Reconstruction of an elbow joint after blast injury by arthroplasty with a custom-made modified total elbow prosthesis: a case report

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In the past, the primary indication for endoprosthesis implantation at the elbow was painful rheumatoid arthritis of the elbow joint in elderly patients.14 According to various follow-up examinations in the literature, the 10-year durability of implanted prostheses for this patient population is between 70% and 85%.9,17,19

In past years, this indication has been increasingly extended to include the immediate treatment of destructive injuries of the distal humerus in an elderly population. The key criterion for this course of action was the assessment that intra-articular components of the distal humerus were unsuitable for reconstruction and that an endoprosthesis could lead to a better functional outcome for this patient population for the short and intermediate term.1,5,11,20

Additional nontraumatic indications for endoprosthesis implantation subsequent to extensive resection of the distal humerus include large amounts of juxta-articular osteolysis, space-occupying lesions, and tumors. In these cases, custom-made prostheses are used and can restore joint function and repair bone defects according to preoperative planning of resection.22,26

Depending on the stability of the joint, unconstrained or semiconstrained types of prostheses are implanted. The types currently in use can be implanted with an intramedullary stem in both the humerus and proximal ulna.

Experience in past years has generally shown that prostheses with lower degrees of freedom have higher rates of loosening. Current standard elbow prostheses allow pronation and supination of the forearm.4

The clinical case presented here involved the loss of the entire elbow joint after a blast injury with a resultant bone defect of approximately 20 cm in length. Such a large defect necessitated an individual approach ultimately requiring a constrained custom-made prosthesis. In addition, it was our objective to connect the radius and the ulna, sacrificing pronation and supination of the forearm, to ensure more stability in the long term and thus increased durability of the prosthesis. In this article, we discuss the preoperative planning and surgical technique and report on functional outcome for a customized constrained elbow prosthesis at 12 and 24 months after implantation.

Case study

The right-handed 38-year-old male patient was working in a foreign country as a security guard and was injured in a bomb attack while standing in front of a building. In addition to multiple fragment and shrapnel wounds of the extremities and the abdomen, he suffered an open craniocerebral trauma and a grade 3 open comminuted fracture of the right elbow joint with a rear soft tissue defect of 8 by 10 cm.

After he was stabilized, the patient was transported to Oman for further care. There, his wounds and the craniocerebral trauma were treated, and he recovered from the soft tissue injuries.

The right elbow joint was resected together with adjacent long bones. The defect was covered with an ipsilateral composite

IRB: The patient gave his informed consent for this report to be published.

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musculocutaneous latissimus dorsi flap. His arm was also immobilized by joint-spanning external fixation.

Six months after the injury, the patient was referred to our hospital for further restorative treatment. Figure 1 provides an overview of findings at the beginning of treatment.

Because we could not rule out a possible infection, we began by organizing the removal of the external fixation in the patient’s home country and initiated additional imaging with regular monitoring of inflammatory markers. White blood cell count and C-reactive protein level were slightly elevated before and returned to normal values after the removal of the fixateur. Figure 2 consists of images sent to us in the course of the treatment, showing the initial bone defects as well as the soft tissue 6 weeks after removal of the external fixation.

When the soft tissue healed well and the systemic inflammation parameters returned to normal, we discussed possible surgical procedures. Options that were considered included arthrodesis, replacement by a live or fresh frozen allograft, amputation at mid–upper arm level, and implantation of a hinged prosthesis.

The arthrodesis option was dismissed because of the length of the defect and poor bone quality; the option of reconstruction with a fresh frozen allograft was dismissed because of the necessary follow-ups, the attributed risk of Charcot arthropathy, and the age of the patient.

On the basis of these findings, the patient then received differential therapeutic advice by e-mail. Two options, amputation at mid–upper arm level followed by corresponding exoprosthesis care or, alternatively, implantation of a constrained, individually tailored hinged prosthesis with all associated complications and risks, were explained to him. The patient ruled out amputation from the very beginning on account of the associated stigmatization in his country.

The patient was then invited to our hospital for surgical treatment. On admission, he showed neither local nor systemic signs of infection. We documented asymptomatic wounds and soft tissue with a resilient, well-perfused flap that had healed with slight scarring. The pulses of the radial and ulnar artery were easily palpated peripherally. We further observed a 10-cm length discrepancy between the patient’s upper extremities.

In neurologic terms, we documented partial lesions of the ulnar and radial nerves. As a result, the patient lacked normal sensibility in the ulnar and radial dermatomes of the hand. He was unable to move the fourth and fifth fingers because of an ulnar motor palsy, but he could actively flex the elbow joint. Bending of the elbow with gravity eliminated was not possible. Owing to the initial trauma and required surgical débridement, the distal triceps, and thus the extensor mechanism of the elbow, was absent.

An examination of the wrist revealed that it was almost completely stiff. The strength of opposition between the thumb and the second and third fingers was diminished (max. 3/5), but the patient could grasp lightweight objects in a pincer grip. In addition, conventional imaging revealed a distinct decrease in bone mineral density, and the patient was diagnosed with a chronic hepatitis B infection.

Figure 3 shows the process of preoperative planning, starting with initial drawings of the simultaneous connection of ulna and radius to the hinged prosthesis and concluding with the manufacturer’s final production sketch.

Surgery was performed under general anesthesia through dorsoradial access on the edge of the flap without arresting the blood supply and with the patient in a prone position. The entire flap was lifted, and the surgical procedure was facilitated by the fact that parts of the anterior articular capsule could still be identified.

The humerus was resected proximally and prepared with an awl for the implantation of a cemented stem. The preparation of the radius and the ulna was more difficult. Here, we had to meet the material specifications of the manufacturer when it came to the minimum thickness of the stem. These specifications considerably exceeded the actual width of the medullary cavity in the radius and the ulna. The medullary cavity was prepared with camulated
Figure 2  Defect situation and condition of soft tissue 6 weeks after removal of external fixation.

Figure 3  Planning diagrams for the endoprosthesis. (1) Prosthesis before modification. (2) Initial design drawing by the authors. (3) First design by the manufacturer. (4) Three-dimensional reconstruction. (5) Dimensional drawing for surgery planning.
drills manufactured by Arthrex, Germany, for anterior cruciate ligament replacement.

Following a test implantation and after the final length of the prosthesis was determined, the definite components were cemented. The remaining deficiency in length was tolerated to ensure tension-free soft tissue closure and a range of motion of 0° to 100° in the elbow joint.

Postoperative primary wound healing was uneventful. Figure 4 shows conventional postoperative x-ray images and the follow-up after 12 months.

To consolidate the soft tissue status, the elbow was immobilized with a removable plaster splint (90° of flexion) until the stitches were removed 10 days after surgery. While still wearing the removable splint, the patient received occupational physiotherapy twice a day and additional continuous passive motion starting on the fifth day after surgery. He actively trained bending his arm from extension up to 90° of flexion. When he was discharged from the hospital 4 weeks after the operation, the patient was able to touch his nose with his thumb and forefinger and to bring small objects to his mouth.

Figure 4  Postoperative and 12-month follow-up, conventional x-ray imaging in 2 planes.

Figure 5  Range of motion and soft tissue status, follow-up after 12 months.
One year after surgery, the patient presented to us again for a clinical and radiologic follow-up. Figure 5 provides an overview of the soft tissue status and the range of motion at that time. Medical treatment was concluded 24 months after surgery when the patient was asked about the functioning of the joint and any related complaints. At that time, he did not have any complaints about his elbow joint. He did, however, report pain and stiffness in his wrist after using his right arm for an extended period and after carrying objects heavier than 1 kg. Figure 6 shows the active range of motion in the right elbow joint after 24 months.

Discussion

This clinical case involved a patient who lost his elbow joint after sustaining a blast injury. We were thus confronted with bone and soft tissue reconstruction. Despite several written requests, we were unable to reach the hospital that provided initial treatment. For this reason, we are unable to present findings for a discussion of possible alternatives to the initial and follow-up treatment.

With regard to reconstructive options, the patient’s wish was that elbow joint function be restored as anatomically as possible. Nevertheless, we still discussed alternatives, such as treatment/permanent immobilization with a custom-made orthosis or amputation. Orthosis or amputation at mid–upper arm level would have resulted in very limited residual arm function for activities of daily life. In addition, amputation would have resulted in disproportionate stigmatization in an Islamic country such as Iraq.

The existing residual functions of the hand included voluntary activation of the flexors and extensors of the forearm. The forearm length foreshortened when forearm muscles were activated, thus rendering the arm distal to the elbow dysfunctional. We assumed that implantation of an endoprosthesis with reconstruction of the length and structural integrity of the forearm would consequently improve the strength and function of the hand.

In our opinion, given the pathoanatomy and the patient’s needs and desires, we thought there were only 3 viable reconstructive options: arthrodesis, allograft implantation, and endoprosthesis reconstruction.

Elbow arthrodesis in various positions is recommended in the literature for infections and defects that cannot be managed by prosthesis implantation or other methods. It can be achieved by internal osteosynthesis or by immobilization with external fixation, with or without the accretion of cancellous bone. The functional outcome of arthrodesis depends on the position chosen. It is therefore recommended to simulate arthrodesis in an orthosis before final surgery. Owing to the mobility of the shoulder girdle, patients can achieve satisfactory and appealing results from the function and use of the affected arm.

Contraindications to arthrodesis (e.g., by interposition of a pedicled bone graft) were the length of the defect, the poor bone quality (decreased bone mineral density), and the necessity of fixation on the distal forearm. In this case, a singular osteosynthesis of humerus and radius would have been possible. However, this would not have taken into account the existing wrist joint incongruity with ulna plus variant. An alternative would have been the fusion of humerus, radius, and ulna, which would have sacrificed pronation and supination. The patient, however, thought that...
immobilization by external fixation and the resulting stiff arm would impair and bother him. He ruled out this approach.

Implantation of a fresh frozen allograft has been described for patients with massive bone loss after trauma, tumor resection, or revision elbow arthroplasty.\textsuperscript{23,24} Dean et al\textsuperscript{7} reported in 1997 on a group of 23 patients who underwent elbow allograft reconstruction with varying results and a high complication rate. Ten of 14 patients with elbow allografts observed for an average of 7.5 years reported satisfactory results. Allograft removal was required in 6 patients on account of infection, instability, nonunion, and resorption. Three patients with instability underwent subsequent successful total elbow arthroplasty. They concluded that this operation was not recommended for routine use and should be viewed as a salvage procedure.

Kharrazi et al\textsuperscript{12} reported on a group consisting of 18 patients with 16 hemiarticular allografts and 3 total elbow osteoarticular allografts and a minimum follow-up of 2 years (mean, 9.9 years; range, 2-12 years). All 3 patients who had a complete elbow allograft reconstruction had a Charcot-like joint develop 5 to 8 years after surgery. From this group, 2 of the 3 patients had unsuccessful reconstructions and ultimately required allograft excision with a residual flail elbow.

Several additional cases in which the elbow joint was replaced with an allograft have sporadically been described in the literature in recent years as a treatment option in isolated cases or as a last resort.\textsuperscript{2,3,18} In such cases, the functional outcomes are promising. Close monitoring is recommended, however, owing to delayed deep infection, loosening, or resorption of the transplant.

The implantation of a fresh frozen cadaveric allograft, which in our view is still experimental, was dismissed because of the requirements of specialized follow-up treatment and the required follow-up osteosynthesis, which involves the same limitations as arthrodesis.

When it came to the implantation of a prosthesis, the most important considerations were permanent stability and the life span of the prosthesis. Experience with the available types of prostheses referred to in the literature shows that a higher degree of freedom and of mobility coincides with a lower rate of loosening. This in turn implies that simple, rigid types of prostheses lead to premature loosening.\textsuperscript{13,16,25} For patients who received an elbow replacement before the age of 40 years, revision rates of 22% within the first 91 months have been cited by Celli and Morrey.\textsuperscript{6} They identified 55 patients who were 40 years of age or younger when they were treated with a semiconstrained total elbow arthroplasty in a group of 758 patients who received a Conrad-Morrey prosthesis between 1982 and 2003. However, 93% of the elbows had good or very good functional outcomes during a mean follow-up of 99 months evaluated with the Mayo Elbow Performance Score.

Taking into account the length of the defect, particularly in the forearm, we planned the simultaneous connection of radius and ulna. Although we sacrificed pronation and supination, the custom-made prosthesis allowed us to achieve long-segment fixation with a cemented stem. We were also able to correct the malposition of the wrist joint by repositioning the radius and the ulna.

As far as we know, the simultaneous fixation in both bones of the forearm in this way is underrepresented in the literature and has thus not been examined with regard to outcome and rates of loosening. It remains to be seen whether this method results in long-term success. The satisfactory functional outcomes seen in the follow-up examinations after 12 and 24 months show that at least this patient is very satisfied, and until now there is no evidence of radiographic loosening. We are aware of the fact, however, that the follow-up is insufficient and that there is a persistent risk of deterioration.

Whether this construction can also be used as a prosthesis for patients who still have an intact extensor mechanism and intact voluntary musculature for pronation and supination is worthy of discussion. Such cases, however, involve significantly higher forces (in particular rotational forces), and it is possible that the activated muscle groups work “against” the prosthesis during pronation and supination. We believe that this makes premature loosening more likely.

In general, however, simple types of prostheses that are tailored to the individual defect situation should be considered alternatives to arthrodesis or amputation, in particular for young patients with destructive gunshot or blast injuries if the soft tissue and part of the functionally relevant musculature can successfully be preserved or restored. In such cases, the functionally achievable outcome must be weighed against treatment with a myoelectric prosthesis or amputation. The function and the sensitivity of the hand are the most relevant factors in these cases.

Conclusion

Blast injuries, and especially large joint defects from improvised explosive device blasts, are rare. Their treatment is complex and includes wound débridement; the reconstruction of soft tissue, bone stock, and ligaments; and, if possible, the restoration of joint function. Because of the resulting instability, stiffness, and post-traumatic osteoarthritis in elbow joints, arthroplasty and arthrodesis represent possible solutions. In the case presented here, we performed an arthroplasty with a cemented, custom-made, hinged, constrained elbow prosthesis. Because of osteoporosis after inactivity and the absent extensor mechanism of the elbow, we decided to connect the ulna and radius bones to the prosthesis by cemented stems in a neutral position with regard to pronation and supination to gain more stability. Although this case involves a unique indication for the
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implantation of an endoprosthesis and has a limited follow-up, we contend that a simple and constrained endoprosthesis is a viable alternative to amputation for victims of military or terrorist attacks with resultant large bone defects (e.g., at the elbow joint). Functional outcome may be limited, but in our opinion, with a well-functioning and sensate hand, it is still better than with a myoelectric exoprosthesis.

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References