



■ INFOGRAPHIC

Impact of implant materials and malalignment in unicompartmental knee arthroplasty

Keywords: Unicompartmental knee arthroplasty, Malalignment, Bone strain, Finite element analysis

**I. Danese,
P. Pankaj,
C. E. H. Scott**

University of
Edinburgh, Edinburgh,
United Kingdom

Unicompartmental knee arthroplasty (UKA) survival remains variable across implants and institutions. A strong relationship has been proven between UKA survival and surgeon volume,¹ implying that achieving well-aligned UKAs is important for maximizing survival. In nearly half of UKA revisions, the indication for revision is unexplained pain,² and elevated proximal tibial strain and micro-damage are thought to contribute to this.^{3,4}

A finite element model of a composite tibia (experimentally validated using digital image correlation and acoustic emission⁵) was used to investigate the effect of tibial component alignment in cemented metal-backed (MB) and cemented all-polyethylene (AP) fixed-bearing medial UKAs.⁶ A linearly elastic analysis was performed with loads up to 2500 N medially (4170 N total load). Standard alignment (medial proximal tibial angle 90°, 6° posterior slope), coronal malalignment (3°, 5°, 10° varus; 3°, 5° valgus), and sagittal malalignment (0°, 3°, 6°, 9°, 12°) were analyzed. The primary outcome measure was the volume of compressively overstressed cancellous bone (VOCB) < -3000 µε. The secondary outcome measure was maximum cortical bone stress (MCBS) over a medial region of interest.

Malalignment had less effect on the VOCB than implant selection. Well-aligned AP implants displayed greater volumes of overstressed cancellous bone and greater antero-medial MCBS than poorly aligned MB implants at both low and high loads. Consistent with previous studies of MB implants,⁷ varus malalignment increased MCBS but decreased VOCB in both implants. Varus malalignment of 10° reduced the VOCB by 10% and 3% in AP and MB implants, respectively, but increased the MCBS by 14% and 13%. Valgus malalignment of 5° increased the VOCB by 8% and 4% in AP and MB implants, respectively, with reductions in MCBS of 7% and

10%. Sagittal malalignment displayed negligible effects.

Supportive of previous work showing AP implants to be more sensitive to polyethylene thickness than MB implants,⁸ this finite element study has shown that UKA tibial component material has a greater effect on proximal tibial bone strain than malalignment. Cancellous bone strain and cortical bone stress had a reciprocal relationship: varus malalignment reduced cancellous bone strain but increased antero-medial cortical bone stress; valgus malalignment did the reverse. Well-aligned AP implants display greater bone strains than malaligned MB implants.

References

1. **Liddle AD, Pandit H, Judge A, Murray DW.** Optimal usage of unicompartmental knee arthroplasty: a study of 41,986 cases from the National Joint Registry for England and Wales. *Bone Joint J* 2015;97-B:1506-1511.
2. **Baker PN, Petheram T, Avery PJ, Gregg PJ, Deehan DJ.** Revision for unexplained pain following unicompartmental and total knee replacement. *J Bone Joint Surg [Am]* 2012;94-A:e126.
3. **Simpson DJ, Price AJ, Gulati A, Murray DW, Gill HS.** Elevated proximal tibial strains following unicompartmental knee replacement—a possible cause of pain. *Med Eng Phys* 2009;31:752-757.
4. **Scott CE, Wade FA, Bhattacharya R, et al.** Changes in bone density in metal-backed and all-polyethylene medial unicompartmental knee arthroplasty. *J Arthroplasty* 2016;31:702-709.
5. **Scott CE, Eaton MJ, Nutton RW, et al.** Proximal tibial strain in medial unicompartmental knee replacements: a biomechanical study of implant design. *Bone Joint J* 2013;95-B:1339-1347.
6. **Danese I, Pankaj P, Scott CE.** The effect of malalignment on proximal tibial strain in fixed-bearing unicompartmental knee arthroplasty: a comparison between metal-backed and all-polyethylene components using a validated finite element model. *Bone Joint Res* 2019;8:55-64.
7. **Simpson DJ, Gray H, D'Lima D, Murray DW, Gill HS.** The effect of bearing congruency, thickness and alignment on the stresses in unicompartmental knee replacements. *Clin Biomech (Bristol, Avon)* 2008;23:1148-1157.
8. **Scott CE, Eaton MJ, Nutton RW, et al.** Metal-backed versus all-polyethylene unicompartmental knee arthroplasty: proximal tibial strain in an experimentally validated finite element model. *Bone Joint Res* 2017;6:22-30.

© 2019 Author(s) et al. This is an open-access article distributed under the terms of the Creative Commons Attribution licence (CC-BY-NC), which permits unrestricted use, distribution, and reproduction in any medium, but not for commercial gain, provided the original author and source are credited.

■ I. Danese, MEng, Mechanical Engineering Masters Student, School of Engineering, University of Edinburgh, Edinburgh, UK.

■ P. Pankaj, PhD, Chair of Computational Biomechanics, School of Engineering, University of Edinburgh, Edinburgh, UK.

■ C. E. H. Scott, MSc, FRCS(Tr&Orth), MD, Consultant Orthopaedic Surgeon, NRS Clinical Research Fellow, School of Engineering, University of Edinburgh, Edinburgh, UK; Department of Orthopaedics, Royal Infirmary of Edinburgh, Edinburgh, UK.

Correspondence should be sent to C. E. H. Scott; email: chloe.scott@nhslothian.scot.nhs.uk

doi: 10.1302/2046-3758.86.BJR-2019-0111

Bone Joint Res 2019;8:226–227.

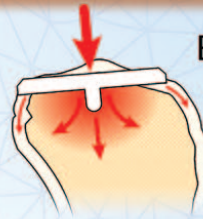


Impact of implant materials & malalignment in unicompartmental knee arthroplasty

I. Danese et al., researchers from University of Edinburgh, Bone Joint Res 2019



of revisions for unicompartmental knee arthroplasties (UKAs) are due to unexplained pain



Elevated strain and microdamage from malalignment may contribute to pain

Study Design

Tibial strain from malalignment was modelled using **finite element analysis (FEA)** for:

all-polyethylene (AP) UKAs metal-backed (MB) UKAs

Outcome measures:

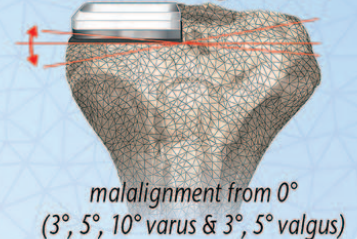
- volume of compressively overstressed cancellous bone (VOCB)
- maximum von Mises stress in cortical bone (MSCB)

Researchers examined both:

Sagittal alignment

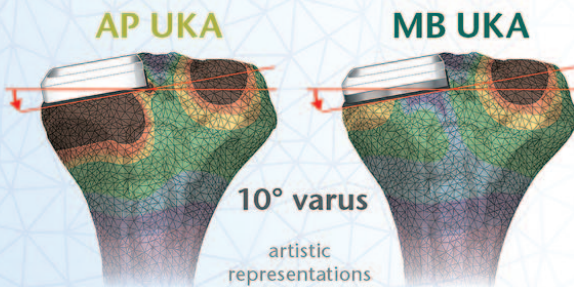


Coronal alignment

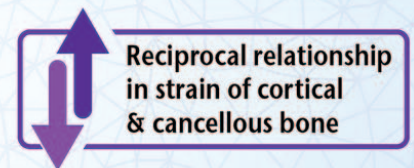


Results

Coronal plane malalignment impacts bone strain



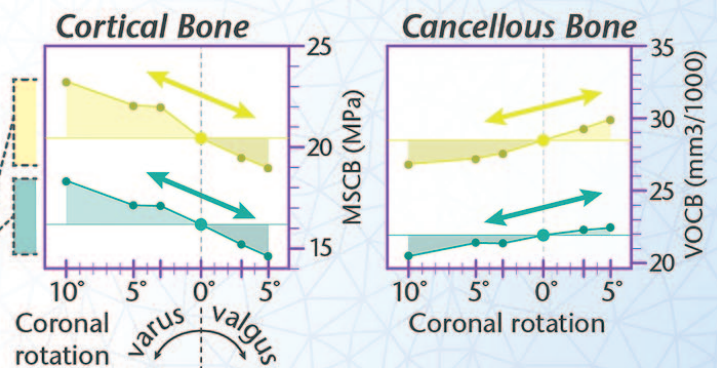
In comparison, changes in strain were negligible for sagittal plane malalignments



Most important factor

Material of UKA has greatest impact on bone strain

Range of strain for AP UKAs is greater than largest MB value



Conclusions

All-polyethylene implants translate greater strain to underlying bone and are more sensitive to coronal plane malalignments than metal-backed UKAs.