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Results of the Use of Bioabsorbable Magnesium Screws for Surgical Treatment of Mason Type II Radial Head Fractures

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Background: In Mason classification type II radial head fractures, compared to plate fixation, fixation with cannulated headless screws and absorbable pins has been reported to provide more favorable postoperative outcomes, including less postoperative limitation in range of motion. The fact that radial head fractures are less prone to weight-bearing during fracture union further supports the use of absorbable screws as a suitable alternative treatment option in radial head fractures. This study aimed to perform fixation through open reduction using bioabsorbable magnesium screws for Mason type II radial head fractures and to report radiographic and clinical results.

Methods: Among patients who visited the orthopedic department from April 2017 to August 2021, 22 with surgical indications were selected for participation. Radiographic tests were conducted at 2 weeks, 4 weeks, 8 weeks, 12 weeks, 6 months, and over 1 year after surgery to confirm the degree of bone union, reduction loss, and degree of H_2 gas production. The Disabilities of the Arm, Shoulder and Hand (DASH) score, Mayo Elbow Performance Score (MEPS), hand grip power, and range of joint motion were measured at the 6-month follow-up to evaluate the clinical efficacy of the operation.

Results: Bone union was confirmed in all 22 cases, and the mean time to union was 10.2 weeks. DASH score was 22.27 on average and no patients complained of significant discomfort after the surgery. The mean MEPS was 91.1. The hand grip power of the affected hand was similar to that of the unaffected hand, being 1.19% weaker on average. These differences reached statistical significance ($p = 0.002$). The range of elbow joint motion was measured: mean flexion, 146.1°; mean extension, 1.4°; mean pronation, 88.2°; and mean supination, 87.9°.

Conclusions: In treating Mason type II radial head fractures, the use of bioabsorbable screws made of magnesium showed satisfactory results in radiographic and clinical evaluations. Magnesium bioabsorbable screws can maintain sufficient stability at the fracture site and have the advantage of avoiding secondary operation for the removal of internal fixation devices.

Keywords: *Elbow, Radial head fracture, Mason type II, Bioabsorbable screw, Magnesium screw*

As the radial head and capitellum form the elbow joint surface, radial head fractures are considered intra-articular fractures.[1] According to the Mason classification, nonsurgical treatment of type II radial head fractures yields positive results. However, cases of mechanical block to forearm rotation or displacement greater than 2 mm warrant surgical treatment.[2] For Mason type II radial head fractures, several effective and safe surgical treatment options are available. These options aim to restore the stability and function of the elbow joint. The surgery is generally performed as an open reduction followed by internal fixation using Kirschner wires (K-wires), screws, plates, headless

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screws, absorbable pins, and absorbable screws. Treatment of Mason type II may cause discomfort, such as postoperative movement limitations, and positive results have been reported using cannulated headless screws and absorbable pins rather than metal plate fixation, which may require secondary surgery for metal removal.[3,4] The fact that radial head fractures are less prone to weight-bearing during fracture union further supports the use of absorbable pins or screws as a suitable alternative treatment option in radial head fractures.

The type and ratio of alloying elements used in magnesium alloys can affect the degradation rate and implant performance. Some elements can slow down the degradation rate or enhance the strength and mechanical performance of the implant, while others can accelerate the degradation rate or weaken the implant's performance.[5,6] As the bioabsorbable magnesium screws degrade, tissue remodeling processes take place. During this process, the degradation by-products of the implant can induce degenerative changes in the tissues or alter the tissue structure.[7] The fast degradation of magnesium-based alloys within the body can decrease the durability and stability of the implant. This can impair the function of the implant or lead to early failure of the implant.[8]

Biodegradable magnesium screws have the characteristic of being gradually absorbed by the body over time. This provides the advantage of a more natural integration with the surrounding tissues and supports the healing process.[9] Biodegradable magnesium screws have excellent biocompatibility, making it safe for use within the human body. This minimizes side effects such as allergic reactions and cellular toxicity.[10,11] Additionally, no additional surgical procedures are required for implant removal, minimizing long-term complications.[11]

The radial head is surrounded by the round ligament and has a non-weight-bearing joint structure. Therefore, it is thought that the fixation required to maintain the position after the reduction of a radial head fracture does not need to be particularly strong. Absorbable pins have weaker fixation strength, and although absorbable screws are weaker than metal screws, this study was planned on the assumption that absorbable screws can provide sufficient fixation without displacement after reduction in Mason type 2 radial head fractures.

METHODS

This study was conducted after deliberation and approval by the Institutional Review Board of Daejeon Sun Hospital (No. DSH-In-22-05) and obtaining consent from the patients for the use of bioabsorbable screws before the surgery.

Patients Selection Method

This retrospective study included 22 patients with radial head fractures who visited our institution's orthopedic department from April 2017 to August 2021. These patients had a displacement of 2 mm or more, angulation in Mason type 2 fractures, or a mechanical block to forearm rotation, and underwent surgery using bioabsorbable magnesium screws (Resomet: U&I Corp., Seoul, Korea) with a follow-up period of at least 1 year. Patients who underwent concurrent surgery on other fracture sites, such as the olecranon and coronoid process, were excluded due to comorbid injuries. Those with a history of fractures and surgery in the same upper extremity were also excluded from the study.

Surgical Technique

One surgeon (CHL) performed all of the surgeries with the patients placed in a supine position under an axillary nerve block. A tourniquet was applied to the upper arm, followed by sterile painting and draping. After fixing the elbow in the flexion position, a medial to downward curved longitudinal incision of approximately 6 cm was made, beginning at the lateral humeral epicondyle, using a Kaplan (lateral) approach. Upon the longitudinal incision of subcutaneous tissue and fascia, the radiohumeral joint capsule was exposed by retracting the extensor carpi ulnaris upward and the anconeus muscle downward. The radial head was exposed after the incision of the annular ligament.

The fracture pattern of the radial head was identified by supination and pronation of the forearm, and a curette was used for the reduction of the impacted fragment. It was fixed using reposition forceps as needed, and temporary fixation was performed using a 1.2-mm K-wire. The depth was measured using a depth gauge along the guide K-wire. A drill guide was placed, and drilling was performed to the measured length using a 2.7-mm drill bit. A tapper was used for tapping while maintaining the drill guide. One or two 2.7-mm absorbable screws were then inserted along the guide K-wire (Fig. 1). Each screw was inserted along the tapped thread slowly to prevent the screw head from breaking. Then, the guide K-wire was removed and the absorbable K-wire was inserted and cut to an appropriate length using a cutter (Fig. 2). An absorbable K-wire was inserted to reinforce the cannulated screw. Copious irrigation was performed, the annular ligament was closed using 2-0 Vicryl sutures, and layered suturing

was performed. Long-arm splints were applied with the elbow flexed at 90° after surgery. Splints were removed from the second week after the surgery, and range of motion exercises were performed in conjunction with wearing an elbow brace.

Measurement of Radiographic and Clinical Outcomes

Radiographic tests were performed at 2 weeks, 4 weeks, 8 weeks, 12 weeks, 6 months, and over 1 year to observe the union of the fractures and degree of biodegradation of the magnesium alloy. Plain radiographs in the anteroposterior, lateral, and bilateral oblique views were taken, and computed tomography was performed additionally when necessary. The timing of the union was evaluated using the radiographs. Fracture union was defined as the disappearance of fracture lines and osseointegration of trabeculae.[3] The presence of broken bioabsorbable screws, displacement, refracture, and nonunion was identified during follow-up observations. Secondary displacement resulting from reduction loss was measured by comparing oblique and lateral views of the fractured elbow to those of the non-fractured elbow to determine if the displacement occurred after the surgery. The timing of H_2 gas formation resulting from the biodegradation of magnesium alloys and absorption was evaluated using radiographs. The period when gas formation appeared the darkest on radiographs was identified as the period when the gas formation was at its peak, and the presence of any clinical symptoms during this period was investigated.

The Disabilities of the Arm, Shoulder, and Hand (DASH) score, Mayo Elbow Performance Score (MEPS), range of joint motion (flexion-extension and pronation-supination), and hand grip power were measured at the 6-month postoperative follow-up for the analysis of clinical outcome. The hand grip power of both hands was measured simultaneously using the same method, and the degree of power reduction on the affected side compared with that on the unaffected side was assessed as a percentage. The grip power was measured using the Jamar Hydraulic Hand Dynamometer (5030J1). During the measurement, the participants assumed an upright posture with the shoulder joint flexed at a 90° angle and the elbow joint extended at 0°. Grip strength was assessed using a four-finger grip. In addition, joint contractures, tendon ruptures and adhesions, osteolysis, and adverse effects of infection were identified.

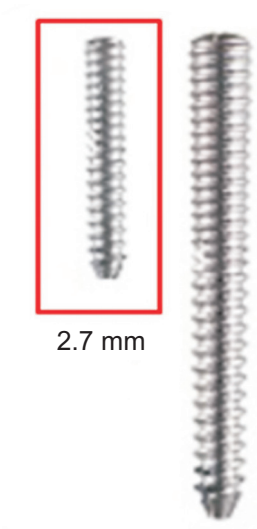

Fig. 1. Bioabsorbable magnesium implants are 2.7-mm headless screws (Resomet; U&I Corp., Seoul, Korea).

Statistical Analysis

All data were expressed as mean. Statistical analysis was done using the SAS ver. 9.4 for Windows (SAS Inc., Cary, NC, USA). Clinical and radiological outcomes were compared preoperatively and postoperatively using a Wilcoxon

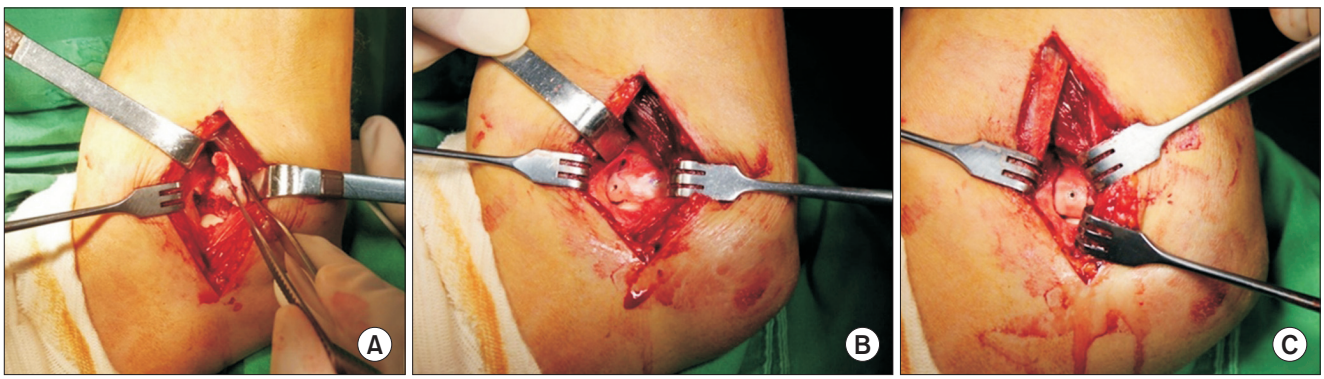

Fig. 2. Intraoperative views of the bone fragments of the radial head. (A) Before reduction. (B) Fixation using two bioabsorbable pins. (C) After reduction.

signed-rank test. A p-value < 0.05 was considered statistically significant.

RESULTS

Overall, 22 patients (10 men and 12 women) with a mean age of 52.3 years (range, 22–69 years) were included. The right elbow was fractured in all 22 patients. The mean outpatient follow-up period was 18.9 months (range, 12–38 months). The cause of fracture was slip downs in 13 cases, fall downs in 7, and bicycle accidents in 2 (Table 1).

Radiographic analysis showed that bone union was achieved in all cases, and no joint incongruency was found. The mean time to bone union was 10.2 weeks (range, 8–16 weeks). A secondary displacement of 1.7 mm was identified on postoperative imaging in 1 case. However, conservative treatment was possible because the patient did not report any clinical symptoms, and bone union was confirmed during the examination at 4 months after the operation (Fig. 3). Gas cavities formed due to H_2 gas formation first appeared at an average of 2 weeks after the surgery, peaked at an average of 8.6 weeks (range, 8–12 weeks), and gradually absorbed and disappeared. Four patients complained of pain and discomfort that may have appeared due to the formation of gas cavities. It was confirmed that the symptoms of pain and discomfort disappeared at the 1-year follow-up after surgery (Fig. 4). Some bioabsorbable magnesium screws can produce gas

Table 1. Data Regarding Patient Demographics

Patient No.	Sex	Age (yr)	Injured side	Dominant side	Follow-up period (mo)	Injury mechanism	No. of absorbable screws
1	M	22	Lt	Rt	12	Fall down	1
2	M	59	Lt	Rt	12	Slip down	1
3	F	53	Rt	Rt	12	Slip down	1
4	F	68	Lt	Rt	16	Slip down	1
5	M	23	Lt	Rt	17	Slip down	1
6	M	67	Lt	Rt	22	Slip down	1
7	F	61	Rt	Rt	12	Fall down	1
8	F	54	Lt	Rt	24	Slip down	1
9	M	48	Lt	Rt	24	Fall down	1
10	F	57	Rt	Rt	12	Slip down	1
11	F	48	Lt	Rt	17	Slip down	1
12	M	37	Lt	Rt	12	Bicycle accident	2
13	F	61	Lt	Rt	34	Slip down	1
14	F	55	Rt	Rt	35	Fall down	2
15	F	54	Lt	Rt	37	Slip down	1
16	F	69	Rt	Rt	38	Slip down	1
17	M	50	Rt	Rt	12	Slip down	1
18	M	59	Rt	Rt	12	Bicycle accident	1
19	M	51	Rt	Rt	12	Fall down	1
20	F	64	Lt	Rt	19	Fall down	2
21	F	50	Lt	Rt	12	Slip down	2
22	M	40	Lt	Rt	12	Fall down	1

Lt: left, Rt: right.

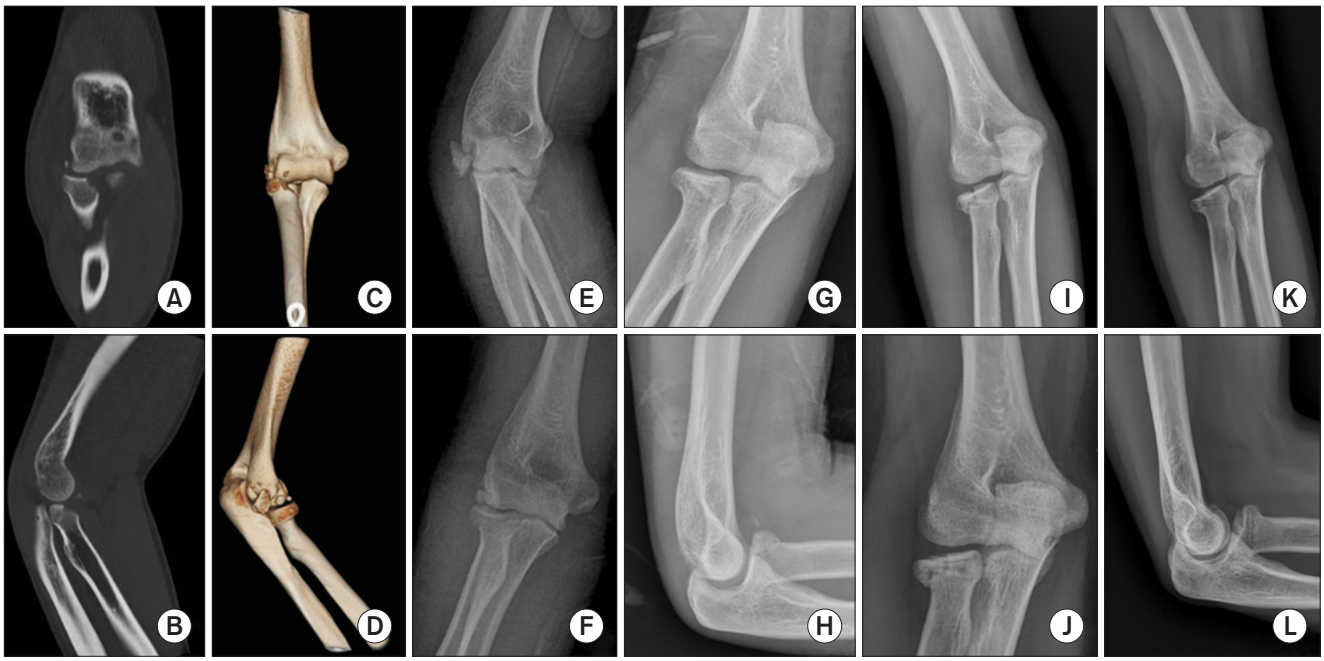

Fig. 3. A 22-year-old male patient, with computed tomography images (A–D) and radiographs showing a Mason type II fracture (E, F). (G, H) Radiographs on the day of surgery. (I, J) Radiographs at 1 week after surgery showing a 1.7-mm secondary displacement. (K, L) Radiographs at 4 months after surgery showing bone union.

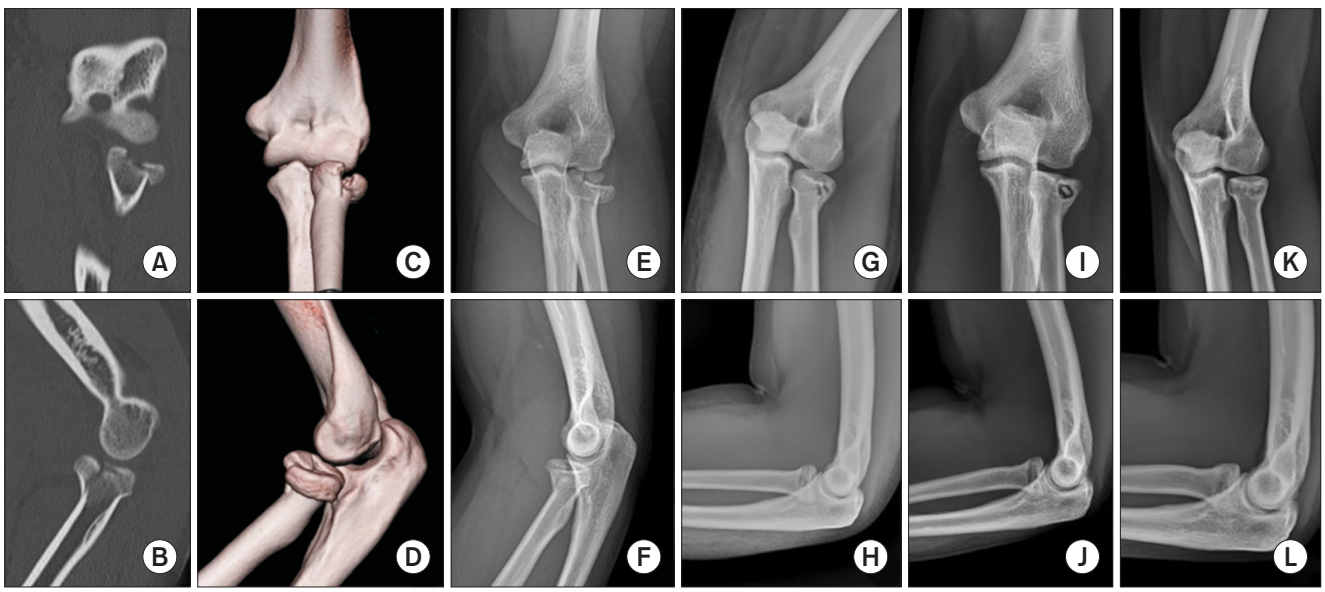

Fig. 4. A 23-year-old male patient, with computed tomography images (A-D) and radiographs showing a Mason type II fracture (E, F). (G, H) Radiographs at 1 week after surgery. (I, J) After 8 weeks, gas formation was at its peak. (K, L) After 1 year, the gas disappeared and was replaced with bone.

while breaking down. This gas can create cavities within tissues, and the formation and expansion of these cavities can apply pressure on surrounding tissues, causing pain. The patient reported experiencing pain at the outpatient clinic when the X-ray showed the maximum amount of gas present after surgery.

The clinical analysis results showed that the mean DASH score was 22.27 (range, 22.5–39.1). No patients complained of major discomfort after the surgery. The hand grip power evaluation confirmed that the hand's

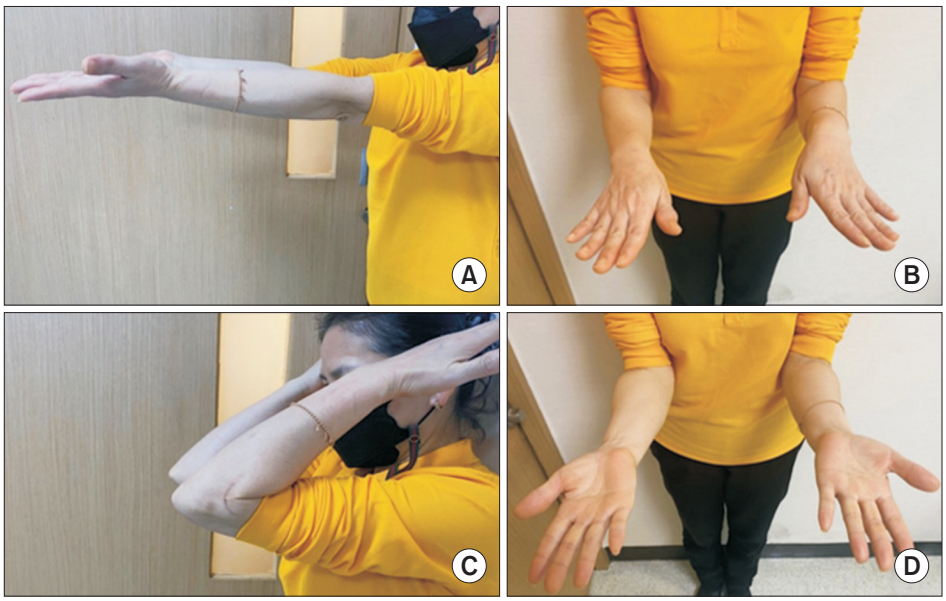

Fig. 5. Functional status of a 55-year-old woman at 1 year after surgery. Elbow range of motion: extension (A), flexion 0°–150° (B), pronation (C), and supination 90°–90° (D).

Table 2. Detailed Case Data Regarding Clinical Results

Patient no.	Union weeks	Peak gas formation (wk)	DASH score	MEPS score	Grip power (Rt/Lt; kg/mm^2)	Hand grip power (%)	Extension/ flexion (°)	Pronation/ supination (°)	Complication
1	8	8	31/20	85	40/40	0	0/145	90/90	1.7-mm secondary displacement
2	8	8	32/14	85	62/54	–13	0/150	90/90	Pain
3	8	8	30/12	100	33/35	–6	0/145	80/80	
4	12	10	32/9	100	22/22	0	0/135	85/90	
5	8	8	30/10	85	42/42	0	0/150	85/90	Pain
6	12	12	40/10	100	38/36	–6	0/150	90/85	
7	11	9	32/9	100	38/36	6	0/150	80/90	
8	12	8	39/9	85	20/14	–30	0/140	90/90	
9	12	8	33/12	85	48/40	–17	0/145	85/85	
10	12	8	48/14	85	26/24	8	0/150	90/90	
11	9	8	30/10	85	24/24	0	0/150	90/90	
12	12	9	34/11	85	42/42	0	0/145	85/85	Pain
13	12	8	30/8	100	26/24	–8	0/140	85/85	
14	9	9	32/10	100	32/30	7	0/150	90/90	
15	8	8	30/8	100	26/24	8	0/150	90/90	
16	8	8	28/8	85	20/20	0	0/145	90/90	Pain
17	8	8	30/12	100	36/30	17	0/150	90/90	
18	12	8	32/10	70	36/32	12	30/150	85/85	Extension limitation (30°)
19	12	8	36/12	100	34/36	–6	0/145	85/90	

Table 2. Continued

Patient No.	Union weeks	Peak gas formation (wk)	DASH score	MEPS score	Grip power (Rt/Lt; kg/mm^2)	Hand grip power (%)	Extension/ flexion (°)	Pronation/ supination (°)	Complication
20	16	12	40/14	100	27/27	0	0/150	90/85	
21	8	8	44/18	70	29/27	–7	0/140	85/85	
22	8	8	30/8	100	34/32	–7	0/140	90/90	
Average	10.2	8.6	33.8/11.3	91.1	33.4/31.4	–1.19	1.4/146.1	88.2/87.9	

DASH: Disabilities of the Arm, Shoulder and Hand, MEPS: Mayo Elbow Performance Score, Rt: right, Lt: left.

gripping power on the affected extremity was 1.19% weaker on average compared with that on the unaffected side. This difference reached statistical significance ($p = 0.002$). There were 3 cases where the decrease was more than 10%. The mean MEPS was 91.1 (range, 70–100). The range of joint motion (flexion-extension and pronation-supination) was measured: mean flexion was 146.1° (range, 135°–150°) mean extension was 1.4° (range, 0°–30°), mean pronation was 88.2° (range, 80°–90°), and mean supination was 87.9° (range, 80°–90°) (Fig. 5). There was 1 case of extension limitation (30°) in the main joint after surgery. In addition, no patients showed side effects such as tendon rupture, osteolysis, or infection that could have resulted from magnesium alloy use (Table 2).

DISCUSSION

There is no single established treatment method for Mason type II radial head fractures. For open reduction and internal fixation, K-wires, screws, plates, headless screws, absorbable pins, and absorbent screws are commonly used.[3] If internal fixation requires the insertion of a screw or a plate on articular surfaces, the head of the screw must be recessed in the cartilage. In the case of protrusion of a guidewire or screw into the joint space during internal fixation, a secondary operation for hardware removal is required due to complications, such as discomfort caused by the metal used for the internal fixation, tendon adhesions and ruptures, muscular atrophy, and osteoporosis, which outweigh the advantage of firm internal fixation.[9,12,13] Additionally, metal screws cause side effects, such as stress shielding and pain persistence.[14] This study investigated the radiological and clinical outcomes of using bioabsorbable magnesium screws in the surgical treatment of Mason type II radial head fractures. Although absorbable screws are weaker than metal screws, they provided sufficient fixation after reduction in Mason type II radial head fractures. Furthermore, there were no occurrences of side effects such as infection or nonunion.

To compensate for the shortcomings of these internal fixation methods, operations have been performed using bioabsorbable pins and screws made of polylactic acid (PLA) and polyglycolic acid (PGA). However, the mechanical strength of these screws is weaker than that of metal screws; the bioabsorbable screws easily break up when inserted, and the fixed bones may refracture due to the rapid loss of strength before union if the absorption rate is too fast.[5,6] Pelto et al.[6] reported that a local inflammatory response occurred in 2 of 24 cases using PGA pins. Tarallo et al.[15] reported persistent postoperative pain in 15.8% of cases and secondary displacement greater than 1 mm in 8.5% of cases using PLA pins. Furthermore, infection through the pin-insertion path is possible, and an inflammatory reaction may occur. Kim and Kim[16] reported that PLA pins produce hydrogen gas *in vivo*, which turns acidic and affects surrounding tissues.

Bioabsorbable magnesium screws have been developed and used to remedy the shortcomings of these bioabsorbable polymer fixtures. Bioabsorbable magnesium screws have been reported to be non-reactive, degrade *in vivo*, have higher rigidity than bioabsorbable polymer fixtures, and enhance bone formation.[10,11] The bioabsorbable magnesium screws used in this study did not damage soft tissues, overcoming the aforementioned shortcomings of pin and plate fixation. It also has the advantage in that metal removal is not required at all. A bioabsorbable magnesium screw is absorbed if it is damaged before bone union or if there is no symptom or severe deformation and surgery is not required. Therefore, conservative treatment is possible without worrying about a foreign body that may cause side effects later.

Tarallo et al.[15] reported a mean MEPS of 97.3, mean pronation of 73.1°, mean supination of 82.3°, mean extension of 5.5°, and mean flexion of 138.2° after surgery using PLA pins. Givissis et al.[17] reported fracture healing outcomes of using PLA pins as follows: no radiological

signs of postoperative osteolysis, no substance-related adverse events, a mean MEPS of 93.8 (range, 20–100), mean pronation of 79°, mean supination of 77°, mean extension of 9°, and mean flexion of 132°. In the current study, the mean MEPS was 91.1 (range, 70–100), and the range of elbow joint motion was measured as follows: mean flexion of 146.1° (range, 135°–150°), mean extension of 1.4° (range, 0°–30°), mean pronation of 88.2° (range, 80°–90°), and mean supination of 87.9° (range, 80°–90°).

In previous studies, the disadvantage of magnesium screws was that the rapid degradation of magnesium could compromise durability and stability.[5,6,8] Additionally, corrosion products formed when magnesium alloys broke down, potentially causing toxicity in surrounding tissues.[7] There are some concerns regarding the use of bioabsorbable magnesium screws such as whether it is possible to have sufficient stability in reducing fractures, whether the screw is biodegradable before bone union and does not cause reduction loss or refracture, and how harmless the use of bioabsorbable alloys is to the human body. Local infection, bone loss, and fistula formation may occur due to inflammatory foreign body reactions to bioabsorbable magnesium screws, although there were no such complications at the 1-year follow-up in the current study. The mean time to bone union was determined to be 10.2 weeks in this study. In all but one case, bone union was confirmed during the 12-week follow-up examination; delayed union was noted in a 64-year-old female patient who did not complain of discomforts such as pain at the surgical site or extension limitation during the 4-month examination, and bone union was confirmed to be completed according to the results of the radiographic examination.

The limitation of this study is that it is a retrospective study rather than a prospective one, with a relatively small patient population and no control groups. However, the fact that the operations were performed by the same orthopedic surgeon at a single institution can be considered a strength. To overcome this limitation, future comparative studies with surgical results using metal screws or plates will be necessary.

Using bioabsorbable screws made of magnesium alloy in treating Mason type II radial head fractures showed satisfactory results in radiographic and clinical evaluations. Bioabsorbable magnesium screws have sufficient fixation force at the fracture site.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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