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# Comparison of short- to medium-term results of Coonrad-Morrey elbow replacement in patients with rheumatoid arthritis versus patients after elbow injuries

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**Background:** The aim of this study was to assess the utility of the Coonrad-Morrey elbow prosthesis in patients with severe elbow dysfunction secondary to rheumatoid arthritis (RA) or post-traumatic elbow dysfunction.

**Material/Methods:** The study involved 35 patients followed up for a mean of 36 months. The patients were divided into those with RA (Group I) and those with post-traumatic elbow dysfunction (Group II). Treatment outcomes were evaluated according to the Mayo Elbow Performance Score (MEPS) and the Disabilities of the Arm, Shoulder and Hand Score (Quick DASH).

**Results:** According to the MEPS, there were 20 (57.15%) excellent, 12 (34.3%) good, 1 (2.85%) fair, and 2 (5.7%) poor outcomes. The mean post-operative Quick-DASH score for the entire study group was 37.73 points. In subgroup analysis, the MEPS-based evaluation revealed: 14 (70%) excellent, 5 (25%) good, and 1 (5%) satisfactory outcome in Group I, versus 6 (40%) excellent, 7 (46.7%) good, and 2 (13.3%) poor outcomes in Group II. The mean Quick Dash scores were 78.64 points in Group I and 76.36 points in Group II. The final MEPS scores in Group I ( $p=0.000018$ ) and Group II ( $p=0.00065$ ) were most markedly influenced by reduction in elbow pain and improvement in the ability to perform activities of daily living (ADL):  $p=0.000018$  in Group I and  $p=0.000713$  in Group II.

**Conclusions:** The treatment outcomes confirm the utility of arthroplasty for severe elbow dysfunctions; they were most strongly influenced by pain reduction and improved ability to perform activities of daily living.

key words: **elbow joint** **elbow prosthesis** **rheumatoid arthritis** **distal humerus fractures**

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## Background

The elbow is a complex joint made up of the humeroradial joint, humeroulnar joint, and the proximal radioulnar joint. It constitutes a complex biomechanical system with 3 degrees of freedom, allowing flexion and extension movements, rotational movements, and physiological varus and valgus motion [1–3]. The elbow joint is strategically important for upper limb biomechanics. Major elbow dysfunction, even with normal function of the other upper limb joints, will not allow for intact performance of basic ADL tasks [1,3,4].

Despite the structural complexity, the elbow joint is resistant to strain and is able to bear static loading forces up to 3 times body weight and dynamic loads up to 6 times body weight. The elbow joint is prone to injury and destruction in the course of systemic disorders. It is the second most often dislocated joint after the humeral joint. Fractures of the elbow region account for approximately 7% of all fractures. Rheumatoid arthritis (RA) involves the elbow in 20–60% of patients [4–6]. The high incidence of elbow injuries and elbow destruction in the course of systemic disorders on the one hand, and the structural and biomechanical complexity of the joint on the other, often make total elbow arthroplasty (TEA) the only effective treatment possible [2,5–8,10–13].

Elbow joint prostheses are divided into linked and unlinked prostheses. Linked prostheses are further divided into constrained and semi-constrained [6,8,9]. Constrained prostheses involve a rigid connection between the ulnar and humeral components, making it impossible to perform physiological varus-valgus movements, which leads to frequent loosening and pain. For this reason, this type of prosthesis is no longer used [6,14–19]. Semi-constrained implants have the ulnar and humeral components connected by means of various types of coupling devices. The manner of coupling makes it possible to perform movements in all planes, approximating the joint's native mechanics, and thus contributes to lowering the complication rate [6,14–19].

Unlike linked prostheses, unlinked (unconstrained) prostheses have no connection between the humeral and ulnar components of the implant. Such prostheses require elbow stability, with intact ligaments, tendons, and articular capsule [5,6,8,9].

The classic indications for total elbow replacement surgery include the presence of pain, movement limitation and instability. The finding of 1 or more of these signs and symptoms, if not amenable to conservative or surgical treatment, should make the attending doctor consider total elbow replacement surgery [4,10–12]. Currently, the most common indications for total elbow arthroplasty are rheumatoid arthritis (Figure 1A–D), failure of treatment of elbow injuries (Figure 2A–D), secondary

degenerative changes, instability, complicated fractures in the elbow region, elbow contractures, and primary degenerative disease [10–13,20].

Contraindications to the surgery include superficial and deep inflammation in the elbow area, elbow dysfunction due to an underlying neurological problem, and lack of patient compliance [21–23].

The aim of this study was to assess the utility of the Coonrad-Morrey semi-constrained total prosthesis in patients with severe elbow joint dysfunction secondary to rheumatoid arthritis or failure of treatment of elbow injury, with special emphasis on comparison of outcomes between these 2 groups.

## Material and Methods

Total elbow arthroplasty with the Coonrad-Morrey semi-constrained prosthesis (Figures 1, 2) was carried out in 35 patients between January 2006 and January 2010. The study group included 20 (57.14%) women and 15 (42.86%) men. Patient age at surgery ranged from 30 to 78 years (mean age 51.8 years). Follow-up duration was 24–64 months (mean 36 months). There were 29 (82.9%) right-handed and 6 (17.1%) left-handed patients. All surgeries were unilateral. The right elbow was treated in 26 (74.3%) patients, and the left in 9 (25.7%) patients.

The study had a prospective design. The evaluation of treatment outcomes was based on the Mayo Elbow Performance Score (MEPS) and the Quick DASH scale [24–27].

MEPS and Quick DASH scores were obtained on admission of a patient to the Department and at a mean of 36 months after surgery. For a detailed analysis of the significance of individual components of the MEPS scale for treatment outcomes, the following 4 domains of the score were distinguished: MEPS-pain, MEPS-arc of movement, MEPS-stability, and MEPS-daily function (MEPS-DL). Differences between pre- and post-operative MEPS and Quick DASH scores were also analyzed. They were coded as MEPS-difference and Quick DASH-difference, respectively.

The patients were divided into Group I of RA sufferers and Group II of patients who had developed elbow dysfunction as a result of unsuccessful previous treatment of fractures of the distal humerus. Group I consisted of 20 (57.7%) patients, including 17 (85%) females and 3 (15%) males, aged 30–65 years (mean 47.7 years). The duration of follow-up in Group I ranged from 22 to 64 months (mean 38 months). There were 16 (80%) right-handed and 4 (20%) left-handed persons. All surgeries were unilateral. The right elbow was treated in 18 (90%) patients and the left in 2 (10%).

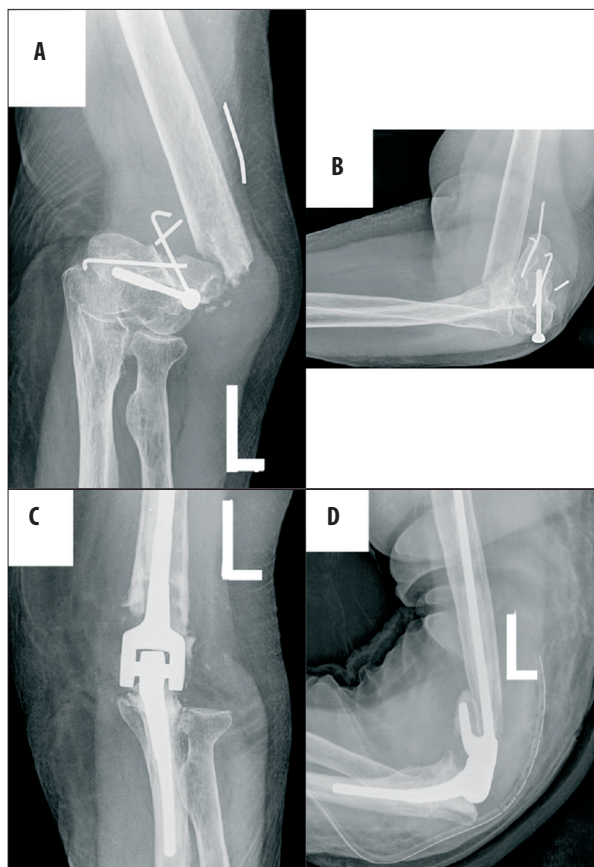


**Figure 1.** Pre and postoperative radiographs of a female patient with RA. (A, B) AP and lateral radiographs showing clear evidence of destruction of the elbow joint in the course of RA. (C, D) AP and lateral radiographs following implantation of a Coonrad-Morrey prosthesis

Group II comprised 15 (42.3%) patients, including 3 (20%) females and 12 (80%) males, aged 50–77 years (mean 65.9 years). The duration of follow-up in Group II ranged from 24 to 52 months (mean 31 months). There were 13 (86.7%) right-handed and 2 (13.3%) left-handed patients. All surgeries were unilateral. The right elbow was treated in 11 (73.3%) patients and the left in 4 (26.7%).

Group I included 2 (10%) professionally active patients (office workers), no patient engaging in sport, and no patients with a history of previous surgery for elbow dysfunction. Involvement of other upper limb joints was noted in all patients in this group. Apart from bilateral elbow lesions, finger and wrist joints were involved in all patients and the glenohumeral joint in 9 (45%). The 6-grade Larsen scale was used for analysis of radiographs and showed Stage 5 RA of the elbow in 11 (55%) cases, Stage 4 disease in 8 (40%) cases, and Stage 3 in 1 (5%) case [28].

In Group II, 11 (73.3%) of the patients were professionally active and engaged in sports regularly before elbow injury. Of these, 4 were manual workers and 2 were white-collar workers; 2 played football, 3 played tennis, and 1 swam regularly.



**Figure 2.** Pre and postoperative radiographs of a male patient following an unsuccessful primary operative fixation of a distal humerus fracture. 1A-AP view, 1B lateral view. (A, B) loosening of the fixation materials and non-union with correct positioning of bone fragments are visible. (C, D) AP and lateral radiographs following implantation of a Coonrad-Morrey prosthesis.

Two patients (13.3%) were not professionally active but engaged in sports regularly (1 jogged and 1 played table tennis). Two (13.3%) engaged only in ordinary everyday activities. Radiographs obtained immediately after the injury and submitted by the patients showed fractures of the distal humerus in all cases. The limb dysfunction was limited to the elbow joint in all patients. All injuries were unilateral and the opposite elbow joints were normal. In line with the Association for Osteosynthesis/Association for the Study of Internal Fixation (AO-ASIF) classification of distal humeral fractures, the fractures were divided into: 2 (13.33%) A3 fractures, 1 (6.67%) B1 fracture, 2 (13.33%) B2 fractures, 2 (13.33%) C1 fractures, and 8 (53.34%) C2 fractures [29]. All patients had undergone several surgeries (2-8, mean 3). The time between injury and elbow arthroplasty ranged from 14 to 2 years (mean 5 years).

Three patients had had infection of the operation site with removal of the fixation and no evidence of active inflammation

**Table 1.** Types of humeral components used for implants in Group I and II.

Size	Flange	Length (cm)	n
<b>Humeral components, group I (n=20)</b>			
Extra-small	Short flange	10.16	5 (25.0%)
Small	Short flange	10.16	9 (45.0%)
Small	Short flange	15.24	2 (10.0%)
Small	Long flange	15.24	1 (5.0%)
Regular	Short flange	15.24	3 (15.0%)
<b>Humeral component, group II (n=15)</b>			
Extra-small	Short flange	10.16	1 (6.7%)
Small	Short flange	10.16	3 (20.0%)
Small	Long flange	15.24	3 (20.0%)
Regular	Long flange	15.24	6 (40.0%)
Regular	Short flange	10.16	2 (13.3%)

n – group size; cm – centimetres.

before the total elbow arthroplasty. In the remaining 12 patients, radiographs had shown instability of the fixation, non-union/pseudoarthrosis, and massive secondary degenerative lesions of the articular surfaces.

### Indications

The indications for surgery in the entire study group were as follows: pain, movement limitation, and elbow instability in 33 (94.3%) patients; movement limitation and pain in 1 (2.85%) patient; and post-traumatic elbow ankylosis in 1 (2.85%) patient.

In the group of RA patients, the indications for surgery in all patients were pain, movement limitation, and elbow instability. The main indications for surgery in Group II were: pain, movement limitation and elbow joint instability in 13 (86.6%) patients; movement limitation and pain in 1 (6.7%) patient; and post-traumatic elbow ankylosis in 1 (6.7%) patient.

Patients with neurological disorders, non-compliant or with incompetence of the extensor mechanism of the elbow, were disqualified from surgery.

### Implant and surgical technique

All patients underwent an elbow arthroplasty with the Coonrad-Morrey semi-constrained prosthesis, consisting of a humeral and ulnar component connected with a metal hinge.

- The humeral component is triangular in cross-section to allow good implant positioning in the medullary canal and to

**Table 2.** Types of ulnar components used for implants in Group I and II.

Size	Length	n
<b>Ulnar components, group I (n=20)</b>		
Small	Regular	18 (90.0%)
Small	Normal	2 (10.0%)
<b>Ulnar components, group II (n=15)</b>		
Small	Normal	9 (60.0%)
Regular	Normal	4 (26.7%)
Regular	Long	2 (13.3%)

n – group size.

minimize the risk of rotational displacement. It also includes an anterior flange to reduce the risk of anteroposterior displacement [3,22,23].

- The ulnar component is quadrangular in cross-section to improve stability and minimize the risk of rotational displacement within the ulnar bone. Anatomical bends in the ulnar component correspond to anatomical bends in the ulnar bone and to reduce the risk of implant loosening [3,22,23].
- The 2 parts are connected with a hinge, allowing 7 degrees valgus-varus and rotation movement [3,22,23].

A variety of types of each component is available and can be freely combined. This helps to choose implant components for a patient so as to best restore elbow anatomy and biomechanics.

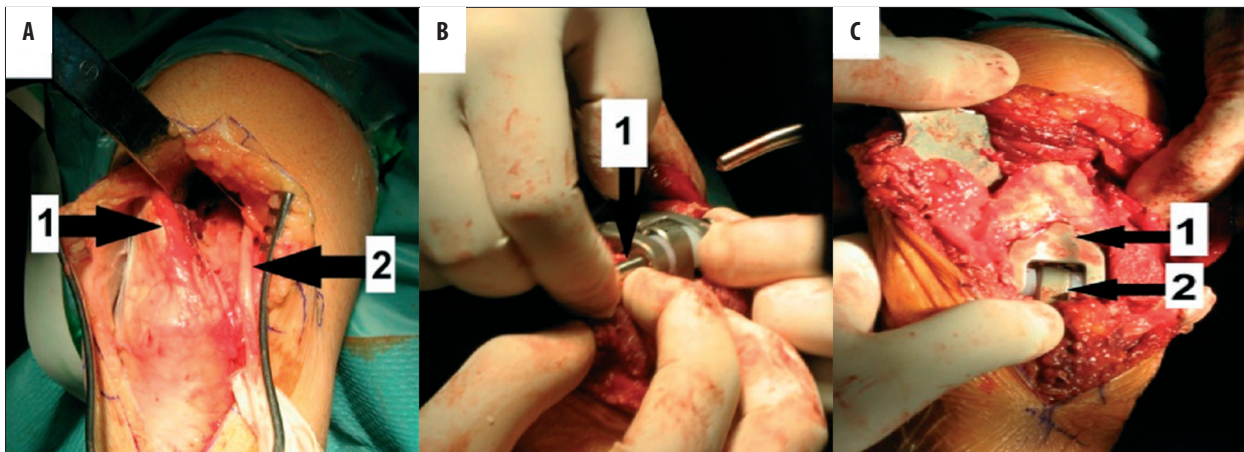
The humeral component is available in 3 sizes (extra-small, small, regular), and 3 lengths: 10.16, 15.24, and 20.32 centimeters (cm) and with a short or long flange. Models with a long flange are employed specifically in patients with large defects of the distal humerus, which are often seen following an injury [3,8,22,23]. Table 1 summarizes the types of humeral components used in the study group.

The ulnar component is available in 3 sizes (extra-small, small, regular) and 2 lengths: regular and long. Table 2 summarizes the types of ulnar components used in the study group.

### Surgical technique

All patients were operated on under general anaesthesia in the prone position with a tourniquet applied to the operated limb. A straight skin incision was made over the apex of the olecranon in all cases. This was followed by isolating and protecting the ulnar nerve (Figure 3A). Next, to ensure better visibility of the joint, the extensor mechanism of the elbow joint was detached and retracted radially according to





**Figure 3.** Stages of arthroplasty procedure. (A) Surgical approach: 1 – triceps brachii, 2 – ulnar nerve. (B) Joining the humeral and ulnar component with a hinge, 1 – metal hinge. (C) Final stage the components are joined together with a hinge and fixed with glue, 1 – humeral component, 2 – ulnar component.

the Bryan-Morrey approach (Figure 3A) [30,31]. Following appropriate preparation of the distal humerus and the proximal ulna, the implant components were inserted and connected with the hinge (Figure 3B). Both components were cemented (Figure 3C). The extensor apparatus was reconstructed during wound closure in all patients by being sewn into apertures made in the ulnar process before implant fixation.

- The mean duration of surgery from incision to dressing was 65.71 minutes (range: 40–131).
- The mean duration of hospital stay was 8.9 days (range: 7–16).

The operated limbs were immobilized (with posterior splint in 90° of flexion) following surgery in all patients. During the first 3 post-operative days, the priorities were to alleviate pain and prevent edema by using ice packs, anti-edema drugs, and elevating the limb. Exercises for the other joints of the operated limb, particularly the fingers and wrist, were started as soon as possible during sessions with a rehabilitation specialist. Patients were also instructed as soon as possible about further management in the immediate post-operative period and following discharge. After 3 days, active, active-assisted or passive exercises for the elbow joint were cautiously initiated and the joint was immobilized intermittently at night and between exercise sessions. Exercises were still performed in the presence of a rehabilitation specialist. During the first 2 post-operative weeks, flexion movements did not exceed 90° to protect the operative wound regardless of whether the patient was still in hospital or had been discharged. More intensive active flexion and extension exercises were introduced after 3 weeks. Daily activities not associated with a substantial strain on the elbow were cautiously allowed at 4–6 weeks post-surgery. During the following 6 weeks, the above exercises were practised more intensively, and at 12 weeks patients resumed basic daily activities.

### Statistical analysis

A preliminary evaluation revealed that the results of the clinical tests (scores) were not normally distributed for all tests and all patient groups. Correlations between the scores were assessed with Spearman's rank correlation coefficient. Scores obtained in mutually independent groups (RA patients vs. trauma patients) were compared with the Mann-Whitney U test. The significance of differences between pre- and post-operative scores was verified with Wilcoxon's signed-rank test. The level of significance was set at  $p=0.05$  for all calculations.

### Results

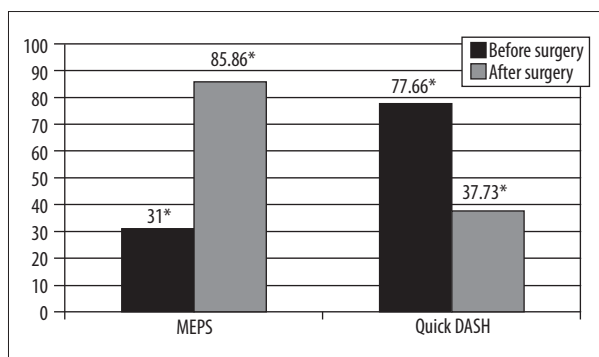
For the entire study group ( $n=35$ ), post-operative MEPS scores ranged from 20 to 100 points (mean 85.86 points). The scores were then converted into descriptive terms, yielding 20 (57.15%) excellent, 12 (34.3%) good, 1 (2.85%) fair, and 2 (5.7%) poor post-operative scores for the entire study group. Post-operative Quick DASH scores for the entire study group ranged from 6.82 to 81.82 points (mean 37.73 points). The detailed breakdown of both scores for all patients and for the subgroups is presented in Table 3. The mean values of descriptive parameters from Table 3 are illustrated in Figures 4, 5.

Of note in Table 3 are the results of Group II patients who had a MEPS of 20 both before and after surgery. These 2 patients developed severe postoperative complications in the form of deep infections necessitating implant removal. Their post-operative MEPS scores did not improve.

Treatment outcomes for all patients and for the 2 subgroups based on the 5-grade MEPS scale are shown in Table 4 and illustrated graphically in Figure 6.

**Table 3.** Pre and post-operative MEPS and Quick DASH scores.

	MEPS before surgery	MEPS after surgery	Quick DASH before surgery	Quick DASH after surgery
<b>All patients (n=35)</b>				
Min	20.00	20.00	63.64	6.82
Max	45.00	100.00	86.36	81.82
Mean	31.00	85.86	77.66	37.73
<b>Group I (n=20)</b>				
Min	20.00	60.00	65.91	29.55
Max	45.00	100.00	86.36	70.45
Mean	31.25	91.5	78.64	42.39
<b>Group II (n=15)</b>				
Min	20.00	20.00	63.64	6.82
Max	45.00	100.009	86.36	81.82
Mean	30.67	78.33	76.36	31.52

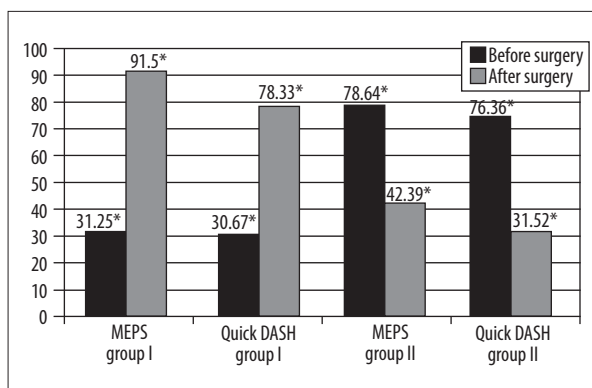


**Figure 4.** Pre and post-operative MEPS and Quick DASH scores for the entire study group, \*mean values.

### Statistical analysis

Statistical analysis of treatment outcomes for the entire study group showed statistical superiority of post-operative vs. pre-operative MEPS scores ( $p=0.00001$ ). Post-operative Quick DASH scores were also significantly better than pre-operative scores ( $p=0.000001$ ). There was also a negative ( $r=-0.41$ ) correlation between pre-operative MEPS and Quick DASH scores, a negative correlation ( $r=-0.4$ ) between pre- and post-operative MEPS and Quick DASH scores, and a less marked positive correlation ( $r=0.38$ ) between pre- and post-operative MEPS scores (Table 5).

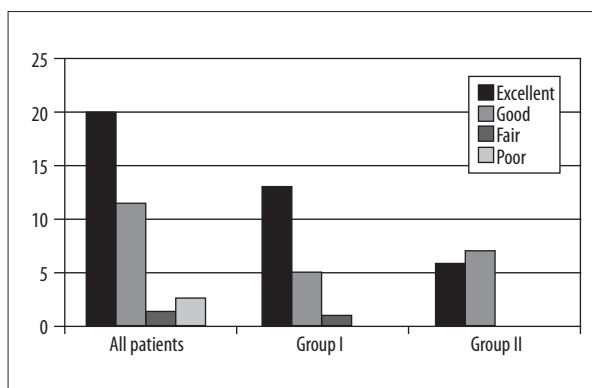
The power of correlations between individual MEPS domain scores and overall scores was also analyzed for both scoring systems in all patients. The strongest positive correlation of  $r=0.48$



**Figure 5.** Pre and post-operative MEPS and Quick DASH scores for the two subgroups.

**Table 4.** Treatment outcomes according to 5-grade MEPS scale.

Treatment outcome according to 5-grade MEPS scale	All patients	Group I	Group II
5 (excellent)	20 (57.15%)	14 (70.0%)	6 (40.0%)
4 (good)	12 (34.3%)	5 (25.0%)	7 (46.7%)
3 (fair)	1 (2.85%)	1 (5.0%)	
2 (poor)	2 (5.7%)		2 (13.3%)



**Figure 6.** Treatment outcomes by group according to 5-grade MEPS scale.

was detected between pre- and post-operative MEPS-pain scores and pre- and post-operative MEPS-DL scores ( $r=0.42$ ). There was also a strong negative correlation of ( $r=-0.42$ ) between pre-operative MEPS-arc of movement and the pre- and post-operative MEPS score difference. Notably, there was also a statistically significant negative correlation of ( $r=-0.39$ ) between pre-operative MEPS-pain scores and post-operative Quick DASH scores (Table 6).

A comparison of pre- and post-operative scores in the 2 subgroups showed that post-operative MEPS and Quick DASH scores were significantly better (Table 7).

**Table 5.** Statistically significant correlations between pre- and post-operative MEPS and Quick DASH scores for all patients.

	n	r	t(n-2)	p
Pre-operative MEPS vs. post-operative MEPS	35	0.38	2.344	0.025
Pre-operative MEPS vs. Quick DASH	35	-0.41	-2.571	0.015
Post-operative MEPS vs. Quick DASH	35	-0.4	-2.519	0.017

n – group size; r – correlation coefficient; t – number of degrees of freedom; p – significance level.

**Table 6.** Statistically significant correlations for individual MEPS domain scores.

	n	r	t(n-2)	p
Pre-operative MEPS-pain vs. post-operative MEPS	35	0.48	3.1	0.004
Pre-operative MEPS-pain vs. post-operative Quick DASH	35	-0.39	-2.43	0.021
Pre-operative MEPS-DL vs. post-operative MEPS	35	0.42	2.69	0.011
Pre-operative MEPS-arc of movement vs. MEPS difference*	35	-0.42	-2.62	0.013

n – group size; r – correlation coefficient; t – number of degrees of freedom; p – level of significance; \* – MEPS difference – difference between pre- and post-operative MEPS scores

The subgroup analysis revealed significantly better Quick DASH scores (p=0.016) in the trauma group. The differences between pre- and post-operative MEPS scores (MEPS-difference) and Quick DASH scores (Quick DASH-difference) were also analyzed. There was a significantly bigger difference between pre- and post-operative MEPS scores in the RA subgroup (p=0.047), and between pre- and post-operative Quick DASH scores in the trauma subgroup (p=0.039).

The RA subgroup also demonstrated significant strongly negative correlations at r=-0.62 between pre-operative MEPS and pre-operative Quick DASH scores, and between post-operative MEPS and Quick DASH scores (r=-0.45). The trauma subgroup registered statistically significant correlations between pre- and post-operative MEPS scores (r=0.82), pre-operative MEPS post-operative Quick DASH scores (r=-0.75), and post-operative MEPS and Quick DASH scores (r=-0.8) (Table 8).

Wilcoxon’s signed rank test demonstrated that post-operative MEPS domain scores (MEPS-pain, MEPS-arc of movement, MEPS-stability, and MEPS-daily function) were significantly better than pre-operative scores (Table 9).

**Table 7.** Statistically significant changes in MEPS and Quick DASH scores (before vs. after surgery).

	n	t	z	P
<b>Group I</b>				
Pre- vs. post-operative MEPS	20	0.00	3.92	0.000089
Pre- vs. post-operative Quick DASH	20	0.00	3.92	0.000089
<b>Group II</b>				
Pre- vs. post-operative MEPS	15	0.00	3.18	0.001474
Pre- vs. post-operative Quick DASH	15	1.000	3.23	0.001225

n – group size; t – test statistic; z – standard random normal variable; p – level of significance.

**Table 8.** Statistically significant correlations between pre- and post-operative MEPS and Quick DASH scores.

	n	r	t(n-2)	p
<b>Group I</b>				
Pre-operative MEPS and Quick DASH	20	-0.62	-3.39	0.003
Post-operative MEPS and Quick DASH	20	-0.45	-2.12	0.048
<b>Group II</b>				
Pre- and post-operative MEPS	15	0.82	5.17	0.00
Pre-operative MEPS and post-operative Quick DASH	15	-0.75	-4.13	0.001
Post-operative MEPS and Quick DASH	15	-0.8	-4.93	0.00

n – group size; r – correlation coefficient; t – number of degrees of freedom; p – level of significance.

The analyses did not reveal any correlation between the stage of RA according to Larsen’s scale and the surgical outcome.

There were a total of 6 (17.1%) complications within the time frame of the study. Of these, 2 (5.7%) were intraoperative fractures [1 fracture of the medial condyle of the distal humeral epiphysis, and 1 fracture of the lateral condyle]. In both patients, the condyles were fixated with screws intraoperatively. Bone union followed and the outcome was good or excellent. Another 2 (5.7%) were transient paraesthesias of the ulnar nerve, which subsided by 7 and 9 months following drug treatment and outpatient physical therapy. Finally, there were

**Table 9.** Statistically significant differences between pre- and post-operative MEPS domain scores.

	n	t	z	p
<b>Group I</b>				
Pre- vs. post-operative MEPS-pain	20	0.00	4.28	0.000018
Pre- vs. post-operative MEPS-arc of movement	20	0.00	4.1	0.00004
Pre- vs. post-operative MEPS-stability	20	0.00	3.5	0.000438
Pre- vs. post-operative MEPS-DL	20	0.00	4.3	0.000018
<b>Group II</b>				
Pre- vs. post-operative MEPS-pain	15	0.00	3.41	0.000655
Pre- vs. post-operative MEPS-arc of movement	15	7.00	3.15	0.001609
Pre- vs. post-operative MEPS-stability	15	0.00	2.8	0.005062
Pre- vs. post-operative MEPS-DL	15	5.00	3.39	0.000713

n – group size; z – standard normal distribution value for Mann-Whitney U test; t – test statistic; p – level of statistical significance.

2 (5.7%) cases of deep infections necessitating re-admission and implant removal, with antibiotic therapy. Both patients had undergone several operations (5 and 8) at other centres. They did not agree to have more surgeries in the future. One patient developed ankylosis of the joint in 90° flexion and internal rotation. The other patient has been using an orthosis on account of considerable instability. Both regularly attend an orthopaedic clinic and a pain treatment centre.

## Discussion

Operative treatment of the elbow joint damaged in the course of systemic disorders (eg, RA) or as a result of injury is an important clinical problem. In our opinion, with such a powerful tool as modern elbow prostheses available to aid those with severe elbow joint dysfunction, it is worthwhile to continue the discussion on indications for total elbow replacement surgery, implant selection criteria, causes of complications, and ways to reduce complication rates.

The subjects in our study were divided into 2 subgroups. The main criterion underlying this division was the nature of

indications for surgery. In Group I, the RA patients had suffered a pathological process of many years' duration, leading to irreversible destruction of the elbow joint. An assessment based on the Larsen scale identified Stage 5 elbow arthritis in 11 patients, Stage 4 in 8 patients, and Stage 3 in 1 patient. Most of the RA patients did not work or engage in sports. As a result, they were less likely to suffer elbow strain or injury that could lead to severe post-operative complications, such as implant loosening or periprosthetic fractures. Our final opinion is that, in advanced RA, total elbow arthroplasty is the treatment of choice.

In Group II the indication for TEA in all patients was failure of previous surgery of fractures of the distal humerus: 2 (13.33%) A3 fractures, 1 (6.67%) B1 fracture, 2 (13.33%) B2 fractures, 2 (13.33%) C1 fractures, and 8 (53.34%) C2 fractures. The question arises whether optimal treatment had been chosen immediately after the injury was diagnosed. Perhaps a primary elbow arthroplasty would have led to superior outcomes, sparing the patients subsequent procedures. In our opinion, the optimal primary treatment for fractures of the elbow region should be by osteosynthesis. We believe so because this type of fracture is more frequently seen in professionally active people who also participate in sports. In such patients, primary osteosynthesis affords the possibility of regaining a pre-injury level of activity. Primary arthroplasty in this group of patients additionally restricts their activity. The presence of a prosthesis precludes overloading, intense sports activity, or physical strain. Additionally, primary osteosynthesis of a fracture does not rule out a joint replacement procedure in the future, as evidenced by the good outcomes of arthroplasty in Group II. Accordingly, we believe that arthroplasty procedures should be used mainly as a treatment for post-operative complications after all other approaches have failed. Certainly, we do see exceptions to what we advocate: for example, primary arthroplasty following a fracture may be considered in elderly patients. This is in keeping with findings of other reports [31,33–35]. However, in our opinion, age should not be the decisive factor in performing a primary arthroplasty in elderly people. As the number of those over 60 or 70 years of age who are still professionally active and play sports has been growing, age is less important than bone quality and lifestyle factors. However, this issue merits a more detailed analysis in future publications.

As stated in the introduction, several types of implants are available. In our opinion, the choice of an appropriate implant is of key importance for the treatment. The implant type should be matched to the patient's clinical status. The indications for surgery in the entire study group were as follows: pain, movement limitation, and elbow instability in 33 (94.3%) patients; movement limitation and pain in 1 (2.85%) patient; and post-traumatic elbow ankylosis in 1 (2.85%) patient.



In such cases, the design of the implant, which appropriately reflects elbow anatomy and biomechanics, serves to reduce the rate of complications associated with excessive pressure from implant components on bone. This is especially important in patients with poor bone quality, as seen in RA. The results obtained in the course of the present study confirm the validity of these implant selection criteria.

The treatment outcomes for all patients confirm the utility of joint replacement surgery in the treatment of severe elbow dysfunctions. Post-operative scores obtained with the 2 scoring systems used were significantly better, both in the entire study group and in subgroup analysis. The results of our study are comparable with those obtained by other authors [36,37]. The significant negative correlation ( $r=0.41$ ) between pre-operative MEPS and Quick DASH scores and the negative correlation ( $r=-0.4$ ) between pre- and post-operative MEPS and Quick DASH scores confirms a considerable effect of elbow function on the performance of the entire upper limb. We believe that it is important to see which MEPS domain most influences the reported improvement in the function of the elbow and the entire limb. The answer is helped by the results of corresponding analysis conducted as part of our study. The strongest positive correlation ( $r=0.48$ ) was detected for MEPS-pain scores and, at  $r=0.42$ , MEPS-DL scores, which shows that these 2 parameters had the greatest influence on the final MEPS score. It is also worth noting a negative correlation ( $r=-0.38$ ) between pre-operative MEPS-pain scores and post-operative Quick DASH scores, showing that reduction in elbow pain was the most important determinant of the post-operative functional status of the limb. However, it should be remembered that a MEPS score depends heavily on pain- and ADL-related aspects.

Looking at subgroup data, despite the finding of a significantly greater difference between pre- and post-operative MEPS scores in the RA group, Quick DASH scores were significantly ( $p=0.016$ ) better in the trauma group. Notably, despite the significantly greater improvement in MEPS, in the RA group it had a less marked effect on the function of the limb. In our opinion this is attributable to the presence of severe arthritic lesions in other upper limb joints in the RA patients, resulting in more spectacular changes in MEPS scores and a less visible effect on Quick DASH scores, which looks globally at upper limb function. Our conclusion is further confirmed by the finding of a stronger correlation in Group II between pre-operative MEPS and post-operative Quick DASH scores ( $r=0.75$ ) and between post-operative MEPS and Quick DASH scores ( $r=-0.8$ ).

It is interesting to analyze the effect of individual MEPS domains on final MEPS scores in both groups. The most significant effect on the final MEPS score in the RA group was noted

for MEPS-pain ( $p=0.000018$ ) and MEPS-DL ( $p=0.000018$ ). The same pattern was also observed in Group II, with  $p=0.000655$  for MEPS-pain and  $p=0.000713$  for MEPS-DL. These results show that the most important factors for patients were pain reduction and improved ability to cope with daily tasks.

An interesting question to ask is what factors may account for the differences in outcomes between the subgroups, and, most importantly, whether these differences were influenced by mean age and physical activity. Our analysis did not reveal a statistically significant correlation between age and treatment outcomes, both for the entire study group and for each subgroup. In our opinion, in the RA group, the prolonged course of illness, chronic pain, inability to practise a sport or, in the case of most patients, take up employment, reduced these patients' expectations of treatment effects, and the involvement of other joints in the operated limb had a decisive influence on the observed difference in the MEPS and Quick Dash scores. The patients in Group II were much more active before the injury than were the RA patients, who were accustomed to the pain and limitations of this severe systemic condition. Thus, a sudden elbow dysfunction was much less tolerable to Group II patients, and the superior Quick dash scores show that improved function of such a strategic joint as the elbow is very important for functional recovery of the entire limb and improved quality of life in the trauma group. However, this conclusion requires a detailed analysis and further studies with longer follow-up.

All patients developed a total of 6 (17.1%) cases of complications [see Results for a detailed description]. Two (5.7%) of these were observed in the RA group. Both were intraoperative complications (fracture of the medial condyle of the distal humeral epiphysis and of the lateral condyle) that were secondary to poor bone quality. Among the patients who had been previously unsuccessfully treated for elbow injuries, there were 4 (11.4%) cases of complications, 2 (5.7%) deep infections, and 2 (5.7%) transient paresthesias of the ulnar nerve. The intraoperative condylar fractures were stabilized with screws during the procedure. Bony union was achieved in both patients and the fractures did not influence their treatment outcomes. Both trauma patients with deep infections required implant removal followed by medication therapy. These complication rates are comparable with those reported by other authors [7,12,16,17,21,24,25,37–39].

At the same time, we need to note that our results were obtained during a relatively short follow-up period of 2–3 years. Reports show that more distant outcomes are inferior, mainly due to complications developing over longer follow-up periods [7,16,17,19,35,36,38,39]. Hence, the observation of our patients needs to continue and the present outcomes should be verified against those obtained over the longer term.

## Conclusions

The treatment outcomes reported in this paper demonstrate that total elbow arthroplasty is a very useful procedure in cases of severe elbow dysfunction. The treatment outcome was most

heavily influenced by reduction in pain and greater comfort of everyday life. The differences in outcomes between the groups were mostly associated with impaired function of other upper limb joints in the RA patients. These results are very promising, but need to be verified against long-term follow-up data.

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