Structural Differences Between Hip Endoprostheses, and Implications on a Hip Kinetics

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Abstract

We compared kinetic characteristic of unipolar, bipolar and total hip endoprostheses, implanted after dislocated femoral neck fracture. Ninety patients were divided into three groups (30 patients in each group); a group with unipolar partial hip endoprosthesis (UPEP), a group with bipolar partial hip endoprosthesis (BPEP) and a group with total hip endoprosthesis (TEP). The patients from different groups were paired by parameters which could influence the long term functional result: follow up period, comorbidities, functional capabilities before injury, etc. After the average follow up 3,8±1,9 years, a measuring of range of hip motions (ROM) was conducted. The largest mean amplitudes in flexion (104°), extension (13°), abduction (35°) and external rotation (38°) was achieved BPEP, the largest adduction (14°) was achieved UPEP, and internal rotation (34°) TEP. Differences in ROMs are partially related to the clinical parameters such as: level of the hip pain, gait pattern, age and rehabilitation period ($P<0,05$). Measuring of ROMs is the most reliable part of the clinical exam and it does not depend on subjectivity of patient, as opposed to other clinical parameters (level of pain, walking distance, aids usage, etc). The results obtained are favorable for the bipolar hip endoprosthesis, and they can be related to the biomechanical differences between the three types of hip endoprostheses. Kinetic advantages of the BPEP as compared to the UPEP, can be explained by the BPEP's structure: two-level mobility and a thinner neck which delays impingement in the late motion phase. In comparison to the TEP, clinical advantages of the BPEP can be attributed to less extensive surgery and scaring.

KEY WORDS: diabetes mellitus, early marker, renal disease, cystatin C, creatinine

Introduction

For elderly patient, hip fracture is frequently a turning point in their physical, psychological and social aspect of life. Only optimal treatment can provide the highest possible independence of patients after the hip fracture, causing a significant increase in life quality and reduction of costs for the assistance of other people. Hip endoprosthesis is the most rational treatment for displaced medial femoral neck fractures in elderly patients. Some surgeons prefer the UPEP, others prefer the BPEP or even the TEP. The first hip endoprosthesis made of a biocompatible material was the vitalic UPEP, constructed by Moore and Bohlman in 1940 (Figure 1, upper part). The first TEP was made of steel and was created by McKee and Watson-Farrar in 1950. In 1974, Bateman created the BPEP with two heads (Figure 1, lower part). The finale attitude towards the type of endoprosthesis that should be implanted after displaced femoral neck fracture in elderly people has not been created yet, but the very fact that Moore's endoprosthesis, with minor adjustments, has been used for more than sixty years speaks a lot for itself. After the invention of the BPEP, the majority of peer-reviewed articles have pointed its superiority in comparison to the UPEP (1,2,3,4,5). Articles in the past 10 years mostly do not report significant differences in long term clinical results between the UPEP and the BPEP implanted after femoral neck fracture (6,7,8,9,10). Generally, it can be stated that the partial hip endoprostheses (unipolar and bipolar) are cheaper and require less extensive surgery in comparison to the total hip endoprostheses. The TEP, according to the majority, achieves the highest Harris hip score (HHS). However, there are disadvantages of the TEP when compared to partial endoprosthesis, such as a more extensive and longer operative procedure, increased blood loss, increased infection and mortality risk, longer rehabilitation period and higher costs (11,12). The TEP could be a satisfactory salvage procedure after the failure of other surgical solutions for femoral neck fracture (13) (Figure 2). In clinical outcome, achieving the sufficient ROMs of the hip following surgery is one of the most important goals of successful treatment. Besides technical characteristics of a particular endoprosthesis, some clinical parameters can also influence the ROMs, too (14). The aim of this article was to determine whether there were any important differences between UPEP, BPEP and TEP, implanted after dislocated femoral neck fracture regarding the functional parameters.

Patients and Methods

The unipolar partial prosthesis is constructed as one piece, that is to say that the head, the neck and the stem are made from the same material, and differ only in radius of the head and length of the neck and the stem. The

FIGURE 1. Partial hip endoprostheses: unipolar- type Aostin-Moore (upper) and bipolar- type Vario Cup (lower).

FIGURE 2. Total hip endoprosthesis - type Lubinus.

	Ref. values	UPEP	BPEP	TEP	Covariance	P*
flexion°	125	103,0	103,8	98,3	rehabilitation, age, pain, gait pattern	0,936
extension°	15	2,0	12,5	11,6	rehabilitation, age, pain, gait pattern	<0,05
abduction°	45	27,7	35,0	30,6	age, pain, gait pattern	<0,05
adduction°	15	13,8	13,4	12,1	pain, gait pattern, rehabilitation	0,640
external rotation°	45	28,9	38,3	37,6	age, pain, gait pattern	<0,05
internal rotation°	40	15,5	33,3	33,6	pain, gait pattern	<0,05

* P=0,05, ANOVA

TABLE 1: Referent values and average values of ROMs (°) in UPEP, BPEP and TEP group

bipolar prosthesis consists of a smaller polyethylene cup, tightened to the stem. The inner bearing radius is 25 mm to which an external metal cup is implanted. The external cup's outside surface articulates with the acetabulum and inside surface with the internal cup. Since a coefficient of friction between metal and the cartilage of acetabulum is larger than a coefficient of friction between metal and polyethylene, the external cup moves only after reaching extreme values of amplitudes. According to laws of physics, less motion implies less acetabular erosion. In addition to this, a thinner neck enables a wider range of movements. This double mobility decreases, at least theoretically, number of motions between the acetabular cartilage and the articulation surface of the prosthesis, and consequently, acetabular erosion. For that reason tripolar prosthesis had been invented. Tripolar prosthesis has three centers of rotation and is already used in France. In USA this kind of prostheisis is still in the phase of preclinical trial. In case of complications, it is possible to transform bipolar and tripolar prosthesis into the total hip prosthesis by an implantation of an artificial acetabulum, while unipolar partial prosthesis should be completely removed in case of certain complications. The group of patients with implanted UPEP (Figure 1, upper part) were treated at Department of Orthopedics and Traumatlogy, Clinical Center Sarajevo. The group of patients with implanted BPEP (Figure 1, lower part), and the group of patients with implanted TEP (Figure 2) were treated at the Department of Traumatology, Clinical Centre Ljubljana. Protocols of presurgical and surgical treatments and rehabilitation were the same in both departments, difference was only in the choice of a prosthesis type. The inclusion criteria were: dislocated femoral neck fracture (type Garden III and IV), implantation of cement hip endoprosthesis as the first operative procedure through lateral hip approach, surgical procedure performed in the period Jan/91-Jan/01, absence of changes visible on X-ray, unilateral lesion of hip, patients over 65 years of age with such a general and cognitive state that allowed examination. Data about gender, age, type of a fracture, rehabilitation period, presence of cardiovascular, neurological, pulmonary diseases and diabetes mellitus, functional capability before the injury (pre-injury HHS) were noted in a special sheet. History data about 694 patients were examined. Ninety participants (30 in each group), whose data about parameters influencing the long term functional result fitted the most, were selected for the study . Patients from the UPEP, BPEP and TEP groups were paired by the factors which could interfere with the long term functional result: gender, side of injury (left/right), follow up period, level of severity of comorbidities and functional capabilities before injury (pre-injury HHS)(15). Harris hip score is sum of scores of functional tests, level of hip pain, range of hip motions, and presence of deformity. Completely healthy hip counts 100 points. All selected patients were reexamined for the purpose of study after a minimal follow up of 24 months. ROMs of the hip operated on and the control hip on the opposite side were measured by Russe's method (16). Referent values of the ranges of hip motions with the fully extended knee were: flexion 1250, extension 150, abduction 450, adduction 150, external rotation 450 and internal rotation 400. One way ANOVA with covariances was used for the statistical analysis (17). Only the covariances that had a statistically significant effect (P=0,05) on the ROMs were included in the model (age, rehabilitation period, level of hip pain, gait pattern), listed in Table 1.

Results

Hospital archive data for 694 patients were collected according to the above mentioned inclusion criteria. In each group 24 participants were females, average age was 76 ± 5,1 (65-92) years. The right and left side injuries were equally distributed (15:15). The mean follow up period was 3,8±1,9 (2-8,6) years. The most common comorbidities were: cardiovascular diseases (20 patients), diabetes mellitus (5 patients), neurological diseases (4 patients) and pulmonary diseases (3 patients) in each analyzed group. Average pre-injury HHS was 95±4,9 (82-100) points. Patients with the BPEP, on average, achieved the largest ROMs in almost all directions (flexion, extension, abduction and external rotation). Only internal rotation and adduction were dominant at patients with the TEP and the UPEP, respectively. Differences in flexion and adduction were statistically insignificant. The level of hip pain and gait pattern influenced on ROM differences between the examined groups in all directions. Age and rehabilitation period were a less common factor influencing on the ROM differences (Table 1).

Discussion

The study of the motion of living things is known as "biokinematics" and it has evolved from a fusion of the classic disciplines of anatomy, physiology, physics, and engineering. For purposes of kinematic evaluation of a hip joint, the bones may be considered as rigid bodies which constitute the kinematic links, and joint as the interface at which relative motion is allowed between two or more rigid bodies. "*In vitro*" experiments can not offer absolutely accurate data, due to many complex characteristics of structures of implant, bone, cement, and some uncertain numerical parameters. This emphasizes a need for clinical studies, which could ensure most realistic data about behavior of different endoprosthetic devices "*in vivo*", as well as information about valuable results of analyses of complications. Generally, the patients with the BPEP achieved the largest ROMs. Only internal rotation was dominant in the patients with the TEP and, adduction was dominant in group with the UPEP. Differences were statistically significant, except of the differences in flexion and adduction. The level of the hip pain and gait pattern significantly influence the difference in range of all hip motions, while age, length of rehabilitation and follow up affect only some directions (Table 1). A similar result was reported by Smrke, hips with BPEP achieve larger ROMs in comparison to the hips with the TEPs (14). However, this is the first article that compares exact long term functional results between unipolar, bipolar and total hip endoprostheses together. Mechanical reason for decreased ROMs in the hip following surgery (as compared to referent values) can be explained by completely new biomechanical relation. Partial replacement of elastic and contractive abductor muscle tissue with nonelastic fibrotic scar tissue and the presence of pain in the hip following surgery contribute to limitation of ROMs, as well. Clinical advantages of the BPEP as compared to the UPEP, can be explained by the BPEP's structure: two-level mobility and a thinner neck which delays impingement in the late motion phase (18). In comparison to the TEP, clinical advantages of the BPEP can be attributed to less extensive surgery and consequently, less pain and scaring, similar as in Chen's report (19). Measuring of ROMs is the most reliable part of the clinical exam and it does not depend on the subjectivity of physician or patient like other parameters in Harris hip score (pain, walking distance, aids usage, etc.). That is the reason why we emphasize the importance of the measuring of ROMs as a sensitive clinical parameter in long-term evaluation of patients with prosthetic hip replacement. Achieving painless and sufficient ROM is crucial for the hip function and, consecutively, for a high level of independence in daily activities of patients (20, 21). Considering the clinical results, blood loss, duration of surgical procedure, possibility of revision, time of functional recovery and price of endoprosthesis, it can be stated that all types of endoprostheses are valuable for the hip surgery. Results of this study support the use of the BPEP in the femoral neck fracture at elderly persons, although the TEP is a logical choice in patients with previously damaged hip. The UPEP is the most rational choice for the patients with short life expectancy and low functional demands (22, 23, 24). The limitations of this study are as follows: the absence of analysis of complications, lack of exact severity of illness score and a relatively short follow up. Due to high mortality in this population, the trilateral character of this study and practical difficulties in matching all supposed factors, this kind of research is a very comprehensive and time consuming activity. To analyze complications, larger series of patients have to be analyzed through a longer period, but it is almost impossible to collect comparable data with such strict inclusion criteria and a much longer follow up period. However, similar studies with even larger limitations have been published in the literature and may have helped clinicians in decision-making.

Conclusion

A choice of endoprosthesis is not the crucial obstacle in a patient's recovery to a pre-surgery state. It is natural that the choice of a hip endoprosthesis must be evaluated in accordance with clinical benefits of the chosen endoprosthesis on the one hand, and with the general condition of a patient and economic factors on the other.

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