according to several studies involved and deformed in more than half of patients. In a series of 300 patients with 10 years' average duration of RA, evidence of elbow involvement was found in 53% (Gschwend 1980). In a series of 47 joints with a mean disease duration of 17 years, Ljung detected radiological rheumatoid involvement in 51% of elbows (Ljung et al. 1995). A lower incidence was found in a follow-up study at the Rheumatism Foundation Hospital (RFH) in 1991 (Hämäläinen et al. 1991), where with a mean disease duration of 14 years 33% of elbows were symptomatic and 20% showed significant radiographic changes.

In a study of Lehtinen et al. the elbow seemed to turn into valgus during the rheumatoid destruction. However, totally unstable joints may also have varus deformity due to mutilating destruction. The ulna tends to subluxate proximally in relation to humerus and the radius moves slightly anteriorly as a consequence of elbow involvement (Lehtinen et al. 2001).

### **2.3.2. Symptoms**

The first elbow symptoms frequently manifest themselves 10-15 years after the onset of the disease (Hämäläinen et al. 1991). The severity of a elbow deformity depends on the activity of synovitis, which may cause destruction of the cartilage, the bones and the ligaments. The initial clinical symptoms are pain and swelling, subsequently instability and often restriction of

movement, infrequently bony ankylosis. Synovitis is often palpable, but sometimes restricted extension is the first sign of early synovitis.

The proximal radial head is often displaced as a result of destruction of the annular ligament and traction force of the biceps muscle (Amis et al. 1982, Lehtinen et al. 2001). This condition, especially with synovitis and joint surface destruction, may cause severe pain in elbow flexion or rotation. Instability develops due to loss of cartilage and bone in the joint surfaces. Sometimes ligaments, especially the medial collateral ligament, are also involved. Instability, osteophytes and synovial swelling may irritate the ulnar nerve. Olecranon bursitis and rheumatic nodules should be differentiated from swelling of the elbow joint.

## **2.4. Diagnostic procedures**

### **2.4.1. Clinical examination**

In evaluation of a patient with RA, a detailed patient history is required. This comprises a number of elements. The duration of disease is of particular relevance and in advanced cases details of previous conservative and operative treatments are essential. When planning operative treatment a surgeon should know whether the patient's disease is in active phase or not. A generally active RA may be a contraindication for surgery. Pain and disability are subjective experiences and personal problems and wishes very variable. Many patients with long-term RA have adapted to their disability.

In the planning of surgical treatment in RA, the general condition of the patient and other possible diseases should be carefully noted. Before deciding on elbow replacement, the clinician should be aware of the condition of the other joints - not only in the upper but also in

the lower extremities. The patient's walking capacity and need for a stick, crutches or a wheel chair should be evaluated, also the ability to transfer to or rise from a chair.

Deformities of the elbow, synovial swelling, skin changes and rheumatic nodules must be noted in inspection and muscular capacity and stability of the joint should be assessed. Synovial swelling and tenderness are determined by palpation. The range of motion in flexion-extension and pronation-supination must be assessed and possible crepitus detected.

#### 2.4.2. Radiological evaluation

Evaluation of elbow damage can be made radiographically and in most cases plain radiographs are sufficient. Use of ultrasonography (US), computerized tomography (CT) and magnetic resonance imaging (MRI) are sometimes indicated in evaluation of synovitis and/or osteolytic lesions in the rheumatoid elbow.

##### 2.4.2.1. Plain radiography

Radiographic changes include soft tissue swelling, periarticular osteoporosis and loss of joint space. Marginal bony erosions, subchondral cysts, subluxation or malalignment of the joint, sclerosis of bone, osteophytes and bony ankylosis can be observed (Larsen et al. 1977). Radiography is an important aid in surgical evaluation and in the decision whether or not to operate. Radiography is also essential in postoperative follow-up (Fig. 2).

**Figure 2.** AP and lateral view of a severely damaged left elbow. The same patient with RA in Figure 1.



### 2.4.2.2. Radiographic grades

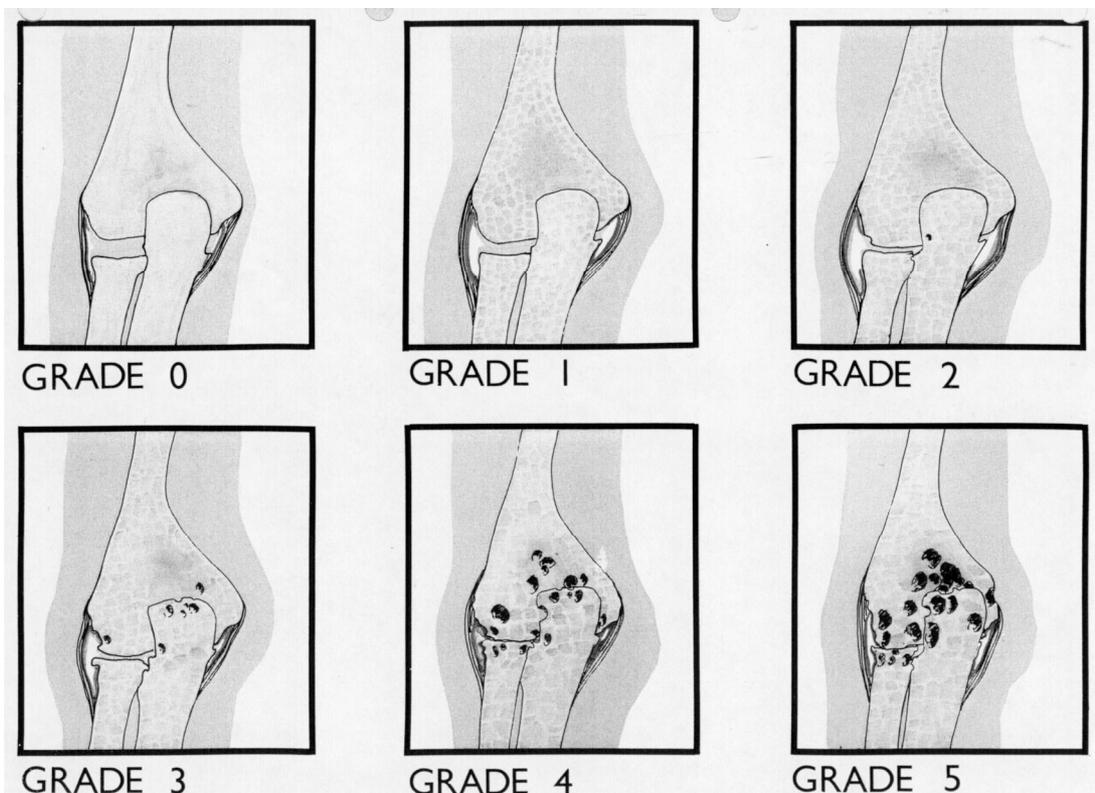
Several methods of evaluation have been developed for radiographic assessment of elbow joints in RA, the Larsen method being the most widely used (Larsen et al. 1977) (Fig. 3).

Originally, there were the grades 0-5 and the sixth has been added later.

The Larsen grades are:

0. normal
1. soft tissue swelling and periarticular osteoporosis
2. slight erosions of the joint and/or minimal loss of joint space
3. erosions of the joint and obvious narrowing of the joint space
4. deep erosions of the joint through the subchondral plate and narrowing of the joint space to a thin line
5. total disorganization of the joint with major bone deterioration or resorption
6. bony ankylosis

**Figure 3.** The original Larsen grades 0-5 of elbow joint.



## **2.5. Treatment**

### **2.5.1. Conservative treatment**

The aim of conservative treatment in a patient with RA is to relieve symptoms and prevent tissue destruction and disability. Treatment comprises a variety of elements; medication, physiotherapy, orthoses and patient consulting (Möttönen et al. 1966, Sokka et al. 1997). Medical therapy can be divided into different categories: analgetics, non-steroidal anti-inflammatory drugs (NSAID), glucocorticoids (steroid) used locally or systematically, and disease-modifying drugs (DMARD). The most commonly used DMARDs are methotrexate (cytostat), sulfasalazine, quinoline derivatives (malarial drugs) and gold compounds. Biologic response modifiers have recently been introduced and so-called tumor necrosis factor alpha inhibitors have been in clinical use for a few years (Barrera et al. 2001).

### **2.5.2. Non-endoprosthetic surgical treatment**

The first known operative treatment was resection arthroplasty for ankylosis of the elbow (Park and Moreau 1805). Subsequently resection arthroplasty with interposition was introduced and several modifications of it were used before the era of elbow endoprosthesis. Synovectomy is no longer as common as before but remains a useful procedure in many cases of rheumatoid elbow with synovitis resistant to conservative treatment. Arthrodesis of the elbow joint is mentioned in the literature as an option for very severe cases. It offers good pain relief but loss of function is so detrimental that it has been almost never used during the last few decades.

### 2.5.2.1. Synovectomy

The first report of synovectomy was presented in 1893 (Schuller 1893). A report of elbow synovectomy in an infectious case was published by Swett (Swett 1923). The combination of synovectomy and resection of the radial head was introduced by Smith-Petersen (Smith-Petersen et al. 1943). According to these reports the operations were undertaken at a relatively late stage. Laine and Vainio published results of early synovectomy in rheumatoid elbow in 1967 (Laine and Vainio 1967). The value of early and late synovectomies is discussed in a multi-centre study by Hagena (Hagena 1991). True early synovectomy is performed before morphologic changes are visible in radiographs [Larsen 0 – 1 (-2)], the aim being pain relief and prevention or retardation of development of destruction in the involved elbow joint. Late synovectomy is more a palliative procedure in the latter stages (often Larsen grade of 3, sometimes even 4). Here the aim is pain relief and reduction of joint stiffness. Expectations and postoperative contentment of the patient are frequently different between early and late cases (Copeland and Taylor 1979).

### 2.5.2.2. Resection arthroplasty

The idea of resection arthroplasty of the elbow was first advanced in 1782 by Park in Liverpool and Moreau in Paris (Park and Moreau 1805). The first operation was performed by Moreau in the 1790s and the first published account of the method was that by Ollier in 1888. The main problem after the resection arthroplasty was severe instability.

### 2.5.2.3. Resection-interposition arthroplasty

Before the time of implant surgery, resection arthroplasty with different soft tissue interpositions was the only surgical solution for advanced destruction of the rheumatoid elbow. Interposition with dermis was introduced by Gschwend and Spirig 1960. The

modification by Vainio was published in the 1960s (Hurri et al. 1964, Vainio 1967). Long-term results were very variable (Kankaanpää 1991). Common problems after this procedure were progressive eroding of the bone structures and increasing instability of the joint and in consequence resection-interposition arthroplasty is no longer used.

### 2.5.3. Elbow replacement

#### 2.5.3.1. Evolution of elbow replacement with endoprosthesis

The earliest attempts to replace the elbow were incidentally performed using custom-made hemiprosthesis. As early as 1927 Robineau implanted a metal humeral component covered with rubber (Robineau 1927). An acrylic prosthesis was introduced in 1947 (Mellen and Phalen 1947) and a vitallium humerus prosthesis in 1965 (Barr and Eaton 1965).

The first custom-made metal hinged prosthesis was implanted in the Netherlands in 1942 (Boerema and de Waard 1986). In the 1960s and 1970s, some total hinged prostheses were in serial production, one of the most famous being that designed by Dee (Dee 1973).

The main problem with constrained hinge models was aseptic loosening and with non-constrained designs early luxation. To avoid these risks number of semi constrained models have been developed, among the best-known semiconstrained linked models being the GSB-III (Gschwend 1980), the Triaxial (Inglis and Pellicci 1980) and the prosthesis designed by Coonrad and Morrey (Morrey et al 1981b).

As an alternative to hinged prosthesis, non-linked models with shorter stems or stemless designs were developed. Here stability of the artificial joint relied on the ligaments and capsular structures. An increased risk of luxation was found to be associated with this type of

prosthesis design (Morrey and Bryan 1982, Gschwend et al. 1996). The first model of the Kudo prosthesis was implanted in 1971 (Kudo et al. 1980). The capitellocondylar prosthesis has been in use since 1974 (Ewald et al. 1980, 1993). The total elbow prosthesis designed by Souter was used for the first time in 1977 (Souter 1981, 1985), and the first Norway elbow prosthesis was implanted by Risung in 1982 (Risung 1997).

Descriptions of the various types of elbow prostheses are somewhat inconsistent. Classification into constrained, semiconstrained and non-constrained or retentive and non-retentive types is not clear. In many connections, the basic concepts "linked" or "non-linked" could be preferred, and the terms "hinged" or "non-hinged" are likewise unambiguous. Obviously a hinge prosthesis may be a totally hinged (fully constrained) or a floppy hinge prosthesis (semiconstrained). More controversial is whether a non-linked prosthesis is always non-constrained. According to some a non-linked prosthesis with highly congruent components (for example the Souter standard models) behaves in vivo as a semiconstrained prosthesis due to tension of the muscles. There are also non-linked prosthesis designs with non-congruent components, e.g. the Kudo, which behave totally non-constrained also under pressure. A non-hinged prosthesis can be non-retentive (Souter standard, Kudo, Norway) or retentive (Souter retentive, so-called "snap fit"). There are differences in the inherent stability of different types of prosthesis from different manufacturers, but also in various components from the same manufacturer. A modern floppy hinge type of prosthesis may have both mediolateral and rotational stability equal to that of a non-hinged prosthesis (Gschwend et al. 1996, Morrey and Adams 1992).

#### 2.5.3.2. Souter-Strathclyde elbow prosthesis

In view of the many disappointing results with hinged prostheses and special problems related to long stems, one of the original goals in the further development of the Souter

prosthesis was to avoid intramedullary stems. The designs of the standard components were based on cadaver studies. The aims in designing the two components were the following: 1. Precise local fixation in the humerus and ulna, 2. Fixation designed to resist rotational forces, 3. Retention of normal ligament function, 4. Minimal constraint compatible with stability. The prosthesis was designed in 1973 and has been in clinical use since 1977. The function of this kind of design is significantly dependent on the support of soft tissues around the joint: joint capsule, muscles, triceps tendon and ligaments; especially the role of the anterior part of the medial collateral ligament is emphasized.

The humeral component is made of vitallium. The fixation of standard humeral components is dependent on the supracondylar arch; supracondylar ridges and condyles. The design is not symmetrical but contoured according to the normal anatomy of the humerus. A stemmed model was planned for cases with severe bone destruction and for re-operations. Originally a stemless ulna component was also planned, but after several tests the all-polyethylene ulnar component was equipped with a short 2.5 cm stem. Moreover, the designer's observation was that the olecranon is eroded down to a thin wafer of bone in many rheumatoid patients, and such cases do not offer a sufficient structure for cement fixation of a stemless ulnar component. The ulnar component is so designed that when fully extended the elbow is in  $8^{\circ}$  valgus and in  $6^{\circ}$  varus angle when in full flexion, resembling the normal carrying angle.

The designer recommended using standard components when possible, the aim being to avoid more severe complications when detachment of the component is needed in re-operations. However, the designer preferred the use of a hinged prosthesis in severe cases with gross bone losses (Souter 1981). In a study by Pöll (1994), the fixation of standard and long-stem humeral components appeared to be equal in laboratory tests. In a study of Shah, an 87% survivorship after 12 years with Souter standard prostheses was introduced. If

revision and radiological loosening were taken together, survival rate was 80% (Shah et al. 2000).

#### 2.5.3.3. Different approaches

Several suitable approaches to elbow replacement are introduced in the literature. There is no study proving one unambiguously better than others. Weakening of triceps function is associated with the use of a triceps releasing approach (Bryan and Morrey 1982), while Kocher's lateral approach preserves triceps insertion and the ulnar collateral ligament (Kocher 1911). This technique was modified by Ewald and associates 1993. Bryan's modification of the triceps-sparing posterior approach was introduced in 1982, also known as the Mayo approach (Bryan and Morrey 1982). A technique in which the triceps tendon is detached from the top of the olecranon was described by Morrey and Adams 1992.

Campbell's direct posterior triceps-splitting approach was first introduced for osteosynthesis of distal fractures of the humerus (Campbell 1922). It has been modified and used in elbow replacements by Souter (Souter 1973). In the transtricipital approach described by Gschwend, the triceps tendon and the periosteum with a small amount of cortex are split in the middle of the olecranon (Gschwend et al. 1996). Wolfe and Ranawat described a technique involving an osteo-anconeus flap. A wafer of bone from the extra-articular portion of the olecranon was detached, providing continuity of the triceps tendon and the anconeus muscle (Wolfe and Ranawat 1990).

#### 2.5.3.4. Indications for total elbow arthroplasty

In most patients evaluated for TEA the diagnosis is RA or a related disease, sometimes posttraumatic arthrosis and only seldom osteoarthritis. Symptoms are usually pain, restriction of movement, crepitation, instability and sometimes ankylosis. In most patients, pain is the primary indication and restoration of stability the secondary (Ewald et al. 1993, Goldberg et

al. 1988). In radiographs bone absorption, erosions and cystic changes are visible, usually representing a Larsen grade of 4-5 (Larsen et al. 1977).

If the indication for TEA is considered due to symptoms and radiographic changes, the patient's desires and ability in daily activities should also be carefully observed. If the patient's profession, pursuits or invalidity of the lower extremities entail heavy loading of the upper extremities, TEA is not always a reasonable solution by reason of a higher loosening risk. Especially if no progression of joint damage is detected in consecutive radiographs, and the bone material appears to be sufficiently hard, conservative treatment could be preferred in these cases. On the other hand, if severe progressive destruction is observed on X-rays, TEA can be indicated even in patients with a relatively high risk. The same also concerns patients subject to an increased risk of infection.

#### 2.5.3.5. Contraindications

An absolute local contraindication is infection in the elbow joint. Inadequate bone stock, extremely thin skin or subcutaneous tissue over the joint may also be absolute contraindications, relative contraindications in milder cases. Severe problems in the patient's general condition may hinder any operative treatment. Nutritional deficiencies or hypoproteinemia related to renal insufficiency may likewise constitute absolute or relative contraindications. If the patient is not able to control the postoperative stress of the elbow, it may be reasonable to refrain from operative treatment (Goldberg et al. 1988).

#### 2.5.3.6. Results of total elbow arthroplasty

##### Relief of pain

A general opinion is that pain relief after TEA is good; patients usually report no or only mild pain at postoperative follow-ups (FU) in more than 90% of cases. Severe or moderate pain is often associated with complications (Gill and Morrey 1998, Gschwend 1999)

##### Range of motion

After TEA, the arcs of flexion-extension and pronation-supination increase. Usually the extension deficit postoperatively in different studies is a mean 25-35°. In the report by Gill and Morrey (1998) the mean arc of flexion was 103°, 13° better than preoperatively. Risung in 1997 presented results of 21° gain in flexion-extension and 23° gain in pronation-supination (Risung 1997).

##### Stability

Prior to TEA, instability of the elbow is much more common problem than stable ankylosis. Stability is usually improved after TEA (Gill and Morrey 1998, Risung 1997). In semiconstrained linked models (floppy hinges) the stability is based at least partially on the prosthesis design. The wear of the bushing may eventually cause increasing instability (Gill and Morrey 1998). In non-linked models the stability of the joint relies on the soft tissues, the joint capsule, the ligaments and the triceps tendon. There is a higher risk of subluxation or dislocation if patient selection or operative technique is inappropriate (Morrey and Bryan 1982, Gschwend et al. 1996)

##### Daily activities

Patients' competence in daily activities is usually improved after TEA (Gill and Morrey 1998, Risung 1997). In many questionnaires the evaluation of function is focused on dressing,

feeding, hygiene and lifting objects. A principal problem in these evaluations is that very often a rheumatoid patient with elbow prosthesis also suffers disability due to shoulder, wrist or hand involvement. For instance, if the patient is not able to comb his or her hair, the reason may be severe shoulder destruction while elbow function may be satisfactory.

### Scoring systems

Several scoring systems have been developed to assess the results of TEA, one of the most popular being that developed in the Mayo Clinic (Morrey et al. 1981b)

### The Mayo Elbow Performance Score

	No. of points
<hr/>	
<b>Pain</b> (45 points)	
None	45
Mild	30
Moderate	15
Severe	0
<b>Range of motion</b> (20 points)	
> 100 degrees	20
50-100 degrees	15
< 50 degrees	5
<b>Stability</b> (10 points)	
Stable	10
Moderate instability	5
Gross instability	0
<b>Daily function</b> (25 points)	
Combing hair	5
Feeding oneself	5
Hygiene	5
Putting on shirt	5
Putting on shoes	5
<b>Maximum possible total</b>	100

Risung presented a scoring system modified after Ewald (Ewald et al. 1993). He recommended that figures for pain, function and motion be given separately (Risung 1997).

#### 2.5.4. Complications of elbow surgery

General complications related to any surgical procedures are not presented in this connection, only typical complications of elbow surgery.

##### 2.5.4.1. Complications of non-endoprosthetic elbow surgery

The ulnar nerve passes the elbow joint so close that nerve damage may easily occur during a procedure. In synovectomies, irritation of the ulnar nerve has been reported in up to 12% of cases in which the lateral approach was used (Copeland and Taylor 1979). The dorsoradial approach has been recommended to avoid the risk of ulnar nerve complications (Gschwend and Steiger 1985). Excision of the radial head may lead to increasing valgus deformity and subluxation of the distal radio-ulnar joint (Taylor and O'Connor 1964). The radial head should therefore be if possible preserved. In resection arthroplasties, typical complications are non-union of the olecranon if osteotomy is used in the approach, and in later phases, progressive bone resorption leading to increasing instability (Hämäläinen and Kataoka 1991, Kankaanpää 1991).

##### 2.5.4.2. Complications of elbow athroplasties

Most publications here are based on short- or mid-term follow-ups (FUs). Hence figures for early complications are well documented, but there are only a few studies concerning aseptic loosening in long-term FU (Gschwend et al. 1996, Gill and Morrey 1998). The significance of experience in avoiding early complications is presented in a paper by Ewald and associates in 1993. At the beginning of their study, in the 1970s and 1980s, the percentages of early complications were high: 30-50%, descending then to 0-20% by the end of the 1980s. From

the 90s there are several reports of TEAs with better short-term results compared with those from the 80s (Ewald et al.1993).

In a study by Morrey with 54 patients and a mean FU of 3.8 years, a total of 22% had complications (Morrey and Adams 1992). Gschwend and colleagues analyzed 22 publications on 828 cases and found complication rates to vary from 20 to 45% (Gschwend et al. 1996). Twenty-three percent of these were considered late complications. Gill and Morrey published survival rates of 94% at five years (78 elbows) and 92% at ten years (46 elbows) (Gill and Morrey 1998).

#### Aseptic loosening

Among late complications, aseptic loosening is the most prominent. The loosening rate is dependent on many factors; the type of the prosthesis, bone stock, supporting soft tissues (ligaments, joint capsule, muscles) and stress in the patient's daily activities (Souter 1989, Gschwend et al. 1996). In the early total hinge models the loosening rate was particularly high: from 25% to even 75% at three years (Dee 1973, Souter 1973, Morrey and Bryan 1982). Significantly better results have been achieved with floppy hinge models, 92.4% survivorship after 10 years in a material of 43 Coonrad-Morrey arthroplasties (Gill and Morrey 1998). In a study by Trail and associates (1999) a material of 186 standard Souter arthroplasties was presented. In the period of 12 years 21 (11.2%) implants were revised for aseptic loosening. In a material of 118 Norway elbow replacements, again two (1.7%) revisions for aseptic loosening were performed during a mean FU of 4.3 years (Risung 1997).

#### Infection

Inglis and Pellicci reported an infection rate of 3% (36 patients), Ewald 5% (64 patients) and Morrey and colleagues 9% (156 patients) (Inglis and Pellicci 1980, Ewald et al. 1980, Morrey

and Bryan 1983). Ewald and group reported a low 2.2% infection rate for 312 capitellocondylar replacements (Ewald et al. 1993). In a material of 83 elbows with a three year FU introduced by Risung, there were two failures due to deep infection and three superficial infections healed with antibiotics (Risung 1997). Gutow published a multi-centre study in 1994. The range of infection rates varied between 0 to 11.5% in 15 studies published in the period 1983-1993 (Gutow and Wolfe 1994).

The infection rate is higher after TEA than after hip or knee arthroplasties. There may be several causes in the background. One is anatomical difference. The elbow joint has a poor soft-tissue coverage, and many patients with long-term RA have very thin skin. Previous procedures are common and this may increase the risk of infection. RA itself, especially with amyloidosis and renal insufficiency, and anti-rheumatic medication may also impair the patient's ability to resist infections in the later phase.

Infection in TEA is a severe complication indicating early aggressive treatment. Antibiotic therapy only is seldom a sufficient treatment in deep infection, but in some cases when operative treatment should be avoided, it may render the infection symptomless.

Usually debridement and irrigation with antibiotics is recommended during the early phase of infection when no significant signs of loosening are visible in radiographs. Gutow recommended parenteral antibiotics for 6 weeks and thereafter long-term oral antibiotic therapy (Gutow and Wolfe 1994). In many reports, however, irrigation and antibiotics have been considered ineffective and removal of the prosthesis was later performed (Morrey and Bryan 1983, Wolfe et al. 1990). Re-implantation may be considered in cases in which infection appears to be eradicated and the soft tissue coverage and the bone stock of elbow are sufficient. Also the general condition of the patient should be adequately sound.

Otherwise, a resection arthroplasty is recommended despite associated problems such as instability of the elbow (Gutow and Wolfe 1994).

### Dislocation

Dislocation is a relatively common early complication when a non-linked prosthesis model is used. According to some authors, a non-linked prosthesis is suitable only in restricted cases when the patient's bone stock and the soft tissues around the elbow joint are sufficiently sound (Morrey and Bryan 1982, Gschwend et al. 1996). If a non-linked model is used, the operative technique plays a prominent role in avoiding dislocations. Correct positioning of the components, and reattachment of ligaments and triceps tendon if a tendon flap is used, are essential for a good result. In some cases, however, it is difficult to estimate the condition of the soft tissues or detect a prevailing soft tissue imbalance resulting e.g. from previous procedures such as excision of the radial head or resection arthroplasty. In different publications the rate of dislocation varies. Figgie presented rates from 3 to 15% in different series with capitellocondylar implants (Figgie et al. 1994). In a study by Risung with Norway elbow prosthesis there were three (2.5%) dislocations in a material of 118 elbow prostheses (Risung 1997). In a material of 186 Souter prostheses, three revisions (1.6%) were undertaken for instability during 12 years (Trail et al. 1999)

### Ulnar nerve disturbance

Ulnar nerve paresthesia, sensory, motor or both, is a relatively common complication after TEA. Ewald and associates reported 11 ulnar nerve complications in 64 patients. Five of them remained permanent (Ewald et al.1980). In a study by Morrey, 11 patients out of 80 evinced ulnar nerve disturbance (Morrey et al 1981b). In the afore-mentioned material of 118 cases presented by Risung, two decompressions of the ulnar nerve were performed after TEA (Risung 1997). There are a variety of techniques to avoid ulnar nerve paresthesia.

Some authors prefer to transfer the nerve anteriorly (Kudo et al. 1980, Bryan and Morrey 1982, Figgie et al. 1994), some others do not reveal the nerve by lateral approach (Risung 1997). Ewald recommends release of the fibrous arch proximal to the entry of the ulnar nerve into the flexor carpi ulnaris (Ewald et al. 1993).

#### Rupture of triceps tendon

Some cases of triceps ruptures are mentioned in most FU studies. In a material of 78 Coonrad-Morrey TEAs there were three avulsions of the triceps tendon (Gill and Morrey 1998). Risung reported four partial triceps ruptures 118 elbows and subsequently changed the approach (Risung 1997).

### **3. PURPOSE OF THE RESEARCH**

The aim of the present study was to evaluate the incidence of rheumatoid changes in elbow, indications and results of elbow replacement with the Souter-Strathclyde prosthesis.

The specific objectives were:

1. To ascertain the incidence of rheumatoid changes in the elbow.
2. To report general clinical and radiological follow-up results of Souter-Strathclyde elbow replacement.
3. To assess the success rate of Souter elbow replacement in severely damaged elbows.
4. To evaluate the results of elbow replacement in cases with preoperative fractures.
5. To examine the success rate without aseptic loosening in different Souter-Strathclyde elbow prosthesis components.
6. To ascertain the incidence of translucencies around prosthesis components after elbow arthroplasty and to assess their possible prognostic value with respect to aseptic loosening.

## 4. PATIENTS

### **Table1.** Patients in Studies I-VI

#### Study I

Title: Incidence of elbow involvement in RA. A 15-year endpoint study.

Original patient material 1973-1975: 121 patients with recent RA

At 15-year FU: 74 patients (56 women, 18 men)

The mean age 42 (17-66) years

Diagnosis: RA sero+

#### Study II

Title: The Souter-Strathclyde elbow arthroplasty. A clinical and radiological study of 525 consecutive cases.

Patient material 1982-1997: 406 patients (372 women, 34 men)

The mean age 57 (20-81) years

Diagnosis (per operation): RA sero+ 480, RA sero- 15, JCA 20, psoriatic arthritis 2, non specific chronic arthritis 5, OA 1, post-traumatic arthritis 2

#### Study III

Title: Souter arthroplasty for elbows with severe destruction

The original patient material is same as in Study II.

Severely destructed elbow joints 158

Patient material: 134 (121 women, 13 men)

The mean age 57 (26-81) years

Diagnosis (per operation): RA sero+ 147, RA sero- 2, JCA 6, psoriatic arthritis 1, OA 1, post-traumatic arthritis 1

#### Study IV

Title: Fractured rheumatoid elbow - treatment with Souter elbow arthroplasty.

The original patient material is same as in Study II (and Study III)

Patients with preoperative fracture 27, one with post-traumatic arthrosis was excluded.

Patient material: 26 (22 women, 4 men)

The mean age 64 (44-81) years

Diagnosis: RA sero+ 26

32 fractures: humerus 20 (5 both medial and lateral condyles)

olecranon 6 (one with fracture of olecranon and medial condyle)

#### Study V

Title: Revisions for aseptic loosening in Souter-Strathclyde elbow arthroplasty. Incidence of revisions of different components in 522 consecutive cases.

The original patient material is same as in Study II. One patient with diagnosis OA and two patients with post-traumatic arthrosis were excluded.

Patient material: 403 (370 women, 33 men)

The other patient information is practically same as in Study II.

#### Study VI

Title: Early radiographic signs predicting aseptic loosening in Souter-Strathclyde elbow arthroplasties. A radiological analysis of 522 consecutive elbow replacements. (submitted).

Patient material is same as in Study V.

#### **4.1. Study I**

During the period 1973-1975 a total of 441 patients with early-onset articular complaints were referred to the Rheumatism Foundation Hospital (RFH) in Heinola. Patients aged 16 years or more with swelling in at least one joint and duration of joint disease of 6 months at most were accepted for the evaluation material. A total of 121 patients with a diagnosis of RA formed the principal evaluation cohort at onset. In subsequent evaluations they fulfilled the 1987 American College of Rheumatology classification criteria for RA (Arnett et al 1988). At the 3 year follow-up 102 patients had RF-positive and erosive RA. Subsequently, a total of 24 patients had died and 4 patients failed to attend the 15-year follow-up. Thus, 74 patients (56 women, 18 men) eventually comprised the subjects of the study. The mean age of the patients at the commencement of the study was 42 (17-76) years. At the 15-year FU, in 1989, the patients were clinically and radiologically re-examined at the out-patient clinic of the RFH.

#### **4.2. Study II**

From 1982 to 1997 a total of 525 primary total elbow replacements with Souter - Strathclyde prosthesis were performed on 406 patients (372 women, 34 men) at the RFH in Heinola, Finland; 119 patients thus underwent a bilateral procedure. The mean age at the time of surgery was 57 (20-81) years. Sixty-four patients died during the follow-up of causes not related to the surgery.

The reason for surgery was RF-positive RA in 480 elbows operated on, RF-negative RA in 15 and juvenile chronic arthritis (JCA) in 20 cases. Two patients had psoriatic arthropathy. In five cases the diagnosis was chronic arthritis without precise definition. One operation was performed for OA and two for post-traumatic arthrosis.

The mean duration of the arthritic, degenerative or posttraumatic joint disease before TEA was 25 (2-70) years, and the mean duration of the elbow symptoms 12 (0-50) years. In most cases the elbows presented advanced destruction, Larsen grade 4 in 151 joints and Larsen grade 5 in 301. There were 34 preoperative fractures, of which 28 were located in the humerus and 6 in the ulna. At the time of surgery 86% of the patients were on continuous NSAID therapy, 54% had systemic corticosteroids and 44% had DMARDs. Previous synovectomy had been performed in 216 elbows, with excision of the radial head in 57 cases, and previous interposition arthroplasty in 50 cases.

#### **4.3. Study III**

The original cohort here was the same as that presented in Study II. In selection of the current study group, 158 elbow joints in 134 patients (121 women, 13 men) fulfilled the criteria of severe elbow destruction: Larsen grade 5 destruction, major bone defects in the distal humerus and proximal ulna, preoperative fractures in the elbow region, or all of the above. Twenty-four patients underwent bilateral procedures. The mean age at the time of surgery was 57 (26–81) years. Eight patients died during the follow-up due of causes not related to the surgery.

The indication for surgery was in most patients RA. One hundred and forty-seven operations were done for RF-positive and two for RF-negative RA, six for JCA, one for osteoarthritis and one for posttraumatic arthrosis. One patient had psoriatic arthropathy. In this series of 134 patients, the mean duration of the arthritic, degenerative or posttraumatic joint disease before replacement was 27 (2-70) years, and the mean duration of elbow symptoms before surgery 15 (2–50) years. Twenty-seven patients had 34 preoperative fractures associated with

advanced destruction: 28 were located in the humerus and six in the ulna. At the time of surgery, 89% of the patients were receiving NSAIDs, 61% corticosteroids, and 44% DMARDs.

Previous synovectomy had been undertaken in 64 joints (45 patients), with excision of the radial head in 49 joints (34 patients) and previous dermis interposition arthroplasty in 18 (15 patients).

#### **4.4. Study IV**

The original patient cohort here was again the same as in Study II. There were 27 TEA patients with preoperative fractures operated on at the RFH during the years 1991-97. One patient with post-traumatic arthrosis and two non-union fractures were excluded. The remaining 26 patients (22 women 4 men) had a diagnosis of RA. The mean duration of the disease was 30 (0-43) years. There were 22 women and 4 men, mean age 64 (44-81) years. The joints were severely involved (Larsen grade 5) even prior to the fracture. The preoperative fracture was on the humeral side in 20 and on the olecranon side in 6 cases. One patient had fractures on both the olecranon and the medial condyle of the humerus. Five patients presented a fracture on both the medial and the lateral condyle of the humerus. Counting the medial and lateral condyle fractures separately there were altogether 32 preoperative fractures in the elbow region.

#### **4.5. Study V**

Here too the original patient cohort was the same as in Study II. One patient with an OA diagnosis and two with posttraumatic arthrosis were excluded. A total of 522 primary total elbow replacements were performed on 403 patients (370 women, 33 men); 119 patients underwent a bilateral procedure. The mean age of the patients at the time of surgery was 57 (20-81) years; 64 died during the follow-up of causes unrelated to the elbow replacement. The diagnostic indication for surgery was in most cases elbow destruction caused by RA; in 480 cases the diagnosis was RF-positive RA, in 15 cases RF-negative RA and in 20 cases JCA. Two patients had psoriatic arthropathy. In 5 cases the diagnosis was chronic arthritis without precise definition.

#### **4.6. Study VI**

The patient cohort here was the same as in Study V, the original patient cohort being thus the same as in Study II. One patient with OA diagnosis and two patients with posttraumatic arthrosis were excluded. A total of 522 primary total elbow replacements were performed for 403 patients (370 women, 33 men), 119 patients undergoing a bilateral procedure. The mean age of the patients at the time of surgery was 57 (20-81) years. Sixty-four patients died during the follow-up of causes unrelated to the elbow replacement. The diagnostic indication for surgery was in most cases elbow destruction caused by RA; in 480 cases the diagnosis was RF-positive RA, in 15 RF-negative RA and in 20 JCA. Two patients had psoriatic arthropathy. In 5 cases the diagnosis was chronic arthritis without precise definition.

## **5. METHODS**

### **5.1. Study I**

#### 5.1.1. Clinical examination

Clinical examination was included in the follow-up but not analysed in this study.

#### 5.1.2. Radiological evaluation

AP and lateral views of all 148 elbows were taken at the 15-year follow-up. The following standard positioning was used for AP views: the patient sitting with shoulder in 90 degrees flexion and elbow extended as far as possible onto the examination table, the hand supinated, radius and ulna in the same plane, and palm facing upwards. The following standard position was use for lateral views: the patient sitting with shoulder in 90 degrees abduction and elbow in 90 degrees flexion on the examination table, and the hand supinated, thumb facing upwards. In some patients flexion deformity of the elbow or stiff and painful shoulder caused practical problems so that the ideal projection was not always achieved.

#### 5.1.3. Statistical analysis

All elbow joints were graded by the Larsen method on a scale of 0-5. The Larsen score (0-100) the wrists, 10 metacarpophalangeal joints and 8 metatarsophalangeal joints were graded and summed, and this result was used for comparison with elbow joints. Statistical comparison between the groups was made using the Jonckheere test for ordered alternatives with exact p-values (Monte-Carlo estimate). Correlation was estimated by Spearmans's coefficient. No adjustment was made for multiple testing.

## **5.2. Studies II - VI**

### **5.2.1. Clinical examination, Studies II - V**

The patients were examined at the out-patient clinic in the RFH preoperatively and at postoperative follow-ups. The clinical evaluation was carried out using the European League Against Rheumatism (EULAR) assessment chart from 1986 onwards (Pöll 1994). This comprises the following items; duration of disease, previous surgery, detailed assessment of elbow symptoms and functional ability and detailed physical examination pre- and postoperatively. Each elbow was evaluated for pain, tenderness, synovial swelling, range of motion, stability and valgus or varus deformity. Rheumatoid changes of the other joints in the extremity were also noted. The patients' subjective assessment of pain and function was asked pre- and postoperatively. Pre- and peroperative information was partially missing in 19 patients operated before 1986, but follow-up results and complications of all patients were reported. Some patients could not attend the follow-up because of poor general condition or other diseases. A total of 64 died during the follow-up. At 1-year FU 467, at 4-year FU 250 and at 8-year FU 58 patients were contacted. Patients with revision of one or both components were excluded from these FU examinations.

### **5.2.2. Radiological evaluation, Studies II - VI**

Elbows were radiographed pre- and postoperatively and at FUs which were conducted 1, 4 and 8 years after surgery. AP and lateral views were always taken. The standard positioning was the same as previously presented for Study I. As noted, in some patients flexion deformity of elbow or stiff and painful shoulder caused practical problems rendering the ideal projection unattainable.

### 5.2.3. Statistical analysis, Studies II - VI

The Kaplan - Meier survivorship method and life tables with 95% confidence intervals were used to analyse the overall survival of Souter arthroplasty (Kaplan and Meier 1958). If only one component was removed, this revision was used as the endpoint for overall curves.

In Study VI the grading of translucencies was based mainly on EULAR assessment chart, but the figures were altered according to the common system (0 = no findings).

The Cox proportional hazard method was used to determine the significance of translucencies for the risk of aseptic loosening.

## **6. RESULTS**

Study I was based on the Heinola Follow-up Survey of Arthritis. Studies II - VI were based on a follow-up of 525 consecutive elbow replacements at the RFH. This section reviews the main results of the series. Further details are presented in the original papers.

### **6.1. Incidence of elbow involvement in RA (Study I)**

Erosive involvement ( $\geq$  Larsen grade 2) was observed in 75 (51%) out of 148 elbow joints in 45 (61%) patients out of 74. Thirty patients had bilateral and 15 unilateral affection. The incidence of mild erosions (Larsen grade 2) was 33%, that of severe (Larsen grade 3-5) 18%. Changes in Larsen grade 4-5 were found in 11% of the patients. Erosiveness was most often found on the capitellum (43%) and the lateral epicondyle (39%) of the humerus or on the olecranon of the ulna (35%). Cystic changes larger than 5 mm were detected most often in the ulna (11%). Osteophytes were found on the ulna in 17%, on the radius in 6% and on the humerus in 5% of joints. The Larsen score (0-100) for peripheral joints correlated significantly with elbow joint Larsen grade on both sides (Table 2).

**Table 2.** Radiographic assessment by the Larsen method of elbow joints in 74 patients with RA after 15 years' disease duration. The relationship between different grades of destruction and corresponding Larsen scores for hands and feet (0-100) is presented.

	Larsen grade of elbow joint				p
	0	1	2-3	4-5	
<b>Right elbow joint</b>					
Number of joints (%)	20 (27)	13 (17)	33 (45)	8 (11)	
Larsen score, mean (SD)	23 (18)	36 (20)	52 (23)	58 (30)	<0.001
<b>Left elbow joint</b>					
Number of joints (%)	16 (22)	24 (32)	29 (39)	5 (7)	
Larsen score, mean (SD)	21 (13)	33 (23)	55 (21)	62 (27)	< 0.001

## 6.2. Clinical and radiological results of Souter-Strathclyde elbow arthroplasty (Study II)

In this work the results of 525 primary Souter elbow arthroplasties performed between 1982 and 1997 were presented. The follow-up period was 1982 - 1998.

### Subjective assessment

At FU assessments the EULAR questionnaire was used. Patients' pre-and postoperative subjective assessment (not presented in the original publication) was as follows (Tables 3-6).

**Table 3.** Pain experience preoperatively (%)

Pain at rest	46.9
Pain at night	52.2
Pain on movement	96.8
Pain under loading or stress	96.8

**Table 4.** Severity of preoperative pain (%)

None	1.7
Occasional twinges	6.1
Mild pain	15.4
Significant pain	70.5
Severe pain	4.6
Not known	1.7

**Table 5.** Postoperative pain status at 1, 4 and 8 years FU.

<u>Subjective assessment at FU</u>	<u>1 yr (%)</u>	<u>4 yrs (%)</u>	<u>8 yrs (%)</u>
Marked improvement	92.2	82.6	82.8
Slight improvement	4.8	9.0	6.9
Same	1.1	6.5	6.9
Worse	0.8	1.9	3.4
Not known	1.1	0	0

**Table 6.** Postoperative function status at 1, 4 and 8 years FU.

<u>Subjective assessment</u>	<u>1 yr (%)</u>	<u>4 yrs (%)</u>	<u>8 yrs (%)</u>
Marked improvement	76.5	64.5	72.4
Slight improvement	12.0	18.1	6.9
Same	7.8	12.3	17.2
Worse	1.3	3.2	3.4
Not known	2.4	1.9	0

#### Learning curve

The significance of experience is presented in Table 7 showing the number of patients who underwent further surgery for early complications.

**Table 7.** Distribution of the number of patients (not operations) reoperated by reason of early complications

<u>Operation ordinal</u>	<u>N (pat.)</u>
1. - 100.	12
101. - 200.	8
201. - 300.	0
301. - 400.	4
401. - 500.	4
501. - 525. (25)	1

## Reoperations for complications

**Table 8.** Complications after 525 Souter-Strathclyde elbow arthroplasties in 406 patients

Complications		Reoperations for complications (N)	
Type	Patients (N)	Early (N)	Late (6 mths <) (N)
Dislocation	26	28	2
Aseptic loosening	30	0	33
Superficial infection	3	2	1
Deep infection	12	6	23
Damage to ulnar nerve	2	2	0
Others	10	2	10

### Dislocations

Twenty-six patients were reoperated 30 times for dislocation. Only two of these cases involved late dislocation. Eighteen (16 early) non-retentive ulnar components were changed to retentive. Ligament or capsule reconstruction was undertaken in 12 patients. Four of these cases involved redislocation and later change of ulnar component. There were 22 dislocations with the small standard ulnar component and 4 with the medium standard. Subluxations were also more frequent with the small ulnar component than with the medium standard (9 versus 4).

## Infections

Two patients required early wound revision due to superficial infection and one infected bursa was removed. Twelve patients underwent 29 operations for deep infection. Six of these presented early and six late complications.

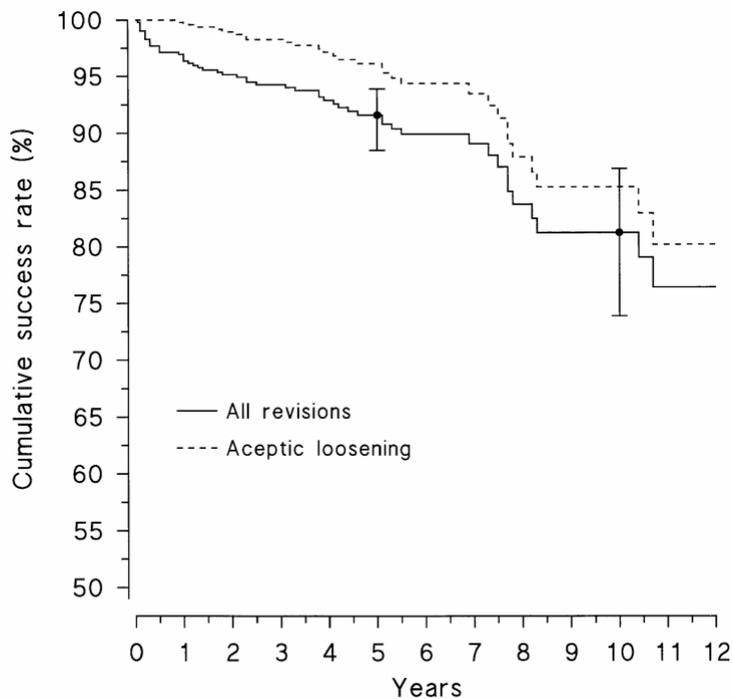
## Ulnar nerve dysfunction

Preoperatively 25% of patients had sensory impairment of the ulnar nerve and at one year follow-up 6%; at four- and eight-year follow-up the incidence of sensory impairment was further slightly decreased. Two severe cases of peroperative nerve damages were noted.

## Aseptic Loosening

Thirty patients out of 525 cases had 33 rearthroplasties for aseptic loosening. In seven cases there was also preoperative fracture. Both components were changed in 20 operations, only the humeral component in 7 and only the ulnar in 6 cases. The cumulative success rate without aseptic loosening five and ten years after surgery according to survival analysis was 96 and 85 per cent (95 % CI 94 to 98 and 79 to 92) respectively. Cumulative success rate without all revision and without aseptic loosening is presented in Figure 4.

**Figure 4.**



#### Other reoperations

Twelve re-operations were performed on ten patients for various reasons. Six patients had reconstruction of the triceps tendon. Further, two fixations of an ulnar fracture with a plate at the level of the component's tip and one release of adhesions because of poor ROM, one bursectomy and two wound revisions for marginal necrosis were performed.

#### Range of movement

Preoperatively the mean active flexion was 33°–133° and at one-year follow-up 32°- 143°. The mean preoperative pronation was 71° and supination 61°, and at one-year follow-up 78° and 69°, respectively. At the 4- and 8-year FUs the figures were practically the same.

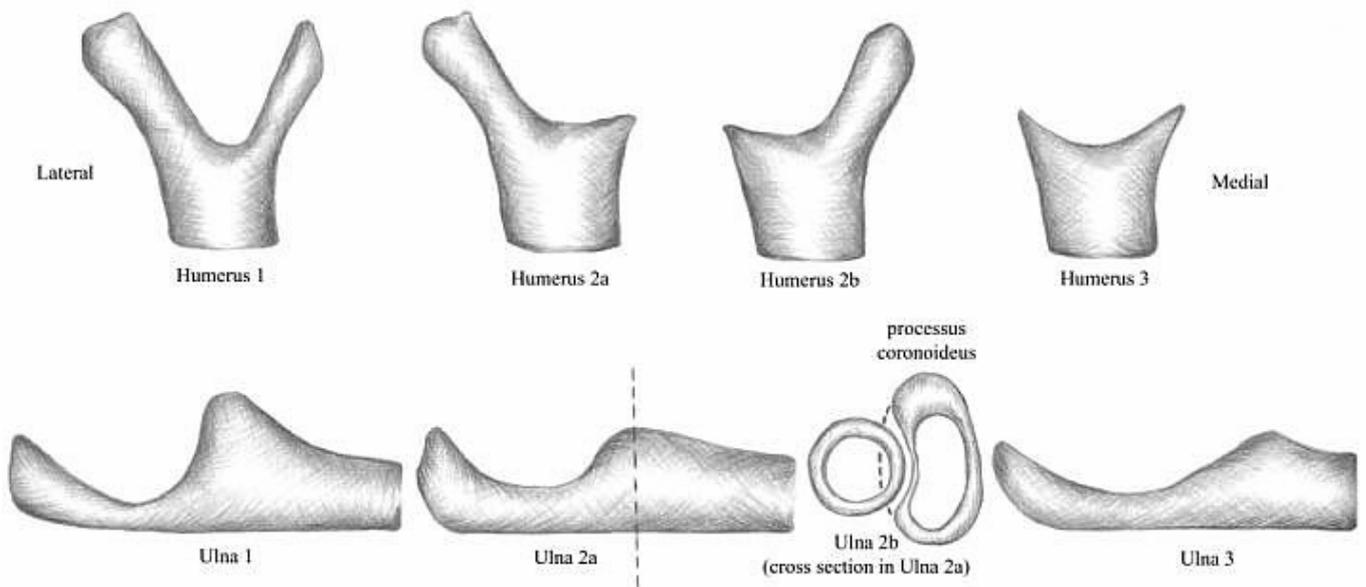
### 6.3. Souter arthroplasty in severely destructed elbow (Study III)

In this work, the aim was to evaluate the results of TEA in more severe cases. In selection of the study group, 158 elbow joints in 134 patients (121 women) fulfilled the criteria of severe elbow destruction: Larsen Grade 5 destruction, major bone defects in the distal humerus, proximal ulna, preoperative fractures in the elbow region, or all of the above. A classification system was presented which describes the frequency of different types of destruction in the elbow (Table 9, Figure 5).

**Table 9.** Number of classified bone defects

<u>Bone defect</u>	<u>Number</u>
Humerus 1	86
Humerus 2a	8
Humerus 2b	2
Humerus 3	4
Total	100
Ulna 1	109
Ulna 2a	3
Ulna 2b	3
Ulna 3	19
Total	134

**Figure 5.** Classification of humeral and ulnar bone loss



### Reoperations for complications

In the whole series, there were five reoperations for early complications and 16 for late.

Change of one or both components was undertaken in 14 patients.

### Dislocations

Three patients were operated on for early dislocation and the all-polyethylene component was changed to a retentive metal-backed component. One patient suffered late dislocation and was successfully treated with capsuloplasty. One patient with early dislocation was successfully treated with a splint for 4 weeks.

### Infections

One patient had an early superficial infection and was treated with antibiotics only. One

was operated on for late purulent bursitis. One patient developed a primary deep infection and five had a late deep infection.

#### Ulnar Nerve Dysfunction

Preoperatively, 25% of the patients (34 patients, 40 elbows) evinced sensory impairment of the ulnar nerve, and at the 1-year follow-up 5% (seven patients, eight elbows), respectively. Two patients had severe peroperative nerve damage with permanent motor and sensory palsy. Four additional patients suffered permanent or long-term motor and sensory impairment, which began or increased after surgery although no visible damage was observed. Twenty-seven patients with preoperative sensory impairment became symptomless after the operation.

#### Aseptic loosening

Eight patients were operated on for aseptic loosening. Two of these also had fracture of the olecranon and one had fracture of the medial condyle in the humerus. Both components were changed in three patients, only the ulnar component in one, and only the humeral component in four patients. The cumulative success rate without aseptic loosening 5 years after surgery was 97% (95% confidence interval, 92% to 99%).

#### Other reoperations

One patient had a second wound suturation because of marginal necrosis and one late reconstruction of the triceps tendon was done.

#### Other complications

Three peroperative fractures of the humeral condyle occurred, these being fixed with cerclage or Kirschner wires. Three late fatigue fractures of a weak humerus condyle also occurred. These healed spontaneously. Six patients had minor wound problems such as

marginal necrosis, but no operations were needed.

Range of motion

Preoperatively, the mean active ROM was 36° to 134° and at the 1-year FU 28° to 143°.

#### **6.4. Fractured rheumatoid elbow and its treatment with Souter elbow arthroplasty (Study IV)**

In this work a cohort of 26 patients with 32 preoperative fractures were studied separately.

Bony healing

Complete union occurred in 16 patients and 11 patients presented non-union; in one of these patients the lateral humeral condyle united, but the medial one did not. Of the total number of 34 fractures 20 united, and 14 did not. Among these 14 non-unions there were two medial humeral condyles where fixation was not attempted in the operation for peroperative technical reasons.

Range of motion

Active ROM at 1-year FU was 38 (mean, 0-65) - 139 (mean, 90-160) degrees.

Pain at FU

One patient suffered from significant, three from mild and one from occasional pains in the operated elbow. Information of two patients was missing. In 19 patients the operated elbow was painless.

## Complications

There were no postoperative superficial or deep infections or ulnar nerve complications in this group of patients. One patient with preoperative olecranon fracture developed spontaneous medial condyle fracture one month postoperatively. Spontaneous union occurred. In one patient a protruding K-wire was cut shorter through a minor incision 3 weeks after the primary procedure.

Six patients presented late complications. In three cases there was radiological loosening of the humeral component. One patient developed a hematogenous deep infection four years postoperatively. One patient had olecranon bursitis and avulsion rupture of the triceps tendon treated operatively. There was also another patient with triceps avulsion which was treated surgically.

### **6.5. Revision arthroplasty due to aseptic loosening (Study V)**

In this work the follow-up time was to the end of 2000; there are thus more cases with aseptic loosening than presented in Study II.

Forty-seven patients out of 522 underwent 51 rearthroplasties for aseptic loosening. In 10 elbows a preoperative fracture was also present at re-operation. Both components were changed in 30 elbows. Revision of only one component was performed on the humeral side in 11 and on the ulnar side in 6 elbows. A second reoperation for aseptic loosening was performed in 4 patients on the humeral side. In survival analysis the total cumulative success rates without aseptic loosening 5 and 10 years after surgery were 96 and 84% (95% CI 94 to 98 and 78 to 89) respectively.

The success rates for the seven most commonly used components are presented in the original paper (Study V). The highest 5 -year survival rate was 100%, the lowest 93%. The corresponding 10-year survival rates were 91% and 76%. Some of the components became available so late that they are included only in the 5-year FU but not in the 10-year FU. Different types of prosthetic components used in the Souter elbow arthroplasty and the number of the loosened components (year first time used at RFH) are presented in Table 10.

**Table 10**

<u>Humeral components</u>		<u>Aseptic loosening N</u>
1. Small std	119 (1982)	18
2. Med. std	151 (1982)	18
3. Large std	5 (1992)	0
4. Med. long stem 7 cm	211 (1985)	4
5. Small long stem 15 cm	35 (1991)	1
6. custom-made	1 (1996)	0
Total	522	
 <u>Ulnar components</u>		
1. All PE, small std	211 (1982)	31
2. All PE, med. std	119 (1982)	5
3. Metal back, non-ret. stem 5 cm	14 (1994)	0
4. Metal back, retentive stem 5 cm	99 (1991)	0
5. Metal back, retentive stem 7 cm	77 (1990)	0
6. Metal back, retentive stem 9 cm	1 (1995)	0
7. Metal back, ret. custom-made	1 (1996)	0
Total	522	

## 6.6. Prognostic value of radiological findings after elbow arthroplasty (Study VI)

In this work radiological changes were evaluated in all postoperative radiographs of 522 consecutive Souter elbow replacements in patients with RA or related chronic arthritis.

A new classification which divides the elbow region into 10 zones was presented (Fig. 6) Our purpose was to find areas, which can be easily distinguished, and secondly the significance of which is different for fixation due to anatomical factors and structures of components. The grading is presented in Table 11 and appearance of translucencies in different zones in Table 12 to follow.

### **Table 11.** Grade of translucency

0 = no translucency

1 = partial linear translucency, 1 mm or less

2 = complete linear translucency, 1 mm or less

3 = wide translucency, 2 mm or less, sharply defined

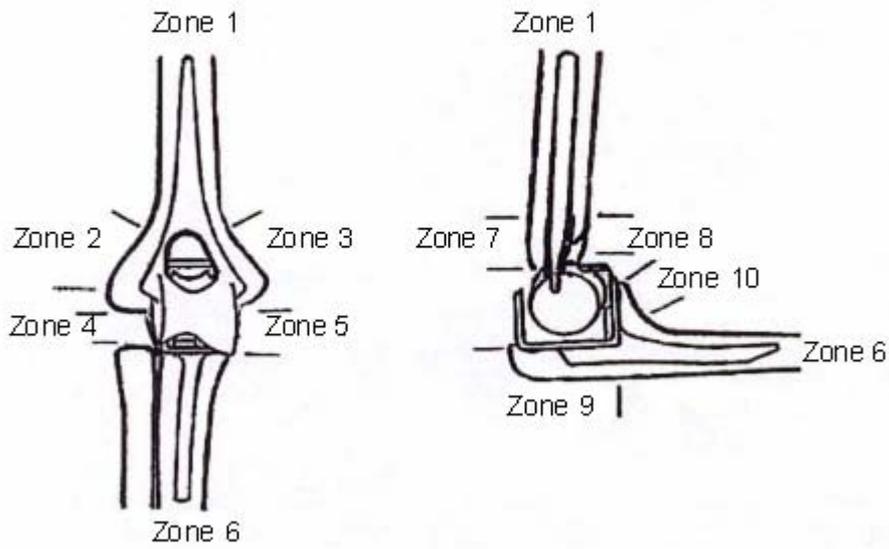
4 = wide translucency, 2 mm or less, not sharply defined

5 = wide translucency, more than 2 mm - possibly scalloping

6 = major bone disruption or perforation, ballooning

7 = total loss of bone structure

**Figure 6. Zones**



ZONE 1										ZONE 2										ZONE 3										ZONE 4										ZONE 5									
Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time																
	POP	1 yr	4 yrs		8 yrs	POP	1 yr		4 yrs	8 yrs	POP		1 yr	4 yrs	8 yrs		POP	1 yr	4 yrs		8 yrs	POP	1 yr		4 yrs	8 yrs	POP		1 yr	4 yrs	8 yrs		POP	1 yr	4 yrs	8 yrs	POP	1 yr	4 yrs	8 yrs									
0	99.0	80.9	70.4	63.8	0	98.5	81.5	67.6	50.0	0	97.5	79.0	64.4	44.8	0	100.0	93.4	84.0	63.8	0	100.0	93.4	84.0	63.8	0	1000	91.7	79.6	56.7																				
1	1.0	17.6	19.2	13.8	1	0.6	15.0	19.6	20.7	1	0.8	16.5	23.6	31.0	1	1	4.5	10.4	20.7	1	1	6.4	14.8	27.6	1	6.4	14.8	27.6																					
2		1.3	5.2	15.5	2		2.1	4.4	15.5	2		1.9	5.2	10.3	2		0.4	3.2	8.6	2		0.4	3.2	8.6	2		0.2	2.8	8.6																				
3		0.2	0.4	1.7	3		0.2	1.2	6.9	3	0.2	0.6	1.2	8.6	3		0.6	1.2	1.7	3		0.6	1.2	1.7	3		0.6	1.2	1.7																				
4			1.6		4			4.0	1.7	4		0.2	1.6	1.7	4		0.4	0.8	1.7	4		0.4	0.8	1.7	4		0.4	0.8	1.7																				
5			2.8	5.2	5			2.4	5.2	5			2.0	3.4	5		0.2		3.4	5		0.2		3.4	5		0.2	0.4	3.4																				
6			0.4		6	1.0	1.1	0.8		6	1.5	1.7	2.0		6		0.2	0.4		6		0.2	0.4		6		0.2	0.4																					
7					7					7					7		0.2			7		0.2			7		0.2																						

ZONE 6										ZONE 7										ZONE 8										ZONE 9										ZONE 10									
Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time			Grade	Time																
	POP	1 yr	4 yrs		8 yrs	POP	1 yr		4 yrs	8 yrs	POP		1 yr	4 yrs	8 yrs		POP	1 yr	4 yrs		8 yrs	POP	1 yr		4 yrs	8 yrs	POP		1 yr	4 yrs	8 yrs		POP	1 yr	4 yrs	8 yrs	POP	1 yr	4 yrs	8 yrs									
0	100.0	94.2	91.6	72.4	0	99.4	91.7	82.0	74.1	0	99.6	85.9	72.8	62.1	0	96.4	33.6	20.4	13.8	0	92.1	16.3	8.0	0	92.1	16.3	8.0																						
1		2.8	4.4	12.1	1	0.2	7.5	10.8	15.5	1	0.4	12.6	18.4	24.1	1	3.1	46.3	38.8	43.1	1	6.5	50.0	38.8	1	6.5	50.0	38.8																						
2		0.9	1.6	6.9	2		0.2	2.0	5.2	2		0.6	2.4	6.9	2	0.6	17.6	33.6	31.0	2	0.4	30.5	44.4	2	0.4	30.5	44.4																						
3		0.2		1.7	3		0.2	0.8	1.7	3		0.4	0.4	1.7	3		0.2	2.4	1.7	3		0.2	0.9	5.6	3		0.2	0.9	5.6																				
4		0.9	1.6	1.7	4	0.2	0.4	2.4		4		0.4	1.2	1.7	4		0.2	1.6	5.2	4		0.4	1.2	1.7	4		0.4	1.2	1.7																				
5		0.2	0.4	5.2	5			2.4	3.4	5			3.6	3.4	5		0.4	1.2	3.4	5		0.2	0.6		5		0.2	0.6																					
6		0.6	0.4		6	0.2				6			1.2		6		1.5	2.0	1.7	6		0.6	0.9	1.6	6		0.6	0.9	1.6																				
7		0.2			7					7					7		0.2			7		0.2			7		0.2																						

**Table 12.** Distribution of the percentual proportion of cases according to the grade of translucency (0-7) immediately postoperatively (POP) and at 1, 4 and 8 years follow-up.

Cox proportional Hazard Model was used to determine the effect of translucencies on the risk of aseptic loosening. At 1-year FU, the translucencies in only two zones (Zone 3, Zone 8) seem to have prognostic value with respect to aseptic loosening of the component. Translucencies in Zone 3 increases the risk 4.17 times (p 0.002) and in Zone 8 2.37 times (p 0.045) (Table 13).

**Table 13.** Proportional hazard model to determine the effect of translucencies at one year FU on risk of aseptic loosening.

Zone	Hazard ratio (95% CI)	P value
1	1.09 (0.51 to 2.32)	0.83
2	1.13 (0.48 to 2.67)	0.78
3	4.17 (1.69 to 10.31)	0.002
4	1.11 (0.26 to 4.77)	0.89
5	0.79 (0.22 to 2.88)	0.72
6	1.64 (0.66 to 4.12)	0.29
7	0.73 (0.31 to 1.75)	0.48
8	2.37 (1.02 to 5.52)	0.045
9	0.89 (0.34 to 2.32)	0.81
10	3.64 (0.47 to 28.21)	0.22

## 7. DISCUSSION

The prevalence of RA in the Finnish population over the age of 16 years is approximately 0.8% (Hakala et al 1993). There are thus approximately 35 000 rheumatoid patients in Finland. Elbow involvement is very rarely seen in the early years of RA, but 15 years after the onset of the disease approximately two thirds of patients have symptoms or/and radiological changes in their elbows.

The 15-year incidence of elbow joint erosions in this inception cohort with RA was 51% (Study I). In cases evincing most advanced destruction (Larsen 4-5) the involvement was almost always bilateral. If one elbow with severe destruction is found upon examination of an RA patient, the other side should be also monitored clinically and radiographically. It is frequently observed that difficult symptoms in the most painful joint may outweigh the symptoms in other joints with less pain, in spite of marked destruction visible in them in radiographs. In our study, the first erosions seemed to occur on the capitellocondylar articular margin in the humerus. In a study by Thomas, it was suggested that the medial joint margin best demonstrates the small changes (Thomas 1969).

Surgical treatment of the elbow is somewhat uncommon. Nowadays, the number of synovectomies performed is decreasing. At the RFH, 17 synovectomies were performed in 2000; in 1990 the corresponding figure was 40 and in 1980 it was 69. This is due partially to improved medical treatment, but it is also possible that in some cases the opportune time for synovectomy has been missed. Ideal timing for synovectomy is difficult to determine and is dependent on co-operation between the operative and conservative departments. On the other hand, the long-term results of elbow synovectomy are controversial.

Approximately one hundred TEAs are performed in Finland annually, nearly half of them at the RFH during the study. Related to the number of patients with RA, the procedure is still rare. Use of TEAs is very variable in different parts of the country according to National Agency for Medicines (The 2000-2001 Implant Yearbook on Orthopaedic Endoprostheses, Table 14).

**Table 14.** Number of municipalities with variable use of TEA. Operations/100 000 inhabitants in different municipalities, average of the years 2000-20001

<u>Operations/100 000 inhabitants</u>	<u>Number of municipalities</u>
10-140	42
1-10	67
0-1	339

Apparently, many rheumatoid patients and even some physicians are unaware of the option of replacement in a damaged elbow. On the other hand, so far as good long-term results are not generally achieved, the logical attitude is to be critical of any treatment.

Usually elbow replacement is performed after a long period from the disease' onset. In a 25-year follow-up study by Palm and associates the median time from diagnosis to operation was 23 (11-26) years (Palm et al. 2002). In our study it was 25 (2-70) years.

Especially in the early years of the study, TEA was very rarely performed, in certain patients with painful elbows not suitable for synovectomy (or resection arthroplasty) but on the other hand without severe bone defects. With growing experience during this study, the right indications and contraindications have been sought. In many individual cases nonetheless it is difficult in preoperative examination, to predict whether a patient will benefit from the

operation or not. Consequently, patient selection is not based on any factual need in a certain population but depends on many random factors. In this study, there was no peer group to be compared to in respect of the natural course of the disease or the results of conservative treatment only.

In the present case, it is impossible to say precisely what is the role of improved operative technique focusing on the total material of Souter arthroplasties as compared with better component selection to reducing the number of early complications. Very satisfactory early results were achieved in the third group of 100 consecutive patient (patient numbers 201-300), where no severe early complications necessitating operative treatment were encountered. In the two following groups of 100 patients, there were again some early revisions. This may be coincidental, but most of these early complications in the later phase of the study occurred for two reasons; firstly there were dislocations related to attempts of a new surgeon with non-retentive standard ulnar components in excessively difficult elbows. Retrospectively, it may be assumed that at least some of these complications could have been avoided with better component selection Secondly, the objective was to determine new limits of TEA in patients with severe problems in general condition, and this may be seen as entailing some deep infections.

During the period from 1990-92 the metal back retentive (snap-fit) Souter ulna component became available, first as a custom-made device. In our material, the role of the retentive ulnar component seems to have been considerable in avoidance of luxation. No dislocations with retentive ulnar components occurred during the FU. Twenty-six patients with non-retentive standard ulnar component suffered luxation, but only 7 of these occurred during the period 1993-1997, when retentive ulnar components were already a commonly used alternative at the RFH. On the other hand, good results are referred from other centres, with

low rates of dislocation when only standard components have been used (Trail et al. 1999). A non-retentive metal back component was first used in 1994 and has become more popular since the close of this study. No dislocations were associated with this model during the FU, but one has occurred after this study in a male patient, who neglected to comply with post-operative loading limits.

The selection of components may have an influence on ROM but this was not systemically examined in this study. Simply, the average ROM in elbows with retentive ulnar component seemed to be somewhat better than with non-retentive, but the groups were unequal in that the retentive model had been used in more severe elbows and in the latter phase of the study. In some difficult cases flexion deformity may be substantial without possibilities of satisfactory ROM, while on the other hand, many elbows with massive bone loss may be so flail that full ROM is easily achieved with any adequate model of prosthesis. The author's experience is that in cases of tight flexion deformity, the location of a component only 2-3 mm deeper may clearly release extension. For example, a medium long-stem humeral component has smaller side flanges than a medium standard component and it is easier in most cases to place deeper, if needed. If a non-retentive ulnar component is used, the joint must be kept tighter to avoid luxation and often some lack of extension in peroperative assessment must be accepted or even preferred. When using a retentive ulnar component, the aim in the operation is full extension. In the present material the mean lack of extension was the same pre- and postoperatively. The results were almost parallel to those published by Souter in 1989.

Patient materials in different countries and hospitals may be somewhat different, as also the timing of operation in different stages of arthritic joint destruction. In our material, 158 elbow joints were considered severely destructed. The limit between "normal" and "severe"

destruction in rheumatoid elbow is artificial and vague. We sought these to define our concept of severe destruction and to create a new classification. The approach was based on elbows in which bone destruction or lost bone structures hindered primary arthroplasty with standard Souter components, or empirically would have caused a failure if a procedure using the standard components had been undertaken in spite of advanced destruction.

The author's experience, especially after this study, is that the ulna 2b-type of destruction is relatively often present at surgery, but is difficult to detect preoperatively in plain radiographs. This ulna 2b destruction has an impact in practical terms in that it may increase difficulties in placing the stem of an ulnar component in the medullary canal. In advanced cases it may so alter the alignment of the stem that the proximal part of the component is forced medialwards. In such cases the author has often bent the stem during surgery (on his own responsibility) in order to achieve better correspondence to the ulnar bone structure. This far no fractures of components have occurred. On the other hand, if the thin secondary cortex adjacent to the proximal radial head is reamed, the result will easily be bone perforation and probably an increased risk of aseptic loosening.

The mid-term results in the cohort of severely damaged elbows were surprisingly good comparing to the total material. The success rate without revision for aseptic loosening at 5-year FU was 97%, while in the total material, including less severe cases, it was 96%. The possible background to this is increased experience gained during the course of the series and the use of components with better survival rate (Study V). It seems that the Souter prosthesis with a retentive ulnar and a long stem humeral component is a viable option for cases involving severe bone loss. It is probably a suitable alternative to a floppy hinge prosthesis, which was previously recommended for more advanced destruction (Souter 1981, Morrey and Adams 1992).

The design of the Souter metal-backed ulnar component offers a good option for bone transplantation, which is not possible to the same extent with floppy hinge models. However, the success of bone transplantation on a destroyed olecranon was not proved in this study and it will also be difficult to confirm it in the future, in consequence of the difficulties in radiographic examinations with metal-backed ulnar components. Judging from some revision cases and partially on lateral view radiographs, the author believes that bone grafting to the olecranon, and especially the use of morsellized bone, could be beneficial.

According to study IV with a material of 26 patients with 32 fractures it is obvious that a fracture in the humeral condyles or olecranon in a rheumatoid elbow is not a contraindication to arthroplasty. Fixation of fractures seems to be preferential to excision of substantial fragments. Even in non-union cases the patients were painless. Separate fixation of a fracture prior to the arthroplasty in rheumatoid destruction is not recommended. Our experience is that the risk of non-union is notably higher without the support of a prosthesis, and even in cases of achieved union subsequent arthroplasty is not essentially less demanding.

Adequate fixation of condyle fragments was evidently essential. Many non-unions were associated with cases of fragment fixation with a single Cerclage wire only. Combination of Cerclage and K-wire gave a more stable result. Plate fixation was used in only one elbow, with an unsatisfactory result. Our previous experience with the use of plate fixation in RA was also unfavourable. In some cases a plate with cable fixation might be more beneficial, but our experience with respect to this is limited.

Bone transplantation was used in almost all fracture cases in the current study. Its effectiveness cannot be proved, but the author believes that it plays a significant role. Since this study there have been several cases with a lost humeral condyle where the missing part was replaced with a small block of allogenic bone, with satisfactory early results.

The designer recommended using where possible standard components of the Souter prosthesis in order to avoid more severe complications when removal of the component is needed. However, he preferred to use a hinged prosthesis in severe cases with gross bone losses (Souter 1981). Pöll recommended the largest possible size of the humeral component for optimal fixation and alignment (Pöll and Rozing 1991).

At the RFH, during the years 1982-1992 the standard humeral components were used routinely. Our experience in many cases was that a small standard humeral component was too small, while a medium standard humeral component might entail excessive bone removal especially inside the lateral condyle, by reason of the bulky lateral peg of the component. The medium-size long-stem (7 cm) model with smaller pegs was preferred, although the intramedullary canal had to be opened. Use of the metal-back ulnar component was also favoured, initially to avoid luxation and later in an attempt to achieve better fixation in cases with severe olecranon destruction.

The aim of study V was to present survival of the seven most commonly used components. We were interested in comparing the success rates of the standard and the long-stem medium humeral component. However, the groups were not similar. Most of the long-stem humeral components were used later and in a more experienced phase of the study. During the first years they were used only in more difficult cases. In the experimental studies of Souter and Pöll it was noted that fixation of different components was approximately equal

against stressing forces (Souter 1981, Pöll 1994). However, according to our results the rate of aseptic loosening of medium long-stem components appeared to be markedly lower: a survival rate of 99% at 5 years with only four loosening cases in the material of 211 components. Likewise the conclusion in a study by Trail was to prefer long-stem components (Trail et al. 1999)

Comparison of the survival rates of the standard all-PE ulnar components and the metal-back ulnar components was also one of the main goals. During this study, no aseptic loosening occurred in the metal-back ulnar component group. In spite of shorter FU, it can be stated that the early results with metal-back ulnar components are clearly better than the outcome with standard components. PE-debris and micromotion of the all-PE-component may cause progressive loosening towards the stem more easily than with the rigid metal-back component.

It was previously assumed that a more rigid retentive ulnar component could increase the loosening risk of the coupled humeral component. In our study, no such evidence was found.

The disadvantage of longer stems was clearly realised in cases of deep infection. Since this study some such cases needing removal of components with good fixation, have been encountered. The author's experience is that detachment of the long stem (7 cm) humeral component is relatively harmless, but removal of the cement mantle requires more work with a risk of cortex perforation. Detachment of a metal-back ulnar component with good fixation is much more demanding. Usually the ulna must be split 3-5 cm distally from the coronoid region. In fact this split usually heals before re-replacement is scheduled – within 2-3 months. The risk of fracture is considerable in cases of a weak olecranon. However, if the number of

deep infections remains relatively low, the total advantage of longer stems is probably more significant.

In cases of an early phase of component loosening the patient is often symptomless. Radiography is the only mode of examination to reveal these imminent problems. The significance of radiolucencies around the elbow prosthesis has been previously studied (Morrey and Adams 1992, Souter 1989). Gschwend et al. (1996) presented the concept that radiographic and clinical loosening should be distinguished from each other, because clinical symptoms may follow relatively late after radiological findings. His opinion was that the criteria for radiological loosening includes a progressive radiolucent line at least 1 mm around the whole component and tilt or subsidence of the component.

At the beginning of the present study the author's assumption was that the thin translucencies very commonly seen in the coronoid region (Zone 10) and in distal parts of the humeral condyles (Zones 2 and 3) are meaningless and that they are mainly dependent on factors in cementing technique. The olecranon area (Zone 9) remained an enigma, because a thin translucency was often already visible at 1 year's FU, but how often it is progressive, resulting in loosening, is unclear.

In study VI all visible translucencies were graded and the sum of appearances presented in Table 2. In all zones the proportion of cases without any translucency (Grade 0) was consistently decreasing during FU. However, the amount of the decrease varies greatly in different zones. For example, at 4-year FU, Grade 0 was found in 91.6% in Zone 6 and 8.0% in Zone 10. One may presume that translucencies in the areas of essential fixation - zones around the stems - could predict aseptic loosening. This could not be verified in the present study. In contrast, at 1-year FU translucencies in Zone 3 increased the risk of aseptic

loosening 4.2-fold, and in Zone 8 2.4-fold. This may be taken to mean that at 1 year FU in the cases of loosening the progression was in so early a phase that no findings in the stem region have as yet appeared. Obviously, loosening of an elbow prosthesis usually happens in the same manner as in hip and knee prostheses, with slow progression in the cement-bone interface beginning from the joint cavity and continuing to deeper parts. Presumably signs of loosening will appear earlier in the area of the medial condyle (Zone 3), because this is usually more seriously eroded and markedly weaker than the lateral condyle (Zone 2). Since for anatomical reasons the fossa olecrani is deeper than the fossa coronoideus and the posterior cortex is thicker than the anterior, thin translucencies are more easily and possibly earlier visible in Zone 8 than in Zone 7.

In the region of the olecranon (Zone 9) translucencies frequently appeared (at 1-year FU Grade 0 in only 33.6%), but they had no predictive value. Apparently, many of them are not progressive. As assumed, the translucencies most often seen in coronoid area, Zone 10, seem to have no prognostic value.

In later course of the FU some zones, located anatomically deeper in the bones might be of prognostic value for aseptic loosening. However, at 4-year FU, in this study, the patient material was so limited (250), that no statistically relevant results were obtained. Unfortunately, some patients skipped the 1-year and some others the 4-year FU. This hampered the possibility of defining statistically the progression of translucencies. However, it is obvious in the light of the figures in Table 2 that many translucencies tend to progress.

The difference may be more semantic than practical, but the author's opinion is that radiological and clinical loosening should not be distinguished from each other with respect to elbow replacement, or for that matter in other endoprosthetic surgery. Our experience,

based on several revisions in which one component was clearly radiologically loosened while the other was surrounded by only very thin but continuous translucency in radiographs, is that at surgery this other component will be found likewise to be loose. Therefore, if a component seems to be radiologically loosened, it should be considered loosened regardless of whether the patient has symptoms or not. A different question is when revision surgery should be performed in the same manner as in loosening of weight-bearing prostheses. Also in the case of hip or knee prostheses, revision arthroplasty is not always immediately necessary upon detection of radiological signs of loosening. The fact nonetheless remains that revision arthroplasty is usually inevitable sooner in weight-bearing joints than in elbows or shoulders.

At the RFH we have some examples of cases in which a continuous thin translucency was detected, but in the absence of symptoms the next FU was set according the scheme after four years. By that time, however, the loss of bone material had already advanced to a difficult grade. It can be recommended that in the TEAs with even thin uninterrupted translucencies, the interval between radiological evaluation should be at most 1-2 years until the necessity for revision is determined, or else it is documented that the translucency is not progressive.

### **Future perspectives**

The history of all endoprostheses is still very short. Hip and knee arthroplasties are already well known to the public, in contrast to TEA, which is a rare procedure. In order to obtain an ideal patient material for TEA, there are two main principles: to share information and carefully select patients for operation. All physicians treating rheumatoid patients should be aware of the options of TEA, so that the possibility of treatment can be presented to the

candidate patient. Surveys of current developments in elbow replacements should also frequently be provided in publications intended for rheumatologists and also in information papers for patients with RA.

The need for elbow arthroplasty in the treatment of rheumatoid patients is manifest and the early and mid-term results at the RFH are at least satisfactory. It must be emphasised that every symptomless year after successful arthroplasty is of great value for a patient with RA.

Not all patients with destruction in the elbow joints suitable for replacement should be operated. Patients running a high risk of complication, or patients who will derive no benefit from an operation due to other personal problems should be excluded from treatment with elbow prosthesis. Absolute contraindications may easily be found, but a more difficult problem is to predict the influence of a certain relative contraindication or a sum of several relative contraindications, as is the case with many rheumatoid patients. In many centres performing elbow replacements, the series are rather small, and thus the experience of relative contraindications remains limited.

Further studies of the current material are possible. Especially, long-term FU results of elbow arthroplasties are needed. It would also be interesting to ascertain the effect of retentive and non-retentive ulnar components on ROM. Previous operations and diagnosis of different types of chronic arthritis may also have an influence on results of TEA.

However, this study did not provide an answer to the fundamental question of whether elbow replacement is a good solution during a life-long course? There are no randomised efficiency studies of this subject available. A young patient with RA may have a long life expectancy and a revision operation or several revisions will probably be needed. The rate of late

complications and the success rate of re-replacements remains to be established, as does the final proportion of hopeless failures. All these aspects should be compared to the natural course of the disease. However, no peer group is available for this study, and obviously, the general trust in arthroplasties is so firm, that it is difficult and probably unethical to arrange such a group for comparison today. An aim in future is to compare the results of different types of prostheses and/or techniques to each other. Arrangements for such studies are complicated. Annual numbers of TEAs are small in separate hospitals. Co-operation between different centres is needed. On the other hand, there may be varying techniques in different hospitals and during long-term studies technical details may change, as well as operating surgeons.

The concentration of arthroplasties in certain centres in Finland is a topical issue, also in discussions concerning more common arthroplasties like hip and knee replacements.

Number of hospitals performing TEAs has varied between 10 and 14 in 1997-2001. (National Agency for Medicines: The 2000-2001 Implant Yearbook on Orthopaedic Endoprotheses).

The annual total number of elbow arthroplasties in Finland is approximately 100. At the RFH the annual number of primary TEAs was 40-70 in the 1990s and 25-30 during the last years.

Consequently, there must be several hospitals in which the annual number of TEAs is less than 10. It may be presumed that in the case of rare arthroplasties like elbow replacement concentration is even more important. Because almost all TEAs are performed for rheumatoid patients, these procedures should be undertaken in the centres, which continuously treat rheumatoid patients. Elbow replacements should be concentrated among a few surgeons in each centre, while for the sake of continuity and improvement of skill, concentration with only one surgeon is not recommendable.

The smaller the annual number of elbow replacements in a hospital, the fewer and safer alternatives for prosthesis should be used. Non-linked models are probably more demanding in surgical technique. In the early phase of the learning curve, a safer choice may be a more stable non-linked model (high anterior claw, corresponding processus coronoideus) or a modern linked model (retentive "snap-fit", floppy hinge). In cases of young patients with relatively good bone structures, possibilities of revision surgery should in future be considered more carefully than with older patients. In primary operations on a young patient, large bone resections, or use of long stem hinged prosthesis should be avoided. All revision procedures for different reasons are more demanding and some of the most severe cases should be treated in only a few centres with maximal experience.

Experience and improvement of techniques in other joint replacements may also be applicable for elbow replacements, for example advances in cementing techniques, development of metallic or plastic materials used in components, and antibiotic prophylaxis. In modern hip or knee prosthesis models, a wide variety of sizes are available. Different sizes and stem lengths are equally necessary in elbow procedures. Extra small sizes are often necessary in JCA patients, but also in small RA patients. In the first arthroplasty, all excessive bone resection and reaming by reason of too large components should naturally be avoided to restore the best options for possible future revision.

Modularity of hip and knee prosthesis components is a common solution to reduce the number of different individual components. Modularity could probably also be realized in elbow prosthesis.

It may be assumed that in the near future the need for and use of elbow arthroplasties will increase, at least if better long-term results are published. On the other hand, in the long

term, the advances in antirheumatic drug therapy hopefully lead to results in which the numbers of elbow replacements, as well as of other procedures for rheumatoid patients, will again decrease.

## 8. CONCLUSIONS

1. In a rheumatoid patient, destruction of peripheral joints correlates significantly with involvement of the elbow joint. Fifteen years after the onset of the disease, almost two thirds of patients evinced rheumatoid changes in their elbow joints. Clinical and radiological examinations of the elbow are more easily neglected than those of the hand. In long-term rheumatoid patients with erosive disease, the elbows should be examined frequently to achieve the ideal timing of treatment.

2. The mid-term results of Souter arthroplasty at the RFH were acceptable but poorer compared with the results of hip and knee replacements. Long-term results are still lacking and may reveal new aspects. The influence of increasing experience was marked at least in the case early complications.

3. Souter arthroplasty was also suitable in cases with advanced destruction of the elbow. The selection of the components was different from the basic material and the operations were performed in a more experienced phase. The mid-term results were even better than those in the total cohort despite the severity of the cases.

4. Fractures in severely damaged rheumatoid elbows were reasonably well treated with Souter arthroplasty. Bone transplantation was almost always used. Certain osteosynthesis techniques seemed to be more successful, but the number of cases was too small for statistical comparison. It appeared that a separate osteosynthesis procedure for a fracture is not needed if arthroplasty is planned.

5. There are different success rates without aseptic loosening in different Souter-Strathclyde elbow prosthesis components. In our material the results were better in long-stem than in standard short-stem humeral components and better with metal-backed than standard all-polyethylene ulnar components. The success rate for humeral components associated with the retentive ulnar components were better than with the non-retentive type.

6. At post-operative FUs, translucencies appeared in different degrees in different areas around the Souter-Strathclyde prosthesis components. In two of the ten zones presented, some predictive value for aseptic loosening was found at one-year FU.

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## 11. ORIGINAL PUBLICATIONS (I - V)