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Which is the Best Solution for Achieving Maximal Interfragmentary Compression of the Scaphoid Fractures – One or Two Herbert Screws?

Nejlepší řešení pro dosažení maximální komprese fragmentů u zlomenin skafoidea – jeden nebo dva Herbertovy šrouby?

L. SIMEONOV

Division of Hand and Microsurgery, University Hospital of Emergency Medicine, Sofia, Bulgaria

ABSTRACT

PURPOSE OF THE STUDY

To compare the treatment outcome of scaphoid facture fixation with one versus two Herbert screws (HBS).

MATERIAL AND METHODS

72 patients underwent open reduction internal fixation (ORIF) following acute scaphoid fracture, and were followed prospectively by one surgeon. All fractures were Herbert & Fisher classification type B, the most common fracture lines being oblique (n=38) and transverse (n=34). Fractures with similar fracture lines were randomly assigned into two groups; fractures stabilized with one HBS (n=42) and fractures stabilized with two HBS (n=30). A specific methodology was developed for placement of two HBS; in the case of transverse fractures, screws were introduced perpendicular to the fracture line, for oblique fractures the first screw was placed perpendicular to the fracture line and the second screw was placed along the longitudinal axis of the scaphoid.

RESULTS

Patients were followed for a total 24 months, no patients were lost to follow-up. Outcome measures included bone healing, duration to bone healing, carpal geometry, range of motion (ROM), grip strength, and the Mayo Wrist Score. Patient rated outcomes were measured using DASH. Bone healing was radiographically and clinically confirmed in 70 patients. There were two non-unions after fixation with one HBS. Radiographic angles in both groups did not differ significantly from the physiological values. The mean duration to bone union was 1.8 months for one HBS and 1.5 months for two HBS. Mean grip strength was 47 kg in the group with one HBS (16-70 kg), 94 % of the unaffected hand, and 49 kg in the group with two HBS, 97% unaffected hand. The average Visual Analog Scale (VAS) score for the group with one HBS was 2.5, while for the group with two HBS was 2.0. Both groups had excellent and good results. For the group with two HBS, they are more. (100% for those fixed with two HBS and for those fixed with one HBS = 95% excellent and good and 5% bad results).

DISCUSSION

A review of the literature confirms that the addition of the second screw increases the stability in the scaphoid fractures by offering added resistance to torque forces. Most authors propose the parallel placing of both screws in all cases. In our study we offer an algorithm for the placement of screws depending of the type of fracture line. For transverse fractures screws are placed parallel and perpendicular to the fracture line, for oblique fractures the first screw is placed perpendicular to the fracture line, and the second screw is placed along the longitudinal axis of the scaphoid. This algorithm covers the main laboratory requirements for maximal fracture compression depending of the fracture line.

CONCLUSIONS

This study of 72 patients in whom patients with similar fracture geometry were separated into two groups fixed by one HBS and fixed by two HBS. Analysis of the results demonstrate that osteosynthesis with two HBS creates greater fracture stability. The proposed algorithm for fixation of acute scaphoid fractures using two HBS is achieved by simultaneously placing the screw along the axial axis and perpendicular to the fracture line. The stability is improved by the equal distribution of the compression force on the entire fracture surface.

Key words: scaphoid fractures, Herbert screw, two screws fixation.

INTRODUCTION

The scaphoid fracture is the most common fracture of the carpal bones (7). Usually the patients are male and physically active (between 25 and 40 years) (6). Most of the diagnostic and therapeutic problems related to the scaphoid have been solved. The contemporary treatment of acute scaphoid fractures is successful (2, 12, 18, 20. The gold standard for scaphoid fracture fixation is the use of a single headless compressive screw. There are, however, areas for improvement. Lack of sufficient compression is one of the reasons for the reported 10% of postoperative non-unions (18). According to laboratory studies, maximal interfragmentary compression can be accomplished with screw placement along the central axis of the bone and perpendicular to the fracture line (4, 9).

Simultaneously achieving both requirements are not always possible. Our hypothesis is that the placement of two Herbert screws (HBS) can cover the requirements. For oblique fractures, the first screw will be placed perpendicular to the fracture line, the second will be placed along the central bone axis. For transverse fractures both screws will be placed perpendicular to the fracture and parallel to each other. From a technical perspective, this can be achieved with second generation HBS.

The purpose of this study is to compare the treatment outcome for one versus two HBS fixation of scaphoid fractures.

MATERIAL AND METHODS

Over a period of 4 years (2016–2020) 72 patients with acute scaphoid fracture were operated and prospectively followed by one surgeon. Patients with similar fracture geometry were separated into two groups fixed by one HBS (n=42) and fixed by two HBS (n=30). There were 61 men and 11 women, the right wrist was affected in 43 patients and 29 had left hand involvement. Patient age range was between 19 and 47 years (average = 31.5 years). 39 fractures were a result of high-energy trauma. The mechanism of fracture is shown in Table 1.

All fractures were type B according to Herbert & Fisher classification (8). The fracture location according the anatomic zones of the scaphoid bone is shown on the Table 2. The following types of fracture line were reported: transverse, oblique, reverse-oblique. Their distribution is shown in Table 3. The fracture diagnosis was made by routine and special X-ray projections. CT scan was performed in 11 patients with long spiral fracture line.

The indication for operative treatment was:
1. Unstable fractures
2. Proximal pole fractures.

Table 1. Patient distribution according to the mechanism of trauma

Mechanism	1 HBS	2 HBS
Fall from own height	22	9
Transport accidents	8	10
Fall from high	6	7
Sports injuries	6	4

Table 2. Fracture distribution according location

Fracture location	I HBS	2 HBS
Proximal pole	10	5
Waist	22	20
Distal pole	10	5

Table 3. Fracture distribution according type of fracture line

Type of fracture line	1 HBS	2 HBS
Transverse	22	12
Oblique	17	16
Reverse oblique	3	2

Table 4. Patient distribution according to time between accident and day of surgery

Time between fracture accident and surgery	1–5 days	5–10 days	10–28 days
Patients	44	21	7

Table 5. Average level of active range of wrist motion

Range of motion	1 HBS	2 HBS
Average flexion	75°	80°
Average extension	50°	45°
Radial deviation	18°	18°
Ulnar deviation	35°	32°

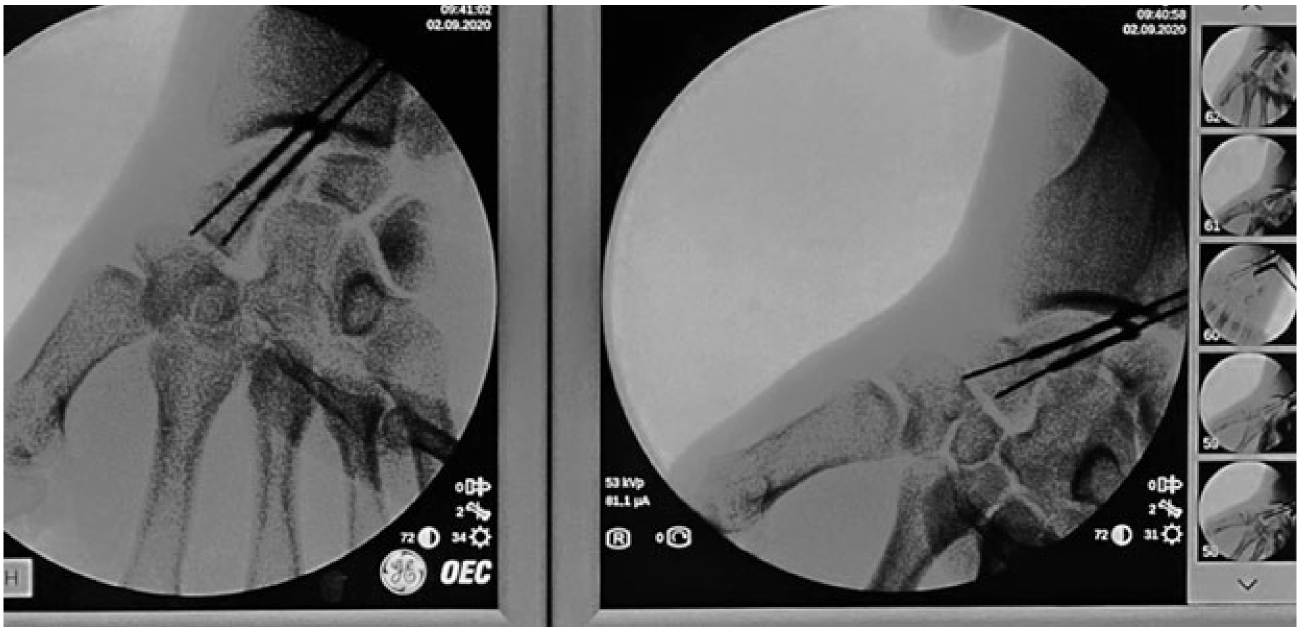


Fig. 1. Both screws were placed into the level of fracture following the K-wires.

All fractures were operated within 28 days of injury (Table 4). The main surgical procedure was ORIF. Regional anesthesia and temporary exsanguination of the forearm were performed. Routine dorsal and volar approaches were used. The dorsal approach through the third extensor compartment was used for fractures of the proximal pole and nondisplaced waist fractures. The volar Russe approach was used for fractures of the distal pole and displaced waist fractures. The operative procedure achieved fracture reduction, temporary K-wire fixation, and one or two HBS placement. 42 fractures had one screw placement and 30 had two screws. This was a key criterion by which the patients were grouped and followed. The average operating time in the group treated with one screw was 45 minutes and 70 minutes for the group with two screws. During the 2-screw fixation technique two K-wires were introduced consecutively, followed by the placement of the screws. Both screws were placed into the level of fracture (Fig. 1). The tightening of the screws were achieved gradually, with the two screws alternating until a subjective compression sensation was obtained. This avoids the well-known “piston effect” when placing the second screw. For fractures with transverse fracture line K wires and screws were introduced perpendicular to the fracture plane and parallel each to other (Fig. 2). For the oblique fractures the first screw was introduced perpendicular to the fracture line and the second one along the central axis of the bone (Fig. 3). The final position of the screws was confirmed by fluoroscopy.

Postoperative management

Postoperatively, the wrist was immobilized in a short cast for two weeks. Pain, edema control, and active motion of fingers began after third postoperative day. Active wrist mobilization began between the second and third weeks.

Follow-up was conducted at the end of the 1st, 3th and 6th months after surgery. Clinical bone union was defined as no tenderness, whereas radiological union was evaluated using the Fillan and Herbert criteria (5). The Disability of Arm Shoulder and Hand score (DASH) – Bulgaria was used to document patient report outcomes (19). The Mayo wrist score was used for functional assessment of the final results (1).

RESULTS

The clinical follow-up was 2 years. The patients were followed in the clinic or through a telephone call at regular intervals. The radiological and clinical characteristics were measured. The radiological criteria were bone healing, duration of bone healing and carpal geometry. (value of interscaphoid, scapholunate, radiolunate and lunocapitate angles).

The measured clinical criteria were active and passive range of wrist motion, grip strength, and level of postoperative pain.

Bone healing was radiographically and clinically confirmed in 70 patients. Nonunion was established for two fractures. Both nonunion fractures were stabilized by one HBS. The radiographic angles in both groups of patients did not differ significantly from the physiological values. The mean durations to bone union for the group with one HBS were 1.8 months, while for the two HBS were 1.5 months.

The reported average range of wrist motion is shown in Table 5.

Mean values of grip strength in the group with one HBS is 47 kg (16–70 kg) which is 94% of the strength

Fig. 2. For fractures with transvers fracture line K-wires and screws were introduced perpendicular to the fracture plane and parallel each to other.

Fig. 3. For the oblique fractures the first screw was introduced perpendicular to the fracture line and the second one along the central axis of the bone.

of the unaffected hand, while in 2 HBS group mean grip strength was 49 kg, which is 97% of the strength of the unaffected hand.

Pain was assessed by the Visual Analog Scale (VAS) which is a 5 item Likert index (from no pain up to severe pain) Average pain value for the group with one HBS was 2.5, for the group with two HBS the VAS score was 2.0.

The final assessment of the resullts was done by "Mayo Wrist Score" and patient report outcome assess-

Table 6. Common assessment of the final results of both groups by "Mayo wrist score"

Results	1 HBS	2 HBS
Excellent /91–100/	24 (60 %)	22 (73.6 %)
Good /80–90/	16 (35 %)	8 (26.4 %)
Bad/65–79/	2 (5%)	0
Very bad /≤64/	0	0

Table 7. The results after patients' self-assessment test by DASH

Results	1 HBS	2 HBS
Excellent (< 24 points)	24	15
Good (25–49 points)	14	15
Bad (50–74 points)	4	0
Very bad (>75–100 points)	0	0

Table 8. The registered complications for the both groups

Type of complication	1 HBS	2 HBS
Nonunion	2	0
Screw tip penetration	1	1
Arthrosis of the STT joint	2	2
Reduced range of motion	2	4

ment using DASH. The values of the evaluations of the two studies are presented in Tables 6 and 7. The final results of the one HBS group assessed by "Mayo Wrist Score" were excellent in 60 %, good in 35% and bad in 5% of the cases, for the patients in the two HBS group the excellent result was 73.6% and good result was 26.4%. The DASH score for the patients from one HBS group were excellent in 24 cases, good in 14 cases and bad in 4 patients. For the patients in HBS two group excellent results were in 15 cases and good in 15 cases.

Complications

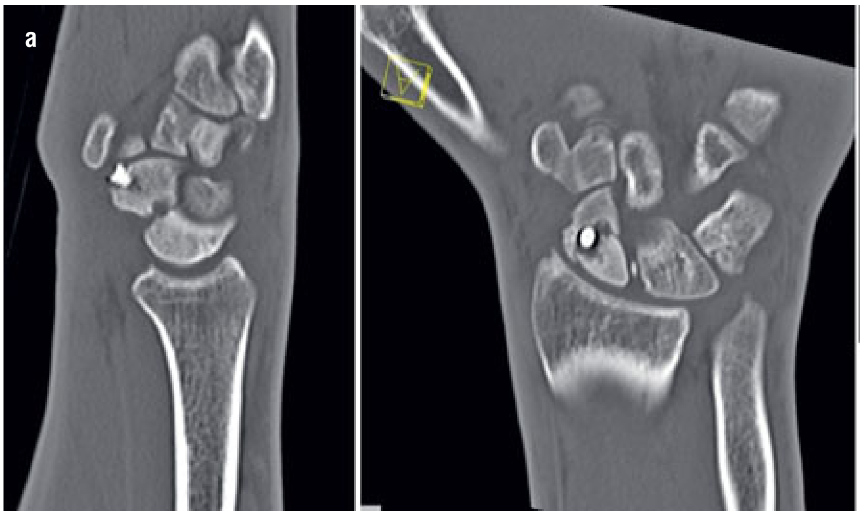
The complications are followed in Table 8**.** On Figure 4a,b is presented a history of a nonunion after internal fixation for acute scaphoid fracture. The patient had pain (VAS-4) and restricted wrist motion. The nonunion was detected by the CT scan. (Fig. 4a) He was reoperated by nonvascularized structural bone graft, harvested on the ipsilateral iliac spine.

DISCUSSION

The first-generation headless compression screw for internal fixation of scaphoid fractures was introduced by Herbert and Fisher in 1984 (10). During the first decade of the new century the second-generation screws were created which resolved any imperfections of first generation. The new screws were smaller in diameter and achieved significantly better interfragmental compression (3, 8). Despite the improved design, the exact placement of the screw remained a challenge. Many biomechanical studies on single screw fixation have been published in the literature. Luria et al. presented an optimal virtual model for fixation of oblique fractures, by single screw (13). The measured load to failure of screw placed centrally in the scaphoid and those screw placed perpendicular to the fracture plane was found equal for both groups. Stiffness was identical in both groups (131 N/mm) and load to failure was similar (central screw, 137 N vs perpendicular screw, 148 N). McCallister et al. presented results after comparative analysis of central and eccentric screw placement in fresh frozen cadaveric scaphoids. For load to 2 mm displacement they found values of 126 +/-74.9 N and 59.1 +/- 47.8 N respectively, and 712 +/- 412 N and 513 +/- 354 N respectively for load to failure (15). According to the study by Moojen et al. on scaphoid kinematics the fracture fixation by one screw may not provide the required rotational stability, during wrist extension-flexion and radioulnar deviation compared to double-compression screw fixation (16). In 2006, Slade notes that "*The augmentation of a centrally located screw structure with an additional implant increases stability of fixation*" (21) Another study notes that osteosynthesis with two screws provides two fixation points that have higher resistance (14). Surke et al. investigated the biomechanical effect of different screw configurations in double screw osteosynthesis in an unstable scaphoid fracture model (22). Specimens were randomly allocated to 1 of 2 fixation groups using 2 internal compression screws positioned in either the sagittal or coronal plane. The authors concluded; "*there are no significant biomechanical differences between the sagittal or coronal aligned double headless compression screws in a scaphoid fracture model with bone loss*"(22).

Initially the technique with two screws was applied for fixation of the scaphoid non-unions (11, 14, 21). Jurkowitsch et al. compared the results of scaphoid nonunion fixation with one screw, two screws, and a plate. Their conclusion was that the most stable fixation was achieved with two screws, followed by the angular-stable plate, and finally with one screw (11). Recently the advantage of using 2 screws for acute scaphoid fractures fixation was confirmed by Yildirim et al. (23). The authors concluded that fixation with two screws achieved maximal compression and stability across the fracture site. The rotational and sharing forces were reduced which improved the quality of bone healing. According to the authors this method allows an earlier start to rehabilitation, which is important especially for professional athletes. In 2017,

Quadlbauer et al. reported on the results of unstable B2 scaphoid fractures fixed by one or two screws (17). The study followed 47 patients. Only 10 of which had complete bone healing after being stabilized using 2 screws. The authors found an increased union rate with 2 screws, but no difference in ROM, grip strength, pain, and outcome scores. According to Quadlbauer et al. the key to sufficient stability is the addition of the second screw which increases the resistance against torque (17).



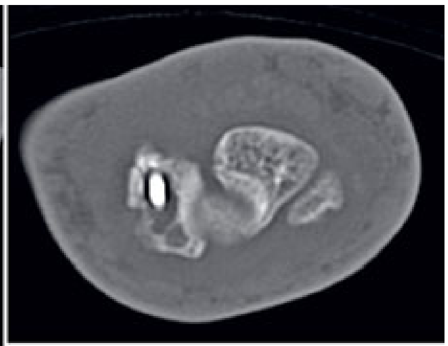


Fig. 4. a – CT scan of a patient with scaphoid nonunion after fixation of acute scaphoid fracture by one HBS; b – operative treatment by debridement of the nonunion, structural bone graft harvested by iliac crest, osteosynthesis by 2 HBS introduced parallel, retrograde and antegrade.

laboratory studies which defined the conditions for obtaining maximal interfragmentary compression as having the screw placed along the central axis of the bone and perpendicular to the fracture line (9, 22). In practice, this is not always possible by one screw, especially for oblique fractures. The cited publications for fixation of acute scaphoid fractures considered only parallel screw placement. Our hypothesis was that both requirements can be achieved simultaneously by placing of two screws, depending of the fracture line. The analysis of the results on this report confirms our hypothesis. For oblique fractures, the first screw is placed perpendicular to the fracture line, the second is placed along the central bone axis. For transverse fractures both screws are placed perpendicular to the fracture and parallel to each other.

Our results demonstrate that the group with fractures stabilized by 2 HBS had better outcomes. All fractures in this group healed. In the group with one HBS there were two cases of nonunion. Both cases had been reoperated by nonvascularized bone graft and fixation with two HBS. The treatment after a failed surgical fixation of acute scaphoid fractures is a challenge. In the most similar cases the quality of the bone is already compromised (Fig. 4a). The contemporary options include nonvascularized bone autograft, different types of vascularized bone grafts, salvage procedures as partial or complete wrist arthrodesis or proximal row carpectomy. The presented case on Figure 4 belong to the group fixed by one HBS. It was treated by structural bone graft harvested from the ipsilateral iliac crest. The fixation was by two parallel HBS introduced retrograde and antegrade simultaneously.

The mean duration to bone union for the group with two HBS was shorter (1.5 months). For the group with one HBS the mean healing duration was 1.8 months. Both groups had excellent and good results. For the group with two HBS, they are 100 % and 95 % for those with one HBS.

The most complications of the two screws technique are; longer surgical time, malposition of screws, intraarticular screw penetration, reduced range of motion and osteoarthritis (11, 14, 17, 23). The reported complications in this report are similar for the both groups. The most common complication is the limited range of motion, a result of accumulated fibrosis in the area of surgical approach which has proved to be an obstacle in the rehabilitation period.

Strengths of the presented study are:

1. An algorithm is presented for the different model of screws placing in transverse and oblique scaphoid fractures.
2. The excellent and good results determine the technique as a means of choice, especially in unstable fractures with oblique and spiral fracture lines.

Weaknesses of this study are the lack of laboratory biomechanical analysis conforming clinical results. Verification of bone healing for majority of the operated patients is made by routine X-ray projections whitought of CT scan.

CONCLUSIONS

The presenting hypothesis that the placement of two HBS can cover the requirements for simultaneously screw placement along the central axis of the scaphoid bone and perpendicular to the fracture line was confirmed. Analysis of the results demonstrate that osteosynthesis with two HBS creates greater fracture stability. The proposed algorithm for fixation of acute scaphoid fractures using two HBS is achieved by simultaneously placing the screw along the axial axis and perpendicular to the fracture line. The stability is improved by the equal distribution of the compression force on the entire fracture surface. The second screw controlled rotation between the fragments.

References

1. Cooney WP, Bussey R, Dobync JH, Linscheid RL. Difficult wrist fractures and perilunate-fracture dislocations of the wrist. Clin Orthop. 1987;214:136–147.
2. Cooney WP, Dobyns JH, Linscheid RL. Fractures of the scaphoid: a rational approach to management. Clin Orthop Relat Res. 1980;149:90e97.
3. Crawford LA, Eric S. Powell ES, Trail IA. The fixation strength of scaphoid bone screws: an in vitro investigation using polyurethane foam. J Hand Surg. 2012;37A:255–260.
4. Faucher GD, Golden ML, Sweeney RK, Hutton WC, Claudius D, Jarrett J. Comparison of screw trajectory on stability of oblique scaphoid fractures: a mechanical study. J Hand Surg Am. 2014;39:430–435.
5. Filan SL, Herbert TJ. Herbert screw fixation of scaphoid fractures. J Bone Joint Surg Br. 1996;78:519–529.
6. Garala K, Taub N, Dias J. The epidemiology of fractures of the scaphoid: impact of age, gender, deprivation and seasonality. Bone Joint J. 2016;98:654–659.
7. Garcia R, Leversage J, Aldridge M, Richard MJ, Ruch l. Scaphoid nonunions treated with 2 headless compression screws and bone grafting. J Hand Surgery Am. 2014;39:1301–1307.
8. Gordon PB, Ferreira LF, Johnson JA, Graham J.W, King. Interfragmentary compression across a simulated scaphoid fracture—analysis of 3 screws. J Hand Surg Am. 2004;29:273–278.
9. Hart A, Mansuri A, Harvey E, Martineau P. Central versus eccentric internal fixation of acute scaphoid fractures. J Hand Surg Am. 2013;38:66–71.
10. Herbert T, Fisher W. Management of the fractured scaphoid using a new bone screw. J Bone Joint Surg Br. 1984;66:114–123.
11. Jurkowitsch, Dall'Ara E, Quadlbauer S, Pezzei C, Jung I, Pahr D, Leixnering M. Rotational stability in screw-fixed scaphoid fractures compared to plate-fixed scaphoid fractures. Arch Orthop Trauma Surg. 2016;136:1623–1628.
12. Kawamura K, Chung K. Treatment of scaphoid fractures and nonunions. J Hand Surg Am. 2008;33:988–997.
13. Luria S, Hoch S, Liebergall M, Mosheiff R, Peleg E. Optimal fixation of acute scaphoid fractures: finite element analysis. J Hand Surg Am. 2010;35:1246–1250.
14. Mandaleson A, Tham S, Lewis C, Ackland D, Ek E. Scaphoid fracture fixation in a nonunion model: a biomechanical study comparing 3 types of fixation. J Hand Surg Am. 2018;43:221–228.
15. McCallister WV, Knight J, Kaliappan R, Trumble TE. Central placement of the screw in simulated fractures of the scaphoid waist: a biomechanical study. J Bone Joint Surg Am. 2003;85:72–77.
16. Moojen TM, Snel JG, Ritt MJPF, Venema HW, Kauer JMG, Bos KE. Scaphoid kinematics in vivo. J Hand Surg Am. 2002;27:1003–1010).
17. Quadlbauer S, Beer T, Pezzei C, Jurkowitsch J, Tichy A, Hausner T, Leixnering M. Stabilization of scaphoid type B2 fractures with one or two headless compression screws. Arch Orthop Trauma Surg. 2017;137:1587–1595.
18. Sabbagh M, Morsy M, Moran S. Diagnosis and management of acute scaphoid fractures. Hand Clin. 2019;35:259–269.
19. Simeonov L. Jacobson P. Clinical and self-report outcome measurement systems for the wrist and hand: current concepts. Orthop Trauma. 2013;4:188–200.
20. Singh H, Taub N, Dias J. Management of displaced fractures of the waist of the scaphoid: meta-analyses of comparative studies. Injury. 2012;43:933–939.
21. Slade J, Merrell G. Minimally invasive management of scaphoid fractures. Oper Tech Plast Reconstr Surg. 2002;9:143–150.
22. Surke C, Lachlan S, Xin Zhang, Ek E, Ackland D, Tham S. J Double-screw osteosynthesis in an unstable scaphoid fracture model: a biomechanical comparison of two screw configurations. J Hand Surg Am. Epub 2021 Oct. 2022;47:1118.e1–1118.e8.
23. Yildirim B, Nicole D, Chhabra B. Two-screw fixation of scaphoid waist fractures. J Hand Surg Am. 2020;45:783.e1–783.e4.

Corresponding author:
Lyudmil Simeonov MD, PhD
Division of Hand and Microsurgery
University Hospital of Emergency Medicine
bul. „General Eduard I. Totleben“ 21, 1606 Pette Kyosheta
Sofia, Bulgaria
E-mail: lyudmilsimeonov@hotmail.com