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**AN *IN VITRO* EXPERIMENT  
TO DETERMINE THE EFFICIENCY OF FIXATION  
OF THE MCKEE-FARRAR ACETABULAR COMPONENT  
IN RELATION TO TORSIONAL FORCE**

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The most important feature contributing to the success of a total hip replacement is the firm and permanent fixation of the components to bone. Loosening of the acetabular component always occurs at the polymethyl methacrylate/bone interface. Fixation between the acetabular component and the polymethyl methacrylate does not appear to give rise to any problems.

*Scope*

The purpose of the experiment was to determine whether the mechanical strength of the standard McKee preparation was greater than one involving less penetration of the trabecular structure of the os innominatum.

Although these experiments have been carried out on dead formalised material it was thought that information might be gained which would lead to the reconsideration of the concept of the fixation of the acetabular component.

The efficiency of the fixation in resisting torsion has been examined for two methods of preparation of the acetabulum:

1. The standard method advocated by McKee – MK method
2. The twelve Dimple method – TD method

## PROCEDURE

*The McKee Method of Preparation* is carried out in the following manner:

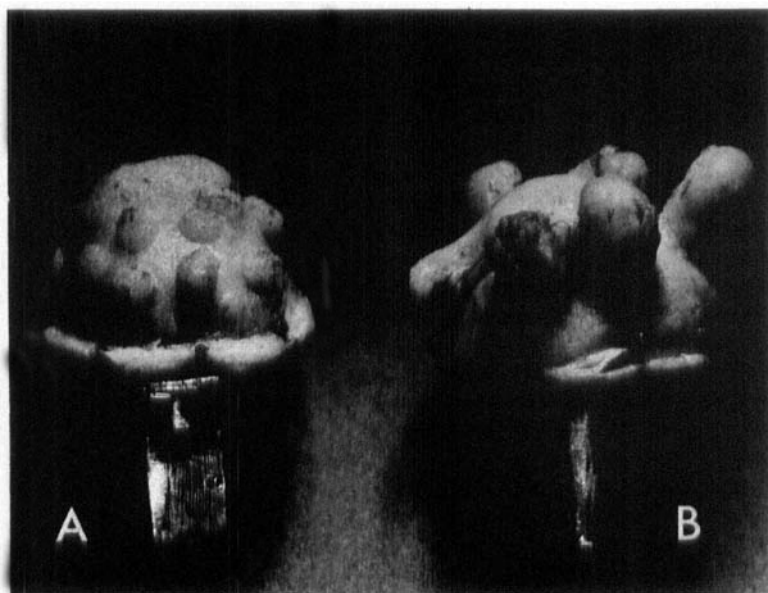
1. The acetabular cartilage is removed, leaving the cortex of the acetabular roof intact.
2. All medial and inferior osteophytes in the acetabulum are removed and the original fovea is uncovered. The fovea is then roughened.
3. The medial border of the intact cortical roof is undermined by about 1 cm.
4. 1.5 cm diameter holes are drilled 0.5 cm deep into the pubic bone and 2 cm deep into the ischial bone.
5. Three drill holes 1 cm in diameter are drilled in the ilium to a depth of 2 cm. These holes should not perforate into the pelvis.

*The Twelve Dimple Method* is as follows:

1. All cartilage is removed from the acetabulum, leaving the cortex of the acetabular roof intact.
2. All osteophytes within the acetabulum are removed until the fovea is uncovered.
3. Twelve dimples, each 0.5 cm in diameter and 0.5 cm in depth, are equally spaced in the acetabulum (excluding the fovea).

Casts of acetabulae prepared by the two methods are shown in Figure 1.

The os innominata were denuded of soft tissues, trimmed and prepared either by the McKee or Twelve Dimple method. A dough of Simplex "P" (non-radiopaque) was placed in the acetabulum and care was taken using digital pressure to pack all the holes and dimples. A modified acetabular component was inserted and



*Figure 1. Acrylic cast of prepared cavities. A-12 Dimple. B-McKee*

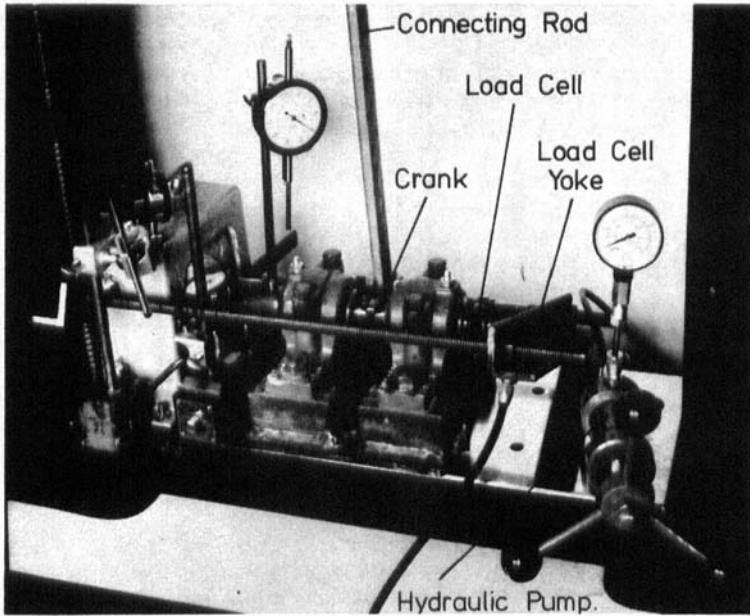


Figure 2.

continuous hand pressure was applied until the cement had polymerized. The specimens were placed in 10 per cent formal-saline solution for 48 hours at room temperature to allow complete polymerization of the acrylic cement. They were then mounted in plaster of Paris in the loading fixture and set up in an Instron Universal Testing Machine.

The plaster was allowed to set for 5 hours prior to use. Before commencement of the test a hole was drilled in the iliac portion of the bone, taking care not to drill into the acrylic plugs, and a 4 mm diameter bone screw was inserted to enable measurement of bone deflections close to the acetabulum to be made. A 15 cm lever was mounted on the modified cup at right angles to the cup axle to permit its angular deflection to be measured. The fixture containing the specimen was bolted to the base plate of the apparatus, and the cup axle was then connected to the horizontal shaft through which the torque was to be applied via a 5 cm crank. After bolting the apparatus to the base plate of the Instron machine a yoke carrying a hydraulic load cell was fitted to enable a constant end load to be applied to the specimen through the horizontal torque shaft (Figure 2). The crank was coupled to the cross head of the Instron by means of a connecting rod. The 5 cm crank and connecting rod were arranged at right angles so that a uniform linear movement of the cross head would provide a virtually constant torque on the shaft for the small range of deflections envisaged.

Dial indicators were mounted such that movements of the lever mounted on the cup, the bone screw and the specimen housing could be measured.

Two specimens were used to determine the order of magnitude of the various

test parameters. Hysterises loading, i. e. successive incremental loading with a return to zero between each load application was adopted since it was hoped to be able to use a pre-determined amount of permanent deformation as an indication of failure, to compliment the work of Parsons et al. (1970). On the basis of the results obtained from these two specimens the following conditions were used:

- Torque* - The torque was increased in incremental steps of 22.5 Nm (200 lbf") allowing the load to return to zero between each increment.
- End Load* - a continuous end load of 1.1 kN (250 lbf") was applied throughout the test.
- Rate of loading* - a crosshead speed of .04 mm/s (.1 in/min) was used, corresponding to a rate of angular deflection of the torque shaft of 5.75°/min.

Failure was defined as continuous rotation of the torque shaft without increase in load, with or without a visible crack between acrylic and bone.

A number of specimens were carefully dissected out from the bone after test to see if any visible cracking of the acrylic had occurred.

Radiographs were made of the first ten preparations before and after applying loads to failure. Although high resolution industrial C film was used no detail of bony failure could be seen and this procedure was discontinued.

## MATERIAL

Human hip bones from subjects about 60 years of age, who had been leading an active life within 48 hours of death (see Table 1 for cause of death). Following death, the bodies were chilled (3.3° C) prior to postmortem examination. After removal at postmortem examination the bones were preserved in 10 per cent formal-saline solution from 3 days to 5 days when they were used for the experiment.

Four standard McKee-Farrar acetabular components of 50 mm outside diameter were modified to include a welded short axle to enable a torsional stress to be applied.

## RESULTS

No visible cracking of the acrylic could be detected.

The peak torques achieved are tabulated in Table 1.

From the dial indicator reading it was possible to determine the deflections of the cup relative to the base and to the bone, measured at the position of the bone screw.

For each preparation, graphs were prepared, plotting displacement of the cup relative to the base against torque. Graph of the mean values of the results are shown in Figure 3.

Analysis of the results showed no significant difference between the two methods of preparation with reference to:

1. Peak torque sustained, and,
2. The slope of the initial straight portions of the graphs, i. e. the torque strength and stiffness of the two methods of preparation would appear to be the same *in vitro* for these conditions of loading.

Table 1.

Spec. No.	Age (years) Sex	R/L	Cause of death	Acetabulum (Diam. × Depth) mm	Method of prep.	Peak torque (Nm)
1	62 M	R	Coronary	51 × 25	MK	} Dummy Runs
2	75 F	R	Carcinoma of Oesophagus	51 × 32	TD	
3	78 M	R	Pneumonia	51 × 32	MK	147
4	85 M	R	Coronary	51 × 25	TD	172
*5	79 F	R	Pneumonia	48 × 22	TD	139
*6	-	L	Pneumonia	48 × 22	MK	163
*7	73 F	R	Coronary	51 × 32	MK	140
*8	-	L	Coronary	51 × 32	TD	249
9	71 F	R	Asphyxia	51 × 22	MK	186
10	81 F	R	Myocardial degen.	51 × 25	TD	153
11	86 F	L	Coronary	51 × 22	MK	198
12	60 M	R	Coronary	57 × 32	TD	250
13	70 F	R	Atherosclerosis	51 × 22	MK	95
14	65 F	R	Pulm. Embolism	52 × 22	TD	154
15	81 F	R	Myocardial degen.	57 × 25	MK	191
16	81 M	R	Coronary	57 × 25	TD	94
17	64 F	R	C.V.A.	57 × 25	MK	170
18	80 F	R	R.T.A.	48 × 22	TD	170
19	60 M	R	Coronary	51 × 25	MK	231
20	84 F	R	Coronary	48 × 25	TD	210

\* paired acetabulae.

The ages and sex of the specimens used for the two methods of preparation were closely matched, and should not have introduced bias into the results obtained. The three left acetabulae (two of them paired) did show higher values than the right, but the sample was small. It was not possible to consider the effect of body weight, as this information was not available.

For a given torque the resisting torque at the bone/acrylic interface will be dependent upon the diameter of the acetabulum, and therefore, the results were compared, grouping them by their acetabular diameter. There was possibly a tendency for the 12 hole preparation to be less stiff though many more results would be necessary to clarify this.

McKEE Acetabular Retention Tests  
— Typical Examples.

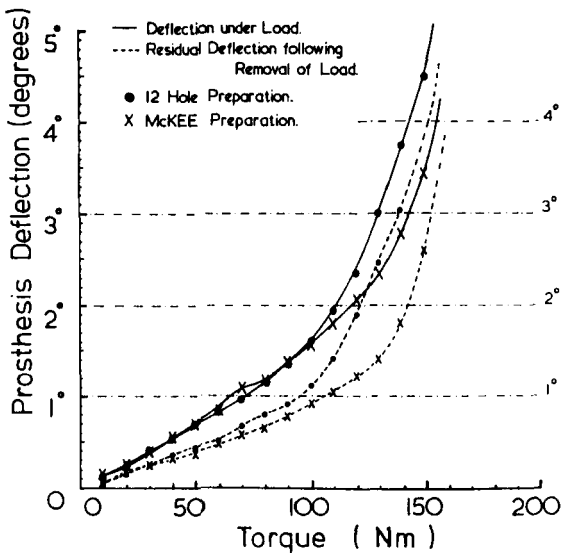


Figure 3. Graph of cup deflection against torque

#### DISCUSSION

There would appear to be no significant difference in the mechanical strength of the fixation to resist torque between the two methods of preparation under laboratory conditions.

The possibility must also be considered that under fatigue loading conditions a difference might appear. The large acrylic plugs or the more extensively disrupted trabecular structure of the McKee preparation might be expected to suffer fatigue failure more readily than the 12 hole preparation. Some fatigue work was attempted but results were inconclusive due to inability of the machine to withstand prolonged cyclic operation.

Examination of the metal and acrylic materials showed no failure. The specimens were prepared by one person using precision drills and measurements.

Examination of the bone specimens used in the experiment showed normal trabecular structure, absence of cysts, osteophytes or any abnormalities. The articular cartilage appeared normal, and the capsule and ligamentous structures were also normal. In orthopaedic practice however, the bone is usually poor, with cysts, osteophytes, and has a

softer and weaker foundation for the acetabular cup, especially in rheumatoid patients.

#### CONCLUSIONS

The results obtained suggest that a re-evaluation of the efficiency of the standard method of preparation of the acetabulum for a McKee replacement should be undertaken. It is possible that, *in vivo*, the drilling of large, deep holes into the trabecular structure of the bone and the subsequent reorganisation of the tissue after polymerisation of the acrylic will affect its mechanical properties. In addition, the blood supply traversing the cancellous bone may be markedly interfered with. Experiments carried out by Thomas (1965) suggest that this area is worthy of further study, since it is suggested that the blood supply to the acetabular roof is from an arcuate branch of the superior gluteal artery which sends smaller branches into the bone from the acetabular rim. Damage done to this blood supply during the creation of the large holes and the heat of polymerisation of the acrylic could lead to areas of necrosis. This would reduce the integrity and hence mechanical strength of the trabecular structure leading to failure under torque loads.

Since completion of our experiment, Andersson et al. (1972) working independently arrived at similar conclusions.

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