Analysis of Cementless Acetabular Cup Rotation

William T. McCartney[1,3] MVB, Dipl (ECVS), DSAS(Orth), PhD, MRCVS

Rubén Lostado-Lorza[2] Ph.D.

Bryan J. Mac Donald[3] B.Eng. M.Sc. Ph.D. C.Eng. MIEI

[1] – NOAH, 38 Warrenhouse Road, Baldoyle, Dublin 13, Ireland

[2] – Department of Mechanical Engineering, University of La Rioja, Logroño, Spain

[3] – Centre for Medical Engineering Research, Dublin City University, Dublin 9, Ireland

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ABSTRACT

Aseptic loosening of cementless acetabular cups is a recognised problem. To investigate this issue, acetabular cups (Kyon, Zurich) were implanted into artificial bone (Sawbones, Malmo) in accordance with manufacturer instructions, and loaded in mediolateral rotation under laboratory conditions. The torque required at different cup depths were recorded. The theoretical forces acting on the acetabular cup were calculated. The angle of the force, relative to the ground, acting on the cup during normal loading, was calculated as 113.48°. The results revealed that even small amounts of depth insufficiency increased the risk of mediolateral rotation of the cup at normal torque forces. The Kyon cup should be implanted with no holes showing at the dorsal acetabular rim.

INTRODUCTION

The objective of this study was to analyse the mediolateral rotational forces acting on an implanted cementless acetabular cup. The aseptic loosening of the acetabular cup is a recognised complication of canine total hip replacement.1 The incidence of cementless cup loosening for the Kyon cup has been reported to be between 2.5-3.7%.2,3,4

METHODS

Acetabular cups (Kyon, Zurich) were implanted into artificial bone (Sawbones, Malmo) in accordance with manufacturer instructions. The inner polyethylene lining had previously been notched and filled with polymethylmethacrylate with a hexagonal bar within the cup at right angles to the cup opening. This al-

Figure 1. *Position three showing 3 rows of holes lateral to the dorsal rim of the acetabulum*

***Table 1** Results of the laboratory testing of cup positions*

Cup position	Distance to acetabular rim mm	Torque measurements NM	Average torque Measurements-NM
0	4	3.9, 4.1, 4.5	4.2
1	5	1.3, 1.8, 2.1	1.7
2	6	0.9, 0.75, 1	0.9

***Table 2** Summary of the forces acting on the cup*

Loading force N	Resultant force on cup N	Torque force generated on the cup NM
300	250	0.975
850	710	2.75
1600	1337	5.2

lowed for the cup to be rotated as one unit using the hexagonal bar. A 1-8 Nm torque measuring tool was attached to the hexagonal bar with the bone/cup construct fixed in a vice.

An indelible mark was made on the part of the cup protruding from the bone. Four different depths of cup implantation were chosen with position 0 being no holes visible lateral to dorsal acetabular rim, position 1 being one row of holes visible lateral to the dorsal acetabular rim, and position 2 and 3 being two and three rows (Fig 1). This corresponded to a distance from the dorsal acetabular rim to the cup edge of 4, 5, 6, and 7 mm for positions 0, 1, 2, and 3 respectively. Three sets of tests were performed for each position. The minimum force required to elicit movement of the cup within the bone socket was recorded. Using mathematical methods, the net resultant forces from loads of 300, 850, and 1,600 N were calculated (Figs 2, 3).

RESULTS

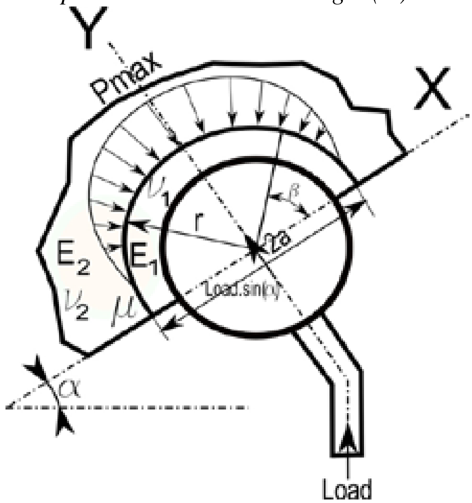
The data from the laboratory analysis are summarised in Table 1. The average torque (Nm) required to move the cup mediolaterally for position 0, 1 ,2, and 3 were 4.2, 1.7 .0.9, and 0.6 respectively. Torque applied in the craniocaudal direction only moved the plastic inner lining within the Titanium shell, and therefore, was deemed irrelevant to aseptic loosening. The data from the theoretical analysis indicated that at 300 N the net resultant load was 250 N and the torque force in a mediolateral axis was 0.975 Nm. At 850 N and 1,600 N the resultant loads were 710 N and 1,337 N respectively, while the torque forces in the mediolateral axis were 2.76 Nm and 5.2 Nm respectively (Table 2). The angle of the net resultant force on the cup in relation to the ground was 113.48°, which is considerably more dorsal to the cup centre which would be 45° to the ground.

DISCUSSION

The force on the cup during normal standing for a 30 Kg dog was calculated to be 250 N, with a resultant mediolateral torque on the cup of 0.975 Nm. In an acetabular cup implanted by press fit into artificial bone, the required torque to move the cup in a mediolateral direction with two rows of holes lateral to the acetabular rim was fund to be 0.9 Nm. At three rows the torque is only 0.6 Nm.

Any loading above 300N will increase the torque to levels of 2.75 Nm for 850 N, which is higher than the torque required to move the cup mediolaterally at a position with 3, 2, and 1 row of holes lateral to the dorsal acetabular rim, with torque limit values of 0.5 Nm, 0.9 Nm and 1.7 Nm respectively. At extreme loading of 1,600 N, the

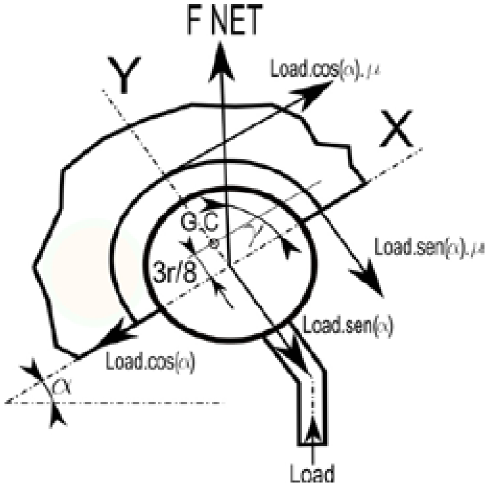
Figure 2. *F NET calculation by the condition of equilibrium of the forces applied on the cup:F NET modulus and angle (Y)*



mediolateral torque on the cup at 5.2 Nm is higher than any of the position torque limits. Although artificial bone is considered as an industry standard for implant testing, it is not known for certain does this property extend exactly to press fit cups and torque. Therefore, the results produced in this study would need to be verified in bone samples as a further study.

From this analysis it is possible to notify caution to surgeons that an acetabular cup not implanted completely under the dorsal acetabular rim will be at risk of mediolateral rotation at normal loading forces. At higher forces, the risk is considerable. An acetabular cup that is even 2-4 mm less implanted will be at risk of rotation because the rotational torque force is higher than the initial bone cup fixation.

Figure 3. *Contact pressure distribution produced by the component of the vertical load on the Y axis*



In conclusion, it can be recommended that implantation of the Kyon cementless cup should aim to have no holes visible lateral to the dorsal acetabular rim to be certain that the initial fixation can resist mediolateral rotational forces sufficiently.

REFERENCES

1. Olmstead ML, Hohn RB, Turner TM. A five year study of 221 total hip replacements in the dog. *J Am Vet Med Assoc* 1983;183:191-194.
2. Guerrero TG and Montavon PM. Zurich cementless total hip replacement: retrospective evaluation of 2nd generation implants in 60 dogs. *Vet Surgery* 2009;38: 70-80.
3. Hummel DW, Lanz OI, Were SR. Complications of cementless total hip replacement: A retrospective study of 163 cases. *Vet Comp Orthop Traum* 2010;6:424-432.
4. Vezzoni A. My last 1000 cases of Kyon total hip replacement. Special session presentation at the 2011 ACVS Annual Symposium. 2011, November 5:Chicago, Il.