Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 20
ISSUES 1-2
January-February
2007

Wear investigations of tools used in bone surgery

J. Marciniak [a], Z. Paszenda [a,*], M. Kaczmarek [a], J. Szewczenko [a], M. Basiaga [a], M. Gierzyńska-Dolna [b], P. Lacki [b]

[a] Division of Biomedical Engineering, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland

[b] Faculty of the Mechanical engineering and Computer Sciences, Institute of Metal Working, Quality Engineering and Bioengineering, Czestochowa University of Technology, ul. Wita Stwosza 24, 02-661 Czestochowa, Poland

* Corresponding author: E-mail address: zbigniew.paszenda@polsl.pl

Received 26.10.2006; accepted in revised form 15.11.2006

Properties

ABSTRACT

Purpose: The main aim of the work was evaluation of wear rate of surgical drills used in orthopaedic procedures with the use of plate bone stabilizers.

Design/methodology/approach: The authors proposed a wear evaluation methodology of surgical drill edges. The drill wear was evaluated on the basis of measurement of point angle (2 κ) and wear land (VB_B i VB_{Bmax}). The measurements were recorded for preselected number of holes n drilled in a bovine femur. Furthermore, structure investigations and hardness tests of surgical drills were performed.

Findings: The investigations revealed diverse wear of the surgical drills. The main mechanism was the wear of the chamfered corner and chisel edge of the drills.

Research limitations/implications: The improvement of service life of surgical drills can be achieved by the correct selection of heat treatment parameters, ensuring the desired geometry of edge and deposition of layer which ensure the significant increase of cutting edge hardness.

Originality/value: The proposed methodology applied for surgical drills is an effective way of service life estimation. The quality of surgical tools influences the safety and the effectiveness of surgical procedures with the use of plate stabilizers.

Keywords: Mechanical properties; Wear resistance; Tool materials; Heat treatment

1. Introduction

An operational surgical instrumentarium is the special group of medical instruments. That group is characterized by irregular and diverse intensity of use. Furthermore, because of a work in chemically active environment it is necessary to sterilize them after each use. The mentioned working conditions of the surgical instrumentarium determine the selection of material which should ensure reliable utilization. The main group of metallic materials applied in surgical instrumentarium are stainless steels divided into three groups: martensitic, austenitic and ferritic steels [1-7]. The main group of tools used in surgical operations are cutting tools. This group includes one-, two- and multiedge tools. The most frequent used multiedge tools are surgical drills and screw taps. They are mainly used in osteosynthesis procedures [3, 8-15].

Surgical drills belong to multiple-use tools. In clinical practice insufficient service life of drills is often observed. Therefore, the main aim of the work was evaluation of wear with the use of the methodology proposed by the authors.

© Copyright by International OCSCO World Press. All rights reserved. 2007

2. Methods

The investigations were carried out on surgical drills of ø 6 mm diameter and L = 160 mm length commonly used in orthopaedic centers (Fig. 1).

In order to investigate the drills, microsections of the selected regions were prepared (Fig. 2). The etching solution was: 100 ml of ethyl alcohol + 3 g of $FeCl_3$ + 1,5 ml hydrochloric acid. The specimens were observed in the LEICA MEF4A light microscope using the magnification in the range 100 -1000x.

Mechanical properties of the selected surgical instrumentarium were evaluated on the basis of the Vickers hardness test. The test was realized with the use of Wilson-Wolpert 401 MVD hardness tester. The applied loading was 9,81 N.

Fig. 1. Investigated surgical drill

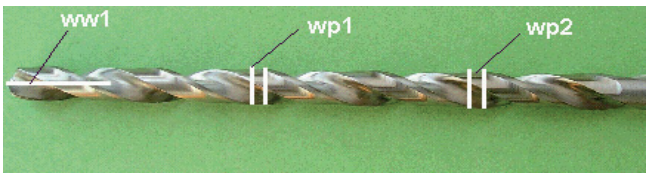


Fig. 2. The surgical drill with marked regions: ww1 – longitudinal microsection, wp1 and wp2 – crosswise microsection

During machining the edge of the tool is mechanically and thermally loaded. It changes properties of the edge and causes losses of the material. Decreasing loss of machining properties of the edge is called a wear. To evaluate the wear grade, indirect and direct indexes are applied.

In the work the wear investigation of the surgical drill used in implantation of the fixation and manipulation system was carried out. The wear grade of the drill was evaluated by the measurement of point angle (2 κ) and wear land (VB_B i VB_{Bmax}) with respect to the initial location of both cutting edges. The measurements were recorded for preselected number of holes n (max. 1000) drilled in a bovine femur with the use of a toolroom microscope. Thickness of the cortical bone was about 10 mm. Furthermore, wear characteristics of the drills were also macroscopically examined.

3. Results

On the basis of the performed investigations it was observed that all tested regions of the surgical drills had the same structure. Metallographic observations revealed the presence of tempered martensite with ferrite mesh both in the surface regions and in the web of the drill (Fig. 3).

Investigations in the edge region of the surgical drill (ww1 – Fig. 2) revealed that the hardness measured along to the cutting edges was in the range 531 HV1÷575 HV1. The measurements carried out on the cross-section of the drill showed that the hardness in the surface region (wp1 and wp2 – Fig. 2) was in the range 517 HV1÷579 HV1.

The measurements of the edge geometry revealed that values of the point angle for the analyzed drills were diverse and were equal 2 κ_1 = 127,5° i 2 κ_2 = 117,5° respectively. After drilling of 1000 holes in the bovine femur the values of the angle decreased and were equal 2 κ_1 = 123,5° i 2 κ_2 = 113° (Table 1).

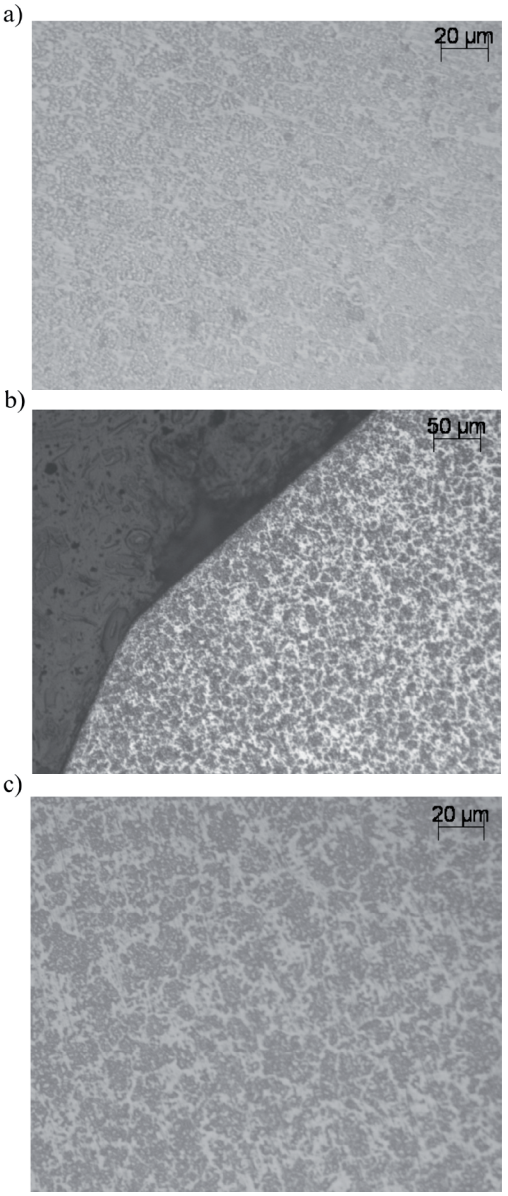
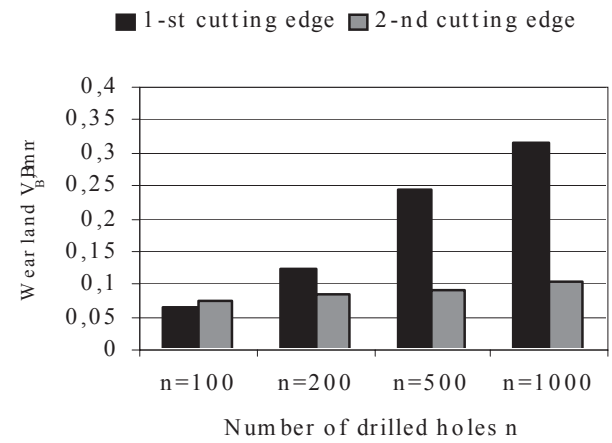


Fig. 3. Tempered martensite with the ferrite mesh in the analyzed regiono of the surgical drill: a, b) ww1 – longitudinal microsection, c) wp 1 – crosswise microsection

Table 1.
Wear grade of the surgical tool

Drill number	Number of the cutting edge	Point angle 2 κ, °		Wear land VB, mm							
		n=0	n=1000	n=100		n=200		n=500		n=1000	
				VB_B	VB_{max}	VB_B	VB_{max}	VB_B	VB_{max}	VB_B	VB_{max}
1	1	127,5°	123,5°	0,065	0,090	0,125	0,195	0,245	0,325	0,315	0,565
	2			0,075	0,115	0,085	0,135	0,090	0,185	0,105	0,295
2	1	117,5°	113°	0,085	0,095	0,095	0,115	0,135	0,135	0,165	0,230
	2			0,080	0,085	0,090	0,120	0,100	0,120	0,115	0,230

a)



b)

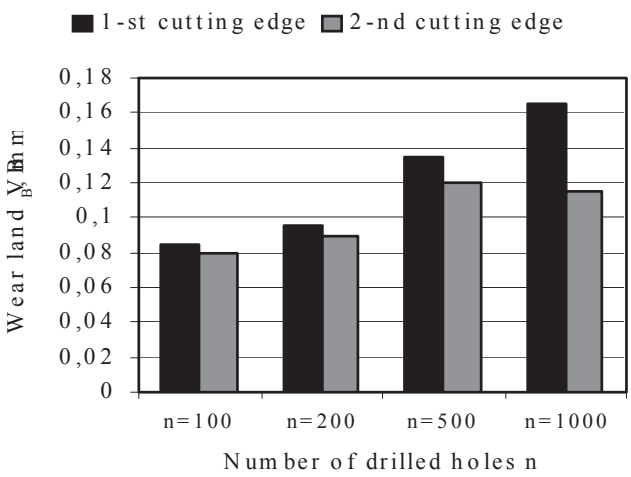


Fig. 4. Results of the wear grade measurements: a – surgical drill no 1, b – surgical drill no 2

The measurements of the wear land revealed that the wear process of the drill nr 1 in the function of drilled holes was diverse on the individual cutting edges. It is proved by diverse values of the analyzed VB_B i VB_{Bmax} parameters. For the drill no 2 the parameters were similar for both cutting edges (Table 1, Fig. 4).

The macroscopic observations allowed to reveal the wear mechanism of the surgical drills. The main mechanism was the wear of the chamfered corner and chisel edge of the drills. Furthermore, on the edge of the 2nd drill after drilling 1000 holes, plastic deformation of the cutting edge were revealed (Fig. 5).

4. Conclusions

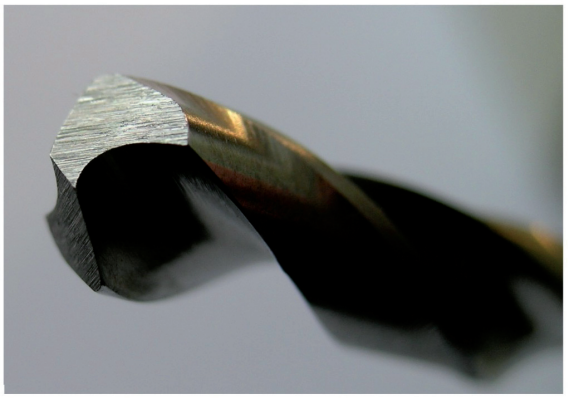
Recently the authors have made an attempt to work out the conditions of forming layers on surfaces of tools used in bone surgery. The aim of the work is an improvement of mechanical properties and wear resistance of tools. The improvement of service life of surgical tools will undoubtedly increase the safety of surgical procedures and reduce costs.

The work presents preliminary investigations on quality of surgical drills commonly used in orthopeadic procedures. The metallographic microscopic observations revealed the unfavorable structure of the investigated tools. The presence of tempered martensite with ferrite mesh indicates incorrect austenitizing parameters – Fig. 3.

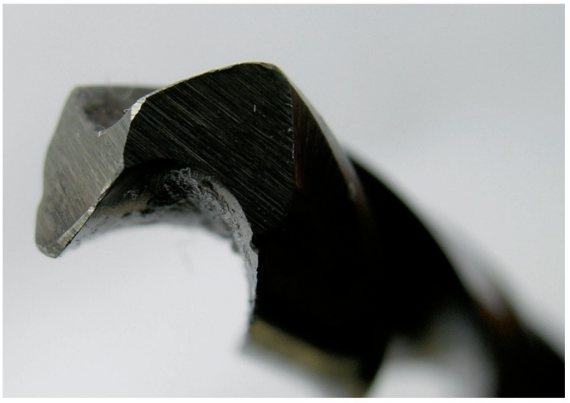
The authors also proposed a wear evaluation methodology of surgical drill edges. The results indicate diverse geometry of the edge of the analyzed tools even in the initial state (point angle – 2 κ). In consequence diverse values of wear land were observed for the preselected number of holes drilled in the bovine femur – Table 1, Fig. 4 and 5.

To sum up it can be stated that the improvement of service life of the analyzed surgical drills can be achieved by the correct selection of heat treatment parameters, ensuring the desired geometry of edge and deposition of layer which ensure the significant increase of cutting edge hardness.

a)



b)



c)

Fig. 5. Cutting edge of surgical drills: a – an initial state, b – cutting edge of the 1st drill after the wear tests, c – cutting edge of the 2nd drill after the wear tests

Acknowledgement

The work was funded by The Ministry of Science as the part of the long-term program "Development of innovation systems in production and utilization 2004-2008".

References

[1] V. Velanovich, Using quality of life instruments to assess surgical outcomes. Surgery 126 1 (1999) 1-4.

[2] A. Kumar, S. Shim, Simulating staffing needs for surgical instrument distribution in hospitals. Journal of Medical Systems, 30 (2006) 363-369.

[3] Z. Paszenda, J. Tyrlik-Held, Surgical instruments. Printing House of the Silesian University of Technology, Gliwice, 2003.

[4] J. Marciniak, Biomaterials. Printing House of the Silesian University of Technology, Gliwice 2002.

[5] J. Marciniak, Metallic biomaterials in S. Blazewicz, L. Stoch, Biocybernetics and biomedical engineering 2000 – Biomaterials-IV. Exit, Warszawa 2003.

[6] J. Marciniak, J. Kaczmarek, Z. Paszenda, J. Szewczenko, J. Tyrlik-Held, Activization of bone union in plate osteosynthesis. Proceedings of the Scientific Conference on the occasion of the 55th Anniversary of the Faculty of Mechanical Engineering „Materials and Mechanical Engineering M^2E'2000", Gliwice, 2000, 313 – 318.

[7] W. Ramotowski, Zespol and Polfix plate stabilizers. Zebra, Krakow 1998.

[8] M. Kaczmarek, J. Marciniak, Biomechanical quality of POLFIX plate stabilizers in multi-level fractures. Acta of Bioengineering and Biomechanics, 4 1 (2002) 783-784.

[9] M. Kaczmarek, J. Marciniak, Biomechanical and clinical evaluation of fixations with the use of the Polfix stabilizer. Medical Review, 59 4 (2002) 38 - 39.

[10] J. Szewczenko, J. Marciniak, Corrosion of steel implants electrically stimulated, Proceeding of the 12th International Scientific Conference „Achievements in Mechanical and Materials Engineering 2003", Gliwice-Zakopane, 2003, 905-910.

[11] M. Kaczmarek, J. Marciniak, Issues of plate osteosynthesis. Proceedings of the 3rd Scientific Conference on Materials, Mechanical and Manufacturing Engineering, Gliwice-Wisla 2005, 325-334.

[12] Z. Paszenda, J. Tyrlik-Held, J. Lelatko, Structure investigations of passive layer on Cr-Ni-Mo implants. Proceedings of the 3rd Scientific Conference on Materials, Mechanical and Manufacturing Engineering, Gliwice-Wisla 2005, 335-340.

[13] M. Kaczmarek, J. Marciniak, J. Szewczenko, A. Ziebowicz, Plate stabilizers in elastic osteosynthesis. Conference CAM3S'2005 "Contemporary Achievements in Mechanics, Manufacturing and Materials Science", Gliwice-Zakopane, 2005, 68-72.

[14] M. Kaczmarek, J. Szewczenko, P. Ociepka, J. Marciniak, Modelling of the Polfix system with the use of finite elements method. Proceedings of the 38th Symposium „Modelling in Mechanics", Wisla, 1999, 171-176.

[15] J. Szewczenko, P. Ociepka, Z. Paszenda, J. Marciniak, Stress and strain analysis of the Polfix system applied in asymmetric two-level fractures. Proceedings of the 15th School of Biomechanics, Biology of Sport 15 8 (1998) 288-292.