© Grigorovskii V.V., Strafun S.S., Timoshenko S.V., 2017

DOI 10.18019/1028-4427-2017-23-1-30-37

Histopathology of the wrist tissues and some clinical and morphological correlations in patients with consequences of scaphoid fractures

V.V. Grigorovskii, S.S. Strafun, S.V. Timoshenko

SI *Institute of Traumatology and Orthopaedics* of NAMS of Ukraine, Kiev, Ukraine

Introduction Posttraumatic osteoarthritis of the wrist (WOA) is of importance among the diseases of the proximal hand. There are few studies in which the dependence between clinical and morphological parameters in patients with posttraumatic osteoarthritis due to a non-united fracture of the scaphoid was studied. **Purpose** To identify the dependence between several clinical parameters on the one hand and morphological parameters of the wrist tissue condition, on the other hand, in patients with consequences of scaphoid nonunion. **Materials and methods** Material were 94 resected samples of the wrist tissues that included the scaphoid obtained from 55 patients in whom the WOA was associated with the consequences of scaphoid fracture nonunion. The following parameters were studied: anamnesis and symptoms, roentgenometric and morphological findings that were graded. Correlation dependence between them was also investigated. **Results** Pathological changes in the wrist tissues were characterized by qualitative and quantitative varieties. They were the consequences of traumatic blood supply disorders in the scaphoid and joint capsule. They manifested themselves as inflammatory, productive-reparative and dystrophic-destructive changes (DDC). Maximum values of Pearson's association coefficient were revealed between the parameters: time since injury – scaphoid surface DDC in pseudoarthrosis zone (r_a = + 0.438; $p < 0.01$); pain – scaphoid osteonecroses (r_a = +0.320; $p < 0.05$); wrist contracture – hypertrophy of the villi of the wrist capsule synovial layer (r_a = +0.320; $p < 0.1$). **Conclusion** Pathohistological and morphometrical studies allowed us to reveal some previously unknown differences and dependences important for understanding the pathogenesis, improvement of diagnosis and prediction of the WOA course which was a result of scaphoid fracture nonunion.

Keywords: wrist, scaphoid nonunion, wrist osteoarthritis, clinical parameters, morphological parameters, correlation dependence

INTRODUCTION

Wrist joint pathology, its diagnosis and management of its consequences are current problems in hand surgery. Wrist joint osteoarthritis (WOA) is a challenging condition among the diseases of the proximal hand involving single or several bones. According to many authors, consequences of scaphoid fractures are one of the causes in the development of posttraumatic WOA. Their clinical manifestations are a persistent pain in the hand, especially when the hand is loaded, and biomechanical wrist disorders [1, 2, 3, 4, 5].

Expressiveness of pathological morphological changes in the joint tissues in WOA varies from case to case and reflects the effects of a number of pathological factors: severity and topography of the primary injury, time since the injury, therapy measures after the injury and surgical interventions, associated disorders of joint biomechanics and inflammation processes [6, 7]. There are few available studies on this problem that diversely characterize the condition of the wrist joint tissues such as joint surfaces and scaphoid spongiosa as well as the joint capsule. Correlation between clinical manifestations in the patients with the affected wrist joint and morphological parameters that characterize the conditions of the affected tissues has not been studied yet.

Study purpose To establish the dependence between some of the clinical symptoms on the one hand and morphological parameters of tissue condition on the other hand with the study of pathological morphological changes in the tissues of the wrist joint in patients with the consequences of scaphoid fractures using a graded quantification of clinical and morphological findings.

MATERIAL AND METHOD

The material for pathomorphological study were 94 fragments resected from the wrist joint tissues, and in particular: fragments of the scaphoid bone (39 samples), semilunar bone and several other bones (12 samples) and joint capsule (43 samples) that were obtained during corrective surgical interventions in 55 patients who had WOA associated with nonunion after scaphoid fractures.

Informed consents on the use of medical findings were

📖 Grigorovskii V.V., Strafun S.S., Timoshenko S.V. Histopathology of the wrist tissues and some clinical and morphological correlations in patients with consequences of scaphoid fractures. *Genij Ortopedii*. 2017. T. 23. No 1. pp. 30-37. DOI 10.18019/1028-4427-2017-23-1-30-37.

received prior to the study from all the patients included.

Parameters of clinical and radiographic findings were recorded one to 2 days prior to surgical interventions with the methods common for this pathology and with the use of measurement devices that passed a metrological checking (**Table 1**).

Table 1

Distribution of clinical cases according to grading of clinical, clinical visualization and biomechanical parameters in patients with scaphoid fracture nonunion

Parameter	Grading and some statistical data	Number of bioptates referred to each grade from the total number of informative bioptates	Incidence of specific morphological parameter grading, % from the number of informative bioptates
Anamnesis parameters			
Patients age at time of wrist injury (years)	Low grade (younger or equal to 25 years) Mean and standard error = 21.62 ± 0.55	29	50.88
	High grade (more than 25 years) Mean and standard error = 35.11 ± 1.78	28	49.12
Time since wrist tissues injury (months)	Low grade (less than 24 months) Mean and standard error = 8.34 ± 0.96	29	50.88
	High grade (equal or more than 24 months) Mean and standard error = 73.00 ± 12.28	28	49.12
Mechanical injury impact force	No evident mechanical injury in the anamnesis	18	29.51
	Low energy trauma: fall on the hand from standing or walking position	36	59.02
	High energy trauma: fall on the hand while running, sport activities, fall from height	7	11.47
Symptoms			
Intensity of pain (DASH scale, according to Duppe et al. [4]	Low grade: weak pain	9	16.36
	Mild: moderate pain	19	34.54
	High grade: severe pain	27	49.10
Soft tissue swelling in wrist area (points)	Low grade: some pitting edema, evening of wrist contours	19	38.00
	Moderate grade: evident edema but skin folds visible	17	34.00
	High grade: glossy skin, skin folds invisible	14	28.00
Wrist capsulitis (points)	Low grade: no visible joint defiguration	11	23.91
	Moderate: visible hypertrophy of the capsule and joint defiguration, solitary ganglion associated with arthritis	15	32.61
	High grade: evident joint deformity, painful hypertrophy of capsule, protrusions on the palmar, radial and dorsal surfaces, multiple ganglions	20	43.48
Wrist contracture	Low grade: range of motion 90 degrees and more	17	31.48
	Moderate: range of motion between 40 and 90 degrees	16	29.63
	High grade: range of motions less than 40 degrees	21	38.89
WOA grade according to clinical visualization (Watson, Ballet [8])	WOA signs absent (grade 0)	19	32.21
	Grade I	13	22.03
	Grade II	15	25.42
	Grade III	12	20.34
Functional disorders (deficit) of the wrist joint (DASH scale), points (Hudak et al. [9])	Low grade (less than 40 points) Mean and standard error = 30.63 ± 1.28	29	56.86
	High grade (more than 40 points) Mean and standard error = 47.89 ± 1,23	22	43.,14
Roentgenometric findings			
Radial-to-semilunate angle (degrees, Linscheid et al. [10])	Low grade (less than 20 degrees) Mean and standard error = 7.59 ± 1.08	27	57.45
	High grade (more than 20 degrees) Mean and standard error = 27.60 ± 1.71	20	42.55
Index of wrist joint height (Youm et al. [11])	Low grade (index more than 0.50) Mean and standard error = 0.517 ± 0.025	21	44.68
	High grade (index equal or lower than 0.50) Mean and standard error = 0.487 ± 0.028	26	55.32
Relative length of the scaphoid compared with the contralateral one, %	Low grade (more than 90 %) Mean and standard error = 93.34 ± 0.41	23	58.97
	High grade (less than 90 %) Mean and standard error = 84.32 ± 1.17	16	41.03

Indication for surgical interventions was a symptomatic pseudarthrosis of the scaphiod bone associated with a corresponding clinical and radiographic findings: pain, deformities and shortened scaphoid in a number of cases, aseptic necrosis of its fragments, intermediate fragment instability in extension, and wrist osteoarthritis (scaphoid nonunion advanced collapse, SNAC) [12].

Removed fragments were used as whole pieces for a histological study, without their grinding. Tissues were fixed in 10% formalin, decalcified in a 5% solution of nitric acid, embedded in celloidin. Slices, 10 μm thick, were obtained, stained with hematoxylin and eosin and hematoxylin-picrofuxin according to van Gieson. Histological study was performed with *Olympus CX-41* and *MBS-2* microscopes. Histopreparations were photographed in a macro-regime on the microscope *Olympus CX-41* with *Nikon D90* camera.

RESULTS

Incidence of specific grading of various clinical, radiographic and skiagraphic parameters in our patients with WOA associated with scaphoid nonunion after fracture is given in **Table 1**.

Histopathology of the articular surface Different grades of dystrophic and destructive changes (DDC) were observed in the areas of the scaphoid articular surface, from moderate (**Fig. 1**) to severely expressed ones (**Fig. 2**).

In a low articular surface DDC grade that corresponded to WOA grade I, the hyaline articular cartilage (AC) was preserved. However, it had inconsiderable dystrophic changes in the matrix and fibrosis of the superficial AC layer. In a moderate DDC grade, destruction of the tissues of the superficial and partially of the intermediate AC zone was observed. The cartilage matrix contained vertical and horizontal fissures while there were portions of chondronecrosis in the areas of the preserved cartilage, manifestations of marked matrix dystrophy, and chondrocyte proliferate clusters. In severe grades of AC dystrophy and destruction, AC was completely or almost completely collapsed. Remnants of a severely dystrophic AC were present on the articular surface or the surface was formed by sclerotic exposed bone. In several cases, proliferate nodes of the cartilage tissue were seen in the subchonral spongiosa, portions of fibrosis in the bone marrow cavities and vascular canals as well as small cysts with a serous mixoid content.

Histology of the pseudoarthrosis surface The main variants of the pseudarthrosis surface structure were as follows:

- Surface with a prevalence of a non-uniform structure of the cartilage tissue with signs of chondrocyte proliferation (**Fig. 2**, **Fig. 3**);
- Surface covered by flattened fibrous tissue of uneven thickness (**Fig. 4**);
- Uneven surface that was non-uniformly formed of sclerotic bone tissue.

End bone plate of the pseudartrosis surface was frequently absent or had an irregular structure with interstitial osteonecrosis, non-uniform osteosclerosis and areas of bone resoption that reflected the condition of reorganization that continued. Swollen fibrous bone marrow was seen in the scaphoid bone marrow cavities that lay in the direct proximity to the pseudarthrosis surface. Osteoclasts were frequent on the surfaces of trabeculae.

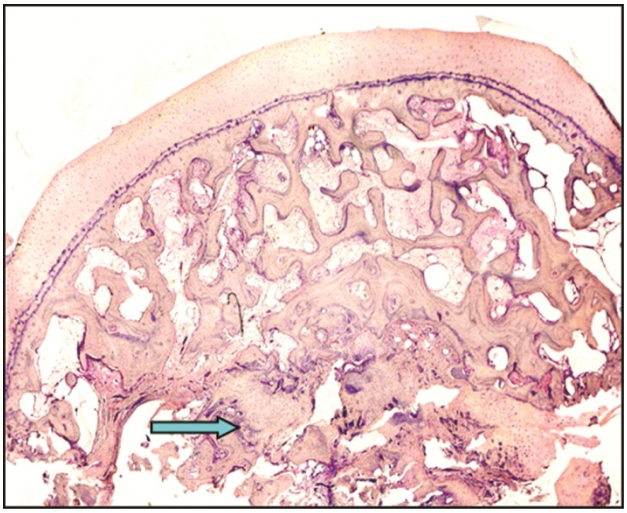

Fig. 1 Low grade changes in the scaphoid articular surface: AC is almost completely preserved. Pseudarthrosis surface contains bony and cartilaginous outgrowth (arrow). Photo of a scaphoid histopreparation of patient D., 30 y.o.; 4 months since injury. Hematotoxylin and eosin stain; Magnification 15 ×

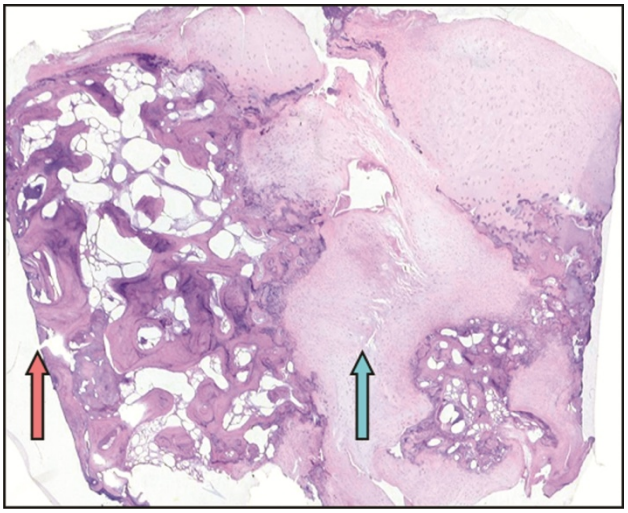

Fig. 2 Scaphoid articular surface represents exposed bone tissue (red arrow); pseudarthrosis surface has outgrowth of cartilage tissue (blue arrow). Photo of a scaphoid histopreparation of patient I., 27 y.o.; 24 months since injury. Hematotoxylin and eosin stain; Magnification 15 ×

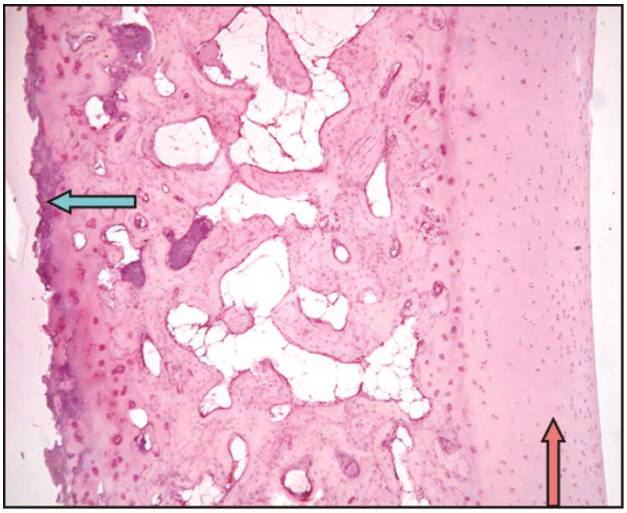

Fig. 3 Pseudarthrisis surface (blue arrow) is partially covered with a destructed cartilage tissue. Articular cartilage (red arrow) is well preserved. Photo of a scaphoid histopreparation of patient X., 40 y.o.; 12 months since injury. Hematotoxylin and eosin stain; Magnification 24 ×

Fig. 4 Interstitial osteonecrosis of the scaphoid spongiosa bars; fibrous bone marrow is seen in bone marrow cavities. Pseudarthrosis surface (arrow) is covered with a thin layer of fibrous tissue. Photo of a scaphoid histopreparation of patient S., 65 y.o.; 4 months since injury. Hematotoxylin and eosin stain; Magnification 80 ×

Histopathology of spongy bone tissue In some bone trabeculae, there were small interstitial necroses presented as groups of empty osteocytic lacunas. In such bars, the superficial bone plates formed layers with vital osteocytes. If the necrosis areas occurred regularly in numerous trabeculae it corresponded to the moderate grade of the parameter. In several scaphoids, the osteonecrosis areas were rather extended (**Fig. 4**). Thereby, there were medullary necrosis areas in the bone marrow and/or fibrosis with middle size loops – the combination of such signs corresponded to a high grade of the parameter expressiveness. Signs of ongoing and/or completed remodeling of lamellar bone tissue seen as cemental lines of fancy drawing (**Fig. 5**) were revealed in the scaphoid spongyosa if osteonecrosis foci were large.

Histopathology of the joint capsule The synovial layer of the joint capsule (JC) developed the villi of different sizes. In several cases, the synovial volli were rather small and not high and slightly protruded over the synovial layer surface. In other cases, the villi were of high outgrowth over the surrounding surface. Fibrosis of the proper plate and its assimilation with the nearby areas of the fibrous layer was observed in the wrist synovial membrane capsule. Areas of nonspecific productive inflammation with hyperemia of the microcirculation flow of the proper plate and focal mononuclear plasmocytic infiltrates of various densities were seen in the synovial membrane of the majority of bioptates. In a small portion of the cases, hyperemia, desquamation of synoviocytes and inflammatory infiltration of JC corresponded to exudative fibrinous inflammation (**Fig. 6**).

Fig. 5 Signs of completed remodeling in the scaphoid spongiosa bars: multiple cemental lines (arrow); fibrous bone marrow. Photo of a scaphoid histopreparation of patient Z., 18 y.o.; 24 months since injury. Hematotoxylin and eosin stain; Magnification 80 ×

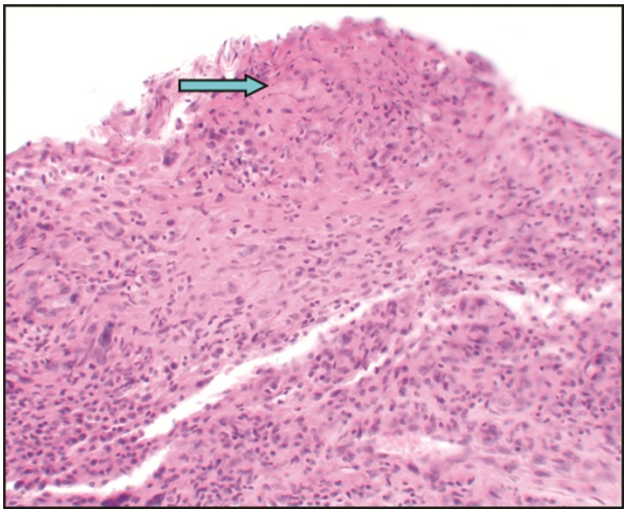

Fig. 6 Non-specific high activity synovitis: absent coating of synoviocytes; accumulations of fibrinous exudate lie on the surface (arrow). Photo of a wrist capsule histopreparation of patient R., 41 y.o.; 156 months since injury. Hematotoxylin and eosin stain; Magnification 160 ×

Correlative dependence between clinical and morphological parameters Distribution of clinical biopsy cases according to the expressiveness grading of several morphological parameters is given in Table 2. Correlation relationship between clinical and morphological parameters is shown in **Table 3**.

Table 2

Distribution of clinical biopsy cases according to the grading in the expressiveness of several morphological parameters that evaluate the pathological changes in the wrist tissues in patients with scaphoid fracture nonunion

Morphological parameter	Description of pathological expressiveness changes corresponding to grades or alternative conditions	Number of bioptates referred to each grade from the total number of informative bioptates	Incidence of specific morphological parameter grading, % from the number of informative bioptates
Dystrophic destructive changes (DDC) in the scaphoid joint surface – corresponding to osteoarthritis grades (Mohr [13]) [1)]	Low grade: DDC corresponds to osteoarthrosis Grade I [1)]	12	28.57
	Moderate grade: DDC correspond to osteoarthritis Grade II	17	40.48
	High grade: DDC correspond to osteoarthritis Grade III	13	30.95
Dystrophic destructive changes (DDC) in the scaphoid pseudarthrosis surface	Low grade: proliferative cartiloginous tissue prevails on the pseudarthrosis surface	17	48.58
	Moderate grade: flattened fibrous tissue prevails on the pseudarthrosis surface and covers bone structure surface	9	25.71
	High grade: areas of exposed bone structures prevail on the pseudarthrosis surface	9	25.71
Osteonecrosis in the spongiosa of affected scaphoid	Low grade: small degree interstitial osteonecrosis in the thickness of bone trabeculae and cortex	12	25.53
	Moderate grade: big-sized interstitial osteonecrosis occupies a considerable volume in bone trabeculae and cortex	17	36.17
	High grade: big focal osteomedullary necrosis	18	38.30
Hypertrophy and hyperplasia of volli and synoviocytes	Absent or low grade: solitary volli that slightly protrude over the synovial membrane surface	21	58.33
	High grade: high volli that outgrow to a considerable height and volume	15	41.67
Activity of nonspecific wrist synovitis	Absent or low grade inflammation: synovial cover is preserved completely, mononuclear infiltration is of small foci and not dense	34	69.39
	Moderate grade: marked vascular hyperemia in the synovial membrane; expressed leucocytic plasmocytic infiltration but not draining	12	24.49
	High grade: expressed inflammatory exudative changes associated with fibrin layers on the surface; sharp hyperemia of the synovial membrane vessels, marked discharging leucocytic plasmocytic infiltration	3	6.12

Notes: [1)] – osteoarthritis grading according to Collins-Otte (см. Mohr [13]).

Table 3

Correlative relationship between clinical and morphological parameters of pathological changes in the wrist tissues in patients with post-traumatic scaphoid nonunion (correlation of clinical manifestations and morphological findings)

Clinical parameters (grading, see Table 1)	Morphological findings (grading, see Table 2)	Pearson's correlation coefficient and its reliability		
		n, number of recorded cases with both parameters findings	r_a *	Assessment of reliability r_a by k=n-1; number – error probability by assessment of the parameter
Time since injury	DDC in the scaphoid pseudarthrosis surface [1)]	**32**	**+0.438**	**<0.01**
Impact force of trauma mechanism	DDC in the scaphoid pseudarthrosis surface [1)]	34	–0.245	NR
Intensity of pain	Osteonecrosis [2)]	**41**	**+0.320**	**<0.05**
Expressiveness of capsulitis	DDC in the scaphoid pseudarthrosis surface [1)]	26	+0.283	NR
	Inflammation activity in the synovial layer [3)]	37	+0.211	NR
Contracture	Synovial layer volli hypertrophy [4)]	**31**	**+0.320**	**<0.1**
Relative length of the scapoid	DDC of the scaphoid articular surface [2)]	25	–0.263	NR
	DDC in the scaphoid pseudarthrosis surface [2)]	21	+0.234	NR

Notes: * r_a – table contains only the pairs of parameters with an absolute value of correlation coefficient >|0,2|; k – number of freedom grades (k=n-1) by assessment of r_a with Student's test; p – error probability by calculation of r_a correlation; [1)] – two grades of the parameter (grades of expressiveness): 1) cartilage tissue – 2) fibrous tissue or exposed bone tissue. [2)] – two grades of the parameter (grades of expressiveness): 1) low or mild (moderate) – 2) high; [3)] – two grades of the parameter (grades of expressiveness): 1) absent or low – 2) moderate or high; [4)] – two grades of the parameter (grades of expressiveness): 1) low – 2) high; NR – differences not reliable due to number of cases (p>0,1).

The prevailing number of parameter pairs (Table 3) showed low parameters of the correlation coefficient that are in the range of very weak values (lower than 0.3 in an absolute value). Only three pairs of parameters studied showed the correlation coefficient absolute value in the range from 0.3 to 0.5:

- *Time since injury – DDC in the scaphoid pseudarthrosis surface*. Correlation is positive, highly reliable and proves that almost in the half of the scaphoid nonunion cases the time since injury correlates with high grade of DDC in the scaphoid pseudarthrosis surface, that is fibrosis or sclerosis and exposure of the bone end plate;
- *Intensity of pain – scaphoid osteonecrosis*. Correlation is positive, reliable and proves that in one third of the cases the severity of pain in the wrist joint area correlates with the size of osteonecrosis in the scaphoid bone, that is high intensity of pain is associated with large foci of spongiosa osteonecrosis;
- *Severity of wrist joint contracture – hypertrophy of volli in the wrist synovial membrane capsule*. Correlation is positive with a probability of error of the correlation coefficient p<0.1, or the wrist contracture of high grade correlates with an expressed hypertrophy of the volli in the wrist synovial layer capsule in one third of patients.

DISCUSSION

The clinical and morphological study conducted by us confirmed the involvement of a number of pathological joint components in the formation of the complex of changes that finally may results in WOA after scaphoid fractures and nonunion [3, 14]. First, those are circulation changes in the scaphoid bone tissue. Vascular disorders probably occur in the first hours following the mechanical trauma and are directly caused by the rupture or compression of the vessels that supply blood to the wrist bones because they are of small size and easy to injure [2, 15]. Acute damage to vessels, and primarily to arteries, that penetrate the bone on the surfaces that lack articular cartilage would cause the foci of acute ischemia in the bone marrow and bone tissue. The final size of the foci of ischemic osteomedullary necrosis will depend on the ability to compensate the disturbed blood supply from the collateral sources in the first hours after the injury. As far as the potential sources of this collateral blood supply to the injured bone used to be injured as well due to trauma, it is obvious that ischemic osteomedullary necroses of the scaphoid might develop.

Each scaphoid fracture is unique in regard to the

damage to bone blood supply sources after the lesions of the articular capsule, interosseous ligaments and other structures. It was indirectly confirmed by the variations in the topography and sizes of osteomedullary necroses as well as by a different character of the necrosis focus organization process and by formation of the pseuarthrosis surface structure that were revealed by us. The features of the latter also show considerable variations that include formation of immature cartilage tissue, irregular fibrous coating or complete exposure of the sclerotic bone end plate.

DDC of the articular surface of the scaphoid and other wrist bones are a remote consequence of the injury to joint structures, including scaphoid fractures, and are considered as manifestations of the advanced WOA [1, 8, 14]. Both the disorders in the joint biomechanics that are associated with the scaphoid nonunion after fracture, and a chronic inflammatory process in the joint capsule play their role in WOA pathogenesis [16, 17]. Grading of the main morphological parameters of the joint structures, in particular correlation of the specific grading incidence encountered (**Table 2**), was defined by us with the use of a rather big morphological material. Correlations between them and a number of clinical parameters such as anamnesis findings, symptoms and roentgenometric data that comprehensively characterize the wrist joint in the posttraumatic period were studied. However, it appeared that a number of clinical parameters do not show close and reliable correlations with the morphological parameters of the scaphoid tissue and joint capsule injury. The correlation associations that have the biggest absolute values were established for pairs of *clinical signs-morphology* and are presented in **Table 3**.

Several authors noted the difficulties in defining SNAC stages in the regular radiographs [18]. This does not completely correspond to the pathomorphological changes that correspond to the grading of DDC in the wrist tissues in such patients. The findings about a weak and unreliable correlation between clinical-radiographic and histological WOA signs obtained by our study indirectly confirm the difficulties of giving an objective assessment of the wrist joint tissues condition in WOA.

Some studies of clinical and morphological relationships in WOA defined the risk factors and prognostic parameters of degenerative changes that develop [19]. However, the authors used only the radiographic method for assessment of scaphoid bone tissue condition. The closest correlation was found by the authors between the location of the fracture in the proximal scaphoid third and fragment instability. The mean values of intercarpal angles increased with the DDC progression but their parameters did not discover a reliable correlation with the nonunion duration as well as for cases treated and untreated. The correlations found allowed the authors to recommend the measures for restoration of carpal stability with surgical interventions that unite the fragments in order to prevent WOA [20].

CONCLUSIONS

1. Clinical manifestations of posttraumatic changes in the scaphoid bone caused by its nonunion vary in the majority of the parameters. The most common symptoms are severe pain, high expressiveness of capsulitis, wrist contractures and reduction in the index of wrist joint height.

2. Pathological changes in the wrist tissues are characterized by a variety of qualitative and quantitative parameters, are consequences of acute traumatic disorders in blood supply to the scaphoid and joint capsule, and are manifested by dystrophic destructive, productive reparative and inflammatory processes.

3. Maximum values of correlation (according to the correlation coefficient) are revealed in the paired parameters “clinical manifestation-morphology”:

- Dependence is positive and highly reliable for correlation: *time since injury – DDC of the scaphoid pseudarthrosis surface*
- Dependence is positive and reliable for correlation: *intensity of pain – scaphoid osteonecrosis*
- Dependence is positive with a probability of the coefficient of correlation error <0.1 for correlation: *severity of wrist joint contracture – hypertrophy of volli in the wrist synovial membrane capsule*

REFERENCES

1. Allende B.T. Osteoarthritis of the wrist secondary to non-union of the scaphoid. *Int. Orthop*., 1988, vol. 12, no. 3, pp. 201-211.
2. Buijze G.A. Scaphoid fractures: Anatomy, Diagnosis and Treatment: PhD Thesis. Amsterdam: University of Amsterdam. Faculty of Medicine, 2013. 286 p.
3. De Cock J., Mermuys K., Goubau J., Van Petegem S., Houthoofd B., Casselman J.W. Cone-beam computed tomography: a new low dose, high resolution imaging technique of the wrist, presentation of three cases with technique. *Skeletal Radiol*., 2012, vol. 41, no. 1, pp. 93-96. doi: 10.1007/s00256-011-1198-z.
4. Düppe H., Johnell O., Lundborg G., Karlsson M., Redlund-Johnell I. Long-term results of fracture of the scaphoid. A follow-up study of more than thirty years. *J. Bone Joint Surg*., 1994, vol. 76, no. 2, pp. 249-252.

5. Haisman J.M., Rohde R.S., Weiland A.J.; American Academy of Orthopaedic Surgeons. Acute fractures of the scaphoid. *J. Bone Joint Surg. Am*., 2006, vol. 88, no. 12, pp. 2750-2758.
6. Gabl M., Reinhart C., Lutz M., Bodner G., Rudisch A., Hussl H., Pechlaner S. Vascularized bone graft from the iliac crest for the treatment of nonunion of the proximal part of the scaphoid with an avascular fragment. *J. Bone Joint Surg. Am*., 1999, vol. 81, no. 10, pp. 1414-1428.
7. Jones D.B. Jr., Bürger H., Bishop A.T., Shin A.Y. Treatment of scaphoid waist nonunions with an avascular proximal pole and carpal collapse. A comparison of two vascularized bone grafts. *J. Bone Joint Surg. Am*., 2008, vol. 90, no. 12, pp. 2616-2625. doi: 10.2106/JBJS.G.01503.
8. Watson H.K., Ballet F.L. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J. Hand Surg. Am*., 1984, vol. 9, no 3, pp. 358-365.
9. Hudak P.L., Amadio P.C., Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand). The Upper Extremity Collaborative Group (UECG). *Am. J. Ind. Med*., 1996, vol. 29, no. 6, pp. 602-608.
10. Linscheid R.L., Dobyns J.H., Beabout J.W., Bryan R.S. Traumatic instability of the wrist. Diagnosis, classification, and pathomechanics. *J. Bone Joint Surg. Am*., 1972, vol. 54, no. 8, pp. 1612-1632.
11. Youm Y., McMurthy R.Y., Flatt A.E., Gillespie T.E. Kinematics of the wrist. I. An experimental study of radial-ulnar deviation and flexion-extension. *J. Bone Joint Surg. Am*., 1978, vol. 60, no. 4, pp. 423-431.
12. Mulford J.S., Ceulemans L.J., Nam D., Axelrod T.S. Proximal row carpectomy vs four corner fusion for scapholunate (Slac) or scaphoid nonunion advanced collapse (Snac) wrists: a systematic review of outcomes. *J. Hand Surg. Eur. Vol*., 2009, vol. 34, no. 2, pp. 256-263. doi: 10.1177/1753193408100954.
13. Mohr W. Arthrosis deformans. In: Doerr W., Seifert G., eds. Spezielle pathologische Anatomie. Berlin, Heidelberg, Hamburg, New York, Tokyo, Springer-Verlag, 1984, vol. 18/I, pp. 257-372.
14. Strauch R.J. Scapholunate advanced collapse and scaphoid nonunion advanced collapse arthritis – update on evaluation and treatment. *J. Hand Surg. Am*., 2011, vol. 36, no. 4, pp. 729-735. doi: 10.1016/j.jhsa.2011.01.018.
15. Kozin S.H. Incidence, mechanism, and natural history of scaphoid fractures. *Hand Clin*., 2001, vol. 17, no. 4, pp. 515-524.
16. Berdia S., Wolfe S.W. Effects of scaphoid fractures on the biomechanics of the wrist. *Hand Clin*., 2001, vol. 17, no. 4, pp. 533-540.
17. McPhail S.M., Bagraith K.S., Schippers M., Wells P.J., Hatton A. Use of condition-specific patient-reported outcome measures in clinical trials among patients with wrist osteoarthritis: A systematic review. *Adv. Orthop*., 2012, vol. 2012, ID 273421. doi: 10.1155/2012/273421.
18. Vishwanathan K., Hearnden A., Talwalkar S., Hayton M., Murali S.R., Trail I.A. Reproducibility of radiographic classification of scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC) wrist. *J. Hand Surg. Eur. Vol*., 2013, vol. 38, no. 7, pp. 780-787. doi: 10.1177/1753193413484629.
19. Mirić D., Bumbasirević M., Vucković C., Lesić A. Development of degenerative changes in the wrist with pseudarthrosis of the scaphoid bone. *Acta Chir. Iugosl*., 2005, vol. 52, no. 2, pp. 73-76.
20. Pillai A., Jain M. Management of clinical fractures of the scaphoid: results of an audit and literature review. *Eur. J. Emerg. Med*., 2005, vol. 12, no. 2, pp. 47-51.

Received: 03.10.2016

Information about the authors:

1. Valerii V. Grigorovskii, M.D., Ph.D., Professor, SI *Institute of Traumatology and Orthopaedics* of NAMS of Ukraine, Kiev, Ukraine, Department of Pathomorphology
2. Sergei S. Strafun, M.D., Ph.D., Professor, SI *Institute of Traumatology and Orthopaedics* of NAMS of Ukraine, Kiev, Ukraine, Head of the Department of Upper Limb Pathology and Hand Microsurgery
3. Sergei V. Timoshenko, M.D., Ph.D., SI *Institute of Traumatology and Orthopaedics* of NAMS of Ukraine, Kiev, Ukraine, Department of Upper Limb Pathology and Hand Microsurgery