■ SPECIALTY UPDATE: KNEE

Zonal fixation in revision total knee arthroplasty

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Revision knee arthroplasty presents a number of challenges, not least of which is obtaining solid primary fixation of implants into host bone. Three anatomical zones exist within both femur and tibia which can be used to support revision implants. These consist of the joint surface or epiphysis, the metaphysis and the diaphysis. The methods by which fixation in each zone can be obtained are discussed. The authors suggest that solid fixation should be obtained in at least two of the three zones and emphasise the importance of pre-operative planning and implant selection.

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As the numbers of primary total knee arthroplasties (TKA) have increased over recent years, there has been a commensurate rise in revision procedures. This trend is likely to continue in the years ahead.[1-4] The results of revision TKA, both in terms of longevity and functional improvement, fall short of those seen following primary procedures.[5-6] Outcomes are related to the indication for revision, with revisions for infection and stiffness having particularly poor outcomes.[7] To attain an acceptable functional outcome, the aim of surgery is to produce a stable knee with a good range of movement, and through which the patient can bear their full weight.

At revision TKA, large bone defects and compromised bone stock can make reconstruction and fixation challenging.[8] The achievement of solid fixation of revision implants is essential to allow early post-operative mobilisation and rehabilitation, and improves the longevity of the construct.[9,10]

The distal femur and proximal tibia may each be divided into three anatomical zones in which fixation can be achieved: zone 1, the joint surface or epiphysis; zone 2, the metaphysis; and zone 3, the diaphysis (Fig. 1). Such a zonal classification system provides a framework for pre-operative planning and permits the understanding of where and how secure fixation can be obtained.

Zone 1: The epiphysis

In most revision TKAs and all re-revisions, zone 1 is compromised by the process of implant failure and removal. To enhance the use of fixation in zone 1, it is necessary to establish a stable surface, free of cement debris, avascular bone and fibrous membrane. When necessary, flat aligned cuts with augmentation of defects aids implant stability and fixation. Augmentation can be by cement, bone graft or metal augment. In the authors' experience, zone 1 fixation can only be reliably achieved with polymethylmethacrylate cement.

Where augmentation is required, it is necessary to achieve fixation in at least one other zone. Diaphyseal stems allow zones 1 and 3 to be linked. As the geometrical centres of the epiphysis and diaphysis are not usually aligned, an offset is often required to both allow optimal coverage at zone 1, and minimise the chance of overhang of the tibial component.

Zone 2: The metaphysis

Most revision knee systems achieve stability by a combination of epiphyseal (zone 1) and diaphyseal (zone 3) fixation. However, achievement of metaphyseal fixation is advantageous and there are now systems available which achieve fixation in this zone.

Fixation in the metaphysis is closer to the point of articulation and, as a result, facilitates restoration of the joint line. The geometric centres of the metaphysis and epiphysis are aligned obviating the need for an offset. Fixation in zone 2 allows the use of shorter diaphyseal stems mitigating the anterior translation effect of the femoral bow and allowing posterior translation of the articular component. Failure to gain adequate fixation in zone 2 can lead to instability of augment fixation in zone 1 through sheer stress and early failure of the revision.[11,12]

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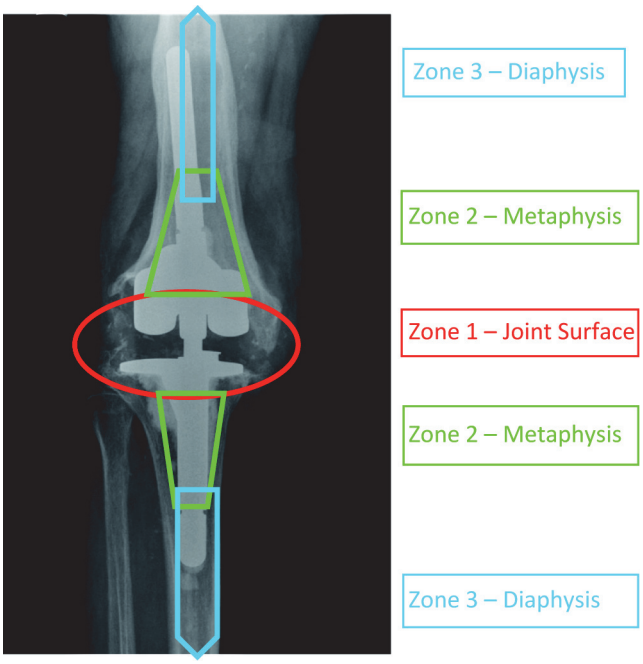

Fig. 1

Radiograph of a failing total knee arthroplasty showing the fixation zones identified in planning the revision procedure.

Metaphyseal fixation can be achieved using cement,[13] or by using porous metaphyseal sleeves such as those available from DePuySynthes (Warsaw, Indiana). Cement fixation in metaphyseal bone is inexpensive, readily available and can be used with either cemented or uncemented stems. Metaphyseal sleeve fixation allows load transfer to avoid stress-shielding and encourage bone on-growth.[14] Fixation closer to the joint space provides better restoration of joint line and axial/rotational stability, even in the presence of cortical or cancellous bone defects and may be an alternative to long stems.[15,16] Metaphyseal sleeves as part of mobile bearing revision system have shown good early- to mid-term results.[17-19] Currently, additional fixation in zone 3 is advocated.

Using metaphyseal sleeves, bone defects can be filled and primary direct implant fixation can be achieved in a single step. Secondary indirect metaphyseal fixation in zone 2 can be achieved using cement, but reconstruction of bony defects must be achieved first. As with zone 1 augmentation, zone 2 reconstruction can be achieved with cement, bone graft (bulk allograft or morsellised impaction graft)[20] or by the use of trabecular metal cones (Zimmer, Warsaw, Indiana, Biomet, Warsaw, Indiana). Trabecular metal cones effectively act as metallic bone graft and provide support by the same principle as an acetabular reconstruction ring. Trabecular metal has a structure similar to cancellous bone, is highly biocompatible and osteoconductive.[21,22] Trabecular metal cones offer the advantages of availability and intra-operative press-fit stability, allowing immediate weight-bearing.[23,24] Zone 2 reconstruction, however achieved, should be seen as distinct from implant fixation, and secure zone 3 fixation with either a cemented or uncemented stem should be considered.

Zone 3: The diaphysis

Fixation in zone 3 by diaphyseal stems has been demonstrated to off-load the metaphysis, where augmentation may have been necessary, thus protecting the implant/cement interface from failure. Stems may be cemented or uncemented, either can offer long-term survival but both have limitations.

Cemented stems are preferred in patients with poor diaphyseal bone and large canal diameter; in patients whose canal geometry does not allow a reliable press-fit for uncemented stems and those with sclerotic or damaged metaphyseal bone (which results in inadequate fixation requiring extension of cementing into the diaphyseal canal). Cemented stem fixation allows the use of shorter stems, provides immediate fixation and, in infected revisions, allows the delivery of antibiotics.[25] However, cemented stems may also lead to bone resorption in the metaphysis over time through stress shielding.[26]

Uncemented stems are indicated in patients with good diaphyseal bone and favourable canal geometry allowing a press fit. Uncemented stems are also preferred in the management of periprosthetic fracture. Uncemented stems appear to have less of an effect on metaphyseal bone density,[27-29] although radiolucent lines of uncertain significance can develop around stems over time. The optimal length and thickness of stems remain poorly defined for both cemented and uncemented designs.[30]

Both cemented and uncemented stems are associated with stem tip pain, which can be a disabling complication of tibial stem use.[31] Biomechanical studies have shown that this results from the stress concentrations engendered by the mismatch in elastic moduli between the stem and surrounding bone.[32,33] Peak contact pressures are highest with long, thick stiff uncemented stems.[34] This may support the use of smaller cemented stems, as long as adequate fixation is attained. Modifications to the design of uncemented stems, including slots or splits in the stem, or the use of more flexible materials such as titanium, may reduce the incidence of stem-tip pain.[31-34] The final decision to use a cemented or uncemented stem depends on the individual patient, the residual bone quality and any history of previous revisions.

In conclusion, reconstruction and fixation are challenging in revision TKA, and are of great importance in the achievement of an acceptable result. The concept of zonal fixation provides a working methodology applicable to both the tibia and the femur when planning revision knee replacement. Each zone should be considered on its own merit and should be used in the context of the surgeon's chosen revision implant system. The classification is equally useful for both cemented and uncemented fixation. Most revisions require a combined approach to fixation and a multi-zone strategy should be adopted. During pre-

operative planning, three questions need to be addressed: which zones are available for fixation, which fixation method is appropriate and which implants are best suited to the case. Failure to ask and answer these questions preoperatively could lead to inadequate fixation and ultimately early failure.

Author contributions

R. Morgan-Jones: Wrote the manuscript.
S. I. S. Oussedik: Wrote the manuscript.
H. Graichen: Approved the manuscript.
F. S. Haddad: Approved the manuscript.

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