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Research Article

Theoretical Justification and Practical Application of the Modified Approach to the Coxofemoral Joint Acetabular Component Endoprosthesis Cement Reinforcing

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ABSTRACT.
In order to increase durability of the cement acetabular component of an coxofemoral joint endoprosthesis the theoretical justification for the expediency of forming in acetabular hollow of only two blind openings localized only in its tectum, strictly at an angle 90 ^{0}is proven. Creation of such openings should be supplemented with a two-moment pressurization of bone cement that has to increase durability of reinforcing the acetabular component. Such decision found practical confirmation during the randomized, open, comparative, and controlled in parallel groups' research on studying the remote results of total cement endoprosthesis replacement of a coxofemoral joint. In the analysis of 1075 surgical interventions it is revealed that application of technical approach with use of the mentioned decision allowed reducing the frequency of auditing endoprosthesis replacement with replacement of acetabular component from 16,4% to 4,4% (P -0,001).

Keywords: endoprosthesis replacement, coxofemoral joint, acetabular component, bone cement, aseptic instability

INTRODUCTION.

One of the most significant problems of cement endoprosthesis replacement of the large joints is the aseptic instability of endoprosthesis components quite often developing after the operation. In relation to a coxofemoral joint this complication is especially significant for an acetabular component. Its aseptic instability takes place twice more often than that of the femoral component [1, 2, 3, 4, 5]. Durability of acetabular component is increased by use of various versions of the operational equipment due to different approaches to the bone cement use [6].

Property of the blind openings formed in a tectum of acetabular hollow to provide more expressed coupling of a cement coat with a bone was initially described G.Russotti et al. and H.Malchau et al. (L. B. Reznik, 2006) [7]. In practice we usually create five to ten similar openings. After that bone cement is pressed and rubbed in these openings a one-stage pressurization takes place [8, 9, 10].

At primary endoprosthesis replacement it is always necessary to consider that the repeated operation made concerning aseptic shaking of acetabular component practically always involves deepening and expansion of acetabular hollow, as well as forming new blind openings that accompanied by inevitable dredging of a bone tissue [11, 12, 13]. Therefore on a case of auditing endoprosthesis replacement for such patients it is important to have peculiar "reserve" of a bone tissue due to initial creation of the smaller number of blind openings [14, 15].

In this regard studying clinical efficiency of small number of the openings formed only in the most loaded zone of acetabular hollow - in the thickness of an iliac bone is expedient. According to J.DeLee and J.Charnly it is a zone I [16]. Expediency of combining such openings with double pressurization of bone cement since the two-stage "pressing" impact on cement weight raises a penetration of bone cement in a bone tissue is also obvious [6].

Research objective – is to increase durability of a cement acetabular component of a coxofemoral joint endoprosthesis due to creation only of two blind openings in a tectum of acetabular hollow and the subsequent double pressurization of the bone cement.

MATERIALS AND METHODS.

The current research method was made by clinical observations of 981 patients, treated in orthopedic office No. 1 of GBUZ Samarskaya regional clinical hospital of V. D. Seredavin during the period from 1996 to 2016. Due to the diseases of a coxofemoral joint the only option available is cement endoprosthesis replacement. 887 people had the affected joint replaced by artificial on one side, and 94 – on both sides. The total number of operations equaled to 1075 surgical interventions. All patients had endoprosthesis with couple of friction "metal-polyethylene" established. On viscosity degree bone cement was medium-viscosity.

Operations for all patients were carried out using endotracheal anesthesia or epidural anesthesia, front and side access, position on the back. After opening the capsule of a coxofemoral joint the acetabular hollow was processed classically: deleting soft tissues and the remains of a cartilage.

Further the maintenance of a surgical grant provided consecutive performance of the standard manipulations pursuing the purpose of creating the strongest contact of bone cement both with a wall of acetabular hollow, and with acetabular component of an endoprosthesis. It was promoted by preliminary forming blind openings in a wall of acetabular hollow and an intraoperative pressurization of cement weight. However the technology of implementing these stages of surgical intervention differed. On the basis of technology distinction all treated patients were randomly (method of the sealed envelopes) distributed on three clinical groups (Tab. 1).

Table 1: Distribution of patients and the operations on groups

Clinical groups	Patient quantity (operations)	
	n	%
First	333 (364)	33,9 (33,8)
Second	322 (352)	32,8 (32,7)
Third	326 (359)	33,3 (33,5)
Total	981 (1075)	100 (100)

First group patients were operated as follows: in a wall of acetabular hollow in any order a drill with a diameter of 6 mm formed six blind openings of 8 mm in depth. After that one dose of not stiffened cement weight was placed, pressed in acetabular hollow and rubbed in a wall of acetabular hollow. The acetabular component of an endoprosthesis was entered covered with a thin layer of cement into the acetabular hollow prepared thus, at an inclination angle of 45 ^{0} and an anteversion angle of 15 ^{0}. The material was slightly pressed and held with the standard positioning device. This is the essence of a one-stage pressurization technique for bone cement.

The second group patients were treated as follows: after forming similar six blind openings the pressurization of bone cement was carried out double-stage. Unstiffened cement weight was entered into acetabular hollow, volume about a half of a mixed standard dose. Then by means of several gauze napkins enclosed in a rubber medical glove, this cement weight was subjected to the expressed pressure within two minutes. It was the first moment of pressurization. Then in acetabular hollow the implanted acetabular component was installed, previously covered with the remained half of cement weight. It was given necessary position and by means of pressurization with the standard positioning device the second moment of pressurization was carried out.

The aspiration to increase efficiency of cement fixing for acetabular component of an endoprosthesis formed the basis of the research we conducted; the ultimate goal was introducing the optimization of the operation stages considered above. For this purpose we tried to answer three key questions:

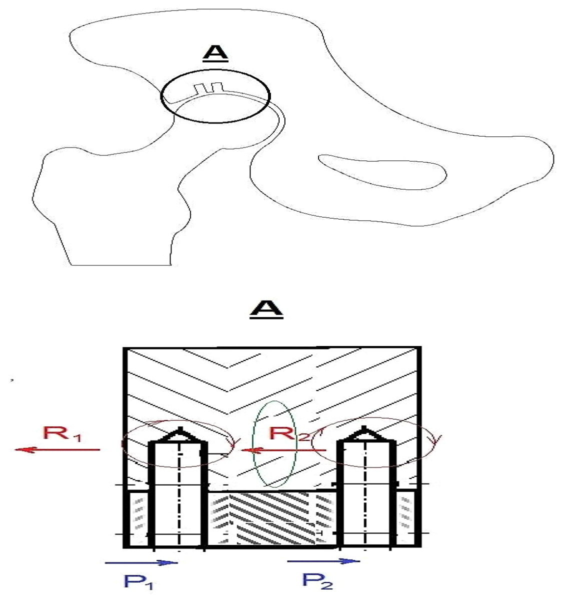
1. What quantity of blind openings in a wall of acetabular hollow is the most justified?
2. Under what angle to the plane of an acetabular hollow surface it is necessary to form these openings?
3. Which of acetabular hollow zones are most suitable for placement of such openings?

Answering the first question, it is necessary to realize the importance of respect for a certain balance. It is logical to assume what the more openings in a wall of acetabular hollow will be created, the greater will the area of contact of a bone and cement weight be, therefore - the fixing of an endoprosthesis will be stronger. At the same time, in a wall of acetabular hollow of a blind opening is made with a diameter of 6 mm and 6 mm in depth followed by irrevocable loss of 169,65 mm^3 of bone. Therefore production of each subsequent opening leads to the progressing weakening of a bone basis to which the acetabular component fastens and, therefore, increases risk of its instability development in the postoperative period. With two created openings loss of bone tissue will make 339,3 mm^3 if there are six openings, the wall of acetabular hollow will lose 1017,9 mm^3 of bone tissue in total.

It would seem from this point of view that making one opening is the best solution. Loss of bone weight is minimalized here, and the area of contact with cement is more than when openings are not formed at all. However in this case endoprosthesis's head pressure force on its acetabular component when finding the patient in vertical position leads to emergence of the rotating effort which is gradually loosening the cement coat. It is possible to eliminate this factor by means of forming the second blind opening which, after filling with cement, begins to play a role of a rotation limiter, minimizing the destroying influence of the rotating effort and increasing angular stability of a cement coat (Fig. 1). At the same time, with two openings the area of bone contact with cement is greater, than with one opening. It means that at the same loadings the local pressure upon a bone will be less as a result leading to connection durability increase.

Thus, on number two blind openings formed in a wall of acetabular hollow are optimum. At increase in number of blind openings there is a weakening of durability of acetabular hollow, and at reduction - the risk of rotational shifts of an endoprotesis acetabular component.

When forming openings in a wall of acetabular hollow (Fig. 2) it is very important to enter a drill strictly at an angle 90 ^{0} in relation to the bone plane (the CD line is parallel to the AB line). Only in this case the cement pin formed after hardening of the cement weight introduced into a blind opening from the different parties will be influenced by equal forces. Otherwise, when the axis of a drill is entered into a bone at an angle, other then 90 ^{0}, rotation force directed on a tangent to a surface of acetabular hollow can be calculated by a formula: Fnl = Fn cos a^2. This force forms the rotary moment working for a cut of a cement pin. In case the angle of a^2 equals zero (the drill is entered at an angle 90 ^{0} to the surface of a bone), cos a^2 also becomes equal to zero, then Fnl = 0, i.e. the destabilizing influence of cement coat loads is excluded. In this we see the answer to the second question.

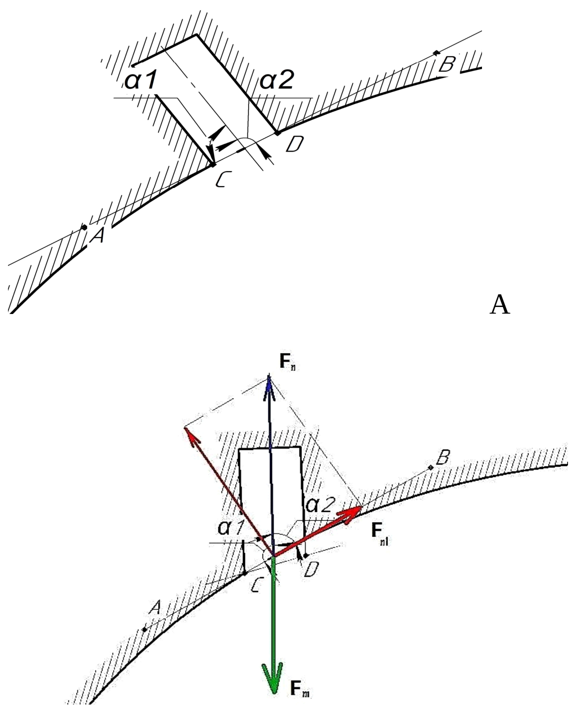


B

Figure 1. A - the scheme of placing two blind openings. **B -** the scheme of action of forces on cement pins and on a bone of acetabular hollow.

Filling of blind openings in a wall of acetabular hollow with cement after its hardening leads to forming two cement pins which work can be considered as collaboration of two console beams. P_1 - the distributed load of the first pin; P_2 - the distributed load of the second pin; R_1 - the jet force operating on the first pin; R_2 - the jet force operating on the second pin. The moments arising in interaxal space are multidirectional that reduces load on a bone (a green ellipse zone)

As for an optimum zone of an arrangement of blind openings in a bone, as their number does not exceed two, technically it is not difficult to place them in the most loaded area of acetabular hollow - its tectum, the corresponding radiological zone I by J.DeLee - J.Charnley. It will not lead to additional weakening of a bone basis and, on the contrary, will promote increase in durability of the acetabular component fixing. This is the answer to the third question.



A

B

Figure 2. A - the scheme of the blind opening created to the plane of acetabular hollow at an angle 90 ^{0}. **B -** the scheme of the blind opening created at an angle, other than 90 ^{0}. There is a destabilizing impact on a cement coat. F_m - body gravity; F_n - the counterbalancing force

Proceeding from the above, we modified technology of cement fixing of endoprosthesis acetabular component, forming only two blind openings 6 mm wide and 6 mm in depth strictly at an angle 90 ° to the surface of a bone and only in the most loaded area, the corresponding radiological zone I by J.DeLee - J.Charnley from the subsequent two-moment cement weight pressurization. The patients operated as stated above made the third group of the real research.

Most of patients were aged 70 and older (67,6%). Distribution on age in groups was approximately identical, without statistically reliable distinctions. The number of women prevailed over number of men that made respectively 58,0% and 42,0% (P -0,05), but these distinctions between groups were similar. Primary coxarthrosis, a fracture of a hip neck and a post-traumatic coxarthrosis were the main indications for total cement endoprosthesis replacement of a coxofemoral joint. Distribution of nosological forms on groups significantly did not differ.

Criterion of inclusion in a research was the fact of fixing the acetabular component of a coxofemoral joint endoprosthesis only at the expense of bone cement of average viscosity with preliminary creation of blind openings in a wall or acetabular hollow tectum. Such approach was applied at the normal density of a bone tissue and a strong subchondral bone plate which condition was defined visually during all 1075 operations. The fact of reinforcing the cement coat by means of two or more spongiform full-carving screws entered into the supacetabular area that performed for patients with the symptoms of the expressed osteoporosis which are visually defined during operation became criterion of an exception. The fact of performance of auditing surgical intervention with replacement only of a femoral component became one more criterion of an exception, i.e. during the research considered only those patients, operation of auditing endoprosthesis replacement which carried out with replacement of one acetabular component, or with simultaneous replacement of both acetabular, and femoral components.

The fact of performance of operation with auditing endoprosthesis replacement with replacement of acetabular component because of the arisen aseptic instability became a final research point that was stated in terms through one, five, ten and 15 years after primary operation. The research was designed in the spirit of randomized, open, comparative, controlled in parallel groups research.

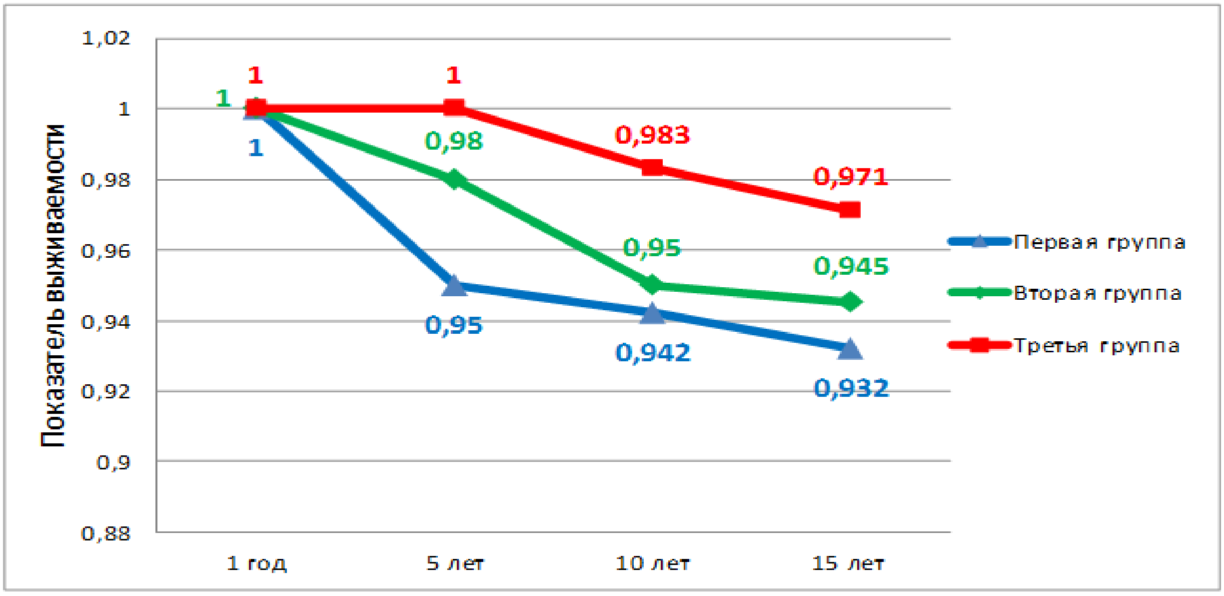
RESULTS AND DISCUSSION.

From all our patients in one year after primary operation none required auditing intervention (Tab. 2). However in the next years operations of auditing endoprosthesis replacement with replacement of acetabular component were carried out for all groups, less - for the third group.

Table 2: Frequency of auditing endoprosthesis replacement operations with replacement of acetabular component (%)

Clinical groups	Inspection terms								Total in 15 years	
	1 year		5 years		10 years		15 years			
	n	%	n	%	n	%	n	%	n	%
First, n=364	-	-	18	4,9	20	5,5	22	6,0	60	16,4
Second, n=352	-	-	7	1,9	17	4,8	18	5,1	42	11,9
Third, n=359	-	-	-	-	6	1,6	10	2,7	16	4,4
P	-		-		$P_{1,3}$ -0,05; $P_{2,3}$ -0,05		$P_{1,3}$ -0,05; $P_{2,3}$ -0,05		$P_{1,3}$ -0,01; $P_{2,3}$ -0,01	

As a result, in all 15 years of a research auditing interventions among first group patients cumulatively made 16,4%, the second - in 11,9% and the third group - in 4,4% of clinical observations. In other words the frequency of operations of auditing endoprosthesis replacement was the smallest in the third group - from patients only with two blind openings created in a tectum of acetabular hollow and the subsequent two-moment pressurization of bone cement. The obtained data subjected to the analysis by Kaplan-Meyer's method [17]. allowed to calculate degree of acetabular component durability. According to the linear chart given (fig. 3), in 15 years after operation of total cement endoprosthesis replacement of a coxofemoral joint durability of acetabular component for patients of the third group was the greatest.

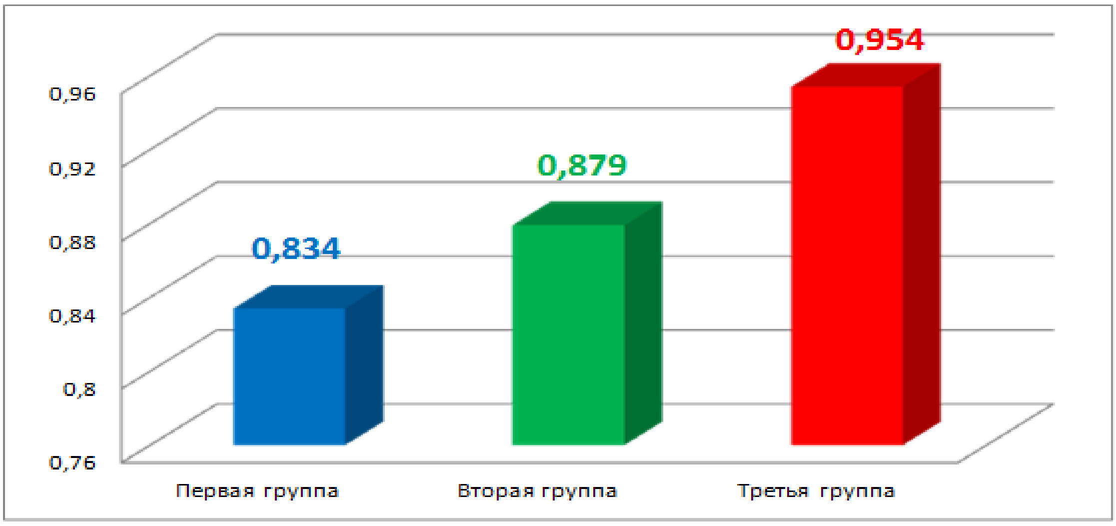


Показатель выживаемости	Durability rate
Первая группа	First group
Вторая группа	Second group
Третья группа	Third group
Год	Year
лет	years

Figure 3. Curves of acetabular component durability (conventional unit.) depending on approach to its cement fixing, calculated by Kaplan-Meyer's method

When carrying out the multiplying assessment provided by Kaplan-Meyer's method and which cumulatively characterizes acetabular component durability at different technical approaches to its cement fixing in 15 years of observation received the results reflected in the chart (Fig. 4). According to its data cumulative acetabular component durability in 15 years was the greatest for patients of the third group.

More and more the provided data confirms undoubted advantages of the approach realized for patients of the third group, which is providing among other equal conditions in the maximum degree stability of the "acetabular component-bone cement - acetabular hollow" complex in general, and not allowing, in particular, clinically defined aseptic shaking the acetabular component of an endoprosthesis.



Первая группа Вторая группа Третья группа	First group Second group Third group

Figure 4. Results (conventional unit) of acetabular component durability multiplying assessment calculated by Kaplan-Meyer's method for the fifteen-year period

CONCLUSION.

Theoretical grounds on expediency of forming only two blind openings executed strictly at an angle 90 ^{0} to a surface of acetabular hollow and localized in its tectum with the subsequent two-moment pressurization of bone cement found the practical embodiment during the long-term randomized, open, comparative, controlled in parallel groups research. Application result of the modified approach to cement reinforcing of acetabular component was decrease in frequency of auditing operations with replacement of acetabular component from 16,4% to 4,4% (P -0,001).

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