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Total elbow arthroplasty in patients who have elbow fractures caused by gunshot injuries: 8- to 12-year follow-up study

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Abstract
Introduction In this retrospective study, we aimed to present 8–12-year clinical and radiographic evaluation of total elbow arthroplasty in young patients who had open fractures due to gunshot injuries.
Materials and methods The study included a consecutive series of seven patients who had insertion of total elbow prosthesis (semi-constrained type) for the treatment of comminuted intra-articular elbow fractures resulting from gunshot injuries between 1994 and 1998. All patients were male and the mean age at the time of operation was 23 years.
Results The average time from the original fracture to the joint replacement was 26 months (range 14–39). The mean follow-up period was 117 ± 15 months. At the time of the latest follow-up, 5 of 7 elbows had a poor result. Radiological evaluations revealed that three patients had ulnar and two patients had humeral component loosening at the last follow-up examination. No intra-operative complications were observed. In the long-term evaluation, two patients had prosthesis loosening that resulted from deep infection and three patients had aseptic loosening that necessitated re-operation. The prosthesis removal was performed.
Conclusion As a result, the patients in whom we implemented total elbow prosthesis in comminuted elbow fractures due to gunshot wounds seemed to get back into active life in the early period without any problem and it seemed that their pain disappeared and their functional capacity increased. In the long period, however, these values showed a distinct decrease with the same patients.

Keywords Total elbow prosthesis · Gunshot injuries · Elbow fractures

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Introduction

The treatment of arthrosis and degenerative changes on the elbow joint depend on rheumatoid arthritis and similar systemic diseases and the treatment of ankylosed and pseudoarthrotic elbows due to the trauma with high energy like gunshot wounds are always problematic [3, 21, 23, 26, 40].

In the treatment of the patients complaining about pain, movement incapacity, and loss of function; arthrodesis, osteoarticular allografts, resection arthroplasty, interpositional arthroplasty, or total elbow prosthesis can be used [23, 26]. The major aims in the treatment are to enable patients have their maximum functions, to stop pain, and to get them back into social life.

Prosthetic replacement of the elbow joint has been successful in a variety of clinical situations, although it has not been put to the same test as total knee replacement has in young, active patients with primary osteoarthritis. The major concerns limiting its clinical application are instability and loosening [38].

Since the introduction of total elbow arthroplasty, many improvements have been made in the design of elbow prostheses. A better understanding of elbow biomechanics has resulted in the development of a reliable and successful procedure for replacing the elbow joint. Most of the elbow prostheses currently in use fall into three categories:

constrained, unconstrained, and semi-constrained. Unconstrained prostheses rely on the integrity of the soft tissues and the surface contact between the humeral and ulnar components for articular stability [9, 16, 20]. Semi-constrained models have a "sloppy hinge" with a polyethylene bushing to provide inherent stability to the ulnohumeral articulation while allowing several degrees of varus/valgus and internal/external rotation laxity [16, 29, 34]. Some authors believe that with progressive joint destruction and lack of ligamentous stability, a more constrained type of elbow prosthesis is indicated [6, 15, 18, 45]. However, considering the constrained prostheses' high-loosening rate, a semi-constrained prosthesis can still be indicated, even in elbows with severe destruction.

When the literature is analyzed, the complication rate of the patients treated with elbow prosthesis as a result of post-traumatic degeneration is higher when compared with the rate of patients with rheumatoid arthritis [8, 15, 19, 40]. But, in the English literature, there is no information about the prosthesis implementation in young patients with extensive bone and soft tissue loss due to gunshot injuries.

In this retrospective study, we aimed to present 8–12-year clinical and radiographic evaluation of total elbow arthroplasty in young patients who had open fractures due to gunshot injuries.

Materials and methods

This retrospective review includes a consecutive series of seven patients who had insertion of total elbow prosthesis (semi-constrained type) for the treatment of comminuted intra-articular elbow fractures resulting from gunshot injuries between January 1, 1994 and December 31, 1998. All patients were males and the mean age at the time of operation was 23 (range 21–28) years. In 5 of 7 patients, the injury was on the left side and in the other two, on the right side. All patients were right-handed (Table 1).

At the time of presentation, two patients had free elbow joint in the pre-operative period; on the other hand, the elbow joint of the other five was ankylosed. One patient (number 1) had ulnar nerve, one patient (number 2) had ulnar and radial nerve, one patient (number 3) had radial and median nerve, one patient (number 5) had ulnar and median nerve, and one patient (number 7) had radial nerve neuropathy.

The emergency interventions of the patients after the gunshot injuries were done in the field hospitals and then their final treatments were complemented in our clinic. Before the prosthesis implementation, the patients had been observed until the "negative" results were taken at least for 3 months in terms of erythrocyte sedimentation rate, C-reactive protein, and white blood cell count to be sure that there was no infection. All the patients were completely informed about the treatment alternatives including prosthesis and gave an approval document about their prosthesis choice (Fig. 1).

During surgery; in order to avoid potential complications, it is essential that the surgeon spends time planning pre-operatively for the anatomical deformities and technical challenges. The operations were performed with tourniquet control. In all elbows, the triceps were elevated off the olecranon from medial to lateral (Bryan–Morrey approach) [4, 5] to preserve triceps muscle under general anesthesia and in lateral decubitis position of the patient. All the elbows had subcutaneous translocation of the ulnar nerve anteriorly. The collateral ligaments, medial and lateral, as well as the anterior capsule, were released. All patients underwent total open synovectomy and radial head excision before implantation. The humerus and the ulna were prepared with standard instruments, and the medullary canals were opened with raspers. A trial reduction was performed with attention to balance and stability of the implant and, if necessary, further soft-tissue release was performed. The prosthesis was cemented in place in all seven elbows. The cultivations were taken and completely reported as negative. Where applicable, the triceps were reattached to the

Table 1 Demographic characteristics and outcomes of the patients

Case number	Age	Time from injury to prosthesis implantation (months)	Early-postoperative follow-up time (months)	Late-postoperative follow-up time (months)	Nerve lesion	Complication	Outcome
1	21	32	29	122	Ulnar	Septic loosening	Poor
2	23	30	39	142	Radial + ulnar	Aseptic loosening	Poor
3	22	16	24	107	Radial + median	Aseptic loosening	Poor
4	24	39	27	120	–	–	Good
5	25	14	18	115	Ulnar + median	Aseptic loosening	Poor
6	28	38	21	114	–	Septic loosening	Poor
7	23	14	17	94	Radial	–	Good

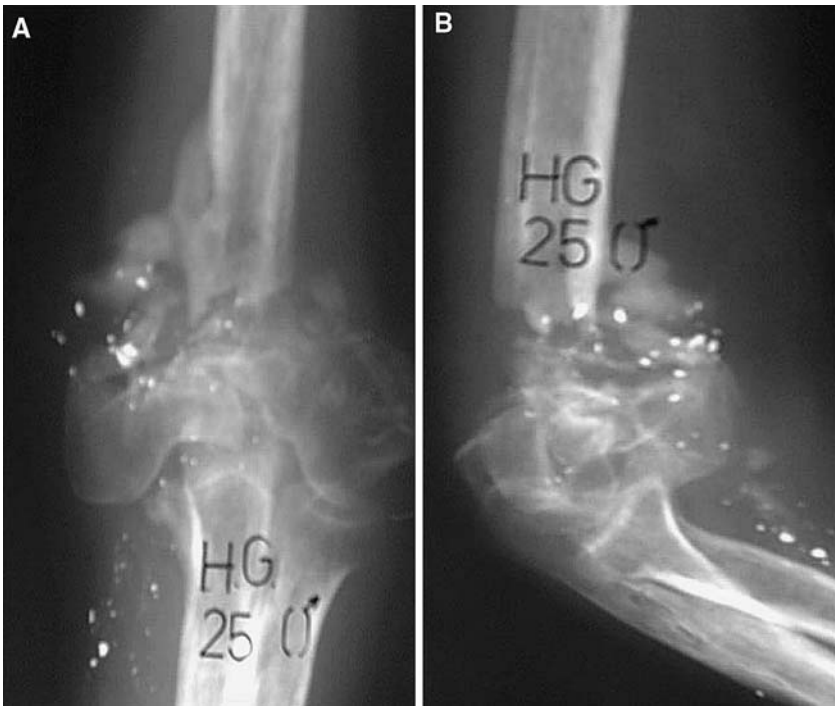

Fig. 1 Anteroposterior (**a**) and lateral (**b**) pre-operative X-rays of Case 5, 27-year-old man with elbow fracture after gunshot injury after 14 months

olecranon with use of large, non-absorbable sutures as described by Bryan and Morrey [5].

The average operation period was 120 min (range 105–145). Drains were placed deep to the extensor mechanism and in the subcutaneous layer. The drainage tubes were removed after 48 h postoperatively. Antibiotics (cephamezine 1 g intravenously, three times in a day and metronidazole 250 mg intravenous infusion, two times in a day) were given pre-operatively and for 72 h postoperatively. A senior surgeon (MK) performed all the procedures.

A splint was applied with the elbow in 90° flexion and it was worn for 1 week. At the end of the first postoperative week, passive exercises were started with continue passive motion (CPM) and it was kept going for 3 weeks, except for the splint exercise. After 3 weeks, active-assisted flexion and extension (gravity-assisted extension if the triceps were reflected) were then begun. A nighttime extension splint was worn for 12 weeks and adjusted as extension improved, and a daytime resting splint (with the elbow at 90° of flexion) was worn for 6 weeks. Therapy was the same for all patients while they were in the hospital and after they had been discharged (average seventh postoperative day) (Fig. 2).

The Mayo elbow performance score [31, 32] was employed to document subjective, objective, and functional characteristics before, early postoperative, and last follow-up of total elbow arthroplasty. This system places the greatest emphasis on pain relief (45 points) and the ability of the patient to perform functional activities (25 points); assessments of motion (20 points) and stability (10 points) are also included. The results are defined as excellent (90–100 points), good (75–89 points), fair (60–74 points), or poor

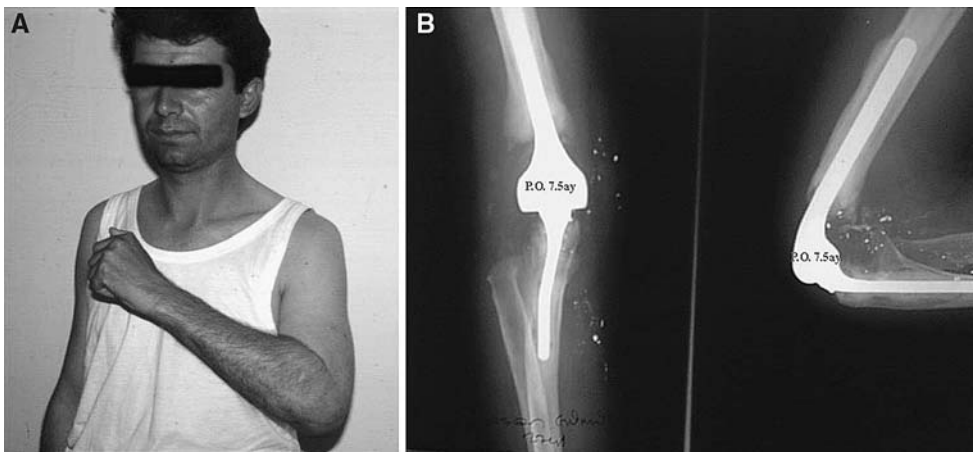

Fig. 2 Seven and a half months after total elbow arthroplasty. Please note the function (**a**) and radiological appearance (**b**)

Table 2 Mayo elbow performance score

Function	Points (total 100 points)
Pain (max 45 points)	
None	45
Mild	30
Moderate	15
Severe	0
Range of motion (max 20 points)	
Arc > 100°	20
Arc 50°–100°	15
Arc < 50°	5
Stability (max 10 points)	
Stable	10
Moderately unstable	5
Grossly unstable	0
Function (max 25 points)	
Able to comb hair	5
Able to feed oneself	5
Able to perform personal hygiene tasks	5
Able to put on shirt	5
Able to put on shoes	5

(<60 points) (Table 2). Excellent and good results were considered satisfactory, and fair and poor results were considered unsatisfactory.

The radiographic evaluation was based on both pre-operative radiographs and radiographs made at the time of the latest follow-up evaluation. The radiographs were analyzed for implant subsidence, radiolucency, periprosthetic fractures (sub)luxation, and periarticular ossifications. For signs of prosthetic loosening, radiographic findings were graded as type 0, which indicates a radiolucent line <1 mm thick and involving <50% of the interface; type I, a radiolucent line at least 1 mm thick and involving <50% of the interface; type II, a radiolucent line more than 1 mm thick and involving more than 50% of the interface; type III, a radiolucent line more than 2 mm thick and around the entire interface; and type IV, gross loosening [40].

The relationship between discrete variables was determined with the Wilcoxon signed-rank test. Factors were tested statistically for association with a satisfactory or unsatisfactory result with use of univariate analysis with the chi-square test. $P < 0.05$ was considered significant.

Results

The average time from the original fracture to the joint replacement was 26 months (range 14–39). The mean follow-up period was 117 ± 15 months. The observation and the evaluation of the patients were made according to the score of Mayo Elbow Performance as pre-operative, post-operative early period (about 25 ± 7.5 months), and late periods (about 117 ± 15 months). The mean pre-operative value was 56.4 ± 7.4 points, the mean early-postoperative value was 88.5 ± 7 points, and the late-postoperative value was 55.7 ± 17.6 points (Table 3). At the time of the latest follow-up, according to the Mayo elbow performance score, 5 of 7 elbows had a poor result. The increase in the Mayo elbow performance score between the pre-operative evaluation and the early-postoperative follow-up evaluation was significant ($P < 0.05$). On the other hand, no statistical difference was observed between pre-operative and last follow-up examinations in terms of Mayo Elbow Performance scores ($P > 0.05$).

In terms of pain relief, initially, two elbows were severely painful, three were moderately so, and two were mildly so. At the time of early-postoperative period, two elbows had mild pain and the remaining five elbows had no pain. And at the latest follow-up, two elbows were not painful, three were mildly so, and two were moderately so. None of the elbows showed severe pain postoperatively. With the numbers available, no significant difference was detected at the level of pain between the early- and late-postoperative follow-up examinations ($P > 0.05$). But, it has been shown that pain decreased significantly after the operation ($P < 0.05$).

In terms of the range of motion: in the pre-operative period, the average flexion was 48° (range 0–90); in the early-postoperative period, it was 80° (range 66–110); and in the last follow-up, it was 50° (range 0–76). When looking at the elbow performance score, it was seen that it was 9.3 ± 5.3 in the pre-operative period, it was 16.4 ± 2.4 in the early-postoperative period, and it was 10.7 ± 5.3 in postoperative advanced period. There was a statistically significant improvement in the range of motion in the early-postoperative period. However, this improvement had significantly decreased at the last follow-up of minimum 8 years.

In the pre-operative period, two patients (28.5%) had gross instability and five patients (71.5%) had ankylosis on their elbows. In the early-postoperative period, all of the patients (100%) had stability. In the advanced period, there was relaxation as a result of bone erosion and osteolysis and the prosthesis of the five patients who had instability that prevented the useful functioning of the elbow were taken out. At the latest follow-up evaluation of the two remaining patients, none in whom the prosthesis was in situ reported any subjective sensation of instability or demonstrated any objective instability. Looking at the elbow performance score, it was seen that it was 7.14 ± 4.88 in the pre-operative period, 10 ± 0.0 in the postoperative early period, and 2.86 ± 4.88 in the postoperative advanced period.

Table 3 Mayo elbow performance scores of the patients

Number	Pain			Range of motion			Stability			Function		
	Pre-operative	Early postoperative	Late Postoperative	Pre-operative	Early postoperative	Late postoperative	Pre-operative	Early postoperative	Late postoperative	Pre-operative	Early postoperative	Late postoperative
1	30	45	30	5	15	5	10	10	0	15	20	15
2	30	30	30	15	20	15	0	10	0	10	25	10
3	15	45	15	15	15	15	0	10	0	15	25	15
4	45	45	45	5	15	5	10	10	10	5	25	5
5	15	30	15	15	20	15	10	10	0	10	20	20
6	45	45	15	5	15	5	10	10	0	15	25	15
7	30	45	45	5	15	15	10	10	10	10	20	20
Total	30	40.7	27.8	9.2	16.4	10.7	7.1	10	2.85	11.4	22.8	14.7

The ability to perform five tasks of daily function—combing hair, feeding oneself, performing hygiene, putting on a shirt, and putting on shoes—was assessed by each patient. The pre-operative scores for daily function was meanly 11.4 ± 3.8, and the score increased to 22.8 ± 2.6 in the early-postoperative period and decreased to 14.3 ± 5.3 in the late-postoperative period and it was stated that it was very close ($P > 0.05$) to the pre-operative period, which significantly increased in early-postoperative period ($P < 0.05$).

Radiological evaluations revealed that three patients had ulnar and two patients had humeral component loosening at the last follow-up examination. The loosening was radiologically categorized as types 0–4 according to Hildebrand and Arks criteria [19]. According to this, two patients had type 2, one patient had type 3, and two patients had the loosening of type 4 and the prostheses were taken out in those patients.

There were no intra-operative complications observed. In the early-postoperative period, there was no major complication like supplemental nerve lesion, triceps insufficiency like avulsions, heterotrophic ossification, and fracture, but in the long-term evaluation two patients had prosthesis loosening that resulted from deep infection and three patients had aseptic loosening that necessitated re-operation. The prosthesis removal was performed on them; however, none of the patients wanted a new prosthesis implementation. All of the patients from whom the prostheses were taken out still live with free elbow joint without any infection and brace (Fig. 3).

Discussion

Management of patients who had comminuted intra-articular elbow fractures resulted from high-energy traumas like gunshot injuries is very challenging [3, 21, 23, 26, 40], with only a few options even theoretically available for operative treatment. In the treatment of the patients complaining about pain, movement incapacity, and loss of function, arthrodesis, osteoarticular allogreft, resection arthroplasty, interpositional arthroplasty, or elbow prosthesis can be used [23, 26]. The major aims in the treatment are to enable patients have their maximum functions, to stop pain, and to get them back into social life.

Arthrodesis reliably relieves pain [27] and restores a strong extremity. However, because it results in great functional impairment [34], arthrodesis of the elbow rarely is considered as a viable option [11, 31]. Interposition arthroplasty may be considered for a young patient, particularly one who has stiffness. Restoration of motion and relief of pain can be achieved with a reasonable but unpredictable rate of success [13, 22, 30, 42]. However, this procedure is

Fig. 3 About 10-year follow-up, the prosthesis removed due to aseptic loosening. Radiological view

technically demanding, with an even higher rate of complications than that associated with semi-constrained total elbow replacement [30]. Interposition arthroplasty also is not considered suitable for patients who perform strenuous physical labor [22]. In addition, marked loss of bone is a contraindication to this procedure [13]. Urbaniak and Black Jr [43] reported the results of allograft replacement of the entire elbow joint after 6 months to 6 years. Seven of ten patients had a satisfactory result. The rate of pain relief was high, with only minimum or mild symptoms in all patients. Complications occurred in three of the ten patients: two patients had a non-union, and one had extensive resorption of the graft associated with chronic dislocation of the elbow. Continued degenerative changes and fragmentation of the allograft were seen in some of the elbows after 2 years. However, other authors reported less favorable results after other total elbow replacements were performed with allografts [10].

The results of total joint replacements with highly constrained designs in the 1970s were disappointing because of the high rates of loosening [10, 14, 29]. Although a decrease in the rates of loosening was reported after the introduction of semi-constrained and unconstrained replacement devices [9, 11, 17, 33, 36], those reports dealt almost exclusively with the treatment of rheumatoid arthritis. There is very little information regarding total joint replacement with an unconstrained or semi-constrained device for the treatment of post-traumatic osteoarthrosis.

Physiological studies have revealed that there is a continuous and linear change in the carrying angle during flexion and extension of the elbow [28]. In addition, internal axial rotation of the forearm occurs near the beginning and external rotation toward the end of rotation. Semi-constrained total elbow arthroplasties allow these physiological changes to occur, thereby reducing stress transmission to the prosthesis–bone interface. A review of the literature reveals improving and encouraging short-term results with several semi-constrained designs when they were used in rheumatoid elbows [2, 8, 25, 32]. Pain relief ranges from 91 to 100%, with good to excellent results obtained in 87–95% of patients. Range of motion in both elbow flexion-extension and forearm rotation increase postoperatively in most series. The revision rate for loosening remains low at 1–5% at follow-up of between 2 and 5 years. We used semi-constrained type elbow prosthesis in all our patients.

The success of the semi-constrained total elbow arthroplasty has been well documented. Morrey and Adams' [32] series of 58 modified Coonrad semi-constrained arthroplasties followed for 3.8 years postoperatively yielded 91% excellent or good results, with 84% of patients without any pain. Similar results were found by Gschwend et al. [17] in their use of the semi-constrained GSB III prosthesis, with 91% excellent or good results at 4 years.

One major advantage of this type of implant is its ability to correct deformity. However, our experience suggests that it does so at the expense of increased rates of wear. Despite the favorable results at the short term, the indication for total joint replacement should still be very restrictive. Unfortunately, other reconstructive procedures are limited. Careful attention to operative technique and experience with the procedure enhance the likelihood of a satisfactory outcome in this challenging young patient population.

On the other hand, as concerning complications, the rates of intra-operative fracture in the literature are difficult to determine because of variations in the methods used to report them. Some authors have not commented on intra-operative fracture, whereas others have reported complete fracture of the humeral shaft, medial condyle, or ulnar shaft in as many as 4% of the elbows [19]. When perforations of the ulnar or humeral cortex were included, rates of intra-operative fracture have been reported to be as high as 9% [41]. The rate of intra-operative fracture was zero in the present series.

Periprosthetic infection occurred in two (18%) of the seven elbows. In other studies, involving the use of many types of implants, rates of deep periprosthetic infection have ranged from 0 to 9% [1, 7, 8, 12, 15, 19, 24, 31–33, 37, 39, 41, 44, 46]. Both patients were treated with a

resection arthroplasty and were not interested in re-implantation. They remained on chronic antibiotic suppression.

Triceps disruption following total elbow arthroplasty is a well-recognized problem, occurring in as many as 31% of elbows in some reports [7, 8, 15, 31–33, 35]. In our group, no elbows had clinically obvious triceps disruption at the time of the latest follow-up.

Gunshot wounds on the elbow are rarely seen when compared with the other sides of the extremities [3]. The major aim in primary treatment is acute fixing of damaged smooth texture and neurovascular structure by saving the bone stock as long as possible, the restoration of joint surface, fighting with infection, and coming into action earlier [3]. But, in spite of all of these attempts, it is very difficult to get the ideal result on gunshot-wounded elbows with high-energy trauma where there is a bone stock loss.

In the long-term observation of semi-constrained prosthesis, which was stable in the early period, it seemed that the prostheses of five of the seven patients (71.4%) were taken out as a result of instability and got unsuccessful results. We observed that one of the most important factors that caused instability is the deficiency of bone stock and the others are extensive smooth texture loss and the deficiency of ligament structure supplement.

As a result, the patients in whom we implemented total elbow prosthesis in comminuted elbow fractures due to gunshot wounds seemed to get back into active life in the early period without any problem and it seemed that their pain disappeared and their functional capacity increased. In long period, however, these values showed a distinct decrease with the same patients. Although our study group is small, according to our data, the long-term observations of semi-constrained elbow prosthesis implemented especially in young patients with bony defects on the elbow resulting from gunshot injuries are not satisfactory.

In conclusion, the criteria like bony deformities, the sufficiency of soft tissue coverage and bone stock, patient accordance and age, pre-operative planning, etiology (either post-traumatic or inflammatory), informing the patients, and asking for their choice positively affect the rate of success.

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