Effects of Pre-cooling and Pre-heating Procedures on Cement Polymerization and Thermal Osteonecrosis in Cemented Hip Replacements

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Abstract

Numerical studies were performed to investigate bone cement polymerization, temperature history and thermal osteonecrosis in cemented hip replacements. The two-dimensional axisymmetric heat conduction equation was coupled with a phenomenological kinetic model of bone cement polymerization and implemented using the finite element method to predict polymerization reaction and temperature development in a model bone-cement-prosthesis system. Thermal osteonecrosis was evaluated based on the temperature history in the bone. In this paper, the effects of pre-cooling and pre-heating of the prosthesis and/or the cement prior to implantation were simulated. It was found that the cement polymerization initiated near the bone-cement interface and progressed toward the prosthesis when both the cement and prosthesis were initially at room temperature. When the prosthesis and/or cement were pre-cooled, a reduction of the peak temperature at the bone-cement interface resulted, and this may reduce thermal osteonecrosis. However, this also slowed the polymerization process, and may result in a weaker bone cement due to incomplete polymerization resulting in lower molecule weight PMMA and higher concentration of residual monomer. If the prosthesis was significantly warmed, bone cement polymerization reversed direction and started from the cement-prosthesis interface, rather than the bone-cement interface, and proceeded toward the bone. This polymerization direction may reduce or eliminate the formation of voids at the cement-prosthesis interface. It is predicted that pre-heating the prosthesis to a temperature of 41^{o}C or above was required to induce initial polymerization at the cement-prosthesis interface in the model system. Experimental studies with the bone-cement-prosthesis models confirmed that voids at the cement-prosthesis interface were significantly reduced by such pre-heating procedure. Numerical results also showed that pre-heating seemed unlikely to produce significant thermal damage to the bone. Thus, the method of pre-heating the prosthesis prior to implantation may decrease the likelihood of cement-prosthesis loosening and increase the life of total hip arthroplasty.

***Keywords*:** Thermal necrosis; Biomaterials; Bone cement; Orthopedic implants; Finite Element