R. J. Grimer DSc FRCS
Consultant Orthopaedic Surgeon
Royal Orthopaedic Hospital,
Northfield, Birmingham B31 2AP, UK.
robert.grimer@nhs.net

L. M. Jeys FRCS
Consultant Orthopaedic Surgeon
Royal Orthopaedic Hospital,
Northfield,
Birmingham B31 2AP, UK.

Amputation was once widely practised for primary bone tumours of the limbs. Yet this situation has changed with limb salvage surgery becoming increasingly popular in the last 30 years. Many different techniques are now available. These include allografts, autografts, endoprostheses and allograft-prosthesis composites. This article reviews these methods, concentrating on the functional outcomes and complications that have been reported.

Limb salvage for bone tumours: *does it work?*

It was once the case that a primary malignancy in the long bone of a limb was virtually guaranteed to be treated with amputation, radiotherapy, or both. Yet this association has dramatically changed. Limb salvage surgery for primary malignant bone tumours became popular in the 1980s thanks to advances in imaging, adjuvant treatments, bioengineering and the skill and enthusiasm of the surgeons who treated these patients. The original methods of reconstruction were largely based on the local skills and expertise available in different centres. This resulted in a number of parallel evolutions of different techniques, all of which have improved with time. More evidence is now becoming available regarding the long-term outcomes of these different types of reconstruction. This article reviews these, concentrating on the functional outcomes and complications that have been reported.

As limb salvage has become more commonplace it has become necessary to properly define the meaning of success (Fig. 1). Some of the earlier scoring systems, such as the American Musculoskeletal Tumor Society (MSTS) score,[1] had the drawback that they were completed by the clinician and may not have truly represented the views and functional capacity of the patient. More recently the Toronto Extremity Salvage Score (TESS)[2] has become more widely used; this is a well-validated scoring system that is completed by the patient. Measuring quality of life has also shown how difficult it is to assess differences between surgical procedures, and has shown that patients with amputations often fare very well.[3]

However, there is still no true longitudinal system of assessing lifetime outcomes for a collective group of patients. The ideal procedure for resection of a tumour would prevent local recurrence, restore function, have few early complications, and would be both long lasting and cost effective. Most reports document the incidence of complications such as

infection, fracture, loosening, the need for revision surgery and the need for amputation. Henderson et al[4] have recently categorised these failures as mechanical (e.g. wear or breakage of an implant) and non-mechanical (e.g. local recurrence, infection). However, no scoring system currently available assesses the impact on the individual of these complications or indeed of the original procedure.

Despite these limitations, a moderate amount of information is available on long-term follow-up of different types of reconstruction.

ALLOGRAFTS

Allografts were very popular in the 1980s and in some centres very good results have been achieved. The best indication for an allograft is after the diaphyseal resection of a long bone. The Nijmegen group reported long-term results of this type of reconstruction in a series of 32 patients.[5] Complications included fractures in 13%, infection in 16% and nonunion in 68%. Meanwhile, Aponte-Tinao et al[6] reported on 83 intercalary femoral allografts. Although allograft survivorship was 76% at ten years, there was a 13% rate of nonunion and a 17% rate of fracture.

Osteoarticular allografts that replace the joint have fared less well. Muscolo et al[7] reported on the use of 75 such allografts around the knee. The overall rate of allograft survival was 78% at ten years although a significant number had required a knee replacement by that time. Meanwhile, the combination of an allograft with a vascularised fibular graft has produced impressive results, especially for mid-tibial replacements.[8]

Not all have had success with allografts. The Münster group reported on 17 patients with osteoarticular allografts; by five years only seven (41%) were still in place.[9] The Rizzoli group reported similar experiences in two studies.[10,11] Ogilvie et al[12] reported a series of 20 osteoarticular allografts, only 40% of which were still *in situ* at five years.

Fig. 1. This patient, aged 26 years, underwent a total femoral replacement in 1980 for osteosarcoma. He worked all his life as an electrician but required three further surgical procedures – two cup revisions and a complete revision of the shaft (replacement for the affected bone) and stem (replacement inside the bone). All were due to wear of the bearing surfaces because he was so active.

AUTOGRAFTS

Autografts have the attraction of being cheap and readily available. Fibular grafts are most popular for long-bone defects. Eward et al[13] reported a series of 30 patients with large defects that were reconstructed with free fibular grafts. The overall complication rate was 53%, with a re-operation rate of 40% although primary union was achieved in 77% at a mean of six months.

Distraction osteogenesis, popular for reconstructing traumatic defects, is rarely used for tumours. Tsuchiya et al[14] reported 19 patients with a mean defect length of 8.4 cm treated with distraction osteogenesis. Functional evaluation showed excellent results in 12 patients, good in five and fair in two.[14]

ENDOPROSTHESES

Endoprosthetic replacements have been used in bone tumour surgery for more than 40 years.[15] The early implants were cemented and mostly based on joint replacements available at that time.[16] Fixed-hinge knees for tumour surgery produced reasonable results, with 58% survival at 20 years.[17] In a large series, Shehadeh et al[18] reported a 47% survival of distal femoral replacements at 15 years, the main causes of failure being aseptic loosening and infection. Uncemented stems have reduced the incidence of loosening but there is still a significant failure rate, the Toronto group reporting a failure rate of 25% within two years.[19] One of the problems of the uncemented implants was stress protection of the femoral shaft leading to bone resorption. This has been combatted by the use of the novel COMPRESS system (Biomet Inc., Warsaw, Indiana), which has promising results in early trials.[20]

The longer-term problems of endoprostheses include component breakage, reported to occur in up to 15% of cases, although less common with modern prostheses.[21] More worrying, however, is the incidence of late infection, a risk that does not diminish with time. It can be related to many factors including the site involved, the use of radiotherapy, chemotherapy, other infective foci and any comorbidities.[22,23]

ALLOGRAFT-PROSTHESIS COMPOSITE (APC)

The concept of using a conventional prosthesis to replace the joint and an allograft to replace any removed bone has proved attractive. However, the results have not been convincing. For example, Biau et al[24] reported 32 proximal femoral APCs. By ten years 19% had failed, leading to the conclusion that APCs did not improve survival compared with megaprostheses. Similar results were found for the proximal tibia.[25]

In the proximal humerus the functional outcome depends on the soft-tissue reconstruction. Early results of both allograft and APC reconstructions around the shoulder were promising but later results were less encouraging as the allograft component tended to resorb. Van de Sande, Dijkstra and Taminiau[26] concluded that an endoprosthetic reconstruction gave the lowest complication rate, and the highest implant survival and functional results when compared with an APC or an osteoarticular allograft.

OTHER METHODS

Surgical diversity has led to other methods of limb reconstruction being developed. One of the oldest is irradiation and reimplantation. The long-term results reported by Poffyn et al[27] are impressive, with 89% of grafts being retained at a mean of ten years. Other methods of sterilising and reinserting bone such as pasteurisation, microwave or cryotherapy have also been reported but with only short-term outcomes (Fig. 2).

CONCLUSIONS

Improvements in surgical technique and prosthesis design are taking place continually. As with changes in joint replacement, modern tumour prostheses are more sophisticated than those produced 20 years ago. However, whether they will provide better long-term results is still unknown. Given the young age at which most patients undergo limb salvage for bone tumours it is likely that most will require at least one further procedure in their lifetime; some will need many. Reducing the number of these and their effect on the patient is one of the

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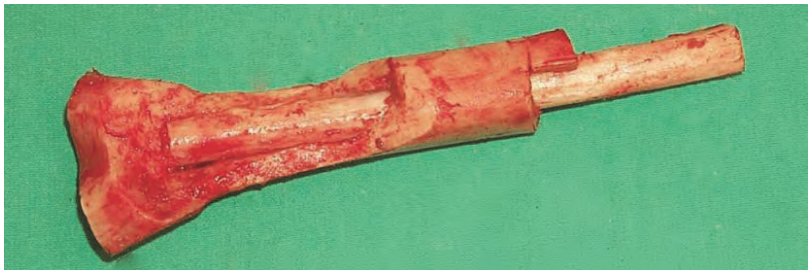

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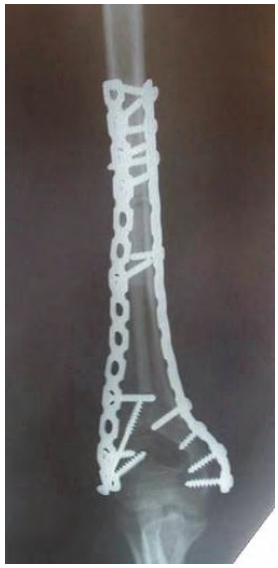

c

Figure 2a – radiograph of a 13-year-old girl with a painless lump over her right elbow. Investigation showed it to be a parosteal osteosarcoma involving the medullary canal. The tumour was resected 1 cm from the elbow joint and 12 cm more proximal. The tumour was removed and the medullary canal cleaned. The bone was then sterilised with 90 Gy of radiotherapy. **Figure 2b** – photograph of a non-vascularised fibular graft which was inserted in the middle of the bone, the construct being replaced with two supporting plates. Within six months the patient had returned to netball and had a full range of movement of the elbow. **Figure 2c** – radiograph at ten years shows a very satisfactory outcome.

challenges for the future. While the problem of aseptic loosening appears to have been largely resolved, the problem of wear debris from bearing surfaces and the risks of infection have yet to be conquered. The ability to reconstruct missing muscle groups after tumour resection needs further work and a system of assessing the lifetime impact of any type of reconstruction needs perfecting. But in summary, does limb salvage for bone tumours work? Yes, but there is much still to do.

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