Institute of Medical & Biological Engineering

# Experimental Prediction of Contact Area in Hip Replacement and Hemi-Arthroplasty

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## Introduction & Aims

- Existing experimental techniques, using Fuji and Tekscan pressure film to assess contact mechanics, are limited by the high conformity of hip joint and effect of the finite thickness and stiffness of additional media [1, 2].
- Discrepancies have been reported when comparing experimental and computational results [3, 4].
- Ongoing studies in our institute on natural hip joint have demonstrated the need for a reliable experimental method.
- This study aimed to validate the "coat and squeeze" technique by assessing contact area in total hip replacements (THRs), and to investigate hemi-arthrolasty (HA) hip contact mechanics when subjected to a variety of loads and joint clearances.

## Materials & Methods

### Validation

- "Coat and squeeze" technique
  Coating the head with viscous liquid polymer (Microset, model 101RF)
  Squeezing the polymer out of area in contact subjected to a certain load
- Experimental vs. analytical contact in THRs
  *Pair 1*: Φ34 Co-Cr head and Φ35 ZTA cup,
  ΔD = 2.077 mm
  *Pair 2*: Φ36 ZTA head and Φ36 UHMWPE cup,
  ΔD = 0.832 mm

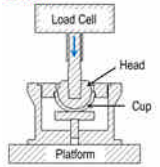


Figure 1 THRs setup

In Hertzian contact theory, contact radius, *a*, at certain load *L* is given as

$$a^3 = \frac{3}{4}\frac{LR'}{E'}$$

where *R*' is the equivalent radius of the head and the cup, and *E*' is the equivalent modulus of components [5].

### Hemi-Arthroplasty Hip Study

- Five acetabula from pigs (age 24~26 weeks)
- Diameter of natural femoral heads
  37.3±1.1mm (mean ± standard deviation)
- Co-Cr heads: Φ37, Φ35 and Φ32
- Diametral clearances: < 1 mm, 2 mm and 5 mm.
- Acetabula were inclined at 35° (equivalent to 45° *in vivo*)
- XY translating table for self-alignment between the head and the acetabulum


Figure 2 HA hips setup

### Compressive Loading Profiles

- THRs: 50N, 200N, 400N, 1600N, 2400N
- HA hips: 10N, 50N, 100N, 200N, 400N
- Peak loads ramped up in 10 seconds.

## Results

### Validation

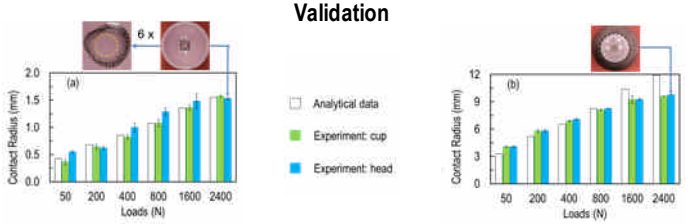


Figure 3 Comparison of experimental and analytical contact radius in THRs.
(a) Φ34 Co-Cr head and Φ35 ZTA cup; (b) Φ36 ZTA head and Φ36 UHMWPE cup

### Hemi-Arthroplasty Hip Study

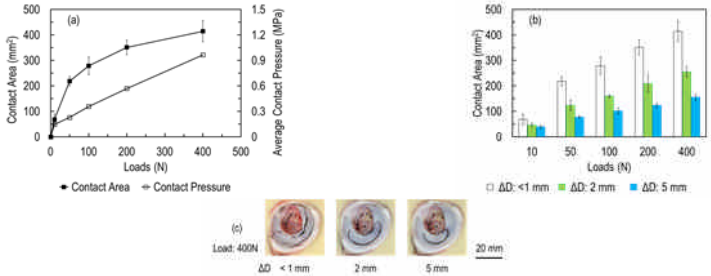


Figure 4 (a) Contact area and average contact pressure; (b) Joint clearances; (c) Contact patches

## Discussion

- Good agreement between experimental measurements and analytical results in THRs study (Figure 3)
- Minimum resolution was below 0.5 mm in contact radius at load of 50 N (Figure 3a)
- In HA hip study, the average contact pressure increased linearly with the varying load. The measured contact area increased in a decaying trend (Figure 4a).
- Contact area decreased significantly as the joint clearance was larger ($p < 0.5$ in one-way ANOVA; Figure 4b).

## Conclusion

- The "coat and squeeze" technique presented in this study has been demonstrated to be reliable to assess contact area experimentally.
- The findings show that the varying loads and the degree of prosthetic femoral head matching natural acetabulum influence HA hip contact mechanics significantly.

**References**
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