Coll. Antropol. **34** (2010) 3: 931–935
Original scientific paper

Biomechanical and Clinical Alterations of the Hip Joint Following Femoral Neck Fracture and Implantation of Bipolar Hip Endoprosthesis

Dragica Smrke[1], Mirza Biščević[2], Barbara UR Smrke[3] and Blaž Zupan[4]

[1] Department of Traumatology, Ljubljana Hospital Center, Ljubljana, Slovenia
[2] Department of Orthopedics and Traumatology, Clinical Center, Sarajevo University, Sarajevo, Bosnia and Herzegovina
[3] Department of Neurosurgery, Ljubljana Hospital Center, Ljubljana, Slovenia
[4] Faculty of Computer and Information Science, Ljubljana University, Ljubljana, Slovenia, and Department of Molecular and Human Genetics, Baylor College of Medicine, Houston, TX, USA

A B S T R A C T

The implantation of a bipolar partial hip endoprosthesis is a treatment of choice for displaced medial femoral neck fracture. We present an experimental study which asses and compare biomechanical and clinical status through period before and after hip fracture and implantation of bipolar partial hip endoprosthesis. This study encompassed 75 patients who suffered from an acute medial femoral neck fracture and were treated with the implantation of a bipolar partial hip endoprosthesis. Their biomechanical status (stress distribution on the hip joint weight bearing area) and clinical status (Harris Hip Score) were estimated for the time prior to the injury and assessed at the follow-up examination that was, on average, carried out 40 months after the operation. Despite ageing, the observed Harris Hip Score at the follow-up examination was higher than that estimated prior to the injury (77.9>69.6; p=0.006). Similarly, the hip stress distribution was reduced (2.7 MPa<2.3 MPa; p=0.001). While this reduction can be attributed to a loss of weight due to late ageing, the principal improvement came from the operative treatment and corresponding restoration of the biomechanical properties of the hip joint. The implantation of a bipolar partial hip endoprosthesis for patients with displaced medial femoral neck fractures improves the biomechanical and clinical features of the hip, what should have on mind during making decision about treatment.

Key words: *femoral neck fracture, arthroplasty, biomechanicanics, status*

Introduction

Displaced medial femoral neck fracture can be treated with an internal fixation or the implantation of endoprosthesis. Two basic types of hip endoprosthesis are used: a total (TEP) and a bipolar partial hip endoprosthesis (BPEP). The BPEP was first introduced in 1974 to reduce friction between the acetabular cartilage and the endoprosthesis as an improvement of the uni-polar hip endoprosthesis[1–3]. The BPEP is a potentially promising alternative to the TEP that can in principle ensure fewer complications after the operation, a shorter operation time and rehabilitation period, and reduce the number of revision arthroplasties. However, recent studies show that despite the higher incidence of femoral neck fractures alongside an increase in the older population, there is no prevailing method for treating this injury[4], with different experimental studies pointing out different benefits of each of the treatment methods[5–7].

In this study we present the results of an experimental study that used retrospective data on patients with an implanted BPEP to study the long-term effects of this particular treatment. The study used methods that quantitatively assess a patient's condition prior to and after the operation. While hip rating systems have been widely used in assessing hip function no standard method has emerged[8]. One frequently used approach is a rating according to the Harris Hip Score which assesses the outcome of hip replacement. The Harris Hip Score addresses the clinical status of the patient but does not include any

Received for publication March 1, 2009

biomechanical information, which is often believed to be the most informative when assessing a patient's hip health condition[9]. For this reason our study complements the Harris Hip Score assessment with an estimation of the stress distribution on the hip joint weight bearing area as proposed by Iglič[10,11]. Our principal finding is that a BPEP not only restores but in some cases also improves both the clinical and biomechanical condition of the patient and, as such, it should be regarded as an effective treatment of a femoral neck fracture. Besides examining the post operative effects of the implantation of a BPEP and providing two complementary views on a patient's condition, another original contribution of our work is its analysis of the interdependencies between these two measures and their sensitivity to the effects of ageing.

Materials and Methods

Seventy five patients (64 female and 11 male) with acute displaced medial femoral neck fracture (33 right and 42 left hips) were operated on at the Department of Traumatology at the University Medical centre in Ljubljana, Slovenia, during the period from the start of 1996 until the end of 2006. Patients with a degenerative disease and anomalies of the hip joint prior to the injury were not included in the analysis. All 75 patients received the same type of surgical treatment that was performed by the same surgeon and included a primary operative procedure using the implantation of a BPEP (Self-Locking, Lima-Lto, Villa Nova, Italy) on a single hip. The diameter of the head of the endoprosthesis matched the diameter of the femoral head as measured after its removal from the acetabulum. In cases where the endoprosthesis did not exactly match the diameter of the femoral head the next biggest diameter available was used. Therefore, in practice for about half of the patients the diameter of the femoral head was increased by 1 millimeter. An anterolateral surgical approach was used in all cases. The group primarily included elderly patients, whose mean age was 75 years. All patients were able to walk after the surgery, although some needed a cane or walker. Patients were examined prior to the operation with the aim of estimating their status prior to the injury, and in the follow-up study no sooner than 12 months after the operation and, on average, carried out 40 months after the operation. Two different methods to estimate a patient's status were used: the clinical status was assessed using a Harris Hip Score, while the biomechanical post-operative condition was assessed through an estimation of the stress distribution on the hip joint weight bearing area that was computed using parameters acquired through the analysis of standard hip X-ray images. The Harris Hip Score (HHS) primarily considers a patient's pain and functional capacity[12]. The score provides an overall assessment of the patient's condition and is evaluated by a physician who considers the patient's ability to walk and climb stairs, their overall mobility and activity, the presence of pain, the function of the hip, the quality of life, and the absence of deformations in general with respect to the injured hip. The HHS uses a point scale from 0 to 100, with the following maximum scores: pain 44 points, function 47 points, range of motion 5 points, and absence of deformity 4 points. A higher HHS is an indication of a better condition. Score values below or equal to 70 are considered low: patients with this score constantly experience problems with their hips (pain, inability to take a longer walk, restricted function of the hip). Score values between 70 and 90 are prevalent for patients with some occasional problems with their hip, while scores above 90 are most often assigned to patients with minimal or no hip problems who may still engage in normal daily activities. As a biomechanical indicator of a patient's status we estimated the peak stress on the weight bearing area (Pmax). Peak stress Pmax was estimated using a mathematical model of a one-legged stance as proposed by Iglič and Kralj[10]. In our study it was computed using the Hip stress software Iglič and others[11]. The inputs to the model are a patient's body weight, inter-hip distance, pelvic height, pelvic width measured laterally from the centre of the femoral head, the co-ordinates of the greater trochanter (insertion point of abductor muscles) in the frontal plane, and the radius of the femoral head and the Wiberg centre-edge angle. For each patient these data (with exception of body weight) were obtained from a manual analysis of standard anteroposterior X-ray images of the pelvis with both hips. Lower Pmax values indicate a better biomechanical status. The experimental data were analyzed using the SPSS v.12.0 and R statistical analysis software.

Results

No significant differences were found between male and female patients with respect to their age ($z=-1.158$, $p=0.247$) and with the time that had elapsed after the operation ($z=-0.062$, $p=0.951$) according to the Mann-Whitney U-test. Gender significantly correlated with the body weight ($z=-2.584$, $p=0.010$) but in our study no discrepancies on Pmax ($z=-0.999$, $p=0.318$) were found among male and female patients. Women had a higher median Pmax of 2.66 MPa with respect to men, where Pmax was 2.31 MPa. Pmax for women at both examinations was also distributed over a wider range (a larger span of 95% of values). Female patients had higher HHS scores at both examinations ($z=-0.246$, $p=0.014$). We found no significant interactions of study variables with the side of the injury, although a higher number of injured left hips might imply the right side of the body as dominating. The median values of the age at the operation date show that women need surgical treatment about 4 years later than men. Descriptive statistics for the study variables are given in Table 1. At the follow-up we noticed an increase of the HHS scores and a decreased Pmax with respect to the initial examination, that is, the status of the patients improved in both clinical and biomechanical aspects. The mean difference between the first and second HHS was 6.4. The correlation was 0.546

TABLE 1
DESCRIPTIVE STATISTICS OF THE STUDY VARIABLES

	Initial examination				Follow up			
	$\overline{X}$	SD	min.	max.	$\overline{X}$	SD	min.	max.
HHS [points]	69.5	19.3	11.0	100.0	75.9	21.6	7.0	98.0
Pmax [MPa]	2.7	0.5	1.8	4.4	2.3	0.6	1.5	4.1
Age at examination [years]	74.6	8.6	42.7	93.7	77.4	8.6	43.7	94.6
Body weight [kg]	65.5	12.5	40.0	98.0	63.4	12.1	42.0	92.0

($p<0.0001$) and a paired t-test proved the positive change of the HHS ($t=-2.802$, $p=0.006$). The mean difference of the peak stresses at the two measurements was 0.31 MPa, but there was no correlation between the matched sets ($r=-0.083$, $p=0.477$). The extent and direction of change between the first and second Pmax measured with the patient could not be explained by a linear correlation. The paired t-test indicated a significant change across the measurements ($t=3.592$, $p=0.001$) in favor of reducing stress. For further analysis, we merged the data from the two examinations to obtain 150 observations and analyzed the relations between our study variables (Table 2 and Figure 1). The results indicate a significant interaction of the HHS with Pmax and Pmax with body weight. Weight has an interaction with a person's age, which indirectly incorporates the length of the period from the operation to the follow up. The peak stress is reduced with the passing of time since the operation. Body weight has a positive correlation with the peak stress, while its correlation with age is negative, as expected.

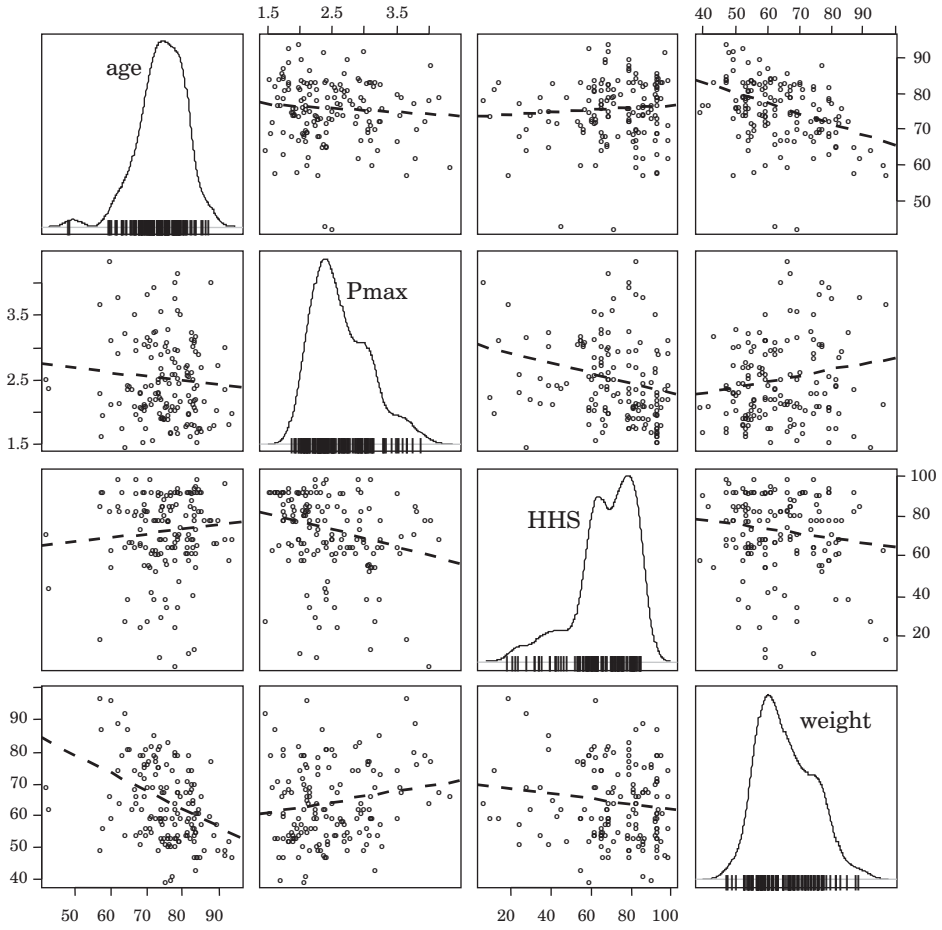

Fig. 1. Scatterplot matrix exposing bivariate correlations between the study variables. Plots on the diagonal show the distribution of values of the study variables. Off-diagonal scatterplots include a linear model fitted on the displayed data (dashed line).

TABLE 2
CORRELATION COEFFICIENTS (r) BETWEEN THE STUDY VARIABLES AND SIGNIFICANCE (p) AS OBSERVED FOR TWO-TAILED DISTRIBUTIONS.

		P_{max}	HHS	Body weight
Age at follow up	r	–0.088	0.085	–0.396
	p	0.282	0.303	<0.001
P_{max}	r		–0.252	0.177
	p		0.002	0.030
HHS	r			–0.126
	p			0.123

Discussion

The principal finding of our experimental study is that both the biomechanical and clinical status as assessed by the HHS and Pmax, respectively, are improved after the implantation of a bipolar partial hip endoprosthesis. With respect to the particular distribution of age in our study population, we may conclude that this procedure is a good choice for the treatment of a medial femoral neck fracture in the elderly. Most importantly, the implantation of a BPEP restores the quality of life to that experienced prior to the operation, or even improves it as indicated by the elevated HHS seen at the follow up examination.

The improvement (reduction) of Pmax is partially due to the lowering of body weight associated with late ageing. In our study and as expected body weight decreased with age: patients in our experimental group lost on average almost 2 kilograms of weight due to the normal process of late ageing. As body weight is used in the computation of Pmax – the greater the weight the larger the stress – the reduction of weight contributes to an improvement in Pmax. This has already been observed for a population of patients with hip anomalies in studies by Mavčič and others[13]. To analyze how much a reduction of Pmax can be attributed to weight loss, we recomputed Pmax at the second examination taking the weight data from the first one that is, assuming that the weight did not change between the two examinations[14,15]. The difference of Pmax at the initial examination and Pmax at the final examination with the adjusted weight was now 0.3 MPa. As the original difference between the two stresses was 0.4 MPa (Table 1), we can observe that while some reduction of Pmax may be attributed to the loss of weight, a major contribution stems from the effects of the treatment. With ever greater life expectancy a growing number of patients will require hip treatment in their very old age. Displaced medial femoral neck fractures can be treated using a bipolar partial hip endoprosthesis. In this paper we presented an experimental study that clearly showed that this particular treatment has had positive effects on the long-term status of patients and could successfully restore the clinical function impaired by the injury and thus improved the overall quality of life. Besides clinical status, which is most often assessed in studies similar to ours, we have also estimated the biomechanical status of the patients and shown improvements in both. While some improvements of biomechanical condition may be due to a loss of body weight as a result of ageing, the prevailing improvements can be attributed to the treatment procedure.

REFERENCES

1. BATEMAN E, BERENJI R, BAYNE O, GREYSON D, Clin Orthop Relat Res, 251 (1990) 54. — 2. COLEMAN H, BANSAL M, CORNELL N, SCULCO P, Am J Orthop, 30 (2001) 313. — 3. OCHS U, EINGARTNER C, VOLKMANN R, OCHS G, HUBER C, WELLER S, WEISE K, Z Orthop Unfall, Suppl 1 3 (2007) 145. — 4. CHUA D, JAGLAL B, SCHATZKER J, Can J Surg, 40 (1997) 271. — 5. HEALY L, IORIO R, Clin Orthop Relat Res, 429 (2004) 43. — 6. RAIA J, CHAPMAN B, HERRERA F, Clin Orthop Relat Res, 414 (2003) 259. — 7. SQUIRES B, BANNISTER G, Injury, 30 (1999) 345. — 8. JOHNSON C, FITZGERALD H, HARRIS H, J Bone Joint Surg Am, 72 (1990) 161. — 9. BRND A, PEDERSEN R, DAVY T, J Arthroplasty, 9 (1994) 45. — 10. IGLIČ A, KRALJ-IGLIČ V, Radiol Oncol, 33 (1999) 263. — 11. IGLIČ A, SRAKAR F, ANTOLIČ V, Clin Biomech, 8 (1993) 233. — 12. HARRIS H, J Bone Joint Surg, 51(A) (1969) 737. — 13. MAVČIĆ B, SLIVNIK T, ANTOLIČ V, Clin Biomech, 19 (2004) 939. — 14. BIŠČEVIĆ M, HEBIBOVIĆ M, SMRKE D, Coll Antropol, 29 (2005) 315. — 15. SMRKE D, BIŠČEVIĆ M, Coll Antropol, 31 (2008) 661.

D. Smrke

Department of Traumatology, Ljubljana Hospital Center, Zaloška 4, 1000 Ljubljana, Slovenia
e-mail: dragica.smrke@kclj.si

BIOMEHANIČKE I KLINIČKE PROMJENE ZGLOBA KUKA NAKON LOMA VRATA FEMURA I UGRADNJE BIPOLARNE ENDOPROTEZE KUKA

S A Ž E T A K

Ugradnja bipolarne parcijalne endoproteze kuka je tretman izbora kod dislociranog loma medijalnog djela vrata femura. Predstavljamo eksperimentalnu studiju koja uspoređuje biomehanički i klinički status kuka prije i nakon prijeloma kuka i ugradnje bipolarne parcijalne endoproteze kuka. Ova studija obuhvata 75 pacijenata koji su imali prijelom medijalnog djela vrata femura i liječeni su ugradnjom bipolarne parcijalne endoproteze kuka. Njihov biomehanički status (distribucija stresa na nosivoj površini zgloba kuka) i klinički status (Harris Hip Score) su procijenjeni u vremenu prije povrede i vremenu nakon povrede, sa prosječnim follow-up periodom od 40 mjeseci nakon operacije. Usprkos starenju, zabilježeni Harris Hip Score na posljednjem pregledu bio je viši u poređenju sa istim prije povrede (77,9 > 69,6; p=0,006). Slično tomu, distribucija stresa na nosivoj površini zgloba kuka bila je smanjena (2.7 MPa < 2,3 MPa; p=0,001). Iako se ovo smanjenje opterećenja može povezati sa gubitkom tjelesne težine u poznim godinama, glavni razlog ovog poboljšanja je sam operativni tretman i uspostavljanje povoljnih biomehaničkih svojstava zgloba kuka. Ugradnja bipolarne parcijalne endoproteze kuka kod pacijenata sa dislociranim lomom medijalnog djela vrata femura poboljšava biomehanička i klinička svojstva kuka, što treba imati na umu kod biranja tretmana liječenja.