UDC 616.728.2-089.844-77

Impact of Various Factors on the Polyethylene Wear Rate in Total Hip Arthroplasty

R.M. Tikhilov, M.I. Shubnyakov, A.A. Boyarov, A.O. Denisov, I.I. Shubnyakov

Vreden Russian Research Institute of Traumatology and Orthopedics
8, ul. Akad. Baykova, 195427, St. Petersburg, Russian Federation

Abstract

Purpose of the study — to determine the rate of polyethylene wear in hip arthroplasty depending on various factors and to evaluate a correlation of wear rate and activity level of the patients.

Material and Methods. 467 patients with degenerative pathology of the hip, 322 (35.8%) women and 145 (31.0%) men, were included in the study. Mean age of patients was 55.0 years without statistically significant differences in women and men (p = 0.743). Daily activity level of 167 patients (35.8%) was assessed using pedometer. The authors evaluated prosthesis head displacement in relation to the center of acetabulum and calculated the rate of polyethylene wear in MediCad. Modified Harris Hip Score and VAS parameters were evaluated for all patients. All data was analyzed and statistical processed.

Results. Average level of activity level was more than 1.9 million steps per year. The overall rate of polyethylene wear depended on the follow up period, the Pearson correlation coefficient r = 0.297 (p<0.001). Mean wear rate was 0,16 mm/year (95% CI 0.15–0.17). At the same time wear rate significantly differed in the groups of standard and cross-link polyethylene, namely 0.18 mm/year (95% CI 0.17–0.19) and 0.11 mm/year (95% CI 0.1–0.11) (p<0.001). The authors identified the following additional factors affecting wear rate in the present study: cup inclination angle, r = 0.241 (p = 0.002), and the level of activity level, r = 0.574 (p<0.001). No evident correlation of wear rate to age, r = 0.14 (p = 0.859), and to BMI, r = -0.094 (p = 0.226), was identified, which apparently is due to a strong impact of confounding factors. Patients' satisfaction with treatment outcomes was assessed by VAS score and in average was 91,1 points (95% CI 90.3–91.9). Harris Hip Score parameters improved in average from 36.5 (95% CI 35.1–37.9) up to 91.6 points (95% CI 91.1–92.0).

Conclusion. Out of the multiple factors affecting the polyethylene wear rate only the inclination angle of acetabular component and a higher level of patient activity level have proven to be statistically significant.

Keywords: total hip arthroplasty, polyethylene liner wear, patient activity level.

DOI: 10.21823/2311-2905-2018-24-1-18-28

Competing interests: the authors declare that they have no competing interests.

Funding: the authors have no support or funding to report.

Cite as: Tikhilov R.M., Shubnyakov M.I., Boyarov A.A., Denisov A.O., Shubnyakov I.I. [Impact of Various Factors on the Polyethylene Wear Rate in Total Hip Arthroplasty]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2018;24(1):18-28. (in Russian). DOI: 10.21823/2311-2905-2018-24-1-18-28.

Maxim I. Shubnyakov. 8, ul. Akad. Baykova, 195427, St. Petersburg, Russian Federation;
e-mail: maximtravmatolog@gmail.com

Received: 20.02.2018. Accepted for publication: 03.03.2018.

Introduction

The national and international literature still considers total hip arthroplasty as one the most efficient surgical treatment for patients with severe hip pathologies [1–6] which in combination with a high demand for orthopedic care accounts for constantly growing number of total hip arthroplasy [7, 8]. Long term studies of large patients groups and multiple publications based on the data of major arthroplasty registers confirm the successful function of artificial joints for 10 years in 95–97% of patients and demonstrate high survivorship in follow up over 20–30 years [9–12]. On the one hand such high efficiency allows a wider application of total joint arthroplasty for treatment of young and active patients [13–15], but on the other hand, the key issue of modern hip replacement which determines long term survivorship is the aseptic loosening of components due to osteolysis induced by polyethylene wear particles [16–18]. There are many articles demonstrating a correlation of higher patients' activity with an accelerated wear of polyethylene liner. Thus, due to constantly increasing number of total hip arthroplasties in relatively young patients with a higher life expectancy and, as a rule, with a higher level of activity the risk of early revisions is rising [16, 17, 19]. The boundaries of young age for hip replacement in the specialized literature vary from 50 to 65 years but the overwhelming majority of studies consider exactly 50 years [5, 17, 19–24]. Young patients have a much higher activity level postoperatively resulting in an accelerated wear of bearing surfaces, and multiple studies reveal correlation of wear rate with development of osteolysis, aseptic loosening and revisions rate. Consequently the implants survivorship after total hip arthroplasty in patients of young age is significantly worse than in other age groups [5, 17, 19–24].

In the present paper the authors aimed to answer a set of questions. Which factors impact the polyethylene wear rate? How the polyethylene insert wear rate is related to activity level? Does the activity level of our "young" patients differ from other studies? Does the activity level of the patient after the surgery depend on etiological diagnosis and age?

Material and methods

The our study is based on 467 cases of primary hip arthroplasty performed from 2001 till 2012 in three trauma and orthopaedic departments of our institute. The inclusion criteria were the availability of immediate postoperative X-rays and X-rays at control examination made in compliance with basic requirements for pelvis radiography [26]. The follow up period varied from 5 to 16 years and in the average was 8.5 years (95% CI from 8.3 to 8.6). Medical documentation provided the data on gender and age of patients at the moment of surgery, their height and weight prior to the surgery, Harris Hip Score, blood loss and time of procedures. Etiological diagnosis was established by radiographic analysis taking into account the case history. During X-rays analysis the authors evaluated a range of qualitative criteria and calculated numerical parameters: share and bony structure of acetabulum and femoral head, uniformity of articular gap, Shenton line malalignment, Tönnis angle, femoral head coverage, minimal width of articular gap, relation of femoral head to Kohler line as well as difference in limbs length and position of rotation center of the femoral head. Processing and analysis of x-rays was made in free software Roman V1.7 and OsiriX Lite.

The 322 women (69.0%) and 145 men (31.0%) were available for study. Indication for hip arthroplasty according to X-rays analysis was a terminal stage of primary arthritis in 236 patients (50.5%), AVN in 61 patients (13.1%), dysplastic arthritis in 152 patients (32.5%), posttraumatic arthritis following acetabular fractures in 13 cases (2.8%) and rheumatoid arthritis in 5 cases (Table 1). The authors observed a significant prevalence of women in the group of dysplastic arthritis — 5.3 times higher, and in the group of primary arthritis — 1.9 times higher, an insignificant men prevalence was observed only in the AVN group — 55.7%.

Mean age of patient in the group was 55.0 years (95% CI 53.9 — 56.1) with no statistical difference in men and women, $p = 0.743$. However, the mean age at the moment of surgery varied depending on etiological diagnosis. The highest value of mean age was reported in the group of idiopathic osteoarthritis — 62.1 years, the least value — in patients with posttraumatic arthritis — 37.9 years, $p<0.001$ (Table 2).

Table 1

Gender patient distribution according to diagnosis

Diagnosis	Women		Men		Total	
	n	%	*n*	%	*n*	%
Primary arthritis	154	65.5	82	34.5	236	100.0
Dysplastic arthritis	128	84.2	24	15.8	152	100.0
AVN	27	44.3	34	55.7	61	100.0
Posttraumatic arthritis	8	61.5	5	38,5	13	100.0
Rheumatoid arthritis	5	100	0	0	5	100.0
T o t a l	322	69.0	145	31.0	467	100.0

Table 2

Mean age of patients with various pathologies at the time of surgery, years

Diagnosis	Mean age, 95% CI		*p*	Total
	Women	Men		
Primary arthritis	$_{61.3}62.6_{63.9}$	$_{59.3}61.4_{63.4}$	0.404	$_{61.1}62.1_{63.2}$
Displastic arthritis	$_{46.7}48.4_{50.2}$	$_{47.1}51.5_{55.9}$	0.127	$_{47.3}48.9_{50.5}$
AVN	$_{44.2}48.2_{52.3}$	$_{42.1}45.3_{48.4}$	0.75	$_{44.1}46.5_{49.0}$
Posttraumatic arthritis	$_{29.2}37.4_{45.5}$	$_{19.8}37.4_{54.9}$	0,943	$_{30.7}37.4_{44.1}$
Rheumatoid arthritis	$_{35.5}49.4_{63.3}$	—	—	$_{35.5}49.4_{63.3}$
T o t a l	$_{53.6}54.9_{56.2}$	$_{53.1}55.1_{57.1}$	0.743	$_{53.9}55.0_{56.1}$

All acetabular implants were divided into three groups. The most frequently used cups were Trilogy (Zimmer, Warsaw, IL, USA) — 262 cases (56.1%) and Duraloc (J&J, DePuy, Warsaw, IL, USA) — 120 cases (25.7%). These groups were supplemented by acetabular components: TMT Modular (Zimmer, Warsaw, IL, USA) in 9 cases (1.9%) and Pinnacle (J&J, DePuy, Warsaw, IL, USA) in 9 cases (1.9%) with polyethylene inserts analogous to Trilogy and Duraloc, respectively (Table 3). These two groups were divided into subgroups where inserts of standard UHMW polyethylene and cross-link polyethylene were used, respectively Longevity (Zimmer, Warsaw, IL, USA) and Marathon (J&J, DePuy, Warsaw, IL, USA). Mean age of patients was not significantly different in subgroups of standard polyethylene and cross-link polyethylene, and was 54,1 years (95% CI 52.6–55.5) and 56,5 years (95% CI 54.8–58.1) respectively, $p = 0.061$. Higher age value in cross-link polyethylene subgroup is accounted for by a different approach to selection of bearing surfaces in different surgical department. Third group consisted of various acetabular components by different manufacturers, all with inserts of standard UHMW polyethylene.

Table 3

Implanted acetabular components and polyethylene liners

Acetabular component	Polyethylene		Total *n* (%)
	UHMWPE	Cross-link	
	n (%)	*n* (%)	
Trilogy/TMT Modular	106 (22.7)	165 (35.3)	271 (58.0)
Duraloc/Pinnacle	129 (27.6)	10 (2.2)	139 (29.8)
Other	57 (12.2)	—	57 (12.2)
T o t a l	292 (62.5)	175 (37.5)	467 (100.0)

To evaluate the degree of prosthesis head displacement against the center of acetabulum and consequently to calculate the polyethylene wear rate in MediCad the authors performed scaling of prosthesis head and acetabulum component on AP pelvis x-rays immediately after the surgery and in a late period. The program calculated the wear rate (in mm) per year and during the period from surgery until control x-ray. The program also calculated the angle of insert wear (angle of head displacement against acetabulum and horizontal pelvis axis) (Fig. 1).

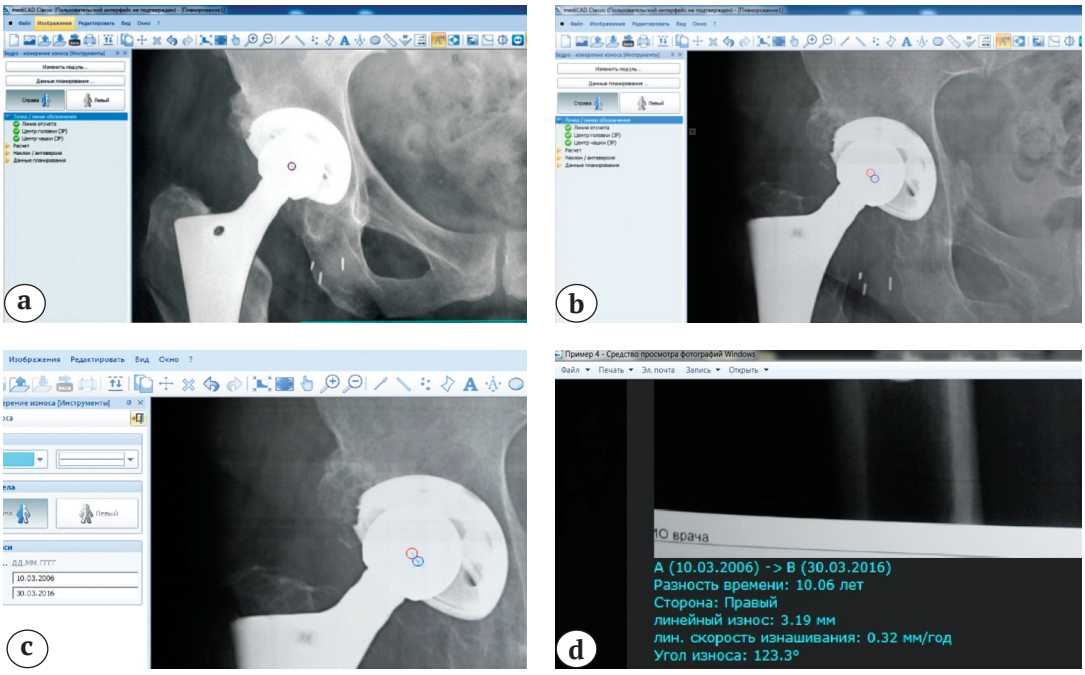

Fig. 1. Estimation of polyethylene insert wear rate:
a — identification of head rotation center relative to acetabular component on X-ray after the surgery;
b — identification of head rotation center relative to acetabular component on X-ray 10 years after the surgery;
c — calculation of linear polyethylene wear;
d — calculation log

To define the activity level impact on liner wear rate in 167 cases (35.8%) the activity level of patients was assessed at control examination in the late follow up period. Evaluation of activity level was made by pedometers (A&D Medical UW-101) where data was continuously registered during 7 days and the average daily parameter was calculated, which is a generally accepted method [22, 23].

Statistical analusis. The obtained statistical data was processed using software IBM SPSS Statistics for iOS (version 24). For mean values a 95% confidence interval was calculated, the median was defined and minimal and maximum values in the data series was demonstrated. Numeric parameters in groups and subgroups were compared by Mann-Whitney U-test and ANOVA Module. Matching of frequency characteristic of numeric criteria was done by non-parametric methods χ^2. A correlation analysis was made using Spearman and Pearson coefficients. Differences were considered statistically significant at $p<0.05$.

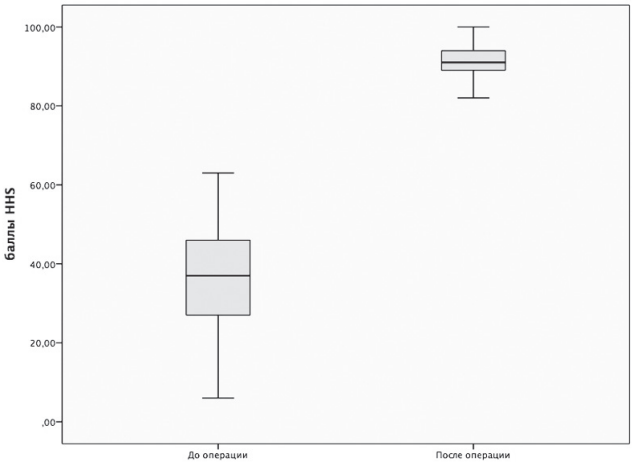

Fig. 2. Harris Hip Score results prior to and after hip replacement ($p<0.001$)

Results

Overall outcomes of hip arthroplasty in the study group were quite favourable. Patients' satisfaction with surgery outcomes by VAS at midterm follow up of 8.5 years averaged 91.1 points (95% CI 90.3–91.9). Harris Hip Score improved in the average from 36.5 points (95% CI 35.1–37.9) up to 91.6 points (95% CI 91.1–92.0) (Fig. 2).

In patients with all types of hip pathology the statistically significant improvement Harris Hip Score was observed ($p<0.001$). The lowest parameters prior as well as after the surgery were obtained in patients with rheumatoid arthritis, the best outcomes were obtained in the group of patients with dysplastic arthritis, however no statistically significant difference was reported between the groups (Table 4).

Table 4

Change of functional status by Harris Hip Score in the patients with various pathologies, scores

Diagnosis	HHS mean values with 95% CI		*p*
	Prior to surgery	After surgery	
Primary arthritis	$_{33,6}35,7_{37,9}$	$_{91,2}91,9_{92,6}$	<0,001
Dysplastic arthritis	$_{34,2}37,1_{40,0}$	$_{91,0}92,0_{93,0}$	<0,001
AVN	$_{35,4}38,3_{41,2}$	$_{90,0}90,9_{91,8}$	<0,001
Posttraumatic arthritis	$_{27,4}33,7_{40,0}$	$_{88,9}91,0_{93,1}$	<0,001
Rheumatoid arthritis	$_{26,3}33,2_{40,2}$	$_{86,5}89,5_{92,5}$	<0,001
T o t a l	$_{35,1}36,5_{37,9}$	$_{91,1}91,6_{92,0}$	<0,001

In accordance with improved Harris Hip Score after surgery the average motor activity of patients at examination within 5 to 16 years follow up (average of 8.5 years) was 5224.3 steps per day (95% CI 5022,3–5426,4) meaning around 1.9 million steps per year. Variability of motor activity was rather high and practically was not related to age, Pearson correlation coefficient was r = -0.123, p = 0.158, due to a big number of active patients in the older age group. Non the less in the patients group below 50 years the mean value of motor activity was 5838.9 steps per day (95% CI 5608.3–6069.5), in the patients group older 50 years — 4997.6 steps per year (95% CI 4774.4–5220.8), p<0.001, meaning 2.1 million and 1.8 million steps per year, respectively.

Activity level was slightly varying in patients groups with different etiological diagnosis. Patients with posttraumatic arthritis demonstrated statistically less steps number, p = 0.005. Daily steps number in patients with osteoarthritis was 5717.9 (95% CI 5467.2–5968.6), with AVN — 5214.4 (95% CI 4701.7–5727.2), with dysplastic arthritis — 5846.3 (95% CI 5346.0–6346.6), with posttraumatic arthritis — 4797.2 (95% CI 3781.3–5813.1) and with rheumatoid arthritis — 5253,0 (95% CI 4081.0–6425.0) (Fig. 3).

Overall wear of polyethylene insert depended on follow up period, Pearson correlation coefficient was r = 0.297, p<0.001. Average wear rate was 0.16 mm/year (95% CI 0.15–0.17), wear rate was statistically varying in groups with UHMWPE and cross-link polyethylene and was 0,18 mm/year (95% CI 0.17–0.19) and 0.11 mm/year (95% CI 0.1–0.11), p<0.001 (Table 5). At the same time in both groups, with UHMWPE and cross-link polyethylene, the authors reported significant value variances depending on many factors including manufacturing company.

The additional factors in the present study that impacted the wear rate of PE liner were the acetabular component inclination, r = 0.241 (p = 0.002), and level of activity, r = 0.574 (p<0.001). There was no evident relation of wear rate with age, r = 0.14 (p = 0.859), or with BMI, r = -0.094 (p = 0.226), which is apparently due to a strong influence of confounding factors.

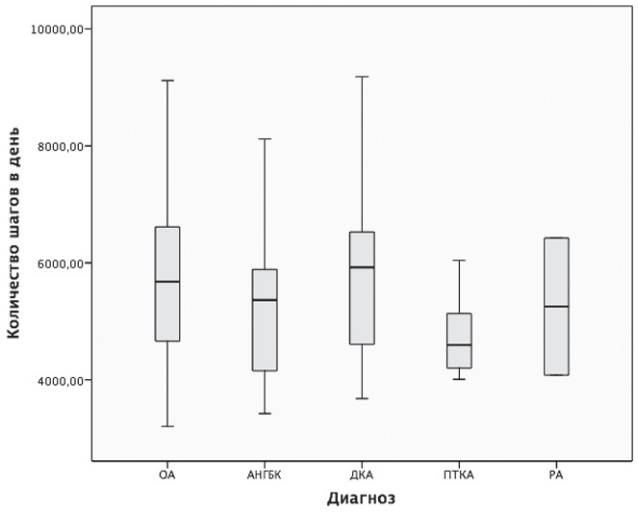

Fig. 3. Average steps number in patients with different pathologies

Table 5

Polyethylene wear rate of by manufacturer, mm/year

Acetabular component	Polyethylene		p	Total
	UHMWPE	Cross-link		
Trilogy/TMT Modular	$_{0.16}0.17_{0.18}$	$_{0.09}0.10_{0.11}$	<0.001	$_{0.12}0.13_{0.14}$
Duraloc/Pinnacle	$_{0.19}0.21_{0.22}$	$_{0.11}0.15_{0.19}$	0.009	$_{0.19}0.20_{0.22}$
Other	$_{0.16}0.18_{0.2}$	—	—	$_{0.16}0.18_{0.2}$
Average	$_{0.17}0.18_{0.19}$	$_{0.1}0.11_{0.11}$	<0.001	$_{0.15}0.16_{0.17}$

Discussion

Up to now the key cause of revision is the aseptic loosening due to osteolysis [28, 30]. Osteolysis can develop in response to any products discharged during prosthesis functioning — polyethylene wear particles, metal debris, metal ions released during fretting corrosion of modular couplings [30, 31]. However the polyethylene insert wear remains the most frequent reason for osteolysis while polyethylene is the major material used in total arthroplasty. Particularly in the US polyethylene is used in 76% of all implanted artificial hip joints [7], and in Russia more than 98% of all prostheses have polyethylene liner [8].

It is well known that osteolysis severity depends on the wear particles number and, accordingly, the more is the insert wear the earlier revision will be required [16, 27, 29, 30]. In turn, the wear rate of PE liner used in hip prosthesis depends on multiple factors, but in the first place of material resistance to wear and conditions for prosthesis functioning [16, 30]. In particular, literature demonstrates that use of cross-link polyethylene allows to decrease wear rate 4–9 times as compared to UHMWPE [18, 33–35]. However, in the present study the authors did not observe such significant variance in wear rate between standard and cross-link polyethylene, at the same time polyethylene of various manufacturers behaved completely different. The least wear rate in the present series was reported for Zimmer polyethylene (Warsaw, IL, USA), and cross-link polyethylene was 1,7 times more resistant to abrasion than Zimmer standard polyethylene. The highest wear rate was reported for standard polyethylene in prostheses manufactured by J&J DePuy (Warsaw, IL, USA), but at the same time J&J DePuy cross-link polyethylene was 1.4 times more resistant to abrasion which considerably contradicts the data of other authors. It's difficult to judge on reasons for such controversial data. The authors can suggest that absence of wear measurement by stereoroentgenometric analysis is a limitation of the current study, but at the same time the conditions of wear measurements were similar for all polyethylene types, and rather large case series can guarantee a real difference between the manufacturers as well as between standard and cross-link polyethylene. Besides, the wear rate of standard polyethylene observed in the present study approximates the values published in many papers or is slightly below [18, 34, 35].

It is not surprising that polyethylene from various manufacturers has different properties of wear resistance in conditions of long term functioning of friction unit. Such names as "polyethylene of ultra-high molecular weight" or "cross-link polyethylene" are no more than general definitions of materials largely variable in their physical properties (molecule mass and correlation of crystalline and amorphous phases), production technology (radiation dose, thermal treatment, additions of antioxidants, etc) and terms of finishing treatment [6]. It can't be excluded that even for known brand products the terms of production change in time which can significantly influence final properties of the finished orthopaedic device not only in respect of abrasion resistance but also extent of aggressiveness of wear particles to periprosthetic tissues. Surgical technique can also have a certain impact of prosthesis function — scratches on the metal head, third-body particles intrusion into the bearing clearance or malpositioning of components can disastrously increase the wear rate [16].

An important result of the present study is the understanding of a direct correlation between the wear rate of bearing surfaces and activity level of the patients, which exceeds minimally twice the figure of 1 million steps per year reported in the 1990s [30]. Accordingly, all prostheses that underwent tribology testing for 20 million cycles are designated for guaranteed 10 years survival, and if patient exceeds average values of motor activity the prosthesis can survive only for 5–7 years. The authors conducted an epidemiological study based on the hip joint register to find out that average age of our patients was only 58 years, which is 10–12 years less than in registers of European countries [8]. Motor activity of our patients corresponds to mean parameters from foreign publications. Consequently, it is necessary to take measures to increase the use of alternative bearing surfaces in total hip arthroplasty in Russian, since up to now almost half of implanted prostheses have a metal-standard polyethylene bearings [8]. The studies conducted by other authors demonstrate that in long term perspective ceramic-ceramic

and ceramic-crosslink polyethylene bearings are advantageous for hip arthroplasty outcomes in young patients [6, 7, 17, 25, 36–38]. However, we need to consider not only the age of operated patients but the etiology of disease — the more pronounced are anatomical and functional alterations in the joint the higher are the changes that patient will not be excessively active after the surgery, and vice versa, good functional status of the patient can predict high activity after joint replacement. The most important in selection of prosthesis is a thorough evaluation of motor activity of the patient prior to surgery, while in preceding prospective studies the authors have proven a high correlation of preoperative and postoperative motor capacity [19]. Besides, the active patients achieve the average motor activity much faster and preserve it for many years.

Thus, based on the present study we can state that polyethylene wear in hip total arthroplasty is a multifactorial process, and any cohort of patients is highly heterogeneous in terms of age and gender, motor activity, body mass index, types of implanted prostheses, bearing surfaces, surgical technique specifics, implant malposition rate. Respectively even long term follow up of large group of patients with a meticulous analysis of long term outcomes does not always solve the issues while the trends for prostheses type selection and production technologies are changing in time, new materials are being developed which might pose new threats, or as Erwin Morscher said "Innovations can solve the problems but often they create new ones" [39]. Apart from above we can't exclude the individual reaction to wear particles manifesting in a greater osteolythic response of surrounding bone in some cases. That's why for choosing a joint prosthesis for young and active patients we should be guided by the whole range of available knowledge, utilize the time-proven technologies and carefully monitor in dynamics the changes in periprosthetic tissues to avoid irreversible consequences of an incorrect choice.

References

1. Murylev V.Ju., Elizarov P.M., Rukin Ya.A., Rubin G.G., Kukovenko G.A. [Endoprosthetics of the hip joint as an opportunity to improve the quality of life of elderly patients with a false neck of the femoral neck]. *Uspehi gerontologii* [Successes in Gerontology]. 2017;30(5):725-732. (in Russian).

2. Aladyshev N.A., Ezhov I.Yu. [The use of short femoral components in hip arthroplasty]. *Politravma* [Polytrauma]. 2017;(4):76-83. (in Russian).

3. Kibitkin A.S., Ksenofontov M.A., Kosmynin D.A., Abdullaev A.K. [Experimental substantiation of the advantages of a pyrolytic friction pair in hip joint endoprosthetics]. *Vestnik Penzenskogo gosudarstvennogo universiteta* [Bulletin of Penza State University]. 2017;1(17):17-21. (in Russian).

4. Loskutov O.A., Naumenko N.E., Loskutov A.E., Sinegubov D.A., Gorobec D.V., Furmanova K.S. [Evaluation of the primary stability of the pressed and screwed-in acetabular components in hip joint endoprosthetics]. *Ortopedija, travmatologija i protezirovanie* [Orthopedics, Traumatology and Prosthetics]. 2017;(1):92-97. (in Russian).

5. Martin J.R., Jennings J.M., Watters T.S., Levy D.L., Miner T.M., Dennis D.A. Midterm prospective comparative analysis of 2 hard-on-hard bearing total hip arthroplasty designs. *J Arthroplasty.* 2018 Jan 31. pii: S0883-5403(18)30056-1.
DOI: 10.1016/j.arth.2018.01.019. [Epub ahead of print].

6. Lachiewicz P.F., Kleeman L.T., Seyler T. Bearing surfaces for total hip arthroplasty. *J Am Acad Orthop Surg.* 2018;15;26(2):45-57.
DOI: 10.5435/JAAOS-D-15-00754.

7. Heckmann N.D., Sivasundaram L., Stefl M.D., Kang H.P., Basler E.T., Lieberman J.R. Total hip arthroplasty bearing surface trends in the united states from 2007 to 2014: the rise of ceramic on polyethylene. *J Arthroplasty.* 2018 Jan 9. pii: S0883-5403(18)30002-0.
DOI: 10.1016/j.arth.2017.12.040. [Epub ahead of print].

8. Shubnyakov I.I., Tikhilov R.M., Nikolaev N.S., Grigoricheva L.G., Ovsyankin A.V., Cherny A.Z., Drozdova P.V., Denisov A.O., Veber E.V., Kuz'mina I.V. Epidemiology of primary hip arthroplasty: report from register of Vreden Russian Research Institute of Traumatology and Orthopedics. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2017;23(2):81-101. (in Russian). DOI:10.21823/2311-2905-2017-23-2-81-101.

9. Hoskins W., van Bavel D., Lorimer M., de Steiger R.N. Polished cemented femoral stems have a lower rate

of revision than matt finished cemented stems in total hip arthroplasty: an analysis of 96,315 cemented femoral stems. *J Arthroplasty*. 2017 Dec 13. pii: S0883-5403(17)31090-2. DOI: 10.1016/j.arth.2017.12.002. [Epub ahead of print].

10. Petsatodis G.E., Papadopoulos P.P., Papavasiliou K.A., Hatzokos I.G., Agathangelidis F.G., Christodoulou A.G. Primary cementless total hip arthroplasty with an alumina ceramic-on-ceramic bearing: results after a minimum of twenty years of follow-up. *J Bone Joint Surg Am*. 2010;92(3):639-644. DOI: 10.2106/JBJS.H.01829.

11. Stefl M.D., Callaghan J.J., Liu S.S., Pedersen D.R., Goetz D.D., Johnston R.C. Primary cementless acetabular fixation at a minimum of twenty years of follow-up: a concise update of a previous report. *J Bone Joint Surg Am*. 2012;94(3):234-239. DOI: 10.2106/JBJS.K.00237.

12. Warth L.C., Callaghan J.J., Liu S.S., Klaassen A.L., Goetz D.D., Johnston R.C. Thirty-five-year results after Charnley total hip arthroplasty in patients less than fifty years old. A concise follow-up of previous reports. *J Bone Joint Surg Am*. 2014;96(21):1814-1819. DOI: 10.2106/JBJS.M.01573.

13. Hrypov S.V., Krasavina D.A., Veselov A.G. [Endoprosthetics of the hip joint in the treatment of secondary coxarthrosis of various genesis in older children]. *Pediatr* [Pediatrician]. 2017;8(S):347. (in Russian).

14. Kozlov A.S., Kuzin A.S., Makhrov L.A., Moiseev S.N., Trubin I.V. [Endoprosthetics of the Hip Joint in Children and Adolescents]. *Moskovskaya medisina* [Moscow Medicine]. 2016;S1(12):129-130. (in Russian).

15. Van de Velde S.K., Loh B., Donnan L. Total hip arthroplasty in patients 16 years of age or younger. *J Child Orthop*. 2017;11(6):428-433. DOI: 10.1302/1863-2548.11.170085.

16. Shubnyakov I.I., Tikhilov R.M., Goncharov M.Y., Karpukhin A.S., Mazurenko A.V., Pliev D.G., Bliznyukov V.V. [Merits and demerits of modern bearing surfaces of hip implants (review of foreign literature)]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2010;(3):147-156. (in Russian). DOI:10.21823/2311-2905-2010-0-3-147-156.

17. Atrey A., Ward S.E., Khoshbin A., Hussain N., Bogoch E., Schemitsch E.H., Waddell J.P. Ten-year follow-up study of three alternative bearing surfaces used in total hip arthroplasty in young patients: a prospective randomised controlled trial. *Bone Joint J*. 2017;99-B(12):1590-1595. DOI: 10.1302/0301-620X.99B12.BJJ-2017-0353.R1.

18. Devane P.A., Horne J.G., Ashmore A., Mutimer J., Kim W., Stanley J. Highly cross-linked polyethylene reduces wear and revision rates in total hip arthroplasty: A 10-year double-blinded randomized controlled trial. *J Bone Joint Surg Am*. 2017;99(20):1703-1714. DOI: 10.2106/JBJS.16.00878.

19. Tikhilov R.M., Shubnyakov M.I., Shubnyakov I.I., Sivkov V.S., Malygin R.V., Tsybin A.V., Lyubchak V.V. [Motor activity of young patients after total hip arthroplasty]. *Sovremennye problemy nauki i obrazovaniya* [Modern Problems of Science and Education]. 2018;(1):66. (in Russian).

20. Liang T.J., You M.Z., Xing P.F., Bin S., Ke Z.Z., Jing Y. Uncemented total hip arthroplasty in patients younger than 50 years: a 6- to 10-year follow-up study. *Orthopedics*. 2010;33(4). DOI: 10.3928/01477447-20100225-18.

21. Martin C.T., Callaghan J.J., Gao Y., Pugely A.J., Liu S.S., Warth L.C., Goetz D.D. What can we learn from 20-year followup studies of hip replacement? *Clin Orthop Relat Res*. 2016;474(2):402-407. DOI: 10.1007/s11999-015-4260-7.

22. Kuhn M., Harris-Hayes M., Steger-May K., Pashos G., Clohisy J.C. Total hip arthroplasty in patients 50 years or less: do we improve activity profiles? *J Arthroplasty*. 2013;28(5):872-876. DOI: 10.1016/j.arth.2012.10.009.

23. Sechriest V.F. 2nd, Kyle R.F., Marek D.J., Spates J.D., Saleh K.J., Kuskowski M. Activity level in young patients with primary total hip arthroplasty: a 5-year minimum follow-up. *J Arthroplasty*. 2007;22(1):39-47. DOI: 10.1016/j.arth.2006.02.083.

24. Greiner J.J., Callaghan J.J., Bedard N.A., Liu S.S., Gao Y., Goetz D.D. Fixation and wear with contemporary acetabular components and cross-linked polyethylene at 10-years in patients aged 50 and under. *J Arthroplasty*. 2015;30(9):1577-1585. DOI: 10.1016/j.arth.2015.05.011.

25. Cash D.J., Khanduja V. The case for ceramic-on-polyethylene as the preferred bearing for a young adult hip replacement. *Hip Int.* 2014;24(5):421-427. DOI: 10.5301/hipint.5000138.

26 Tikhilov R.M., Shubnyakov I.I., Pliev D.G., Bogopol'skii O.E., Guatsaev M.S. [Possibilities of radiography in the early diagnosis of hip joint pathology]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics in Russia]. 2017;23(1):117-131. (in Russian). DOI:10.21823/2311-2905-2017-23-1-117-131.

27. Gallo J., Slouf M., Goodman S.B. The relationship of polyethylene wear to particle size, distribution, and number: A possible factor explaining the risk of osteolysis after hip arthroplasty. *J Biomed Mater Res B Appl Biomater.* 2010;94(1):171-177. DOI: 10.1002/jbm.b.31638.

28. Kinkel S., Wollmerstedt N., Kleinhans J.A., Hendrich C., Heisel C. Patient activity after total hip arthroplasty declines with advancing age. *Clin Orthop Relat Res.* 2009;467(8):2053-2058. DOI: 10.1007/s11999-009-0756-3.

29. Pokorný D., Slouf M., Veselý F., Fulín P., Jahoda D., Sosna A. Distribution of UHMWPE wear particles in periprosthetic tissues of total hip replacements. *Acta Chir Orthop Traumatol Cech.* 2010;77(2):87-92.

30. Schmalzried T.P., Shepherd E.F., Dorey F.J., Jackson W.O., dela Rosa M., Fa'vae F. et al. Wear is a function of use, not time. *Clin Orthop Relat Res.* 2000;(381):36-46.

31. Jiang H., Wang Y., Deng Z., Jin J., Meng J., Chen S. et al. Construction and evaluation of a murine calvarial osteolysis model by exposure to cocrmo particles in aseptic loosening. *J Vis Exp.* 2018;(132). DOI: 10.3791/56276.

32. Gaudiani M.A., White P.B., Ghazi N., Ranawat A.S., Ranawat C.S. Wear rates with large metal and ceramic heads on a second generation highly cross-linked polyethylene at mean 6-year follow-up. *J Arthroplasty.* 2018;33(2):590-594. DOI: 10.1016/j.arth.2017.09.006.

33. Samujh C., Bhimani S., Smith L., Malkani A.L. Wear analysis of second-generation highly cross-linked polyethylene in primary total hip arthroplasty. *Orthopedics.* 2016;39(6):e1178-e1182. DOI: 10.3928/01477447-20160808-02.

34. Choi W.K., Kim J.J., Cho M.R. Results of total hip arthroplasty with 36-mm metallic femoral heads on 1st generation highly cross linked polyethylene as a bearing surface in less than forty year-old patients: minimum ten-year results. *Hip Pelvis.* 2017;29(4):223-227. DOI: 10.5371/hp.2017.29.4.223.

35. Hopper R.H. Jr, Ho H., Sritulanondha S., Williams A.C., Engh C.A. Jr. Otto Aufranc Award: crosslinking reduces THA wear, osteolysis, and revision rates at 15-year followup compared with noncrosslinked polyethylene. *Clin Orthop Relat Res.* 2018;476(2):279-290. DOI: 10.1007/s11999.0000000000000036.

36. Turakhodzhaev F.A., Magomedov Kh.M., Kalashnikov S.A., Zagorodnii N.V. [Total hip artroplasty using a pair of friction ceramic-cross-linked polyethylene observation period of 10 years]. *Vestnik Rossijskogo nauchnogo centra rentgenoradiologii Minzdrava Rossii* [Bulletin of the Russian Scientific Center of Roentgenoradiology of the Ministry of Health of Russia]. 2016;16(3):5. (in Russian).

37. Morrison T.A., Moore R.D., Meng J., Rimnac C.M., Kraay M.J. No difference in conventional polyethylene wear between yttria-stabilized zirconia and cobalt-chromium-molybdenum femoral heads at 10 years. *HSS J.* 2018;14(1):60-66. DOI: 10.1007/s11420-017-9579-z.

38. Hernigou P., Roubineau F., Bouthors C., Flouzat-Lachaniette C.H. What every surgeon should know about Ceramic-on-Ceramic bearings in young patients. *EFFORT Open Rev.* 2017;1(4):107-111. DOI: 10.1302/2058-5241.1.000027.

39. Morscher E.W. Failures and successes in total hip replacement — why good ideas may not work. *Scand J Surg.* 2003;92(2):113-20. DOI: 10.1177/145749690309200202.

INFORMATION ABOUT AUTHORS:

Rashid M. Tikhilov — Dr. Sci. (Med.), Professor, Director of Vreden Russian Research Institute of Traumatology and Orthopedics; professor of Mechnikov North-Western State Medical University, St. Petersburg, Russian Federation

Maxim I. Shubnyakov — Researcher, Hip Pathology Department of Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation

Andrei A. Boyarov — Researcher, Hip Pathology Department of Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation

Alexei O. Denisov – Cand. Sci. (Med), Academic Secretary, Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation

Igor I. Shubnyakov — Dr. Sci. (Med.), Chief Researcher, Vreden Russian Research Institute of Traumotology and Orthopedics, St. Petersburg, Russian Federation