INTRODUCTION: A major concern when assessing failure in total joint arthroplasties is that of cement performance under fatigue loading. Acrylic bone cement failure has been identified as one of the major causes of aseptic loosening and is felt to be avoidable through increased cement strength and reduced porosity. Normal physiologic load levels applied to bone cement in vivo range from 3 to 11 MPa. The ability of acrylic bone cements to withstand such fatigue is generally assessed through the application of a sinusoidal load until failure. With the emergence of new bone cement formulations (Osteopal™ and Versabond™ of Smith and Nephew, Endurance™ of DePuy) in recent years, the performance these cements possess relative to more established cements (Simplex-P™ of Howmedica and Palacos-R™ of Smith & Nephew) needs to be defined. The relevance of the present study lies in its assessment of new acrylic bone cements in securing hip or knee replacements. The ultimate goal is to more accurately characterize the relationship between cement properties and their expected lifetime before failure and to determine if the newer cements offer any improvement over older cements.

METHODS: Vacuum mixing has been reported to reduce porosity and enhance fatigue life of acrylic cements. Each cement was, therefore, vacuum mixed per manufacturer recommendations using a Stryker Mixvac II System. The mixed cements were then injected into a standard hourglass-shaped mold with an inner diameter of 5 mm. The cement specimens cured for at least one week in a 37°C solution of phosphate-buffered saline (PBS) solution (pH = 7.4) before being tested. During the curing period, the specimens were x-rayed onto mammography film allowing visualization of any large pores. A criterion for exclusion from the study was recognition of a pore of 1mm or greater diameter. The radiographs were then evaluated to assess porosity of all test specimens regardless of pore size. The test specimens were placed inside of an environmental chamber filled with PBS and maintained at 37°C for the testing phase. A servo-pneumatic load frame applied a fully reversed tension-compression fatigue cycle to failure at a frequency of 10 Hz and stress levels of 15.0, 12.5, 10.0 or 9.0 MPa. This provided two test load levels within physiologic limits and two above.

RESULTS: Survival trends of each of the 169 specimen fatigue lives are plotted in figure 1. The rates at which each cement increased in fatigue life as the cyclic fatigue load decreased are clearly disparate. While there was a strong correlation seen between the porosity of individual cements and the corresponding fatigue lives, each cement formulation had its own unique characteristic slope. There were significant decreases seen in the porosity of the newer cements. However, the average radiographic porosity of the cements seen in figure 2 did not necessarily predict the survival rates seen in the fatigue experiment.

DISCUSSION: This data verifies previous work performed at the 15 MPa levels and also illustrates the danger of deviating test parameters too far from the conditions to which the samples were intended. Testing above physiologic loads can distort the effective in vivo life that can be experienced with cement use. There has been a clear attempt by the manufacturers of these acrylic cements to reduce the porosity of their respective products. Yet the results of this study indicate that there is more to increasing fatigue life than focused porosity reduction. The variability observed in cement behavior under fatigue demonstrates that a more complex interaction with strength and environment is taking place. While porosity contributes to improved cement performance, other properties such as cement chemistry and interaction with radiopacifiers and various enhancing drugs may also play a factor in the resistance to fatigue loads. These other variables should be considered when evaluating cements.

REFERENCES:

ACKNOWLEDGMENTS: Work supported by Smith & Nephew Richards Inc., DePuy Inc. and the Malcolm and Dorothy Coutts Institute for Joint Reconstruction and Research.