II ABSTRACT

Bone stock loss represents a major problem in revision hip surgery. Impaction grafting with morsellised bone graft compacted into the bone cavity provides a structural and biological matrix for mechanical stability and graft incorporation. Demand for allograft bone is outstripping supply and problems exist with antigenicity and quality. A need results for a synthetic graft for use as a bone graft extender. This thesis was concerned with developing laboratory techniques for mechanical evaluation of bone and synthetic graft materials for use in impaction grafting.

A die-plunger compression test and a shear-box shear test procedure were designed to derive fundamental graft properties. Two *in-vitro* impaction grafting models, an ovine and a human scaled set-up, were developed for endurance testing of the initial mechanical stability of compacted grafts under cyclic loading as found *in-vivo*. The impaction procedure was standardised using a device called the impactometer. Impaction energy and momentum were altered to investigate the influence of graft compaction parameters on stability.

Compression tests showed the viscoelastic/plastic nature of bone grafts. Stiffness of human graft is significantly affected by the bone mill type but not by preparation techniques such as washing, freezing or irradiation. Ovine graft had similar properties to human bone and can be recommended as an experimental substitute for *in-vitro* testing. Ceramic graft substitutes showed entirely different properties to bone being significantly stiffer with less relaxation and recoil. Ceramic stiffness was most strongly affected by porosity. In bone/ceramic graft mixes, properties combined according to the mixing ratio with small bone fractions having a dominant effect. Shear tests confirmed the mechanical advantage of ceramic grafts.

Exponential subsidence recorded during the endurance tests using the ovine and human models indicated their validity as experimental models. Impaction energy was the single most important factor influencing mechanical stability. Graft materials of higher compression stiffness showed higher stability against subsidence. Most bone/ceramic mixes were mechanically superior, the higher the ceramic fraction and the stiffer the ceramic phase. The stability of graft mixes was less variable and subsidence less sudden and steep than for human bone. Torsional stability and set caused by the final impaction blow correlated well with stability against subsidence.

Mechanical testing protocols have been successfully developed for evaluating bone graft and substitute materials. In order to provide optimum stability in clinical impaction grafting, bone grafts must be well impacted while blood is removed. Ceramic granules of low friability enhance the stability and lower the variability in bone graft mixes and can be recommended as bone graft extenders for clinical use in impaction grafting.