EC ORTHOPAEDICS
Research Article

Surgical Technique of Impaction Bone Grafting in Revision Total Elbow Replacement

Suddhajit Sen*, Toni Luokkala, Sumedh Talwalkar, Amar Malhas and Bodo Purbach

Department of Orthopaedics, Wrightington Hospital, UK

***Corresponding Author:** Suddhajit Sen, Department of Orthopaedics, Wrightington Hospital, UK.

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Abstract

Background: Impaction bone grafting is a well-established technique for revision of Femoral and Acetabular bone loss in Total Hip arthroplasty. With increasing number of Elbow arthroplasties in the last few decades there is a parallel increase in revision surgery. Osteolysis and bone defect in Humerus and Ulna are common problems, as aseptic loosening remains the major cause of failure in Elbow Arthroplasty. Impaction bone grafting has been used to mitigate this problem but there is very limited information available about the technique in literature.

Methods: We are describing our technique of impaction grafting used in 2 cases of revision Elbow arthroplasty done at Wrightington with Femoral head allograft. Our aim was to enhance the shear resistance property of the graft and we postulate graded particle size, angular particle shape and removal of fat and bone marrow by washing improve shear strength of impacted allograft. Our methodology involved using our technique on saw-bone model and measure the shear resistance property of the impacted graft.

Results: All our patients have demonstrated excellent radiological parameters in early follow up. We are aiming to continue follow up to present our mid-term results.

Keywords: *Impaction Bone Grafting; Revision Total Elbow Replacement; Allograft; Osteolysis; Graded Particle Size; Prospective Case Series*

Introduction

Total elbow arthroplasty (TEA) for rheumatoid and osteoarthritis of the elbow has become a reliable surgical solution. TEA is still quite an uncommon procedure with 1.4/100 000 annual incidence in western countries, which is significantly lower compared to other arthroplasties such as knees. In 2016 692 TEA has been done in United Kingdom according to National Joint Registry (NJR). However, the incidence of TEA is slowly increasing and its use has been extended to trauma in relatively young patients [1]. As a result, complications and revision surgery has been under stricter scrutiny to address the underlying causes of failure [2]. The rate of complications after TEA is historically reported to be significantly higher (43%) compared to other large joint replacements. These include infections, aseptic loosening, ulnar nerve neuropathies, instability, dislocations, intraoperative fractures, prosthesis failures and heterotopic ossification [3]. Implant failure is most commonly associated with aseptic loosening [3]. This is compounded by stress shielding, osteolysis, loss of bone while implant removal and/or infection. The end result is usually severe host bone loss [4,5]. There are several techniques described for surgical management of severe bone loss with cortical destruction. Methods range from long stem custom implants to bypass the defect, cortical structural allograft, allograft-prosthesis composite to impaction bone grafting [6]. Severity of bone loss proportionately increases the challenge of revision surgery. The surgical objective should serve dual purpose of conferring mechanical stability to the revision implant and biological aid to restore bone stock [4]. Loebenberg., *et al.* [7] was the first to describe impaction bone grafting for revision total elbow arthroplasty. Most of the research on this technique has been performed on hip arthroplasties.

The most typical type of osteolysis is resorption of the endosteal bone with associated cortical thinness and sometimes ballooning effect which produce insufficient bone stock and compromises the bone-cement interface. This problem has been effectively managed in hip and knee surgery with impaction bone auto- or allografting. In revision TEA impaction grafting with morselized bone graft has been described in two previous retrospective studies [6,7]. However, there is limited data available on impaction grafting used in revision TEA and the detailed technique of morselized impaction bone grafting is not to our knowledge been published previously.

Purpose of the Study

The purpose of this study was to investigate and describe the steps of impaction bone grafting for revision TEA in a prospective case series.

Materials and Methods

Our study is a prospective series of 2 patients and we are presenting a detailed description of our technique.

Step 1: Preparing the graft

Fresh frozen unprocessed Femoral head from Wrightington bone bank used for the allograft. This was decorticated and stripped off all the cartilage. Pea sized morsels of cancellous bone created with bone nibblers instead of a bone mill. This was done to create a wide range of particle size (well graded).

Step 2: Graft rinsing

Graft material rinsed several times in warm saline to wash away the marrow fat. The prepared graft assumes a spongy texture.

Step 3: Preparation of the medullary cavity

All debris removed from the joint and medullary cavity (Figure 1 and 2).

Figure 1

Figure 2

Step 4: Graft impaction

Medullary cavity is turned into a rigid but porous containment area by using cement plug. Trial implants inserted to assess the size and left in the cavity to serve as a template. Graft material impacted with high-energy impaction and cyclical loading around the trial stem. Effective impaction leaves the graft-stem interface rigid enough to allow removal of trial stem leaving a stable mantle of bone graft acting as a scaffold for the prosthesis (Figure 3 and 4).

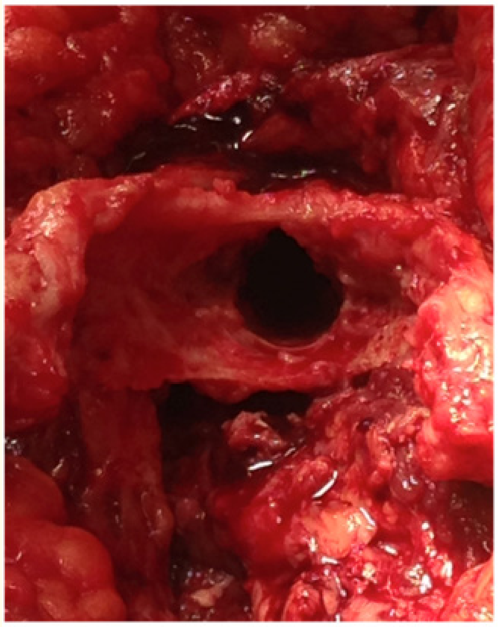

Figure 3

Figure 4

Step 5: Cementing the implant

Cementing of actual prosthesis is done in usual manner (Figure 5-14).

Figure 5

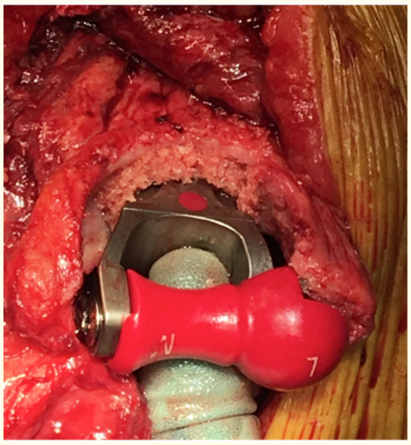

Figure 6

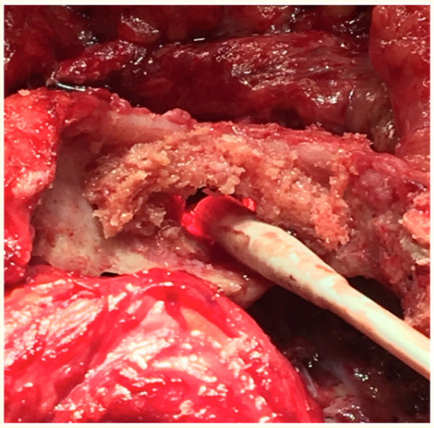

Figure 7

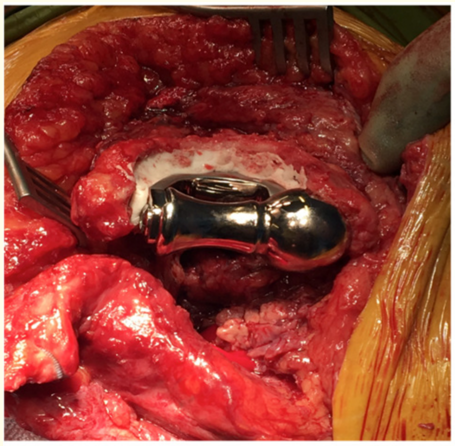

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

Figure 14

Results and Discussion

Impaction bone grafting or a similar technique was first described by Hastings and Parker for treatment of protrusio acetabuli in rheumatoid arthritis [8]. Slooff., *et al*. in 1984 modified the technique of impaction grafting and named it such [9].

Mechanics and biology

An ideal graft must confer early mechanical stability and aid late biological incorporation to improve bone stock [4]. This is a complex relationship. Early mechanical stability depends on shear resistance and cohesive properties of the graft. Most useful scientific information on shear strength of bone graft material comes from soil mechanics. In this context morselized bone is akin to compacted friable particulate aggregate. Borrowing from soil mechanics it has been observed that the following principles of graft preparation confer highest shear resistance properties [10]:

1. A rigidly contained graft.
2. Well-graded particle-size; which means a broader range of particle sizes.
3. A porous containment to allow fluid escape and thereby prevent pore fluid generation.
4. Use of large energy impaction.
5. Use of vibration while impacting.
6. Sequential layered compaction of well-impacted material [10].

These principles appeal to the mechanics of the graft but the biology of osseo-integration demands consideration of several other factors. It is worth discussing these factors from a dual perspective of biology and mechanics.

Graft material

Allogenic cancellous bone graft provides osteoinduction and osteoconduction but rather poor structural support. Allogenic cortical bone graft provides structural support and minimal osteoinduction if not freeze dried [11]. Morsellized cortical impaction allograft showed superior structural support over cancellous graft in a cadaveric study on femoral bone defects [12]. Several studies were performed to experiment with graft additives to improve structural strength. But in their study Oakley and Kuiper showed pure allograft bone without graft extenders retain superior cohesion [13]. They also showed adding clotted blood improves cohesion and rinsing had no effect [13]. In another study by Kuiper it was showed that cancellous allograft gains better structural stability when cortical additives are added to it. One of the major objectives of impaction grafting is biological incorporation to improve bone stock, which require osteoinduction and osteoconduction. Thus, from a biological perspective, cancellous graft with cortical additive is probably a better choice. More studies are needed to confirm these findings.

Particle size and grading

Soil mechanics lends us the knowledge that shear strength is the most important property to resist stress for a granular aggregate like bone graft. Shear strength depends upon internal friction and interlocking angle of the particles [10]. This leads to the conclusion that a well-graded (broad size range) angular and porous particle is ideal for maximum shear resistance. Here lies the conflict between biology and mechanics. An ideal-grade particle distribution will tend to fill the voids between larger particles with smaller particles. Which theoretically prevents bone ingrowth and graft incorporation [4]. It is postulated that the benefits of early mechanical stability from well-graded particles offset this biological disadvantage. More evidence is required to determine the truth.

The ideal particle size for femoral impaction grafting is 3 - 5 mm. For acetabular grafting larger bone chips are recommended [14]. There are no recommendations available for elbow replacement. It is observed in the study that larger bone croutons than what can be produced from commercial bone mills are structurally more stable [10].

Effects of rinsing

The theoretical advantage of rinsing is replacing fat and marrow from the interstices of the graft by normal saline. Saline being less viscous moves through the pores of the graft easily and provides much less resistance to impaction [10]. This leads to enhanced mechanical stability [15]. Rinsing wash away growth factors and detrimental for autologous bone. Rinsing wash away immunogenic factors which could inhibit incorporation of allograft [4,14]. Overall effect of rinsing seems beneficial for allograft.

Compaction

Impaction improves mechanical stability by densely packing the graft material (compaction) and improving cohesion. The compacting effect of impaction depends on the vigour of impaction and number of cycles [16]. It is unclear what effect impaction have on biology of the graft.

Effect of cementing

Penetration of cement into the pores of the bone graft constitutes a mechanical construct conferring structural stability. An *in vitro* study has confirmed better stability of femoral stems when cemented compared to un-cemented [17].

Effect of mechanical loading

Mechanical loading is a biological stimulus for new bone growth and osseous remodelling for the impaction allograft. Early loading requires early mechanical stability to allow loading. Effect of loading has been confirmed in animal studies [18].

Conclusion

This is a prospective case series and we wish to follow our patients for the next foreseeable future. Our primary aim is to refine our method of grafting technique to achieve consistently reproducible results. We recognise that this is only a two case series at this stage and we are only presenting short-term (1 year) follow up. It is our aim to build up a larger case series and present medium term follow up in the next five years.

Conflict of Interest

The author(s) declare that there is no conflict of interest.

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