International Orthopaedics (SICOT) (2012) 36:2501–2506
DOI 10.1007/s00264-012-1666-7

ORIGINAL PAPER

Radial head arthroplasty using a metatarsal osteochondral autograft

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Received: 23 August 2012 / Accepted: 12 September 2012 / Published online: 4 October 2012

Abstract

Purpose Treatment of comminuted fractures of the radial head is controversial, and considerable effort has been made to restore optimal function of the elbows, either by surgical reconstruction or prosthetic replacement. This report presents our experiences in treatment of unreconstructable radial head or neck fractures using osteochondral autografts harvested from the base of the second metatarsal bones.

Methods Five patients with radial head and one with a radial neck fracture underwent treatment with osteochondral autografts. After excision of the unreconstructable radial head, the second metatarsal base was harvested and transplanted to the radius using the intramedullary nailing technique.

Results The reconstructed elbows were examined clinically and radiographically for a mean period of 44.8 months (range, 24–72 months). At the last follow-up, in flexion-extension, the mean elbow mobility was 130°/10°. In supination-pronation, the mean elbow mobility was 73.3°/66.7°, with a mean loss of supination of 19.2° and loss of pronation of 12.5°. Grip strength was 91%, compared with the contralateral limb. The mean Mayo Elbow Performance Score was 94.2. The mean score of AOFAS rating system to the lesser toe was 93.7 points.

Conclusion Radial head arthroplasty with an osteochondral autograft from the second metatarsal base appears to be an effective alternative for treatment of unreconstructable radial head fractures. A larger group of patients and a longer follow-up period will be required in order to ease concerns regarding the donor site; however, none of the patients who underwent this procedure showed any complications during follow-up.

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Introduction

Treatment of comminuted fractures of the radial head or neck is controversial, and considerable effort has been made to restore optimal function of the elbows, either by surgical repair or prosthetic replacement [1]. A simple excision of the radial head has been recommended as a valid treatment. However, delayed complications, including elbow instability and proximal migration of the radius, have been reported in several clinical studies, particularly in cases with associated interosseous membrane disruption or a medial collateral ligament injury [2, 3]. A number of different substitutes for replacement of the radial head have been introduced. Although there has been some interest in the use of radial head allografts, potential adverse effects, such as collapse during the revascularization period, fracture, nonunion, and disease transmission, make them less optimal [4, 5]. Currently, prosthetic replacement of the radial head is used widely. However, there are still concerns regarding potential long-term problems related to metal materials, including capitellar changes caused by erosion and osteoporosis, proximal radial migration, and late osteoarthritis [6–8]. As with the use of osteochondral autografts for reconstruction of other joints [9, 10], reconstruction of the radial head with a shaped osteochondral autograft would be a better physiological treatment modality.

This paper reports on our preliminary experience in treatment of unreconstructable radial head or neck fractures with osteochondral autografts using proximal 1.5–2.0 cm of the second metatarsal bones.

The institutional review board (IRB) approved this report on our clinical experience with the use of osteochondral autografts in treatment of unreconstructable radial head or neck fractures in six cases. All patients were informed that data regarding their clinical and radiological examinations would be submitted for publication.

Patients and methods

Between January 2000 and December 2008, approximately 540 cases of fractures around the elbow were treated surgically at our level 1 trauma center, and 42 cases of radial head or neck fractures were included. Among radial head or neck fractures, radial head excision was performed in two patients, and six patients underwent radial head arthroplasty using osteochondral autografts. Radial head replacement with a metal prosthesis was not performed during the above period.

The surgical indication of the osteochondral autograft was surgically unreconstructable radial head and neck fractures with small fragments, and, before surgery, all patients received thorough counseling regarding the proposed procedure, as well as an alternative procedure, arthroplasty with a metal prosthesis.

Table 1 lists the details of the patients' demographics. Patients consisted of three men and three women with a mean age of 36.8 years (range, 29–48 years) at surgery. The injury mechanism was a fall on the outstretched hand from a standing height in four cases and a fall from a greater height in two cases. The mean time interval between injury and surgery was 11.8 days (range, two–36 days).

Five patients had a radial head fracture (four cases of Mason type III; 1 case of type IV) and one had a radial neck fracture. Ipsilateral olecranon fracture was combined in one patient. Five radial head fractures had multiple small fragments and were unreconstructable. In the case of the radial neck fracture, the diagnosis was made after three weeks of trauma, and the remaining radial head was very short and bone resorption was present. No irradiation therapy or indomethacin was used to prevent heterotopic bone formation. The reconstructed elbows were examined radiographically every month for six months after surgery, and every three to six months thereafter. Active flexion and extension with the forearm in neutral rotation, and active supination and pronation with the elbow in 90º of flexion were measured for both elbows using a standard goniometer. Grip strength was tested using a Jamar Dynamometer (Asimov Engineering Corp, Santa Monica, CA) for both hands. The Mayo Elbow Performance Score for the elbows [11] and American Orthopaedic Foot and Ankle Society rating system [12] to the lesser toes were used to record elbow and foot function at the final follow-up visit.

Plain radiographs of the elbows were taken in order to determine the level of graft incorporation, loose body formation, or degeneration of the radio-capitellar joint, heterotopic ossification, bone resorption, and graft failure. Radiographs of the donors' feet in the standing position were also taken in order to determine whether articular derangement or arthritic changes in the tarsometatarsal joint had occurred.

Surgical technique

Surgical approach and excision of the radial head

All procedures were performed by the senior author (HKJ). Under general anesthesia, the patient was placed on the operating table in the lateral position and the surgical limb was placed in a tourniquet.

Skin incision, dissection and excision of radial head was performed as in the usual lateral approach technique, and the cuff of the proximal end of the radius was trimmed perpendicular to the axis of the radius using an oscillating saw. After measurement of the distance between the capitellum and the proximal end of the radius, the space was packed with a wet sponge and the tourniquet was deflated during the procedure in order to harvest the osteochondral autograft from the foot.

Graft harvest

The base of the second metatarsal bone of the non-dominant foot was selected as a substitute for the radial head, and the

Table 1 Demographic data

Case	Age, gender	Side	Mechanism of injury	Fracture type of radial head or neck	Time from injury to surgery (days)	Length of graft (mm)	Combined injuries	Follow-up (months), OP date
I	31, female	Right dominant	Fall from the fourth floor	Mason IV	36	18	Proximal humerus and ulnar fracture	72 (2003-11-11)
II	48, female	Right dominant	Fall to the ground	Nonunion of radial neck fracture	21	15		48 (2004-12-21)
III	39, male	Right dominant	Fall to the ground	Mason III	2	21	Medial collateral ligament rupture	53 (2006-10-18)
IV	37, male	Right dominant	Fall from the second floor	Mason III	5	19		39 (2007-07-01)
V	38, female	Left, non-dominant	Fall to the ground	Mason III	2	15		33 (2007-08-08)
VI	29, male	Left, non-dominant	Fall to the ground	Mason III	5	20		24 (2008-10-02)

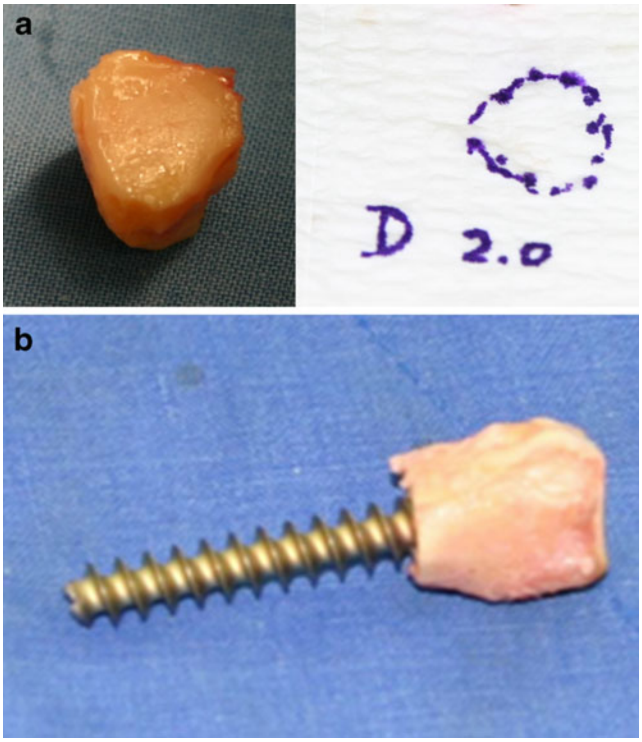

Fig. 1 a Harvested osteochondral block after trimming of the plantar corner. **b** Osteochondral block assembled with an inserted AO screw shank

articular surface of the proximal part was slightly concave and perpendicular to the shaft of the metatarsal bone.

After locating the base of the second metatarsal bone using a fluoroscope, a dorsal, longitudinal incision was made over the second metatarsal base and cuneiform bone. Branches of the superficial and deep peroneal nerves and dorsalis pedis artery were preserved, and the toe extensor tendons were retracted in order to expose the second metatarsocuneiform joint.

The second metatarso-cuneiform joint capsule was incised transversely. The medial and lateral border of the proximal part of the second metatarsal bone was isolated subperiosteally from the recess formed by three cuneiform bones using a beaver blade and a curved mini-osteotome. The measured length of the second metatarsal bone, including articular base, was harvested using an electrical saw. Because the articular surface of the second metatarsal bone is triangular in shape, the three corners should be trimmed in order to mimic the round radial head (Fig. 1a). The incised periosteum and skin were closed meticulously.

Graft incorporation

End-to-end apposition of the osteochondral autograft to the radius was achieved using the intramedullary nailing technique. A full thread AO screw (diameter, 3.5 mm cortical/4.0 mm cancellous; length, 35–45 mm) was used as the mini-rod after cutting off the head of the screw. Using a 2.5-mm drill bit and 3.5-mm taper, a threaded hole was made in the medullary canal of the osteochondral block. The prepared mini-rod was inserted into the osteochondral block and tightened with a grip device (Fig. 1b). The projected mini-rod of the osteochondral block was driven manually into the marrow cavity, and the elbow joint was moved in order to ascertain instability. An additional pinning would be useful for achievement of firm fixation. The split capsule and extensor muscles were closed tightly and the extent of passive elbow motion, stability, and articular correlation was checked under the fluoroscope.

Rehabilitation

Elbows were immobilized at 90º of flexion with the forearm in the neutral position using a dorsal block, and a long-arm fiberglass splint for a period of two weeks. Active finger, wrist, and shoulder motion was encouraged immediately after surgery. After two weeks, the splint was removed, and active and assisted passive motion exercise of the elbow was started, and patients were allowed to perform light activity, such as writing, using chop sticks, computer typing, or picking up newspapers. From six weeks, gradual strengthening exercises of the elbow and forearm were allowed, and the patients attempted to perform their activities of daily living. Sports activity as well as their previous occupational activity was permitted after six months.

Table 2 Postoperative clinical results

Case	Elbow motion (injured/opposite) (degree)				Grip strength (injured/opposite) (lb)	Mayo elbow performance score	American Orthopaedic Foot and Ankle Society rating system
	Extension	Flexion	Supination	Pronation			
1	10/0	130/140	75/85	65/75	65/76	100 (excellent)	97
2	0/0	125/125	80/90	65/80	52/20	95 (excellent)	97
3	15/0	135/145	90/90	70/80	88/96	95 (excellent)	97
4	5/5	130/140	80/90	60/75	95/112	100 (excellent)	87
5	10/0	140/145	70/85	70/85	63/83	80 (good)	97
6	20/0	120/135	45/80	70/80	92/98	95 (excellent)	87

Fig. 2 A plain radiograph showed spontaneous fusion of the donor site

Regarding the donor foot, patients were instructed to begin active ankle motion without weight-bearing for two weeks, and then partial weight-bearing in a short-leg walking brace. Full weight-bearing was allowed at four to six weeks.

Results

Elbow and donor foot

The mean follow-up period was 44.8 months (range, 24–72 months). At the last follow-up, in flexion-extension, the mean elbow mobility was 130°/10° (range, 120°–140° flexion; 0°–20° loss of extension). In supination-pronation, the mean elbow mobility was 73.3°/66.7° (range, 45°–90° supination; 60°–70° pronation), with a mean loss of supination of 19.2° and loss of pronation of 12.5°. Grip strength was 91 % compared with the contralateral limb. The mean Mayo Elbow Performance Score was 94.2 (range, 100–80), with one good and five excellent results.

At the time of the final follow-up, the usual walking patterns were normal in all patients and there was no tenderness over the dorsal and plantar aspects of the second metatarsal bone. Only one patient complained of slightly dull pain around the bone defect during running. The mean score of the American Orthopaedic Foot and Ankle Society rating system to the lesser toe was 93.7 points (range, 97–87) (Table 2).

Radiographic evaluation

In terms of the donor feet, plain radiographs demonstrated spontaneous fusion of the second tarso-metatarsal joint in two patients (Fig. 2). Four patients (cases I, IV, V and VI) revealed complete graft incorporation (Fig. 3); however, the other two patients (cases II and III) showed irregularity of the interface between the grafts and host radius, which suggested partial union with fibrous tissue (Fig. 4). Ectopic new bone formation around the osteochondral graft was recognized in one patient (case VI). Bony changes, such as graft resorption or secondary osteoarthritis, were not observed in any patient. The axis of the new radial head went straight toward the center of the capitellum in all cases. No abnormal findings, such as secondary osteoarthritic changes, joint subluxation, or deformity of the adjacent tarso-metatarsal joint, were observed (Fig. 5).

Discussion

Little information is available to provide a concensus for reasonable treatment of unreconstructable fractures of the radial head. Early or late excision of the radial head has been advocated [2, 3, 13, 14]. However, several complications, including valgus or posterolateral rotatory instability, proximal migration of the radius, and distal radioulnar and radiocarpal joint

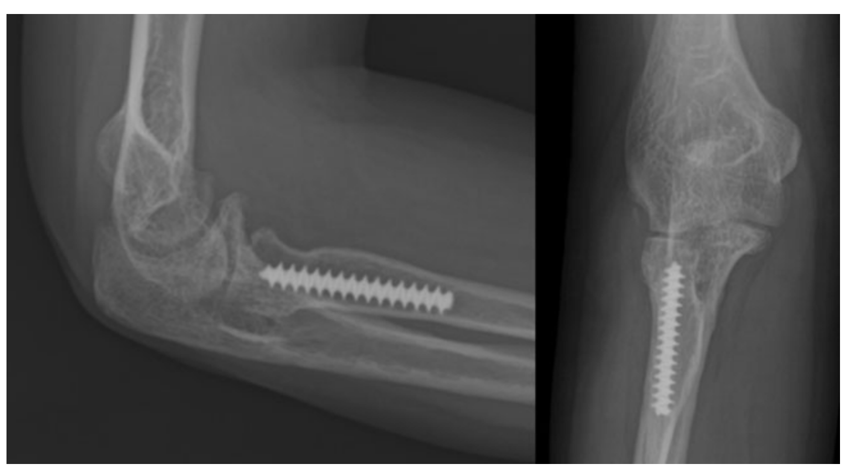

Fig. 3 Anteroposterior and lateral radiographs of the donor foot in the standing position (72 months after surgery). Defect at the second metatarsal base is present without new bone formation. No abnormal findings, such as articular derangement or arthritic change, were observed

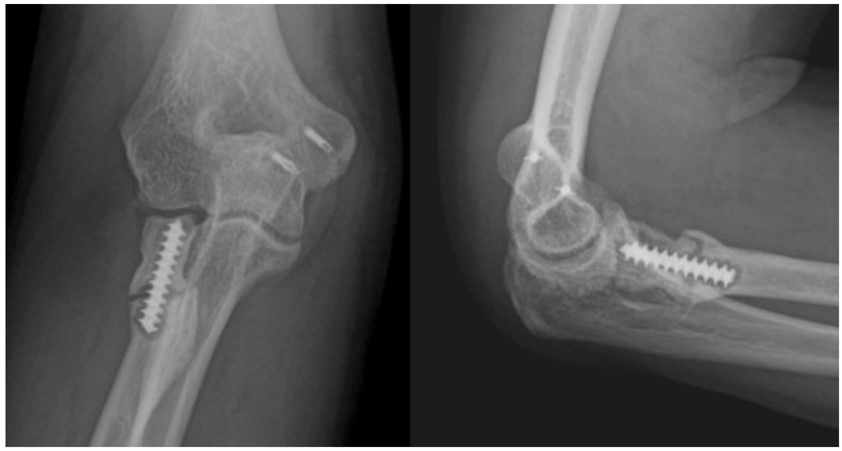

Fig. 4 Anteroposterior and lateral radiographs of the elbow of case III. Plain radiographs revealed fibrous union at the autograft-host junction with a hypertrophic callus and a radiolucent halo around the metal screw

problems have been proposed [15–17]. A recent study reported that radial head excision resulted in a change in elbow kinematics and an increase in varus-valgus laxity in specimens with intact ligaments, which were corrected after radial head arthroplasty [18]. Considering that the aim of treatment is to restore a stable elbow joint, radial head arthroplasty would be more desirable than radial head excision alone. However, radial head arthroplasty with a precise replication of the normal anatomy of the radial head is difficult to achieve [19–21], and complications, including loosening, wear, and capitellar erosion, have not yet been settled [6–8].

In this series, osteochondral autografts from the second metatarsal bone base were used for replacement of an unreconstructable radial head. There are several advantages in employing these substitutes. First, the autograft offers the key ingredients required for achievement of bone fusion, which include osteogenesis, osteoclastic resorption, osteoinduction, and osteoconduction. Some authors have used a fresh osteochondral allograft [10]. However, in contrast to an autograft, the function of the allograft was as a scaffold for maintenance of the osteoconductive property alone. This drawback may contribute to less than optimal results, including partial resorption and subchondral collapse in clinical application of the allograft for radial head fractures [4, 5]. Furthermore, frozen osteochondral allografts are stored at −70 °C to −80 °C in order to decrease or eliminate immunogenicity, which inevitably results in impaired viability of the transplanted cartilage [22]. Second, an osteochondral block harvested from the second metatarsal bone provides a smaller dimension than the original radial head. After excision of the radial head, the restraining action and tensile stress of the annular ligament, capsule, and extensor tendon origin could not be maintained, and loosening of these structures may result in anterior subluxation during flexion and pronation, as well as posterolateral rotator instability during supination; therefore, repair of the split capsule and common origin of extensor tendons in appropriate tension are essential in radial head arthroplasty. The osteochondral autograft in the present study occupied less space in the elbow joint, and, consequently, tighter repair of the capsule and common origin of extensor tendons was possible.

Another important point to consider is that in some countries, a metal prosthesis is not available, or the country's health insurance does not cover commercial use of metal prostheses. In those cases, this osteochondral autograft could

Fig. 5 Anteroposterior and lateral radiographs of the donor foot in the standing position (72 months after surgery). Defect at the second metatarsal base is present without new bone formation. No abnormal findings, such as articular derangement or arthritic change, were observed

be an economical and useful substitute for treatment of unreconstructable radial head fractures.

In contrast to a metallic prosthesis, the radiocapitellar joint space was preserved, and osteopenia of the capitellum [8] was not observed in the author's case. Articular contact between capitellum and osteochondral autograft is extremely physiological, and this better durability might be another advantage of the osteochondral autograft in a radial head replacement.

However, because of the possibility of late failure of graft-host incorporation, the fact that fibrous union was noted in two cases is a concern. In order to improve the results of osteochondral graft for radial head reconstruction, in future surgery, preparation of a longer intramedullary screw stem, injection of medical cement into the proximal radial medulla, and additional pinning and bone graft of the donor metatarsal defect should be seriously considered.

Regarding the donor site, the Lisfranc ligament injury was made iatrogenicaly. In real traumatic situations, a disruption of the Lisfranc ligament is often associated with injuries to the adjacent capsuloligamentous structures, which can lead to surrounding tarsometatarsal instability and significant loss of foot function [23]. However, the precise detrimental consequence of subtle isolated Lisfranc ligament injury is unclear. In addition, ligaments unrelated to clinical Lisfranc injuries, as well as Lisfranc ligament complex, should be dissected for reproduction of a measurable displacement in the tarsometatarsal joint [24]. As shown in the results for foot function, no tarsometatarsal joint disruptions were found in this case series, and spontaneous fusion of the donor sites occurred in two cases. While its precise cause is unclear, it may be evidence of less harmful injury to the adjacent tarsometatarsal joint during harvest. However, long term follow-up will be necessary to ensure the safety of this surgical procedure. A larger group of patients and a longer follow-up period will be required in order to ease concerns regarding the donor site; however, none of the patients who underwent this procedure showed any complications during the follow-up period.

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