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Editorial

Biological fixation of total hip arthroplasty: Facts and factors

1. Introduction

Since Charnley's first design of low friction arthroplasty,[1] a lot of improvements have emerged on the design, materials, and implant fixation systems. The aim of all the innovations has been to improve the long-term survival of the implants. Implant to bone fixation was achieved by means of bone cement during the initial days that was introduced by Charnley. Cemented THAs have been used with high success rates in the past. Even though the survival of cemented total hip arthroplasty (THA) is said to be good and follows the modern cementing techniques, it has always been a concern in young and more active patients.

Cementless hip arthroplasty has emerged in the late 1970s, as a better alternative to cemented systems. In the cementless design, primary fixation is based on a tight press-fit of the implant into the bone and secondary or definitive fixation largely relays on a biological anchoring in bone, needed for the long-term survival of the implants.[2] Now, uncemented THA is the widely accepted surgery for arthritic diseases of the hip joint. The bone-ingrowth rates in porous-type cementless implants encourage the biological fixation of cementless THA, both the stem and cup sides. The success of biological fixation is mainly dependent on meticulous surgical techniques and primary stability of the implant anchorage.[3] Biological fixation in which the prosthesis is directly fixed to the bone is considered as the best and ultimate fixation method. Absence of cement at the implant bone interface reduces the mechanically unstable interface.

Cementless THAs have many advantages like lower intramedullary pressure, fewer emboli, and less hemodynamic disturbances.[4] Large numbers of studies with trans-esophageal echocardiography have shown that cemented stem produces significant embolic cascades. The use of uncemented stem in osteoporotic stove pipe femoral canal requires larger stem to achieve good fixation and stability. Cemented stems were routinely recommended for these types of femoral anatomy, but the major drawback is the difficulty of cement pressurization to achieve ideal cement mantle and high risk of embolic phenomena.

Theoretical advantages and disadvantages of both cemented and cementless fixation are debated largely with supporting data. The major reports of large series of cases regarding to this debate suggested that short-term results of cemented primary THA are excellent but deteriorate with time. In contrast, the results of uncemented primary THAs are not only satisfactory in the short run but tend to improve as the time advances.[5] Uncemented primary THAs are a rational treatment in the young, active male. Without any controversy in revision surgeries, cemented techniques are unsatisfactory.

Biological fixations in THA are a reliable alternative, mainly in young people, which can definitely assure long-term survival provided they have certain requirements like good design, sound choice of bearing surfaces, and meticulous surgical technique. Better understanding of the osteointegration mechanism and interfaces makes the surgeons to select biological fixation as the best option.

2. Basic science of biological fixation

Cementless techniques in THA were originally aimed for patients with normal bone structure and quality. Different varieties of devices have been using since their introduction of cementless fixation in the U.S. in 1977. We are now in an era with good implant designs for the biological fixation of THA. Bone will grow on to the surface of metal implant if it has certain special "topography", called porous ingrowth or osseointegration. Osteointegration or osseointegration refers to a direct bone-to-metal implant interface without any interposition of non-bone tissue.[6] The bone must be prepared precisely for the biological fixation as the close apposition to bone is mandatory for bone to grow up to the smooth surface (osteointegration) or into the pores of the porous surfaces (porous ingrowths).

Albrektsson et al. described "osseointegration" as the attachment of lamellar bone on to the implants without intervening fibrous tissue.[7] After the implantation, it will take approximately four to twelve weeks for osseointegration and will be continued for up to three years.[8] Micromotion of the implant is minimized by adequate osseous contact and firm fixation.[9] Micromotion of $<$20 mm results in predominantly bone formation, more than 150 mm leads to fibrous tissue formation and between 40 and 150 mm results a combination of bone and fibrous tissue formation.[10] The excessive micromotion will inhibit osseointegration of uncemented components which is based on new bone ingrowth and ongrowth.[11] Bone growing inside a porous surface is the ingrowth and bone growing onto a roughened surface is ongrowth. These are determined by the surface characteristics of an implant. A pore size between 50 and 400 mm is necessary for ingrowth and 30–40% of voids within the coating should be maintained for the mechanical strength.[7] Sintered beads, fiber mesh, and porous metals over the surface are the ways of creating ingrowth surfaces.[12] Ongrowth surfaces have a roughness ranging from 3 to 5 mm and this is created by grit blasting or plasma spraying.[8] Hydroxyapatite is osteoconductive and enhances growth of mineralized bone onto the implant. It is a calcium phosphate compound which is plasma sprayed directly on the

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implant.[13] The optimal thickness of the coating is 50 mm for the osseointegration, which does not compromise its strength.[14]

Cobalt-chromium-molybdenum alloys and titanium-aluminum-vanadium alloys are most commonly used for cementless femoral stem designs due to their qualities of circumferential and continuous fixation surfaces.[15] Theoretically, titanium-based alloy is said to be more efficient in interface stress transfer to the host bone because of its lower elastic modulus compared with cobalt-based alloy.

A key factor for rapid osseointegration of an implant is the high initial stability. Press-fitting of a slightly oversized component is the method by which we achieve the initial stability. Implant geometry, roughness and coating, technique of preparation, and bone quality are the common factors that influence the initial stability or primary fixation.[16]

3. Primary THA

Compared to earlier years, THAs are being performed in much more large numbers in younger and more active patients.[17] Loosening due to osteolysis is the main cause of failure in these patients. Hence, the main focus is extending the durability and survivorship of these components. The revision for aseptic loosening is very low with uncemented total hip replacement. Apart from the best fixation methods of implants, optimum positioning of the femoral and acetabular components is mandatory for the better results and longevity.[17]

The revision rate is particularly the lowest in young patients under 65 years, where it is expected to have higher physical demands with higher failure rates secondary to loosening. Femoral fracture is the only reason for early revision with uncemented stems. Hence, it is related to the surgical technique which can be improved by better surgical training.[18]

Long-term failure of the fixation of cemented femoral components was primarily mechanical and it is continuing as slowly developing fractures in the cement mantle.[19] The loosening rate of uncemented femoral component is less than 0.5%.[20] Apart from a very uncommon complication of unrecognized intra-operative femoral fractures, uncemented stems perform better than cemented stems. Removal of a well-cemented femoral stem in revision total hip arthroplasty is a surgically challenging situation which requires multitude of surgical techniques and instruments.[21]

The most common reason for revision in cemented THA is acetabular loosening. Survival rates of uncemented acetabular cup are as high as 98.8% at 10-year follow-up. The fixation did not deteriorate over time and was associated with a low rate of osteolysis.[22] The fixation of this press-fit socket did not deteriorate over time and was associated with a low rate of osteolysis.

4. Revision THA

Cemented revision procedures have very poor results because of the mechanical failure secondary to poor cement interdigitation and fixation that results excessive micromotion.

In contrast, uncemented revisions offer the promise of durable biologic fixation due to encouraging bone ingrowth. In revision cases with substantial bone loss, primary stability may be difficult to obtain. So the surgeon should therefore need to make a better choice of either cemented fixation or opt for biological cementless fixation near the center of rotation and fill in bone loss area or fixing the cup in place on the residual acetabular bone.[23] In the revision THA, favorable results of cementless fixation in acetabular component have been reported in many studies. Good primary stability and implant bearing on more than 50% of the patient's bone are mandatory for the better results.

Loosening of an acetabular cup due to osteolysis can be well managed by an impacted cementless cup with additional screw-fixation with good results.[24] Cementless fixation provides satisfactory results, but in cases where there is substantial bone substance loss, it is not always possible to obtain primary stability and the guarantee of secondary biological fixation. It is not possible to use primary hemispheric implants in revision cases where less than 50% weight bearing of the cementless implant on the patient's bone. Several other viable options are possible in these situations like using bilobed cups,[25] cups implanted with high placement,[26] and jumbo cups.[27]

Allograft can be used to fill the large cavitary bone loss, before impacting cementless cup with screw fixation which ensure satisfactory results.[28] Filling with structural allograft can compromise the biological fixation in cases where the weight bearing on the patient's bone is less than 50%.[29]

Tantalum implants have become popular options for both primary and revision of acetabulum where the material can fill structural bone loss. Trabecular metal acetabular revision system (TMARS) cup-cage construct is a recent innovation to address massive acetabular defects.[30] Here, the trabecular metal shell (TM shell) of the size of last reamer should be impacted and held in place by screws drilled into the area of available bone through the shell, usually the posterosuperior portion. The appropriate-sized TMARS cage was then used and its flanges have to be contoured to seat on the patient's ilium and ischium. The TMARS cage on the TM shell was being held in place by its inferior flange in to the slot in ischium and screws to the ilium through its superior flange. Suitable-sized liner was then cemented in position over the cup-cage construct, whereas in some designs allows a locking mechanism for the polyethylene insert.

"Cup-cage" construct is a recent concept of modular revision system that uses porous metal augments. These augments are placed in the bony defects which act like structural bone graft substitutes. The cup then is supplemented with a cage fixed into the ilium. It is to offload the porous metal cup to allow time for bony ingrowth and cup stabilization.[31]

Modern triflange cups are another encouraging option of biologic fixation in revision as it incorporates porous ingrowth surfaces. It is indicated in cases of massive acetabular bone loss and pelvic discontinuity.[31]

The octopus acetabular system is a titanium structure to reconstruct the normal anatomy to restore accurate position and alignment of cup.[32] This is the only available cage that helps the biological fixation due to its porous coating.[32] It has three legs that help to gain good fixation on to the normal bone. Allograft or auto graft is used to fill the defect, then the inferion leg is engaged in the obturator foramen, and the acetabular ring is positioned with 45° abduction and 15° anteversion. Other legs are fixed with screws. Acetabular shell is then fixed to the ring by screws.

5. Conclusion

Thousands of patients are benefited by THA in terms of pain relief and improved quality of their life. Advances in orthopedic surgical techniques and implant designs and biomaterials now offer predictable surgical results in majority of patients. Despite the overwhelming success of this surgical procedure, the debate continues about the optimal method of fixation.

Acrylic bone cement has been used widely in the past for the component fixation of THA. The poor results and the problems of acrylic cement prompted have encouraged surgeons to use alternative surfaces to allow biologic fixation. Currently, varieties of acetabular and femoral implants with biologic fixation methods are available.

The indications of uncemented THA have expanded to include elderly patients as well. Even though they have impaired bone quality and limited healing capacity, the biomechanically optimized uncemented implant designs offer better results in them also. Biological fixation is the only viable option in revision cases where there is significant bone loss, since there are varieties of reconstructive implant options and the longevity of their survivals.

Conflicts of interest

The author has none to declare.

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