**Drill and Jig Design to Improve Cement Fixation of the Acetabular Cup During Total Hip Replacement**

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**Introduction**

Successful replacement of hips is the only solution for severe degenerative diseases such as osteoarthritis (Bird, 1995). During cemented fixation of the acetabular cup, anchorage holes are drilled in the acetabulum, then cement is introduced and pressurised to create cement pegs within the anchorage holes. During physiological activities, the bone cement interface of the acetabulum experiences high compressive and shear stresses (Harkess, 1998) and therefore the anchorage holes have a major contribution in improving the stability and the torsional strength of the cemented acetabular component. The efficiency of these holes depends upon the stress distribution around the neck of the cement peg.

A survey of current practice in the cemented fixation of the acetabular cup in total hip replacement in 1999 shows wide variations in the number, geometry and distribution of anchorage holes drilled in the acetabulum. More than one quarter of the Consultants who participated in the survey use a particular size of drill because it is the standard one provided in theatre. Moreover, it is not easy for Orthopaedic Consultants to drill anchorage holes perpendicularly to the acetabulum floor under operating conditions. Many consultants felt that anchorage holes were important but were not aware of the influences of size and depth on the stress distribution in the cement mantle.

The aim of this study is to provide guidelines to the designs of an efficient drill bit and jigs that could assist orthopaedic surgeons produce the desired geometry and distribution of anchorage holes perpendicularly to the floor of the acetabulum.

**Methods**

Two dimensional finite element models of a reconstructed hip with straight, tapered and chamfered anchorage holes with different depths were created to investigate the effect of geometry on torsional resistance at the bone-cement interface. The same procedure was carried out for the change of angle of inclination from the perpendicular to the floor of the acetabulum (Mootanah et al., 2000). Three-dimensional finite element models of a reconstructed hip with three 8 mm diameter anchorage holes and another one with six 4 mm diameter anchorage holes were created to study the effect of distribution of anchorage holes on the resistance to torque (Mootanah et al., 1999).

Laboratory investigations were performed on reconstructed Shetland Pony acetabulae, using a bi-axial testing machine to validate results obtained from finite element analyses. Shetland pony acetabulae were used because they have similar geometry and material properties to human bone. Compressive loads of 2 KN, corresponding to three times body weight, was applied at an angle of 45\(^\circ\) to the vertical with (a) three 12 mm diameter anchorage holes and (b) six 6 mm diameter anchorage holes drilled in the acetabulum. Torque applied to the simulated acetabular cup was increased at a constant rate until failure of the cement mantle occurred.

**Results**

Results from finite element analyses show smoother stress distributions and a decrease in principal stress values in the cement mantle for a 10\(^\circ\) tapered (7%) and 45\(^\circ\) chamfered (14%) anchorage holes with the same surface area. Decreasing the depth of anchorage holes resulted in an increase in principal stress.
values of 4% for the straight hole, 5% for the chamfered hole and 20% for the tapered hole. An inclination of $10^\circ$ from the perpendicular resulted in a 6% rise in the principal stress in the cement mantle. Principal stress values for the model with 6 smaller anchorage holes were 1.5 times higher than for the model with 3 larger anchorage holes. These results were in line with those obtained from the experimental investigations.

Discussion

The results show that torsional resistance at the bone-cement interface may be increased by:
1. drilling anchorage holes with chamfered necks,
2. drilling anchorage holes perpendicularly to the floor of the acetabulum,
3. drilling three large anchorage holes rather than six smaller anchorage holes; this was in line with experimental results obtained by other investigators (Mburu et al., 1999; Oh, 1983).
4. drilling anchorage holes to depth equal to diameter; increased depth has little effect on the stress distribution in the cement mantle for a chamfered hole but increases the risks of perforating vital organs and blood vessels.
5. Deeper anchorage holes increase the bending moments acting on the cement pegs and therefore reduce the long-term stability of hip replacement.

Therefore, a special drill bit was designed to create anchorage holes with chamfered geometry and depth equal to diameter and a special jig was designed to assist Orthopaedic Surgeons drill three large anchorage holes perpendicularly to the floor of the acetabulum in theatre.

The proposed drill bit

The proposed drill bits have diameters of 8 to 12 mm, depending on the size of the acetabulum, and are 2 mm chamfered at $45^\circ$ from the top, as per figure 1. The proposed drill bit will enable Orthopaedic Surgeons drill anchorage holes with chamfered neck in the same operation. It has a cutting depth equal to the diameter, which will keep the bending moments on the anchorage holes low and ensure that penetration of the inner side of the pelvis and vital organs or blood vessels does not occur.

The proposed jig

The proposed jig has a hemispherical shape and may be manufactured from 28 mm diameter to 56 mm diameter in 2 mm gradations, to match the size of commonly available reamers. 16 mm diameter guiding holes, spaced at $120^\circ$ radially with angle of inclination of $20^\circ$, passing through the centre of the hemisphere, are pre-drilled in the 56 mm diameter jig. This will enable the 12 mm diameter drill bit with 2 mm chamfer to glide in during the drilling process. Smaller jigs will have smaller guiding holes. The proposed jig will be seated into the reamed acetabulum and will be used as a guide to drill the desired geometry and distribution of anchorage perpendicularly to the floor of the acetabulum. The depth of the anchorage holes will be controlled by the cutting depth on the drill bit.

The guiding holes in the jig are reinforced with stainless steel sleeves, reducing the amount of wear debris from the jig material during drilling. Stainless steel is a biologically inert material and any debris...
created during drilling is unlikely to cause tissue reaction. The jig material should be transparent and clear for easy use.

A handle fixed to the top of the jig will allow the surgeon to secure the jig into place and prevent it from rotating while drilling anchorage holes.

**Proposed jig for the deteriorated acetabulum**

In some cases, the patient’s quality of acetabulum is poor and may contain cysts or have low bone stock. The jig described above might not be appropriate because it would then be desirable to create anchorage holes in the locations of the cysts and not at locations pre-determined by the guiding holes in the jig. Moreover, the bone stock might be lacking in some areas and it would not be appropriate to drill anchorage holes in these regions. In such cases, a more flexible design of jig is proposed, where the consultant will be able to drill anchorage holes perpendicularly to the floor of the acetabulum in the preferred regions and not at pre-determined locations.

The proposed jig consists of a transparent lid\(^1\) and a hemispherically shaped support\(^2\), which is manufactured from 28 mm diameter to 56 mm diameter in 2 mm gradations, to match the size of commonly available reamers. The lid is slotted into the key-way\(^3\) at the top of the hemispherical support and is allowed to rotate freely by means of bearings. The central part of the lid consists of a 20 mm diameter ball\(^4\) with a 16 mm diameter hole\(^5\) drilled through the centre. The ball is allowed to rotate in the direction perpendicular to the top surface by means of two stainless steel pegs\(^6\) that are allowed to rotate freely into a slot in the lid. The drill is guided through the hole in the centre of the ball, which is located in the centre point of the top surface of the hemisphere. In this way, the anchorage holes will always be drilled perpendicularly to the floor of the acetabulum. The jig is hollow and the base has wide slots. This will allow the drill bit to reach the maximum area possible of the acetabulum. The drill guide will be allowed to rotate freely vertically and horizontally and will allow the surgeon to move the drill to the desired location, while keeping the drill bit perpendicularly to the acetabulum with maximum and easy access to any location in the acetabulum.

**References**

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