NEW POTENTIAL FOR LARGER HEADS IN THINNER LINERS WITH DURASUL(TM) HIGHLY CROSS-LINKED POLYETHYLENE

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Introduction

The use of larger femoral head sizes has been proposed to increase hip stability (Morrey et al., 1993, Sahni et al., 1998). In the past, larger heads have not been utilized because of the increased wear associated with conventional polyethylene. However, Durasul™ highly cross-linked polyethylene possesses advantageous wear properties for acetabular systems (Muratoglu et al., 1999). If Durasul has in reality resolved wear issues, larger heads can be used to provide increased stability. For larger heads to be compatible with the average patient size, it is clinically advantageous to have thinner Durasul liners. However, potential differences between the performance characteristics of currently available Durasul liners (wall thickness $\geq 5$mm) and of thinner Durasul liners may exist.

A theoretical stress analysis (Kurtz et al., 1999) demonstrated that larger heads produce lower head/liner contact stresses in the Durasul Inter-Op™ system. Kurtz’s theoretical stress analysis can be used to predict the minimal acceptable thickness of Durasul liners. In the theoretical analysis, an undesirable increase in contact stress develops only when the liner thickness falls below 3mm (Kurtz et al., 1999). Therefore theoretically, a 4mm thick liner will not experience abnormally high contact stresses under physiologic loads, and will improve product performance by allowing the use of larger heads in vivo.

![Figure 1: Kurtz’s Theoretical Model of Contact Stress vs Insert Thickness (Kurtz et al., 1999)](image)

To measure the actual stress levels, and to ensure the Durasul liners do not experience excessive stresses under physiological loads, a method (O’Connor et al., 1998) for determining contact stresses was employed on 4mm Durasul Inter-Op liners. Fuji film was placed between a femoral head and an acetabular liner. A load was then applied to the femoral head, inducing stress in the polyethylene. The intensity of the color change on the Fuji film was used to determine the contact stress. For comparison, contact stress measurements were also taken from 5mm liners. The in vitro 4mm contact stress measurements were to verify that the 4mm liners are not in the region of Kurtz’s model where contact stress dramatically increases. The 4mm Durasul liners were tested with 28, 32, and 38mm heads. The contact stress between the congruent surfaces of the 4mm and 5mm Durasul Inter-Op head/liner were evaluated.
Methods

Assembly of components: Simulating surgical technique, two strikes were applied to each liner/shell with a slaphammer via a rim impactor, thereby engaging the snap-lock feature.

Fixtures and Procedure: The contact stress tests were conducted using Low Range Fuji Film (Fuji Photo Film Co., Ltd. Tokyo, 106-8620, Pre-scale LWR270 10M 1). Similar to O’Connor et al (O’Connor et al., 1998), a cross-shaped strip of Fuji film was placed in the liner and the liner was loaded to 2003 N (450 lb, 3X body weight) with a femoral head. The stress-marked Fuji film was then scanned and image analysis was conducted with Adobe PhotoShop 5.0 (Adobe Systems Incorporated, 345 Park Avenue, San Jose, CA 95110). The contact stresses were measured at the center region of the cross (Figure 2).

Kurtz’s theoretical model employs a 2670 N (600lb) load for the liner. This study employed a load of 2003 N (450lb). The lower load was chosen because the range of the Fuji film (low or medium) did not cover the range of stress found in the liners. The lower load was chosen for feasibility, with Low Range Fuji Film.

Several calibrated imprint areas were also created using a precision-machined standard. A calibrated Instron (Instron Corporation, Canton, MA 02021) provided the load. The exact contact stress was calculated from these imprints, and a stress calibration curve was created using PhotoShop and MS Excel. The average contact stress in each 4mm and 5mm Durasul contact imprint was evaluated via the stress calibrated curve.

Results and Discussion

28mm Heads: The average ± s\textsubscript{n-1} contact stress in 4mm liners (28 x 43mm) and 5mm liners (28 x 45mm) was 7.09 ± 0.38MPa (1029 ± 55psi) and 6.26 ± 0.22MPa (908 ± 31psi), respectively. A student’s t-test found the two groups to be statistically different (p<0.05).

32mm Heads: The average ± s\textsubscript{n-1} contact stress in 4mm liners (32 x 47mm) and 5mm liners (32 x 49mm) was 6.35 ± 0.31MPa (921 ± 45psi) and 6.85 ± 0.46MPa (993 ± 66psi), respectively. A student’s t-test found no statistically significant difference between the two groups (p>0.05).

38mm Heads: The average ± s\textsubscript{n-1} contact stress in 4mm liners (38 x 53mm) and 5mm liners (38 x 55mm) was 7.39 ± 1.02MPa (1071 ± 147psi) and 6.35 ± 0.31MPa (939 ± 35psi), respectively. A student’s t-test found no statistically significant difference between the two groups (p>0.05).
In Kurtz’s theoretical model, an undesirable increase in contact stress develops only when the liner thickness falls below 3mm, indicating the liner is too thin (Figure 1). The experimental results of this study illustrate that there is little difference between the contact stress of the 4mm and 5mm liner (Figure 3). In fact, two of the three head sizes tested (32 and 38mm) demonstrated no statistically significant difference in liner thickness. The third head size (28mm) exhibited only a small stress increase (12%). Because 4mm Durasul liners did not exhibit a dramatic difference in contact stress, when compared to typical liners, the integrity of the 4mm liners is not threatened. The experimental results in this model confirm Kurtz’s prediction (Figure 3). The contact stress levels in 4mm liners are safe, and will improve product performance by allowing the use of larger heads in vivo.

Figure 3: Six Data Points for Comparison with Kurtz’s Theoretical Results

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