Mechanical properties of normal avascular and revascularizing cancellous bone: an animal experiment

Gardeniers, J.W.M.; Favenesi, J.A.; Huiskes, H.W.J.; Slooff, T.J.J.H.

Published in:
Acta Orthopaedica Scandinavica

Published: 01/01/1987

Document Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
- A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Several researchers have attempted to evaluate the material properties of cancellous bone (stiffness, strength) (Behrens et al. 1974, Carter & Hayes 1977, Galante et al. 1970, McElhaney et al. 1970, Townsend et al. 1975). Of considerable interest in clinical practice is the question of how the material properties are affected in avascular and revascularizing trabecular bone when compared with normal trabecular bone.

**Material and methods.** Using a sterile surgical procedure, the anterosuperior segments of the left femoral heads of African Pygmy Goats were devascularized and isolated, but kept in situ, using acrylic cement. Forty-four goats were used and divided into six groups. The control group was not operated on. Three avascular groups were killed 6, 12, and 24 weeks after the operation. The fifth group was operated on twice: first, to devascularize and isolate the segment and, secondly, to revascularize the same segment by drilling a hole through the acrylic cement barrier. The last group was also operated on twice, similar to the fifth group, but in addition an arteriovenous bundle was transplanted into the segment through the drill hole (Hori 1981). Eleven goats in this group were killed after 12 weeks and 5 goats after 24 weeks.

Specimens for mechanical tests were obtained from all the material of the first five groups. All the test specimens were cylindrical, 5 mm in diameter and 4-mm thick and cored from the anterosuperior segments in the principal trabecular direction. Each specimen was subjected to unconfined compression to failure on a Zwick testing machine at a cross-head speed of 1 mm/min. Yield strength and Young’s modulus were determined. The apparent density of each sample was assessed (Carter & Hayes 1977). Histologic examinations were carried out to check avascularity and revascularization using normal and UV light microscopy. No specimens were obtained from the last group, which was subjected to loading in vivo and evaluated only histologically.

Three human postmortem femoral heads were used, and a total of 45 specimens were obtained for testing to assess the validity of the testing methods and as a means of comparison.

**Results.** The results confirm that the mechanical properties of cancellous bone, both human and goat, are principally functions of apparent density (Carter & Hayes 1977, Galante et al. 1970, McElhaney et al. 1970) (App. dens. goat 0.59-1.48 g/cm³). No differences in strength were observed between normal, 6-, 12-, and 24-week avascular cancellous bone in goats (Figure 1) (yield strength: 4.7-54.6 MPa). This was also true for the stiffness, Young’s modulus (E: 84-1,434 MPa). The strength and stiffness observed in the human specimens were generally in agreement with those published earlier (Behrens et al. 1974, Carter & Hayes 1977, Galante et al. 1970 McElhaney et al. 1970). Decreasing strength and stiffness with increasing age were also observed (Weaver & Chalmers 1966). Very different results were obtained for the revascularizing specimens of group 5. The average yield strength was found to be significantly less than in the normal and avascular specimens (Figure 2). The corresponding apparent density was essentially equal, on an average. In the last group, 16 goats with an arteriovenous bundle transplantation, all the anterosuperior segments were loaded in vivo during a period of 13 weeks (11 goats) and 24 weeks (7 goats). Of the first 11 goats (1 infected excluded), eight segments showed no signs of collapse and two displayed a small partial collapse. In the 24-week group (3 infected excluded), the remaining two segments showed no signs of collapse.

**Conclusions**

1. The quality of the cancellous bone matrix if isolated in vivo under normal loading conditions remains unchanged.
2. Collapse of the femoral head during avascular necrosis is due to the revascularizing process.
3. Transplantation of an arteriovenous bundle may prevent collapse.

**References**


