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Impaction Grafting for Revision Total Hip Arthroplasty

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Abstract: Impaction grafting for revision total hip arthroplasty is increasingly being used in cases complicated by substantial bone loss. Many techniques using cemented and noncemented designs with or without bone graft have had unpredictable outcomes and are the source of continuing debate. This new technique uses morselized allograft, impacted into a constrained femoral envelope, creating a new medullary canal into which a collarless, polished, tapered stem is cemented. Preliminary results of impaction grafting have been positive. However, the aspects crucial to its success remain unclear. Complications following this procedure are similar to those seen with other types of revision procedures. Many surgeons familiar with the limitations of the impaction grafting systems are modifying the original technique. Further investigation is necessary to establish which aspects of impaction grafting are critical to its success. This article reviews the principles behind the development of this procedure, its complications, limitations, and some modifications currently being used.

Introduction

Revision total hip arthroplasty for aseptic loosening of femoral implants presents a myriad of problems. Multiple areas of bone deficiency often secondary to osteolysis present a reconstructive dilemma. Many techniques using cemented and non-cemented designs with or without bone graft have met with unpredictable outcomes and are the source of continuing debate [1,8--10,13--15,17,18,20,23,26]. Complications following these procedures have been numerous and have prompted investigators to search for etiologic factors [7,11,16,19,24,25].

A new technique utilizing morselized allograft impacted into a constrained femoral envelope was described by Gates and McCollum [4] in 1990, and later modified by

Gie et al. [5] in 1993. Preliminary results have been generally positive [2,5,21].

Impaction grafting relies on the formation of a neomedullary canal using morselized cancellous bone graft impacted tightly into the deficient proximal femur. After a thin layer of polymethylmethacrylate (PMMA) is interdigitized in the bone chips, a polished, collarless taper stem is placed into the canal. The patient is encouraged to bear weight early so that hoop stresses are exerted on the cement mantle as a radial compressive force. A unique prosthetic femoral component has been developed for use in impaction grafting, however, the factors in this technique which are integral to its success (Figures 1 and 2) remain unclear.

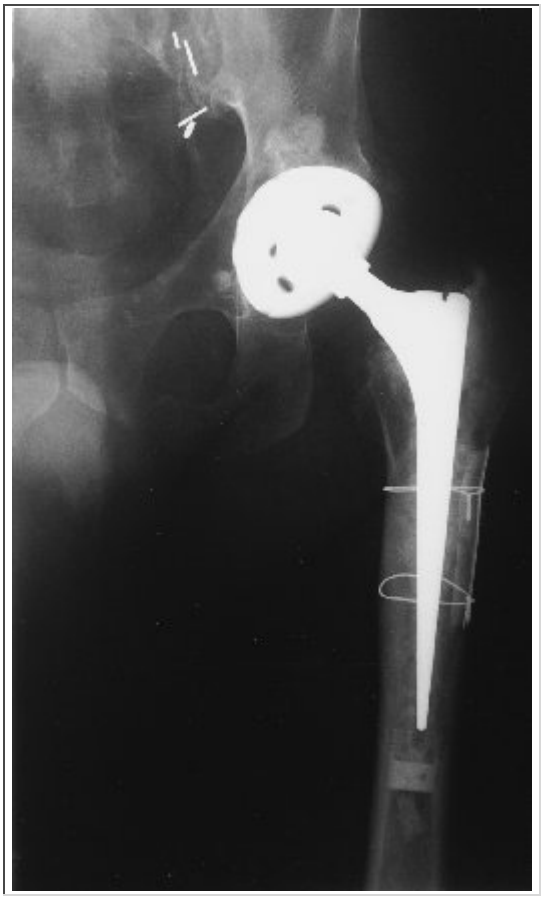

Fig. 1. Preoperative anteroposterior view demonstrating severe osteolysis surrounding the femoral prosthetic. Note the cortical thinning both medial and lateral with a cortical defect in zones 2 and 3.

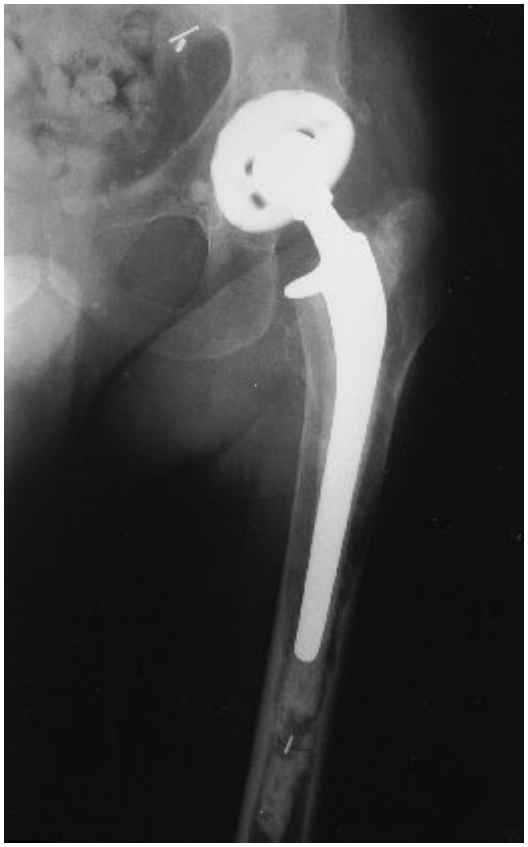

Fig. 2. Anteroposterior view after impaction grafting technique using the CPT system. A cobalt-chrome mesh was applied laterally to reinforce the deficient cortex prior to impaction. The osteolytic regions are now filled by bone graft. The acetabular component was not revised.

Technique

The impaction grafting surgical technique was originally described by Gie et al. [5] and Simon et al. [21]. It was devised as an adaptation of acetabular reconstruction techniques used by Gates and McCollum, [4] and Slooff [22] for treatment of acetabular bone deficits. Zimmer (Warsaw, Indiana) currently manufactures the CPT™ (Collarless Polished Taper) Revision Hip System. This system was developed in conjunction with W. E. Michael Mikhall and James J. Elting.

The Surgical Technique focuses on six major steps as summarized by Etling:

1. **Removal** of the old implant and cement, along with debris or fibrous membranes, revealing the often patulous, incompetent femoral envelope.
2. **Restriction** of the canal 3 cm below either the distal-most osteolytic defect or the end of the new implant using a bony pedestal, residual PMMA, or a cement restrictor.
3. **Reinforcement** of the incompetent or patulous femoral shell and cortical defects circumferentially with either fine cobalt-chrome screening or strut allograft fixed with cerclage wires.
4. **Impaction** of the femoral canal distal to proximal with 3mm to 5mm frozen cancellous bone chips. Tamping of the graft is done with a small-diameter packer followed by a larger one to ensure distal filling. Over-sized double-taper wedge stems or tamps (usually starting with two sizes larger than intended implant) are used to deliver more allograft, which creates the neo-medullary canal. The tamping process is repeated, progressing down in tamp size until the planned size is firmly seated. A trial reduction can then be performed to confirm stability.
5. **Cement** is placed in a retrograde fashion through a proximal seal, interdigitizing with the bone chips.
6. **Implantation** of a polished, collarless taper stem is performed while the cement is hardening. Cement pressurization is maintained during this process.Post-operatively the patients are mobilized rapidly and encouraged to partially weight bear for 3 months with the aid of crutches or a walker.

Results

There have been two reports thus far that describe the short-term outcome following the impaction grafting technique. In 1995, Etling et al. [2] reviewed the results of his first 37 revision total hip arthroplasties at 2 to 5 years. He reported overall satisfactory results in 35 hips, with one failure caused by an indolent late infection and another caused by a fracture at the tip of the prosthesis after a septic episode. No stems had to be removed secondary to loosening. The average Harris Hip Score was 84 (range 42--100) with 22 of 27 patients achieving 78 or above.

In 1993, Gie et al. [5] reported satisfactory results with few complications in 56 hips reviewed after 18 to 49 months. All but three hips showed either no change in position or evidence of bone healing, and these three hips showed localized resorption. Two failures occurred in patients who had fractures of the femoral shaft. One patient had a preoperative fracture distal to a loose component which was treated conservatively at revision. The other fracture occured in the post-operative period. Both cases resulted in a non-union.

A histologic report was published by Ling et al. [12] in 1993 on a femur retrieved 3.5 years after impaction grafting of large cortical defects. They concluded that the allograft chips were incorporated and were replaced by viable cortical bone. They also commented that the interface between cement and bone resembled that of primary cemented arthroplasty.

The complications of impaction grafting thus far reported are similar to those reported for all revision total hip arthroplasties and do not seem to be specific to the impaction grafting technique or the prosthetic used. No cases of femoral loosening have been reported. Gie [5] reported two intraoperative fractures (2/68 cases), which required reduction and plating. In one of these cases, the stem

pierced the femoral shaft in the postoperative period. Elting [2] reported one case of post-operative femoral fracture. Dislocation has been reported by Elting in three cases, Gie [5] in three cases, and at the University of Pennsylvania in two cases. One of these dislocations was associated with dissociation of the femoral component-cement interface [6]. Sepsis has been described by Elting in two cases. Medical complications have included one case of pulmonary embolus described by Elting, as well as two cases of cerebrovascular accidents and one case of disseminated intravascular coagulopathy reported by Gie. There has not been any clear evidence that any of the described complications occurs more frequently with the use of impaction grafting.

Discussion

When the impaction grafting technique was first introduced to the international orthopaedic community in the late 1980s, many devices were showing unacceptably high failure rates for revision total hip arthroplasty [1,8--10,13]. The concept of cementing a prosthesis into a base of crushed, cancellous allograft was viewed with skepticism. However, as favorable results are being reported, enthusiasm for this technique is growing especially when revision surgery is complicated by bone loss [5]. A technique focused on replenishing the lost bone rather than filling the voids with either cement or a larger prosthesis has obvious advantages.

Because few modifications of the original technique have been used, the aspects crucial for the success of impaction grafting remain unclear. As the demand for impaction grafting systems grows in the United States, other prosthetic manufacturers are developing versions of the impaction grafting concept. These new systems include different prosthetic designs and modifications to the impaction grafting techniques. Future examination of outcomes after some of these modifications have been used will assist in determining the crutial aspects of this technique.

The CPT™ prosthesis with its double taper and polished surface is a radical design when compared to other devices currently used for revision arthroplasty. This design is based on the concept that the tapered prosthesis will subside within the cement mantle as the PMMA undergoes cold flow. Small amounts of subsidence establish hoop stresses which when appropriately loaded, increase the graft's tendency to become incorporated into the host [3]. Although cold flow does occur within cement, the amount is so small that it is difficult to measure radiographically. Therefore, it is also difficult to determine the interface where the subsidence is occurring.

Unfortunately, the CPT™ prosthesis has many shortcomings. Although this device is available in five sizes, they are all only 130mm in length. In addition there are no special revision styles such as neck or calcar replacement types. These limitations are often significant when extensive proximal femoral osteolysis forces the surgeon to cement a CPT™ stem either proud in a mesh supported by a bone graft bed, or further down the host femur leading to soft tissue tensioning problems which are difficult to solve because of limited neck lengths. Furthermore, the polished surface thought to allow for cold flow and subsidence has the potential downside of femoral stem-cement dissociation following relocation of a dislocated CPT™ stem [6]. The original technique recommends the use of liquid cement imparted into the neocortex under pressure in order to maximize penetration and inter-lock [5]. With this technique, cement can penetrate significantly throughout

the graft to the point where it may approach the host bone. Because cement impairs graft healing, penetration that is too deep may actually be detrimental.

Many surgeons familiar with these limitations are modifying the original technique. For example, different femoral stems that have good long-term results are being used. Thus far these prostheses are not designed to be used specifically with the impaction grafting technique (Figures 3 and 4). Furthermore, some surgeons are considering the use of more viscous cement to prevent over-penetration of the cement within the neocortex.

Fig. 3. Preoperative anteroposterior view of a hip with aseptic loosening. There is evidence of extensive acetabular and femoral cement-bone lucencies. Note the pronounced cortical thinning along zones 5 --7, with the prosthetic moving into varus position.

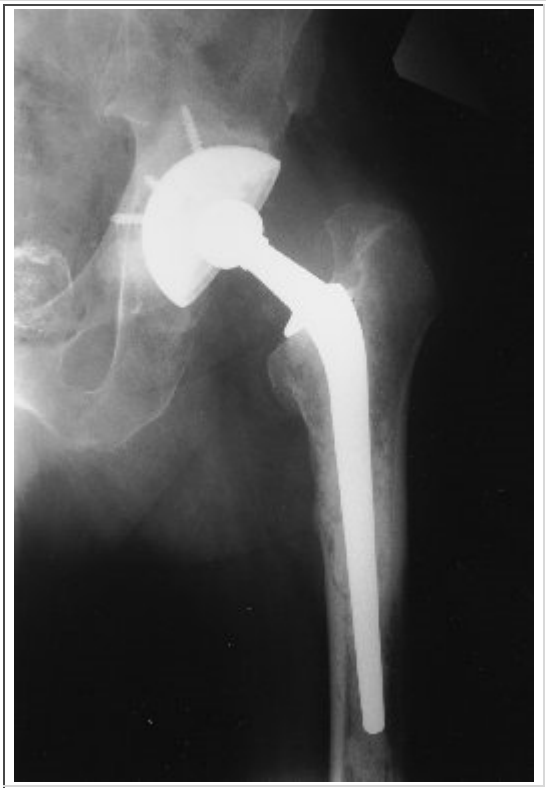

Fig. 4. Postoperative anteroposterior view after impaction grafting technique with the use of a 165cm Spectron™ and a porous coated, press-fit Reflection acetabular cup (Smith+Nephew Richards, Memphis, TN). The longer device enabled the distal areas of osteolysis to be surpassed by the prosthesis. Note the creation of the neomedullary canal with bone graft.

Impaction grafting, although somewhat of a mystery at the current time, is still a powerful tool in revision total hip arthroplasty. Although the long-term follow-up is not yet available, short-term data suggest that it is quite a promising technique. In addition, if failure does occur after impaction grafting, the bone stock would be more favorable for repeat surgery. With time and modification of the technique, the aspects paramount to the success of impaction grafting will become more clear.

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