Jan MARCINIAK, Zbigniew PASZENDA, Marcin KACZMAREK,
Janusz SZEWCZENKO, Marcin BASIAGA,
Silesian University of Technology, Gliwice
Monika GIERZYŃSKA-DOLNA, Piotr LACKI
Czestochowa University of Technology, Czestochowa

THE QUALITY OF TOOLS USED IN BONE SURGERY

Keywords

Bone surgery, surgical drills, martensitic steels, plate stabilisers, tool wear.

Abstract

This paper presents investigation results of surgical drills used in osteosynthesis procedures realised with the use of plate stabilisers. In particular, structure investigations and hardness tests were performed. Furthermore, a methodology of the wear evaluation of surgical drills was suggested. 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 the selected number of holes n (max. 1000) drilled in a bovine femur.

Introduction

Medical instruments include a very wide range of geometrically and functionally diverse group of products. This group includes both tools and medical devices. An operational surgical instrumentarium is the special group of medical instruments. This group is characterised by an irregular and diverse intensity of use. Furthermore, because of a work in a chemically active environment (body fluids, drugs) it is necessary to sterilise them after each use. The mentioned working conditions of the surgical instrumentarium determine the selection of materials that should ensure reliable utilisation. The main group of metallic materials applied in surgical instrumentarium are stainless steels divided into three groups: martensitic, austenitic and ferritic steels [1–5].

The main group of tools used in surgical operations are cutting tools. This group includes one-, two- and multi-edged tools. The most frequently used multi-edged tools are surgical drills and screw taps. They are mainly used in osteosynthesis procedures [6].

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 theevaluation of wear with the use of the methodology proposed by the authors.

1. Experimental procedure

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

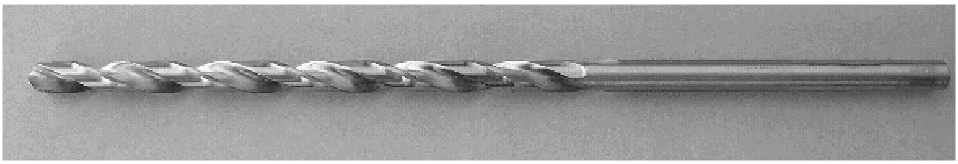


Fig. 1. Investigated surgical drill

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 realised with the use of Wilson-Wolpert 401 MVD hardness tester. The applied loading was 9.81 N.

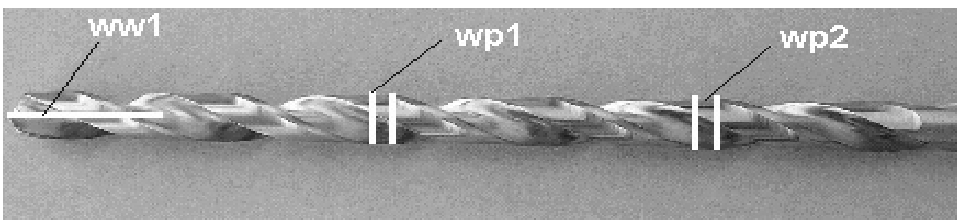


Fig. 2. The surgical drill with marked regions: ww1 – longitudinal microsection, wp 1 and wp2 – crosswise microsection

During machining the edge of the tool is mechanically and thermally loaded. It changes the 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 research, the wear investigation of the surgical drill used in the 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 a selected 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.

2. Results and discussion

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 (longitudinal microsection ww1 – Fig. 2) revealed that the hardness measured along 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 (crosswise microsection wp1 and wp2 – Fig. 2) was in the range 517÷579 HV1.

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

The measurements of the wear land revealed that the wear process of the drill no 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).

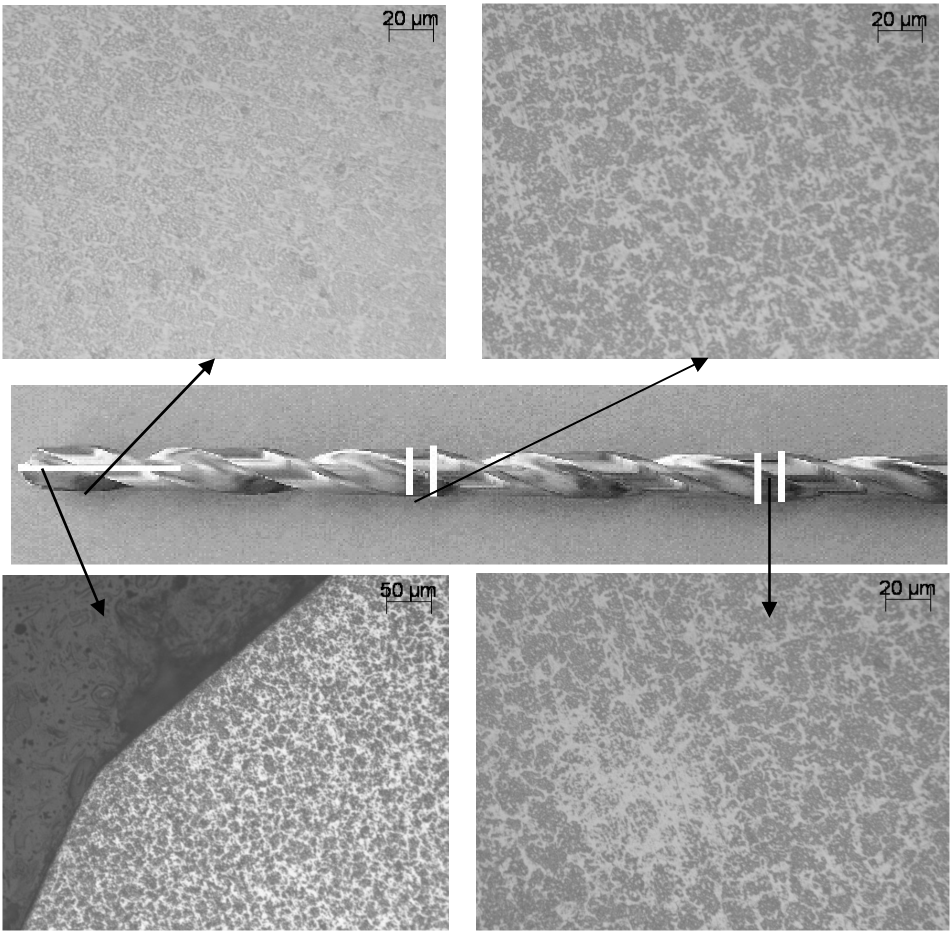
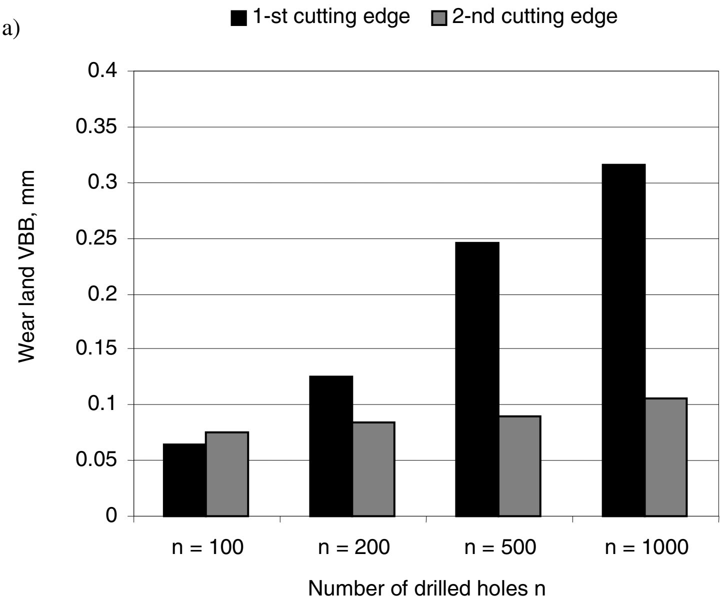


Fig. 3. Tempered martensite with the ferrite mesh in the analysed region of the surgical drill

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)

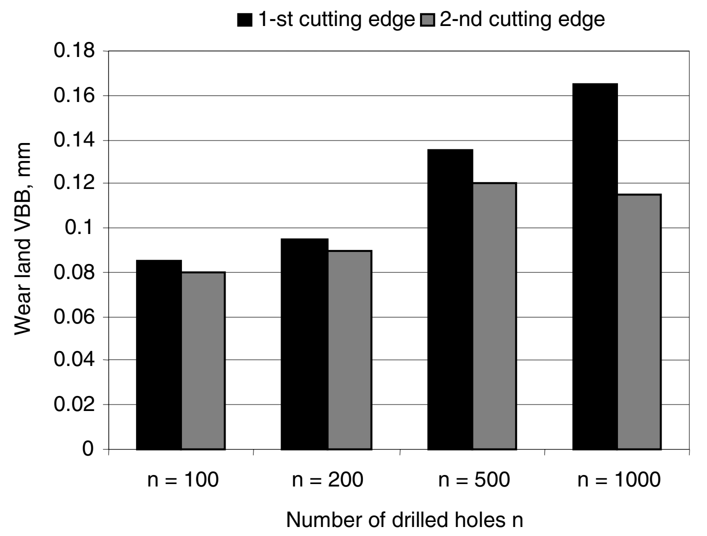
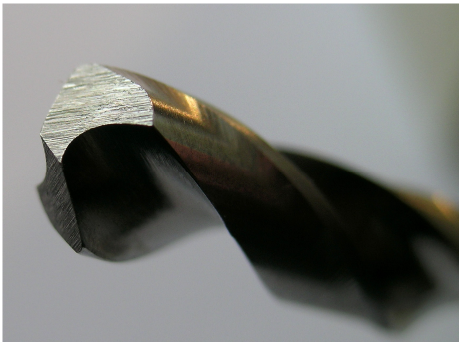


Fig. 4. Results of the wear grade measurements: a – surgical drill nr 1, b – surgical drill nr 2

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 in the mechanical properties and wear resistance of tools. The improvement of the service life of surgical tools will undoubtedly increase the safety of surgical procedures and reduce costs.

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

The work presents preliminary investigations on the quality of surgical drills commonly used in orthopeadic procedures. The metallographic microscopic observations revealed the unfavourable 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 the diverse geometry of the edge of the analysed tools even in the initial state (point angle – 2 κ). In consequence, diverse values of the wear land were observed for the selected 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 analysed surgical drills can be achieved by the correct selection of heat treatment parameters, ensuring the desired geometry of edge and deposition of the layer which ensure the significant increase of cutting edge hardness.

Acknowledgements

Scientific work financed by the Ministry of Science and Higher Education and carried out within the Multi-Year Programme "Development of innovativeness systems of manufacturing and maintenance 2004–2008".

References

1. Velanovich V.: Using quality of life instruments to assess surgical outcomes. Surgery 1999, 126, 1, 1–4.
2. Kumar A., Shim S.: Simulating staffing needs for surgical instrument distribution in hospitals. Journal of Medical Systems, 2006, 30, 363–369.
3. Paszenda Z., Tyrlik-Held J.: Instrumentarium chirurgiczne. Wydawnictwo Politechniki Śląskiej, Gliwice, 2003 (in Polish).
4. Marciniak J.: Biomateriały. Wydawnictwo Politechniki Śląskiej, Gliwice 2002 (in Polish).
5. Marciniak J.: Biomateriały metaliczne. [W:] Błażewicz S., Stoch L. (red.): Biocybernetyka i inżynieria biomedyczna 2000 – Biomateriały. Akademicka Oficyna Wydawnicza Exit, Warszawa, 2003 (in Polish).
6. Ramotowski W.: Stabilizatory płytkowe. Agencja Wydawnicza Zebra, Kraków, 1998 (in Polish).

Recenzent:
Stanisław BŁAŻEWICZ

Badania jakości narzędzi stosowanych w chirurgii kostnej

Słowa kluczowe

Chirurgia kostna, wiertła chirurgiczne, stale martenzytyczne, stabilizatory płytkowe, zużycie narzędzi.

Streszczenie

W pracy przeprowadzono badania jakości wierteł chirurgicznych stosowanych w zabiegach osteosyntezy z wykorzystaniem płytkowych stabilizatorów kostnych. W szczególności przeprowadzono badania struktury i pomiary twardości narzędzi. Dodatkowo zaproponowano metodologię oceny stopnia zużycia wierteł chirurgicznych. Stopień zużycia wiertła oceniano poprzez pomiar wartości kąta wierzchołkowego (2 κ) oraz szerokości starcia na powierzchni przyłożenia (VB_B i VB_{Bmax}). Pomiarów dokonywano kolejno po wywierceniu założonej wstępnie ilości otworów n (max 1000) w wołowej kości udowej.