Effects Of 25kGy Gamma Irradiation And Supercritical CO₂ Sterilization Techniques On The Permeability Of Bovine Cortical Bone

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Background:

The flow of interstitial fluid (ISF) and blood through bone is considered an imperative mechanism effecting bone remodelling and fracture healing. ISF and blood flow enhances the transport of nutrients to cells and provides a means for waste removal. The role of fluid flow has clinical implications in the realm of bone grafting procedures using allograft bone. The healing response of allograft bone and effective bone regeneration requires osteogenesis, osteoinduction, and osteoconduction which involve a complex cascade of differentiation factors, signalling molecules, bone morphogenetic proteins and osteogenic (bone forming) cells. The migration of these bone-forming molecules to the site of healing is essential and is facilitated by the fluid flow through bone and bone allograft. Bone is known to be porous, and how well these components permeate through bone allograft is determined by the permeability of the graft.

Supercritical carbon dioxide (SCCO₂) is an existing technology that has been shown to be effective in achieving terminal sterilization of bone allografts while preserving the biomechanical and biological properties of bone which are known to be compromised by traditional sterilization methods such as Gamma irradiation. Under supercritical conditions, CO₂ exists in both the liquid and gas states and is able to diffuse into microporous structure of bone and dissolve lipids and remove unwanted antigenic materials. We hypothesized that SCCO₂ technology will increase the overall permeability of bone by clearing the vascular channels of bone and removing organic and cellular debris within the bone microstructure.

Methods:

Forty cortical bone specimens, 500µm thickness, were machined from bovine femurs and divided into four different groups (n=10 per group): control – no treatment, Gamma irradiation - 25kGy, SCCO₂ control - no additive, SCCO₂ - sterilant additive (peracetic acid/hydrogen peroxide). Following treatment a custom made jig was used to measure permeability at two different pressure levels (150kPa and 250kPa). Results were statistically analysed using one-way ANOVA.
Key Results:

- There was an increase in permeability of all bone samples at 250kPa compared to 150kPa
- SCCO$_2$, with or without additive, was found to significantly increase permeability of bone (p<0.001) compared to the control group at both pressure levels
- No statistically significant difference was found between SCCO$_2$ control group and SCCO$_2$ additive group
- Gamma irradiation (25kGy) was found to significantly decrease permeability of bone (p<0.001) compared to the control group at both pressure levels

**Figure:** Permeability of cortical bone samples increased when samples were treated with SCCO$_2$ and decrease when exposed to Gamma irradiation (25kGy). These differences were evident and statistically significant (p<0.001) at both pressure levels.

Clinical Benefits:

Treatment of bone tissue with SCCO$_2$ not only offers a clean and a terminally sterile allograft bone but also helps increases bone permeability. Increased permeability facilitates flow of blood and ISF through implanted allograft to the site of healing which may promote earlier bone healing clinically.