

5.5 THA Ceramic-Ceramic Coupling: The Evaluation of the Dislocation Rate with Bigger Heads

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Summary

According to Charnley, the rationale to reduce the head diameter in THA is in decreasing the friction torque and the volumetric wear, but, employing a ceramic-ceramic coupling instead of a metal-polyethylene one, bigger diameters can be used without increasing in a considerable way neither the volumetric wear rate nor the friction torque.

The rationale of this study is to evaluate if, using a bigger diameter head, the artificial joint is more stable.

In the last two and half years a new acetabular component, with 36 mm liner head alumina-alumina coupling, has been developed and implanted.

We performed a randomized perspective study to investigate the rate of dislocation of the prostheses in the first three months after operation. We matched two cohorts groups, comparable in diagnosis and age, in which the surgical technique (postero-lateral approach), the surgeons, the neck geometry and the off-set of the stem were the same.

In the first one (225 cases, from March 2001 to December 2002) 36 mm heads were implanted, and in the second one (151 cases, from January 2001 to December 2002), 28 mm heads were used. We compared the number of dislocations: 2 (0.88%) in the first group and 7 (4.64%) in the second.

The data confirmed that there is a statistically significant ($p=0.02$) dislocations decrease in the 36 mm heads group.

Introduction

Concerning hip arthroplasty, throughout the years, many different proposals of head diameters and coupling were made. Charnley was the first that demonstrated the need to reduce the diameter of the femoral heads to decrease the friction torque and the volumetric wear rate [1], which are fundamental for the prosthesis survival. That is true for the metal-polyethylene coupling and it is also partially true for the ceramic-polyethylene coupling [2]. The head diameter reduction was possible only at the cost of a reduction of the joint stability and consequent increase of the dislocation risk [3, 6].

In the meantime the ceramic-ceramic coupling had a progressive diffusion thanks to its lower friction coefficient and to its higher wear resistance [2]. The ceramic is an inert material with high biotolerability [7]. After some initial failures that depended to either the errors of heads and necks design ("skirt heads") [8] or to the fact that the bone doesn't ingrow the ceramic [2], this material has shown to be reliable also in the ceramic-ceramic coupling if used, as a liner, in a metal cup. The ceramic risk fracture, thanks to the technological research, is very low and the belated loosening due to the ceramics stiffness are not reported [9, 14].

The 28 mm diameter heads have been the most used till now.

If the neck geometry remains the same, it is possible to increment the joint movement and stability by increasing the head diameter [3,15,16]. That's because, with this standard, the angle to which the neck comes into conflict with the cup rim (Fig. 1), and the distance that the head must cover before getting out of the liner are increased (Fig. 2).

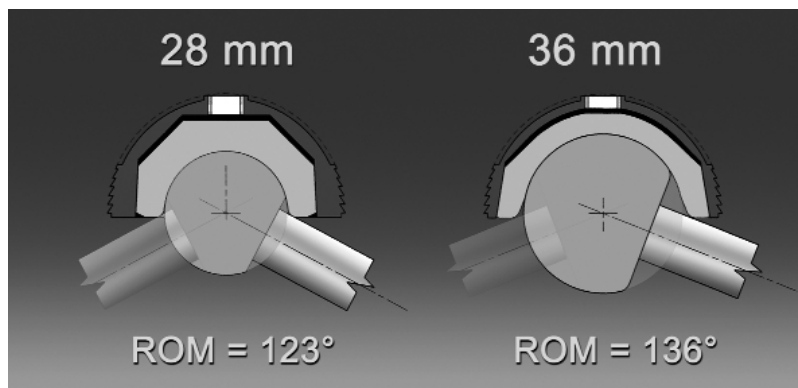


Figure 1:
Increased range of motion (with the same geometry of the neck).

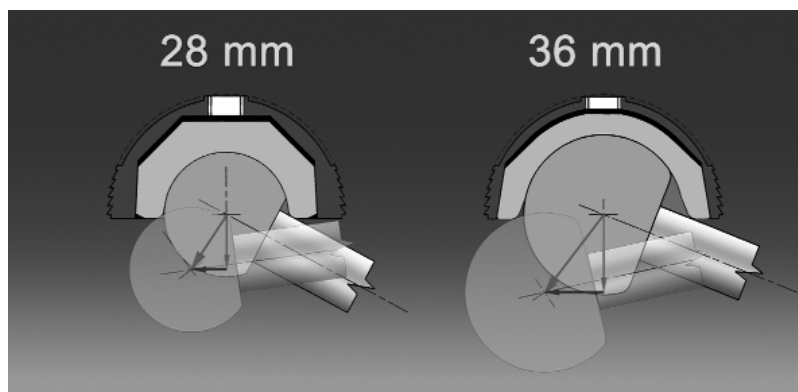


Figure 2:
More difficult dislocation.

With a ceramic-ceramic coupling, the diameter of the head can be increased because, during physiological loads, the friction torque ($M = \text{friction moment}$), thanks to the lower friction coefficient of the ceramic, doesn't significantly get higher (Fig. 4). Reducing the friction torque, proportional to the head radius (r) and the friction coefficient (μ), as focused by Charnley [1], means decreasing the shear forces at the bone-cup interface (Fig. 3). These forces are described in this way:

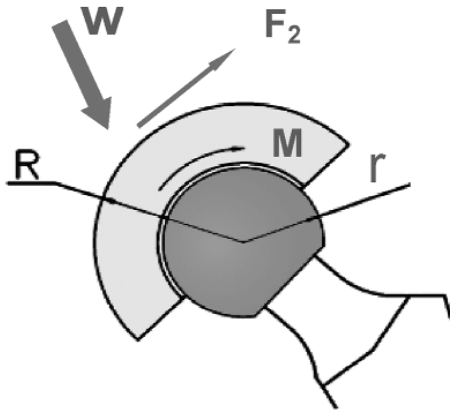


Figure 3:
 $M = \mu r W$ $W = \text{joint load}$

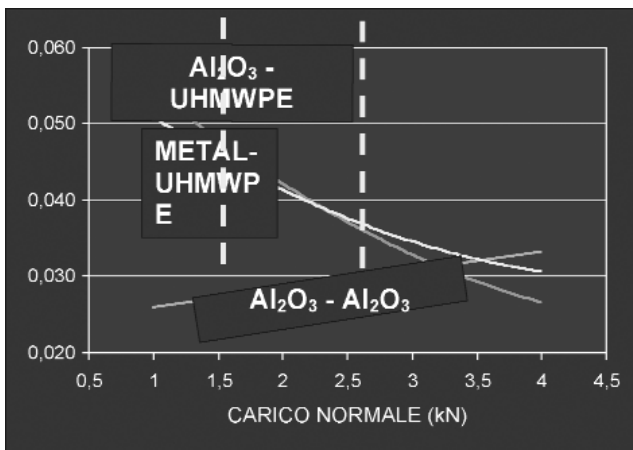


Figure 4:
 Friction coefficient in a range of standard loads (Dalla Pria 1998).

Increasing the head diameter from 28 to 36 mm the friction torque gets higher of a factor of 1.29 times; since the ceramic-ceramic friction coefficient is inferior of 1.33 times than the metal-polyethylene, the friction torque doesn't increase.

Although the wear debris is proportional to the head diameter. If we consider that the linear wear (mm/year) is quite constant for any head diameter, the volume of wear (V) can roughly be written:

$$V = \pi r^2 \times \text{Linear wear}$$

If we increase the head diameter from 28 to 36 mm, in the metal-polyethylene or ceramic-polyethylene coupling, there is an increase of the volumetric wear rate of 2.6 times (Fig. 5), while in the ceramic-ceramic coupling there is an increase which is lower of almost 100 times than the metal/ceramic-polyethylene one.

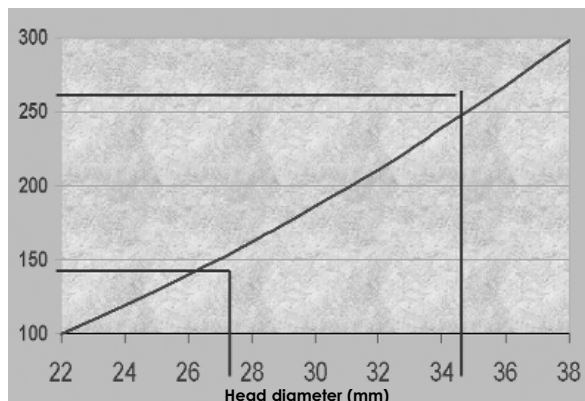


Figure 5:
Volumetric wear rate related to the head diameter (UHMWPE-metal).

Thanks to the material characteristics, we can overcome the problems described by Charney, even if they still maintain all their validity making problematic to use big heads with other coupling [17]. In this way, using a ceramic-ceramic coupling instead a conventional polyethylene there is no need to use small diameter heads and large diameter heads can give us only benefits without disadvantages. At the actual state of technology the 36 mm diameter, for the ceramic, is the ideal compromise between optimal head dimensions and liner safety.

According to these theoretical statements, a new acetabular component that uses liners in ceramic for 36 mm heads has been projected [15, 18]. It is used in a titanium press-fit cup. The cup is porous coated; the primary stability is improved by fins which are parallel to the equator and it could be increased with the addition of screws. The ceramic of the liner is alumina with a cone angle of 18°, higher than the ones currently used, that makes the introduction and the extraction more easy and safety.

In the last year a new type of ceramic (BIOLOX®Delta) has been introduced. This ceramic has a possibility of fracture 12 times inferior than the alumina. That makes possible to produce liners with a small thickness (36 mm for at least 50 mm cups and 32 mm at least 44 mm cups) with higher safety and very small risks of fracture.

The aim of these study is to compare the risk of dislocation, after hip arthroplasty, in two homogeneous (numerically, age, diagnosis, operators and surgical technique) groups of patients; the first with 36 mm diameter ceramics heads and the second with 28 mm diameter heads.

Patients and Methods

We compared 2 randomized groups of patients: a perspective consecutive series of primary hip arthroplasty with 36 mm diameter heads and another one with 28 mm heads, in order to verify the number of dislocations in the first three months after the surgical operation. The neck geometry and the off-set of the stem were the same. The two groups were also homogeneous for patients age, operators (R.G.C., C.P., L.Z.), surgical technique (postero-lateral approach with

capsular and external-rotator muscles reconstruction) and post-operative treatment (bed position with abduction pillow between the legs, beginning of walking in the second day with 2 crutches). There was not a complete pre-operative diagnosis homogeneity. In fact in the second group the fractures are more numerous. We don't know if this element determines modifications of the dislocation risk, but it doesn't seem so [6, 19].

The first group is composed of 225 cases of 36 mm heads (from March 2001 to December 2002): mean age 64 years and 9 months, 83 males and 142 female. Diagnosis: 175 degenerative arthritis, 25 DDH, 16 femoral neck fractures, 4 post-traumatic arthritis, 2 SA, 4 femoral head necrosis, 1 Paget disease.

The second group was of 151 cases of 28 mm heads (from January 2001 to December 2002): mean age 66 years, 44 males and 107 female. Diagnosis: 92 degenerative arthritis, 26 DDH, 30 femoral neck fractures, 3 post-traumatic arthritis.

For the statistic analysis we used the chi-square-test.

Results

In the group with 36 mm heads there were 2 dislocations (0.88%) in two male patients: the first was an anterior sub-dislocation reduced with a close reduction in a patient with DDH and the second required an open reduction in a patient with a severe post-traumatic arthritis. There were no recurrent dislocations.

In the 28 mm heads group the dislocations were 7 (4.63%), 5 females and 2 males. This percentage is not very different than the ones reported by other Authors [20, 6]. The diagnosis were: 2 primary arthritis, 2 DDH and 3 fractures. Again, we don't know if the number of fractures, higher in the second group, is significant. We intend to increase the number of patients to eliminate this discrepancy. In all the cases a close reduction was performed. 4 had not further dislocation episodes. In the three cases in which there were recurrent dislocations we proceeded to a substitution of the head with 10.5 mm neck (diagnosis of femur neck fracture), to a substitution of the cup that was excessively antverse (in a case of dysplastic arthritis) and to a total revision with 36 mm head (in a primary arthritis)

These results show a significant reduction of the dislocation risk in the group of patients operated with 36 mm diameter heads (0.88% versus 4.63% in those with 28 mm heads). This difference is statistically significant ($\chi^2 = 5.42 - p = 0.02$) and it confirms the theoretical assumptions from which the study departed.

	Cohort 1		Cohort 2	
	cases	dislocations	cases	dislocations
Degenerative arthritis	175	0	92	2
DDH	25	1	26	2
Fracture	16	0	30	3
Post-traumatic arthritis	4	1	3	0
(Necrosis, SA)	5	0	0	0

Discussion

According to this study, we could assert that the theoretical lower dislocation risk of hip arthroplasty with coupling of larger diameter, is confirmed in the clinical evidence.

The alumina-alumina coupling with heads of bigger diameter doesn't significantly increase the wear and the friction torque and therefore it is possible to use 36 mm diameter heads increasing the stability and the joint excursion.

The 36 mm heads can be use for cups of 50 mm and greater; while for the 44, 46 and 48 mm cups the head diameter is 32 mm. That makes possible an extension of the indications, a reduction of the dislocations, a better biocompatibility and resistance. The disadvantages depend on the fact to introduce a new standard with an increase of the stock and consequently the possibility of error, particularly in case of partial revisions; but 36 mm is becoming the new standard for big diameter heads.

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