

Title

Total Elbow Arthroplasty: A Prospective Clinical Outcome Study of Discovery Elbow System with a
4-Year Mean Follow-Up

Running Title

Clinical Outcome of the Discovery Elbow

Authors:

1. **Dr Omid Alizadehkhayat.** Associate Professor in Health Sciences (MD, PhD). School of Health Sciences, Liverpool Hope University, Liverpool, UK
2. **Mr Ahmed Al Mandhari.** Shoulder and Elbow Fellow (MD). Upper Limb Unit, Royal Liverpool and Broadgreen University Hospitals, Liverpool, UK
3. **Dr Christos Sinopidis.** Consultant Orthopaedic Surgeon (MD, PhD). St' Lukes Hospital, Thessaloniki, Greece
4. **Ms Amanda Wood.** Research Nurse (MSc). Musculoskeletal Science Research Group, Institute of Translational Medicine, University of Liverpool, Liverpool, UK
5. **Professor Simon Frostick.** Professor of Orthopaedics (MA, DM, FRCS). Musculoskeletal Science Research Group, Institute of Translational Medicine, University of Liverpool, Liverpool, UK

Corresponding Author:

Professor Simon P. Frostick
Musculoskeletal Science Research Group,
Institute of Translational Medicine,
University of Liverpool
Liverpool UK, L69 3GA

Phone: +44 151 706 4120 Fax: +44 151 706 5815

Email: s.p.frostick@liverpool.ac.uk

Disclaimer: Professor Frostick received royalties and consultant payments from Biomet Inc.

Ethical Approval: Sefton Research Ethics Committee - REC Number: 08/H1001/109

Trust Study Number: 3735

1 **Total Elbow Arthroplasty: A Prospective Clinical Outcome Study of Discovery Elbow**
2 **System with a 4-Year Mean Follow-Up**

3 **Abstract**

4 **Background:** Total elbow arthroplasty (TEA) is increasingly used for the treatment of
5 advanced elbow conditions to reduce pain and improve function. However, TEA is still
6 associated with a higher complication rate compared to the total hip and knee arthroplasty
7 despite advances in the design and surgical techniques. This prospective clinical study reports
8 the outcome of the Discovery Elbow System (Biomet Inc., Warsaw IN, USA) system which
9 has been in clinical use in the UK since 2003.

10

11 **Methods:** The study included a total of 100 Discovery elbows (April 2003 to January 2010)
12 with a minimum 2-year follow-up including 75 primary and 25 revisions (60 % females and
13 40% males; mean age, 62 years). Outcome was assessed by means of Liverpool Elbow Score,
14 pain experience, patient satisfaction, range of movement, and radiographic imaging.

15

16 **Results:** Mean follow-up was 48.5 months (range: 24-108 months). Liverpool Elbow Score
17 improved from 3.79 to 6.36 ($P<.001$). Pain-free patients were substantially increased from
18 7% preoperatively to 64% at the final follow-up. Patient satisfaction rate was over 90%. The
19 arc of flexion-extension and pronation-supination increased from 72° to 93° and from 86° to
20 111°, respectively ($P<.001$). Major post-operative complications included deep infection
21 (2%), progressive aseptic loosening requiring revision (primary, 5%; revision 12%),
22 persistent ulnar neuropathy (3%), and periprosthetic fracture (primary, 6.8%; revision, 8%).

23

24 **Conclusion:** Discovery elbow resulted in improved function, reduced pain, and high patient
25 satisfaction. Long-term results are required for assessing the survivorship of this system.

26

27 **Keywords:** Total Elbow Arthroplasty; Discovery Elbow; Clinical Outcome; Elbow
28 Prostheses.

29 **Level of Evidence:** Level III

30 BACKGROUND

31 Total elbow arthroplasty (TEA) has increasingly become a popular reconstructive procedure
32 due to improved surgical techniques, advanced implant designs, and enhanced clinical
33 outcomes.³⁹ The modern era of TEA began in the late 1970s when the prosthetic design
34 evolved following several key developments: the use of high-density polyethylene as a
35 bearing surface to metal, the use of methyl methacrylate bone cement, and the
36 implementation of biomechanical science to reproduce normal joint kinematics.⁷ Modern
37 TEA implants are designed as linked or unlinked. Linked implants are coupled together
38 through a hinge allowing for some degrees of laxity in the medial, lateral, and rotational
39 planes consistent with normal elbow kinematics. A “sloppy hinge,” design is associated with
40 a reduced rate of aseptic loosening and instability of the articulation.³² Unlinked implants
41 are not mechanically coupled and mostly rely on matching shapes of the bearing surfaces,
42 adequate bone stock, and, the integrity of capsular and ligamentous structures.^{5,7} Unlinked
43 designs have been associated with higher rate of instability as their stability mainly depends
44 on their geometry and surrounding soft tissues (ligaments and bone stock) rather than the
45 intrinsic constraint of the articulation.⁵

46

47 The use of unlinked prostheses may be preferred when there is less bone or articular
48 destruction and in younger patients who may need later revision surgery. From the other
49 hand, the increased stability of the linked implants has expanded their use in conditions with
50 increased bone destruction and ligamentous incompetency such as advanced stages of
51 rheumatoid arthritis, posttraumatic and degenerative osteoarthritis, and complex distal
52 humerus and intra-articular fractures (particularly in elderly patients).^{5,7,21}

53

54 Despite considerable developments in the prosthetic design, TEA has been associated with a
55 high rate of complications, ranging from 20% to 45%, compared to other main total joint (hip

56 and knee) replacements^{14,25,37} potentially because of the difficulty of surgical procedure in a
57 complex joint with minimal soft tissue support.¹⁰ Gschwend et al,¹⁴ reviewed the literature
58 and reported an overall complication rate of up to 43% including aseptic loosening,
59 infections, ulnar nerve complications, instability, disassembly, dislocation, subluxation,
60 intraoperative fractures, fractures of the prosthesis, implant loosening, periprosthetic fracture,
61 triceps insufficiency, and ectopic bone formation. In another review, Little et al,²⁵ reported a
62 complication rate of 14%-80% including deep infection and septic loosening (up to 10%),
63 ulnar neuropathy with permanent dysfunction (up to 10%), hinge failure (up to 6%), and
64 polyethylene bushing wear (14% to 47%) for various semiconstrained prostheses.

65

66 The Discovery Elbow System (Biomet Inc, Warsaw, IN, USA), was developed with the
67 intention of addressing some of above issues associated with previous linked designs by
68 means of decreasing polyethylene bushing wear, reinforcing anatomic stem design, restoring
69 natural elbow joint biomechanics, and producing a hinge that could be easily revised.¹⁶ The
70 Discovery elbow has been in clinical use in the UK since 2003. The structural specifications
71 and design rationale of the system have been described in full details by Hastings and
72 Theng¹⁸ and Hastings.¹⁶

73

74 This study aimed to 1) report functional and radiological outcome of the Discovery elbow in
75 a large series of primary and revision TEAs with various elbow pathologies; and 2) compare
76 the clinical outcome and complications with published literature on other prostheses.

77 PATIENTS AND METHODS

78 One hundred Discovery elbows with a minimum 2-year follow-up were included in the study.
79 All TEAs were performed in a single centre by the same surgeon (April 2003 to January
80 2010). The technical properties of the prosthetic system and surgical technique have been
81 described in full details by Hastings et al.¹⁶

82 The mean age of patients (females, 60 %; males, 40%) was 62 years (range: 22-86), weight
83 71.8kg (\pm 18.3), and height 166 (\pm 12.5). The mean follow-up period was 48.5 months (range:
84 24-108 months). Inclusion criteria were advanced arthritis unresponsive to non-operative
85 management, acute distal humerus fracture and revision for loosening of other elbow
86 prostheses in skeletally mature patients (>18 years old). Exclusion criteria included
87 systematic metabolic diseases affecting the bone formation and active infection. The main
88 underlying pathologies (diagnoses) are outlined in Table1. Primary and revision TEA
89 comprised 75% and 25% of the cases, respectively. Study received approval from a local
90 research ethics committee and all patients gave informed consent prior to the surgery.

91

92 FOLLOW UP ASSESSMENT**93 Functional Outcome**

94 Main clinical information and data including underlying pathology (primary diagnosis), type
95 of TEA (primary, revision), follow-up period, pain experience, patient satisfaction, range of
96 movement (flexion/extension of the elbow and pronation/supination of the forearm), and
97 complications were collected using a purpose-designed elbow arthroplasty proforma. A
98 validated elbow score, Liverpool Elbow Score (LES), was also used for functional
99 assessment.^{33,38} The patient-rated section of the LES has good correlation to MEPS and has
100 been suggested as an outcome measure for evaluating results of TEA.⁴ The AO handbook for
101 Musculoskeletal Outcomes Measures and Instruments rated this score as a superior quality

102 outcome assessment tool compared to the Mayo Elbow Performance Score (MEPS).³⁶ A
103 score of 0 and 10 indicate worst and best outcome, respectively.

104

105 Radiographic assessment

106 Where available, the anteroposterior and lateral views of pre- and postoperative plain x-rays
107 (Figure.1) were reviewed for humeral and ulnar stem alignment in sagittal and coronal
108 planes, aseptic loosening, periprosthetic fracture, dislocation, and hypertropic ossification.
109 Imaging assessment pattern followed the principles explained in a recent comprehensive
110 radiographic review of TEA.²⁹ For assessing the component alignment, angles between the
111 axis of the shaft of humerus and the stem of the humeral component and between the axis of
112 the shaft of ulna bone and the stem of the ulnar component were measured in the early post-
113 operative x-rays.¹² A malalignment of $>10^\circ$ was considered as significant.^{11,12,37}
114 Periprosthetic fracture was evaluated based on Mayo Classification System (Figure.2).²⁸

115

116 Data Analysis

117 Continuous and descriptive data are reported as mean and standard deviation (Mean \pm SD)
118 and 95% confidence interval. Categorical data are described using proportion and percentage.
119 Paired Student *t* test or ANOVA were used to compare the preoperative LES and ROM with
120 those at the final follow-up for the entire patient group and according to underlying pathology
121 (primary diagnosis) and type of TER (primary, revision), as appropriate. The level of
122 significance was set at 5 % ($p < 0.05$). SPSS package (IBM SPSS Statistics for Windows,
123 Version 21.0. Armonk, NY: IBM Corp.) was used for data analysis.

124 **RESULTS**

125 **Functional Outcome Results**

126 Preoperatively, 61% and 21% of patients experienced severe and moderate pain, respectively
127 which was then reduced to 11% and 14% post-operatively. The percentage of pain-free
128 patients was substantially increased from 7% preoperatively to 64% at the final post-
129 operative follow-up. In terms of patient satisfaction, 63%, 8%, and 23% of patients were
130 classified as 'Very Satisfied', 'Somewhat Satisfied', and 'Satisfied', respectively. Only 6%
131 remained unsatisfied with the outcome mainly involving revision cases.

132
133 The mean preoperative and final follow-up LES were 3.79 (± 1.71) and 6.36 (± 1.85),
134 respectively which highlighted a significant improvement ($p < 0.001$). Similar improvements
135 were observed for all main pathology groups (inflammatory and non-inflammatory arthritis,
136 and Fracture), however, LES improvement was significantly higher in the primary (6.41 ± 17)
137 compared to revision TEA (5.78 ± 14) ($p < 0.05$). Table 2 summarises the results of ROM for
138 flexion and extension of the elbow and pronation and supination of the forearm for entire
139 patient group and according to the main diagnoses. Except elbow extension (extension lag)
140 all movements including flexion-extension and pronation-supination arc were significantly
141 improved. ROM improvements in revision TEA were comparable with those of primary
142 TEA.

143 **Radiographic Assessment Results**

144 Imaging was available for 88 TEAs (88%) (primary, 70; revision, 18). Table 3 presents the
145 degree of alignment of humeral and ulnar components (stems) in both sagittal and coronal
146 planes. Around 90% of the evaluated TEAs presented with a good alignment ($< 5^\circ$) for both
147 components in both planes. A significant malalignment ($> 10^\circ$) was seen in one primary TEA
148 elbow; however it was not associated with early loosening.

149 The overall incidence of periprosthetic fracture was 14.8% (primary, 6.8%; revision, 8%)
150 involving humeral condyles and olecranon in 9.1% and 5.7% of elbows, respectively. All
151 fractures were classified as Mayo Type 1 and managed conservatively. Hypertrophic
152 ossification occurred in 6.8% of TEAs (primary, 5.7%; revision, 1.1%).

153 In the primary group, areas of non-progressive lucency were noted around the bone-cement
154 interface of 10 TEAs without any further progression. Marked osteolysis around the humeral
155 component observed in two cases but the prosthesis remained stable with no need for
156 revision. Four TEAs developed significant osteolysis and required revision of either humeral
157 component (n=3) or both humeral and ulnar components (n=1). In the revision group, non-
158 progressive lucency was noted in seven TEAs. Marked osteolysis occurred in one elbow
159 (humeral component); however, prosthesis remained stable with no need for revision. Three
160 revision cases developed progressive loosening of both humeral and ulnar components; two
161 underwent 2nd revision and one is awaiting revision.

162 **Complications**

163 In addition to the complications reported in the radiographic assessment results
164 (malalignment, periprosthetic fracture, aseptic loosening, and hypertrophic ossification), deep
165 infection occurred in 2 cases (both required a 2-stage revision), persistent ulnar neuropathy in
166 3 cases (managed with nerve decompression and transposition), and prosthetic failure
167 (dissociation of the condyle and screws from main components) in 1 case (revised).

168 **DISCUSSION**

169 Despite recent developments in the design of elbow prostheses, advances in surgical
170 techniques, and marked improvements in pain and function, TEA is still associated with high
171 complication and revision rates compared to hip and knee arthroplasty.^{7,38,40} This high
172 complication rate is partly related to the anatomical characteristics of the elbow such as
173 insufficient bone stock for implantation and lack of strong supporting soft tissue.^{3,23}

174
175 Elbow prostheses have been used for decades in linked (e.g. Coonrad-Morrey, GSB III,
176 Triaxial, Discovery System) and unlinked (e.g. Kudo, Souter-Strathclyde, IBP) or both linked
177 and unlinked (e.g. Acclaim) modes. The Discovery elbow is a linked prosthesis with a design
178 that mimics the anatomical characteristics and kinematics of the elbow joint. The present
179 study reports the clinical outcome of TEA with this system over a 4-year mean follow-up and
180 compares the results with other reports. However, direct comparison of clinical outcomes
181 amongst different TEA implants is a challenging task because of heterogeneity in reporting
182 methods of function, pain experience, patient satisfaction, and radiographic assessment.

183
184 Pain relief is one of the prime benefits following any joint arthroplasty. In the present study,
185 around 64% of cases had no pain at the final follow-up. The majority of the studies on TEA
186 have used percentage of patients with no pain or mild pain as measure of success of the
187 procedure. By that standard, 78% of our cases had either no pain or only mild pain at final
188 follow-up. The percentage of patients with no pain or mild pain after undergoing Acclaim,⁶
189 Souter-Strathclyde,³¹ GSB III^{14,22,34} and Coonrad-Morrey^{25,35} have been reported as 64%,
190 67%, 50–92% and 60-100%, respectively. Overall the patient satisfaction rate for our series
191 was 94% with 63% of patients reporting maximal satisfaction (Very Satisfied). A study of
192 different linked prostheses (11 elbows) reported a 73% satisfaction rate.⁴⁰ In a study of 51
193 elbows using the Coonrad-Morrey prosthesis, Hildebrand et al,¹⁹ reported patient satisfaction

194 of 9.2/10 in inflammatory arthritis and 8.6/10 in posttraumatic arthritis. A recent study of
195 Discovery Elbow replacement patients in 46 elbows reported a patient satisfaction rate of
196 9.1/10.¹⁷

197

198 Functional capacity was markedly improved in our cohort of patients according to the LES
199 which integrates both patient self-evaluation and clinician's assessments. The majority of
200 TEA studies, however; chose to use MEPS for functional assessment. Considering the strong
201 correlation between LES and MEPS,⁴ the marked improvement found for the LES in the
202 present study are in line with those reported for other prostheses.^{2,24-26,30} The mean
203 improvement in flexion-extension arc in our TEA series was 21°. Based on systematic
204 reviews of semiconstrained linked and unlinked TEA prostheses, the average improvement in
205 flexion-extension arc ranged between 12°-39° with a weighted improvement of 26°.^{25,38}
206 According to individual studies, the mean improvement in flexion-extension arc with
207 Acclaim,⁶ Souter-Strathclyde,³¹ GSB III,^{20,22} and Coonrad-Morrey prostheses³⁵ were 23°, 15°,
208 19°-33° and 17°-26°, respectively. A recent study of 46 Discovery elbows reported an
209 improvement of 40° in flexion-extension arc.¹⁷ The mean improvement in pronation-
210 supination arc in our series was 25°. This movement arc has been reported as 21°-28° for
211 Coonrad-Morrey prosthesis³⁵ and 31°-67° for GSB III prosthesis.^{20,22} Hastings et al,¹⁷
212 reported an increase of 29° in pronation-supination arc with Discovery elbow. It has to be
213 taken into consideration that our reported results combine both primary and revision TEAs.

214

215 Deep infection remains the most worrying complication with a rate of around 4% infection
216 reported in longer-term TEA studies.^{9,25} The overall incidence of deep infection in our series
217 was 2%. The incidence of deep infection with GSB III TEA has varied between 4%-
218 11%.^{14,22,34} Studies on Coonrad-Morrey TEA have reported an infection incidence rate of
219 6%-8%.^{19,25} Hastings et al,¹⁷ recently summarised complications for Coonrad-Morrey, GSB

220 III, Solar, and Discovery prostheses in 595 TEA patients (561 primary, 34 revision) and cited
221 the average rate of deep infection as 2.9%.

222

223 Progressive aseptic loosening requiring revision occurred in 4 primary (5%) and 3 revision
224 (12%) of our series. This complication has been reported in association with other linked
225 prostheses including Coonrad-Morrey (0%-7%),^{1,13,15,19,25} GSB III (4%-29%),^{8,14,20,34} and
226 Souter-Strathclyde (up to 31%).^{15,24,30} Summarising the complication reports from linked
227 devices, Hastings et al,¹⁷ and Kelly et al,²² have cited the average rate of primary aseptic
228 loosening as 8.9% and 4%-50%, respectively. In a recently published study of 46 Discovery
229 elbow cases, the rate of aseptic loosening was 2.2%.¹⁷

230

231 The overall rate of periprosthetic fracture and cortical perforation was 14.8% (primary, 6.8%;
232 revision, 8%) in the present study. All fractures were classified as Mayo Type 1 and required
233 conservative management. The incidence of periprosthetic fractures with Acclaim,⁶ GSB
234 III,^{20,34} and Coonrad-Morrey¹⁹ has been reported as 36%, 16%-21%, and 23%, respectively.

235

236 Incidence of persistent ulnar neuropathy requiring surgical intervention was 3% in our series.
237 Ulnar neuropathy is seen more commonly in rheumatoid arthritis as close proximity of the
238 nerve to the elbow joint can lead to inflammation of the nerve due to synovitis in the nearby
239 elbow joint and valgus instability can lead to stretching of the ulnar nerve.²⁷ The incidence
240 rate of ulnar neuropathy with GSB III, Coonrad-Morrey, and Acclaim has been reported as
241 11%-14%,^{8,22} 12%-26%,^{1,19} and 8%,⁶ respectively. Summarising the complications of TEA in
242 595 patients, Hastings et al,¹⁷ cited a rate of 4.4% for ulnar neuropathy.

243

244 The present study provided comprehensive prospective clinical outcome data on for the
245 Discovery elbow arthroplasty. The study included a large cohort of primary and revision
246 TEAs which reduced the scope of selection bias. Furthermore, clinical and radiographic

247 assessments were performed by independent assessors other than the principal surgeon
248 thereby decreasing the possibility of information bias. There were, however, some limitations
249 to the study. First, study included both primary and revision TEAs which might have some
250 effect on reported outcome results. In order to address this, significant differences between
251 primary and revision TEAs in outcome measures (e.g. LES) and complications rates are
252 highlighted in the paper. Second, study used LES as a key functional assessment tool. This
253 reduced the scope of comparisons with other studies into some extent as based around half of
254 recent outcome reports used MEPS.²⁵ Hence, MEPS was added into our functional
255 assessment tools a few years ago and being completed in addition to LES for all prospective
256 TEAs. Third, a 4-year mean follow-up provides a relatively reasonable period for functional
257 outcome report but a longer term follow-up is required for assessing late complications and
258 survivorship of the prosthesis.

259 **CONCLUSION**

260 The results indicate that Discovery elbow is a system viable option for the treatment of
261 advanced inflammatory and non-inflammatory elbow conditions where a TEA is indicated.

262 This was reflected in significant improvements in LES, range of movement, pain experience,
263 and a high patient satisfaction score at a 4-year mean follow-up. The incidence of
264 complications was either comparable or less than that reported for other linked prostheses.

265 We need to wait for the long term results of this prosthesis to assess its survivorship.

266 **References**

- 267 1. Aldridge JM, 3rd, Lightdale NR, Mallon WJ, Coonrad RW. Total elbow arthroplasty with
268 the Coonrad/Coonrad-Morrey prosthesis. A 10- to 31-year survival analysis. *The Journal of*
269 *bone and joint surgery. British volume* 2006; 88:509-14. 10.1302/0301-620X.88B4.17095.
- 270 2. Amirfeyz R, Blewitt N. Mid-term outcome of GSB-III total elbow arthroplasty in patients
271 with rheumatoid arthritis and patients with post-traumatic arthritis. *Archives of orthopaedic*
272 *and trauma surgery* 2009; 129:1505-10. 10.1007/s00402-009-0876-y.
- 273 3. Angst F, John M, Pap G, Mannion AF, Herren DB, Flury M et al. Comprehensive
274 assessment of clinical outcome and quality of life after total elbow arthroplasty. *Arthritis and*
275 *rheumatism* 2005; 53:73-82. 10.1002/art.20911.
- 276 4. Ashmore AM, Gozzard C, Blewitt N. Use of the Liverpool Elbow Score as a postal
277 questionnaire for the assessment of outcome after total elbow arthroplasty. *Journal of*
278 *shoulder and elbow surgery* 2007; 16:S55-8. 10.1016/j.jse.2006.08.008.
- 279 5. Banagan KE, Murthi AM. Current concepts in total elbow arthroplasty. *Current Opinion in*
280 *Orthopaedics* 2006; 17:335-39 10.1097/01.bco.0000233729.71880.dc.
- 281 6. Bassi RS, Simmons D, Ali F, Nuttall D, Birch A, Trail IA et al. Early results of the
282 Acclaim elbow replacement. *The Journal of bone and joint surgery. British volume* 2007;
283 89:486-9. 10.1302/0301-620X.89B4.18197.
- 284 7. Bernardino S. Total elbow arthroplasty: history, current concepts, and future. *Clinical*
285 *rheumatology* 2010; 29:1217-21. 10.1007/s10067-010-1539-7.
- 286 8. Cesar M, Roussanne Y, Bonnel F, Canovas F. GSB III total elbow replacement in
287 rheumatoid arthritis. *The Journal of bone and joint surgery. British volume* 2007; 89:330-4.
288 10.1302/0301-620X.89B3.18488.
- 289 9. Chafik D, Lee TQ, Gupta R. Total elbow arthroplasty: current indications, factors affecting
290 outcomes, and follow-up results. *American journal of orthopedics* 2004; 33:496-503.

- 291 10. Corradi M, Frattini M, Panno B, Tocco S, Pogliacomi F. Linked semi-constrained total
292 elbow prosthesis in chronic arthritis: results of 18 cases. *Musculoskeletal surgery* 2010; 94
293 Suppl 1:S11-23. 10.1007/s12306-010-0070-y.
- 294 11. Figgie MP. Anatomy, Biomechanics, and Kinematics of Total Elbow Replacement. In:
295 R  ther W, editor. *The Elbow*: Springer Berlin Heidelberg; 1996, p. 20-34. (ISBN No. 978-3-
296 642-79741-5)
- 297 12. Futai K, Tomita T, Yamazaki T, Murase T, Yoshikawa H, Sugamoto K. In vivo three-
298 dimensional kinematics of total elbow arthroplasty using fluoroscopic imaging. *International*
299 *orthopaedics* 2010; 34:847-54. 10.1007/s00264-010-0972-1.
- 300 13. Gill DR, Morrey BF. The Coonrad-Morrey total elbow arthroplasty in patients who have
301 rheumatoid arthritis. A ten to fifteen-year follow-up study. *The Journal of bone and joint*
302 *surgery. American volume* 1998; 80:1327-35.
- 303 14. Gschwend N, Scheier NH, Baehler AR. Long-term results of the GSB III elbow
304 arthroplasty. *The Journal of bone and joint surgery. British volume* 1999; 81:1005-12.
- 305 15. Guttler K, Landor I, Vavrik P, Popelka S, Sosna A, Krasensky J. [Total elbow
306 replacement in patients with rheumatoid arthritis]. *Acta chirurgiae orthopaedicae et*
307 *traumatologiae Cechoslovaca* 2011; 78:423-30.
- 308 16. Hastings H, 2nd. Minimally constrained elbow implant arthroplasty: the discovery elbow
309 system. *Techniques in hand & upper extremity surgery* 2004; 8:34-50.
- 310 17. Hastings H, 2nd, Lee DH, Pietrzak WS. A prospective multicenter clinical study of the
311 Discovery elbow. *Journal of shoulder and elbow surgery* 2014; 23:e95-e107.
312 10.1016/j.jse.2013.12.033.
- 313 18. Hastings H, 2nd, Theng CS. Total elbow replacement for distal humerus fractures and
314 traumatic deformity: results and complications of semiconstrained implants and design
315 rationale for the Discovery Elbow System. *American journal of orthopedics* 2003; 32:20-8.

- 316 19. Hildebrand KA, Patterson SD, Regan WD, MacDermid JC, King GJ. Functional outcome
317 of semiconstrained total elbow arthroplasty. *The Journal of bone and joint surgery. American*
318 *volume* 2000; 82-A:1379-86.
- 319 20. Jensen CH, Jacobsen S, Ratchke M, Sonne-Holm S. The GSB III elbow prosthesis in
320 rheumatoid arthritis: a 2- to 9-year follow-up. *Acta orthopaedica* 2006; 77:143-8.
321 10.1080/17453670610045830.
- 322 21. Kamineni S, Morrey BF. Distal humeral fractures treated with noncustom total elbow
323 replacement. *Surgical technique. The Journal of bone and joint surgery. American volume*
324 *2005; 87 Suppl 1:41-50.* 10.2106/JBJS.D.02871.
- 325 22. Kelly EW, Coghlan J, Bell S. Five- to thirteen-year follow-up of the GSB III total elbow
326 arthroplasty. *Journal of shoulder and elbow surgery* 2004; 13:434-40.
327 10.1016/S105827460400045X.
- 328 23. King GJ. New frontiers in elbow reconstruction: total elbow arthroplasty. *Instructional*
329 *course lectures* 2002; 51:43-51.
- 330 24. Landor I, Vavrik P, Jahoda D, Guttler K, Sosna A. Total elbow replacement with the
331 Souter-Strathclyde prosthesis in rheumatoid arthritis. Long-term follow-up. *The Journal of*
332 *bone and joint surgery. British volume* 2006; 88:1460-3. 10.1302/0301-620x.88b11.17807.
- 333 25. Little CP, Graham AJ, Karatzas G, Woods DA, Carr AJ. Outcomes of total elbow
334 arthroplasty for rheumatoid arthritis: comparative study of three implants. *The Journal of*
335 *bone and joint surgery. American volume* 2005; 87:2439-48. 10.2106/JBJS.D.02927.
- 336 26. Maheshwari R, Vaziri S, Helm RH. Total elbow replacement with the Coonrad-Morrey
337 prosthesis: our medium to long-term results. *Annals of the Royal College of Surgeons of*
338 *England* 2012; 94:189-92. 10.1308/003588412x13171221589775.
- 339 27. Mansat P. Surgical treatment of the rheumatoid elbow. *Joint, bone, spine : revue du*
340 *rhumatisme* 2001; 68:198-210.

- 341 28. O'Driscoll SW, Morrey BF. Periprosthetic fractures about the elbow. *The Orthopedic*
342 *clinics of North America* 1999; 30:319-25.
- 343 29. Petscavage JM, Ha AS, Chew FS. Radiologic review of total elbow, radial head, and
344 capitellar resurfacing arthroplasty. *Radiographics : a review publication of the Radiological*
345 *Society of North America, Inc* 2012; 32:129-49. 10.1148/rg.321105733.
- 346 30. Prasad N, Dent C. Outcome of total elbow replacement for rheumatoid arthritis: single
347 surgeon's series with Souter-Strathclyde and Coonrad-Morrey prosthesis. *Journal of shoulder*
348 *and elbow surgery* 2010; 19:376-83. 10.1016/j.jse.2009.09.016.
- 349 31. Rozing P. Souter-Strathclyde total elbow arthroplasty. *The Journal of bone and joint*
350 *surgery. British volume* 2000; 82:1129-34.
- 351 32. Sanchez-Sotelo J. Total elbow arthroplasty. *The open orthopaedics journal* 2011; 5:115-
352 23. 10.2174/1874325001105010115.
- 353 [REDACTED]
- 354 [REDACTED]
- 355 [REDACTED]
- 356 34. Schneeberger AG, Hertel R, Gerber C. Total elbow replacement with the GSB III
357 prosthesis. *Journal of shoulder and elbow surgery* 2000; 9:135-9.
- 358 35. Shi LL, Zurakowski D, Jones DG, Koris MJ, Thornhill TS. Semiconstrained primary and
359 revision total elbow arthroplasty with use of the Coonrad-Morrey prosthesis. *The Journal of*
360 *bone and joint surgery. American volume* 2007; 89:1467-75. 10.2106/JBJS.F.00715.
- 361 36. Suk M, Hanson BP, Norvell DC, Helfet DL. *AO handbook of outcomes measures and*
362 *instruments. . In. New York: Thieme Medical Publisher; 2005; 142-7.*
- 363 37. van der Lugt JC, Rozing PM. Systematic review of primary total elbow prostheses used
364 for the rheumatoid elbow. *Clinical rheumatology* 2004; 23:291-8. 10.1007/s10067-004-0884-
365 9.

366 [REDACTED]

367 [REDACTED]

368 [REDACTED]

369 39. Voloshin I, Schippert DW, Kakar S, Kaye EK, Morrey BF. Complications of total elbow
370 replacement: a systematic review. *Journal of shoulder and elbow surgery* 2011; 20:158-68.
371 10.1016/j.jse.2010.08.026.

372 40. Wright TW, Wong AM, Jaffe R. Functional outcome comparison of semiconstrained and
373 unconstrained total elbow arthroplasties. *Journal of shoulder and elbow surgery* 2000; 9:524-
374 31. 10.1067/mse.2000.109408.

375 **Figure and Table Legends**

376 **Figure1.** Lateral and anteroposterior x-rays of an elbow with osteoarthritis before (a-b) and
377 6-year after total elbow arthroplasty with Discovery Elbow (c-d).

378 **Figure2.** Graphic illustration of the Mayo Clinic classification system used for describing
379 periprosthetic fractures in elbow arthroplasty. It is important to differentiate between different
380 types of fractures as those affecting the hardware stems (types 2 and 3) will potentially
381 require revision. (Reprinted with permission from RadioGraphics.²⁹)

382 **Table1.** Incidence of diagnoses for primary and revision Total Elbow Arthroplasty (TEA)

383 **Table2.** Comparison of pre- and postoperative elbow and forearm range of motion with
384 Discovery Elbow according to main underlying pathologies in all patients (primary and
385 revision)

386 **Table3.** Prosthesis alignment in primary and revision Total Elbow Arthroplasty (TEA)

Table1. Incidence of diagnoses for primary and revision Total Elbow Arthroplasty (TEA)

Main Diagnoses and sub-diagnoses	Incidence (%) (n = 100 elbows)
Inflammatory Arthritis	
Rheumatoid Arthritis	54
Juvenile Rheumatoid Arthritis	2
Psoriatic Arthritis	2
Non-Inflammatory Arthritis	
Degenerative Osteoarthritis	17
Traumatic Arthritis	14
Haemophilic Arthropathy	3
Nail-patella syndrome	1
Distal Humerus Fracture (acute and non-union)	7
Total TEA	<u>100</u>
Revision TEA	
Inflammatory Arthritis	16
Non-Inflammatory Arthritis	7
Fracture	2
Total	<u>25</u>

Table2. Comparison of pre- and postoperative elbow and forearm range of motion with Discovery Elbow according to main underlying pathologies in all patients (primary and revision)

Elbow/Forearm ROM	All Patients		Non-Inflammatory (Osteoarthritis)		Inflammatory (Rheumatoid Arthritis)		Fracture	
	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
Flexion	100 (24)	118 (17)**	101 (26)	118 (18) *	100 (20)	117 (16)**	92 (38)	115 (28)
Extension lag	28 (14)	25 (14)	28 (11)	25 (12)	28 (16)	26 (16)	23 (15)	18 (17)
FLX-EXT ARC	72 (28)	93 (27)**	73 (30)	93 (26)*	72 (27)	92 (26)**	87 (33)	97 (44)
Pronation	48 (23)	61 (21)**	49 (25)	64 (18)*	46 (23)	59 (22)*	61 (17)	64 (15)
Supination	38 (26)	50 (25)**	42 (26)	55 (21)*	35 (26)	45 (25)*	52 (23)	51 (29)
PRON-SUP ARC	86 (45)	111 (42)**	91 (48)	119 (35)**	81 (44)	104 (42)*	113 (39)	115 (41)

-FLX, Flexion; EXT, Extension; ROM, Range of Motion; Pre-op, Preoperative; Post-op, Postoperative.

-Significant difference at $P \leq .05$ (*) and $P \leq .001$ (**).

Table3. Prosthesis alignment in primary and revision Total Elbow Arthroplasty (TEA)

Degree of Malalignment	Coronal Plane		Sagittal Plane	
	Humerus	Ulna	Humerus	Ulna
PRIMARY TEA				
Less than 5 degrees	61	57	48	63
5-10 degrees	9	13	22	6
More than 10 degrees	0	0	0	1
REVISION TEA				
Less than 5 degrees	16	16	14	17
5-10 degrees	2	2	4	1
More than 10 degrees	0	0	0	0



TYPE 3

TYPE 2

TYPE 3

TYPE 1

FRACTURE TYPES

