Critical Geometric Attributes of Titanium Lattices for Enhanced Osteointegration in Mandibular Reconstruction

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Introduction

Endoprosthetic reconstruction following jaw resection surgery is essential in avoiding autografts. Whilst still not fully adopted in practice, the recommended pore size to enhance osteoblastic penetration into metallic implants is said to be 400-600 µm. However, such pore sizes result in similarly-sized ingrown bony spicules, rendering osteointegration insufficient for large implants. Pore sizes of millimetres are more suitable, effectively converting the implant into a lattice. This work aimed to identify the critical geometric attributes of such lattices to achieve maximum osteointegration.

in vivo

A fit-for-purpose surgical approach to the mandibular ramus in sheep was developed through cadaver experiments. Five Merino sheep were used. Each animal received four titanium implants (MAXONIQ, Australia), two per side, each bearing a unique design (Fig. 1). Animals were intravitally labelled using three different fluorochromes at two-week intervals. Implants were retrieved 24 weeks postoperatively.

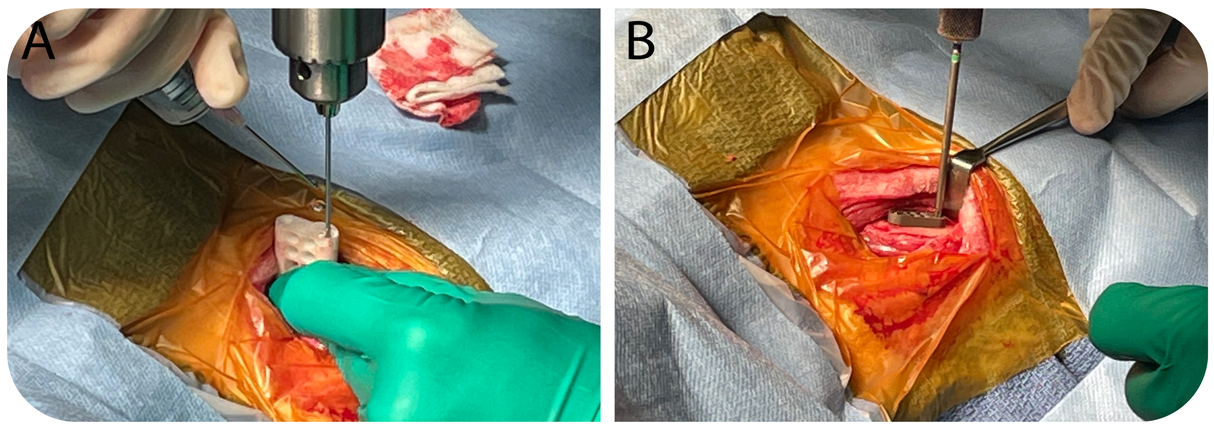


Fig. 1. The technique used to apply the miniplates. (A) The custom three-dimensional (3D) printed (Nylon) guide helps work within a relatively confined space while protecting the soft tissues from the rotating drill bit. (B) The dorsal miniplate is applied first, as dorsally as practicable. A narrow Senn retractor can help create more room for the screwdriver during screw placement. See ***Sanaei et al. Veterinary Surgery. 2026;1-13****.*

MicroCT (Fig. 2) and histomorphometry were used for evaluation. A repeated measures ANOVA was used for statistical analysis (Fig. 3).

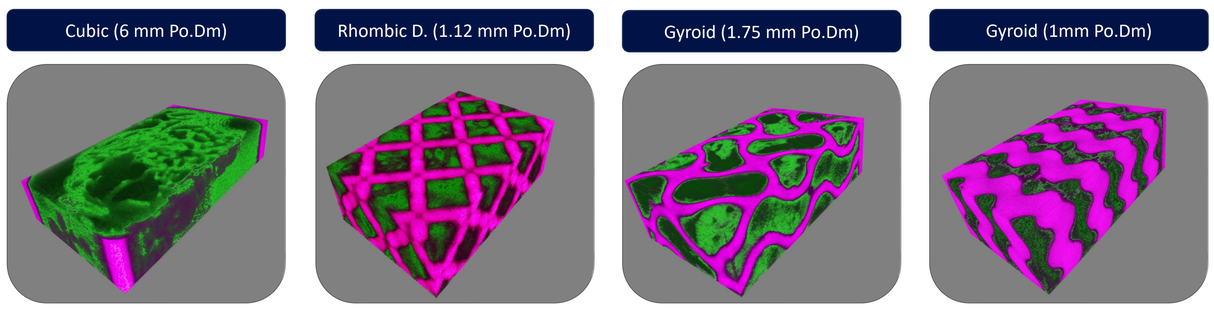


Fig. 2. MicroCT scan visualisation of each lattice type using CTVox software. Green regions represent bone ingrowth into the implants, which are displayed in purple.

Evaluation of intravital labels revealed that once formed, the ingrown bone in all of the lattices had similar 'mineralising surfaces', 'mineral apposition rate' and 'bone formation rate'.

Conclusions

1. The model provides a safe platform for implantation, suitable for testing other biomaterials intended for maxillofacial applications.
2. Lattice geometry, and not just porosity, is a significant determiner of osteointegration.
3. Various lattice designs can be utilised strategically in a single design to achieve the desired clinical outcome.

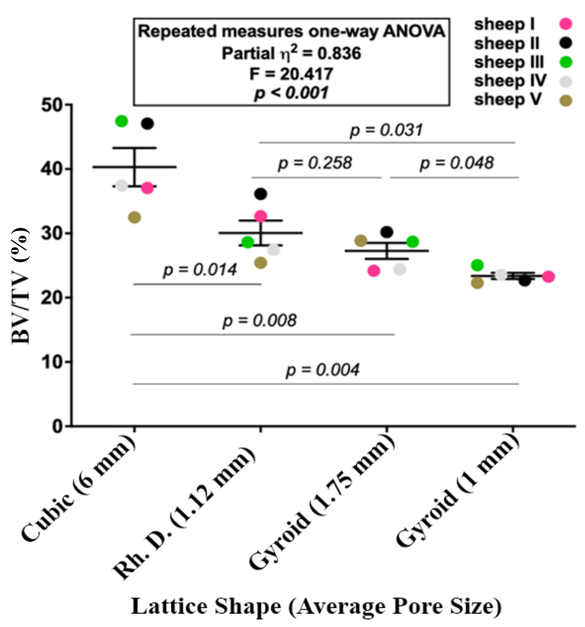


Fig. 3. Micro-CT data demonstrating the effect of lattice shape and pore size on osteointegration. BV, volume of bone ingrowth; TV, total volume available for bone growth (total pore volume); Rh.D., rhombic dodecohedron; numbers in brackets specify pore diameter; Error bar = SEM.

in vitro

An *in vitro* cell culture model was subsequently developed to reproduce *in vivo* results and evaluate novel lattice designs (Fig. 4).

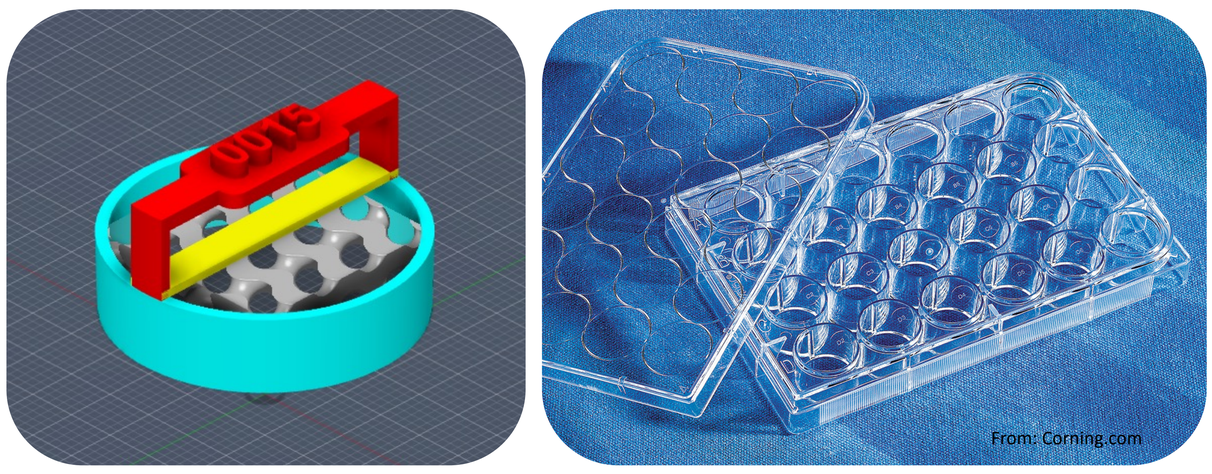


Fig. 4. G23 titanium inserts were designed to fit 24-well cell culture plates. Inserts were placed over confluent monolayers of Kusa4b10 cells on GelMA bases and maintained for 4 weeks.

CCK-8 assay and DNA quantification were used to measure cell ingrowth. Various experimental variables were adjusted to reproduce the *in vivo* results including the use of endothelial cell co-cultures. A linear model was used for analysis (Fig. 5).

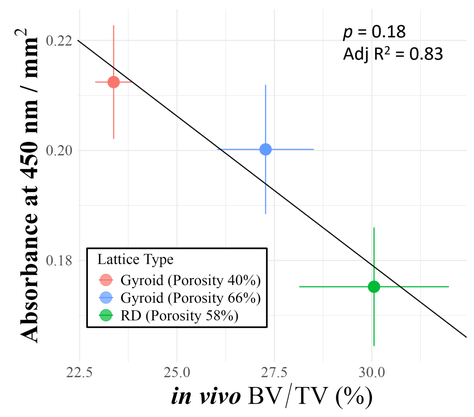


Fig. 5. The in vitro system ranked lattice structures in reverse order: better performing lattices in vivo performed worse in vitro. CCK-8 absorbance values were normalised to surface area available for growth.

This *in vitro cell culture* model was then used to examine the influence of geometric parameters, quantified using the BoneJ plugin in ImageJ, on cell ingrowth into novel lattice structures. A linear mixed model was used for analysis (Table 1 & Fig. 6).

Table 1. Model estimates predicting cell ingrowth based on lattice geometry.

Predictor	Estimate*	SE	*p*
(Intercept)	-0.43	0.11	0.0002
El.Th (mm)	0.19	0.03	<0.0001
Ellipsoid Factor	0.20	0.05	<0.0001
DA	-0.04	0.04	0.330
Porosity (1)	0.78	0.11	<0.0001
Conn.D (mm^{-3})	-0.02	0.03	0.450

* Change in absorbance per unit increase in predictor

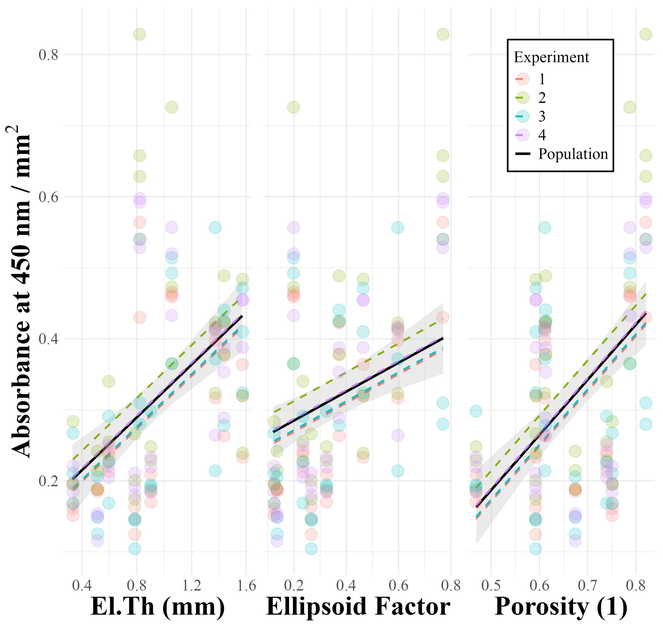


Fig. 6. Relationships between geometric parameters and cell ingrowth (CCK-8). Trend lines represent predictions from the linear mixed model; points show individual observed values. El.Th, element thickness.

Conclusions

1. *In vitro* performance does not reliably predict *in vivo* outcomes: lattices performing well *in vivo* may perform poorly *in vitro*, although porosity positively influences responses in both contexts, highlighting the complexity of extrapolation between models.
2. *In vitro*, Variation in cell ingrowth is better explained by underlying geometric parameters than by lattice shape as a categorical predictor.
3. Geometric parameters provide novel, quantitative insight into the design of surgical lattices.



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