Introduction:
The importance of a secure liner locking mechanism in modular acetabular components has been reported by several groups. The development of locking mechanisms with tighter tolerances has led to increased intraoperative assembly forces. This has caused some surgeons to report intraoperative shell dislodgment on attempted liner insertion. One manufacturer with a particularly tight locking mechanism recommends, “cooling of the polyethylene liner” prior to assembly “to ease liner insertion”. The purpose of this study was to evaluate practical methods of cooling modular acetabular liners and its resultant effects on assembly forces.

Materials and Methods:
Twenty Ultra High Molecular Weight (UHMW) polyethylene liners and five matching titanium shells were obtained from two separate manufacturers. Each had a unique locking mechanism design. Liners were hand placed onto the shell prior to placement within the test apparatus. Liner shell assemblies were then performed by pressing the liner into the shell with a standard 28 mm impactor, at a rate of 10 N/sec for load control testing (Figure 1). All specimens were then loaded to 5000 N. Five liners of each design were assembled at room temperature (23°C). A separate group of liners were then impacted after undergoing cooling cycles using one of two techniques. The first group was cooled by placing the liner within its original factory packaging, in a commercial freezer at -16°C for one hour. The second cooling condition involved placing the opened liner in an ice bath for five minutes. This was the technique described by a manufacturer as previously mentioned. All testing was performed on an MTS Universal Testing Machine and data recorded on an X-Y Plotter. It was then converted into measurable data and analyzed using SPSS Multivariate Analysis. Post-hoc (Tukey’s HSD) and T-test were performed, and p < 0.05 was considered significant.

Results:
A “double dip” was observed on the load deformation curve for both designs (Figure 2) under all conditions. This dip represents incomplete seating of the liner on the shell. This was verified by visual inspection of each liner-shell construct. Upon further loading to 5000 Newtons complete seating was observed in every specimen. The existence of this “dip” has not been previously reported in liner-shell testing. In order to evaluate the difference between acetabular designs, a comparison was made between the mean assembly forces at room temperature. The interference fit design (M=836.22 N) showed a higher force to assembly when compared to the locking ring design (M=435.9 N). Figure 3 contrasts the assembly of these designs at room temperature.

Our data showed that cooling the liners had a significant effect in the assembly forces in the interference fit design (Ice Bath: M=667.2 N, SD=142.4, SE=±463.6; Freezer:533.7 N, SD=97.7, SE=±48.8, p=0.02). Post-hoc analysis revealed that the Freezer cooling method (MD = 302.4 N, SE = ±90.1, p=0.016) was significantly lower in assembly force than the Ice Bath and room temperature condition. For the locking ring design Post-hoc analysis (Tukey’s HSD) revealed that both the ice bath and the freezing cooling conditions resulted in significantly lower in assembly force than the room temperature condition (Ice Bath M=320.25, SD=19.89, SE=±8.89 p=0.001; Freezer M=324.70 N, SD=12.18, SE=±5.44, p=0.001). Both cooling conditions, the ice bath submersion and freezer storage did not significantly differ from one another. The assembly forces in the cooled liners were lower for both cooling techniques (figure 4 & 5).

Discussion and Conclusion:
A locking mechanism that securely holds the polyethylene liner within the acetabular shell is an important design factor in THR. Micro motion within the assembled liner-shell construct has been documented. This motion can be reduced by improving the locking mechanism design as well as by using low tolerances in the manufacturing process. Both of these changes may bring about increased assembly forces. The testing outlined in this report evaluates new methods of lowering intraoperative assembly forces with two current designs of modular acetabulae. The results of our testing show that cooling of an UHMW polyethylene liner prior to assembly into an acetabular shell will significantly lower the force necessary for complete seating. This finding might become even more significant when the third generation liner-shell locking mechanisms are released over the next few years.

Our data also demonstrated that acetabular assembly force varies greatly between designs. The interference fit assembly required nearly twice the force when compared to the locking ring design (see Figure 3). These results apply only to the specific designs tested and cannot be generalized to all acetabulae with similar locking mechanisms. It does, however, clearly demonstrate that locking mechanism design is a major determining factor in the intraoperative force required to assemble modular acetabulae.

Both brief storage in a commercial freezer and five minute submersion in a slush bath proved to be an effective means of lowering acetabular assembly forces. Our experimental protocol also shed some light on a problem not well described in the THR literature: the incomplete seating of the PE liner. McGrory, et al (1) recently reported on 9 reoperations in primary and revision THR caused by incomplete liner seating. As reported by the authors the clinical outcome of an incompletely seated liner varied from dislocations and dissociation, to “self seating” and fracture of the wire. Incomplete seating may be a phenomenon that occurs more than it has been previously reported.

Figure 1. Liner at 10 Newton’s

Figure 2. “Double Dip” curve.

Figure 3. Assembly Forces Room Temperature.

Figure 4. Assembly Forces

Figure 5. Assembly Forces

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