



# The Current Concepts of Total Hip Arthroplasty

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## INTRODUCTION

Joints deformed or injured by trauma, different forms of arthritis, infection and other causes tend to aggravate rather than regenerate. These progressive joint abnormalities may lead to severe pain, claudication, and nonfunctional ambulatory status, and tend to manifest more evidently in the hip joint than in the knee or ankle joints. Orthopaedic surgeons have continued their efforts to cure these joint disorders over centuries. Treatment choices include pharmacotherapy and conservative interventions, but surgery is the best option in many cases. Total hip arthroplasty (THA) is the most commonly performed adult reconstructive hip procedure and almost one million are being implanted annually worldwide, and projected to grow at a faster rate<sup>1)</sup>. The author of this study aimed to review the advancements in THA that have occurred through trial and error.

## THE HISTORY OF HIP ARTHROPLASTY

The first recorded successful hip arthroplasty was femoral osteotomy between the greater trochanter and lesser trochanter in the fused hip, performed by John

Rhea Barton in 1826 in Philadelphia<sup>2)</sup>. Since then, surgeons have sought alternative methods to replace the removed joint. Until now, the two main questions raised by investigators are: i) what are the alternative materials that can be used in a joint replacement?; ii) how can these materials be fixed firmly? Looking for answers to these questions can be regarded as a history of hip replacement in the early years.

The first question is about bearings, and investigators have explored a variety of materials including glass, ivory, metal alloys (e.g., Co-Cr), synthetic substances, polyethylene and ceramics. Glass, ivory and nylon are no longer used, while polyethylene and ceramic materials are widely used as they improve limitations. The second question is how to make a successful fixation, as related to both the design of the prosthesis and the actual fixation method including cemented and cementless. In 1958, Philip Wiles of London implanted matched acetabular and femoral components made of stainless steel as hip replacements in six patients with Still's disease. The acetabulum was stabilized with screws and the head component with a stem, side plate, and screws<sup>3)</sup>. But, these implants were not successful. After that, it has been attempted to fix femoral prosthesis to the femoral canal. Before bone cement was introduced, fixation of prostheses into the medullary canal was uneasy, so more than 50 different prosthetic designs were developed until the 1950s. Components were designed as short or long stems. Based on the clinical outcomes that a long-stem prosthesis was more stable and a metal implant was more durable than a non-metal implant, Thompson and Austin Moore inserted a long-stem prosthesis without cement<sup>4,5)</sup>. Although stem designs and surgical techniques on fixation of the femoral prosthesis with a metal stem have been improved, the basic principles are still valid until today. Since prosthetic fixation in the acetabulum is also

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challenging, Ring, Sivash and others intended to fix implants using a screw or a threaded cup but failed in achieving long-term stability. Around the same time, McKee and Watson-Farrar<sup>6)</sup> developed the metal-on-metal (MoM) prosthesis using a long intramedullary stem and a screw-type acetabular cup an overall success rate of 51% between 1956 and 1960. However, they redesigned the cemented-type cup in 1960s. After first introducing polymethylmethacrylate (PMMA) bone cement<sup>7)</sup>, which became very popular and successful implant.

## THE CHARNLEY LOW-FRICTION ARTHROPLASTY

In 1950s, Frederik R. Thompson of New York and Austin T. Moore of South Carolina developed prostheses which replaced only the femoral head. And these were commonly used to treat hip fractures and arthritis cases<sup>4,5)</sup>. This type of hip arthroplasty, called hemiarthroplasty, was used in the diseased femoral head, but did not resolve acetabular problems. Despite tremendous popularity for these prostheses in the 1950s, clinical results were hardly predictable. On the other hand, Charnley<sup>8,9)</sup> aggressively pursued effective methods of replacing both the femoral head and acetabulum and obtained favorable long-term results by introducing bone cement, which was used to achieve primary stability for dental implants. His most important intellectual breakthrough was his concept of the low-friction arthroplasty. Previously, all surgeons had substituted prostheses that were the same size and configuration as normal human anatomy. Charnley greatly reduced the diameter of the head on the femoral stem to a diameter of 22 mm to improve the frictional torque. Maurice E Müller in Switzerland introduced a design with a femoral head diameter of 32 mm for hip joint stability. In 1958, Charnley attempted to use polytetrafluoroethylene (Teflon) bearings, but the clinical outcomes were poor<sup>9)</sup>. After an initial failure with the use of Teflon as a bearing surface, he adopted high molecular weight polyethylene which showed satisfactory clinical performance. This was the beginning of the “total hip arthroplasty”. Charnley THA had been commonly performed after gaining widespread popularity in the United Kingdom and the United States, and long term survivorship rates reached up to 95% at 10-year follow-up and more than 80% at 25-year follow-up; however, a relatively high failure rate (68%)

was demonstrated in physically active patients<sup>1,10,11)</sup>. To sum up the achievements of Charnley, he increased long-term implant survivorship by using bone cement, first used polyethylene bearings, and described the concept of the “low friction arthroplasty” as a solution to wear problems. In addition, he tried to improve weaknesses by recognizing vulnerability of hip arthroplasty to infection. It is no exaggeration to say that most modern hip replacement concepts have advanced from Charnley’s achievements. Therefore, identifying why and how Charnley THA has evolved is a good means of better understanding the latest hip replacement techniques.

## CEMENTED VS. CEMENTLESS HIP ARTHROPLASTY

### 1. Cemented Total Hip Arthroplasty

The greatest benefit of using bone cement in hip arthroplasty is to secure firm initial stability. Since this stability is achieved regardless of bone quality, this intervention can be applied to elderly patients, tumor cases, revision cases associated with severe bone loss and others. On the contrary, the disadvantages of bone cement are the potential risk of cardiopulmonary disturbance, called bone cement implantation syndrome<sup>12-14)</sup>, and challenging surgical techniques and concerns about long-term survivorship. Even though the cause of aseptic loosening has been clarified as polyethylene debris instead of bone cement, Aseptic failures of cemented arthroplasties were at one time thought to result from a biologic reaction to the cement, and the term ‘cement disease’ was coined<sup>15)</sup>. Multiple studies have reported that the cemented acetabular cup, in particular, has a higher loosening rate than the cementless implant when used for more than 10 years, and despite advances in cementing technique, reductions in the failure rate have not been achieved. That was the reason why the use of the cemented acetabular cups has decreased<sup>16-18)</sup>. By comparison, the cemented femoral component is still being used in many cases, and has revealed favorable clinical performance for more than 15 years as the concept of hybrid THA<sup>19-21)</sup>. This is because that this component has secured satisfying durability along with improvements in cemented femoral component designs and cementing techniques.

There are two important concepts related to the design

of the cemented femoral stem. First, a taper slip design is designed to obtain stronger stability with slight subsidence of the femoral component within the cement mantle utilizing the viscoelastic properties of cement. This design is characterized by its polished surface and reduces the shear stresses at the bone-cement interface by increasing compressive force by having a distally tapered design<sup>22</sup>. Another design is a composite beam model that is made to improve limitations of femoral stem fixation through formation of a strong mechanical bonding at the stem-cement interface. This model strengthens the bonding by creating a rough stem surface or adopting the precoating method with PMMA. Since the latter design has brought increases in loosening rates of the bone cement and marrow cavity, the taper slip model is accepted as the standard design.

In regards to prosthetic material, metals with higher modulus of elasticity such as Co-Cr alloy or stainless steel are preferred rather to titanium alloys, because stresses imposed on the cement can be decreased. Moreover, most prosthetic designs have distal centralizers for a uniform thickness of the cement mantle.

Robin Ling first pointed out the importance of careful preparation of the bone surfaces and of forcing the cement into the bone by pressure<sup>23</sup>. It was developed as the second-generation cementing technique, which improve interlocking shear strength by bone lavage and drying in prior to cementing for removing fat, blood, and other debris, and using plug before cementing to make sufficient compression by blocking the distal portion. Furthermore, blood mixing is prevented through retrograde cementing via a cement gun. The third-generation cementing technique enhances the physical properties of cement by reducing cement porosity via vacuum mixing or centrifugation and pressurization. The-fourth generation cementing technique adds to the third-generation concept of stem centralization both proximally and distally to ensure an adequate cement mantle.

Due to these improvements in stem design and cementing techniques, hybrid THA demonstrate comparable survival rate to those of cementless THA. And cementing techniques have a low risk of complications associated with cementless THA such as periprosthetic fracture and thigh pain<sup>19</sup>. Currently, cementless THA is predominantly performed because of the rapid progression of cementless design, shorter operating time, and technical difficulties of cementing<sup>23</sup>.

However, cemented THA still remains the standard option for primary revision THA, and can be an alternative choice to resolve problems of cementless THA. Therefore, understanding the advantages and disadvantages of surgery and precise surgical technique is crucial.

## 2. Cementless Total Hip Arthroplasty

The early prostheses, before Charnley introduced bone cement, were cementless. However, it was not biologic fixation and often failed due to absence of long-lasting fixation. The 1970s was a time of intensive basic experimental research on surface coating and tissue ingrowth. These investigations delineated two basic criteria for bone ingrowth into porous surfaces. First, bone ingrowth could be achieved into microporous surfaces when pore size was between 50 and 500  $\mu$ m. Second, for this bone ingrowth to be achieved, a stable implant with minimal interface motion was necessary<sup>24</sup>. Osseointegration following cementless fixation is divided into ongrowth or ingrowth of bone according to histological characteristics. Bone ingrowth refers to bone formation within the porous structures of the implant and is observed on surfaces treated with bead coating, plasma spraying, tantalum porous coating and others. Bone ongrowth is used to describe the development of bone onto rough surfaces finished with grit blasting, hydroxyapatite (HA) coating and others. For this reason, cementless stem design has been developed toward 'fit and fill' concept in the intramedullary canal to get the stability as increasing the contact surface between bone and stem as much as possible, and is a current standard femoral component design.

Since the introduction of the cementless acetabular cup, different cup designs have been attempted to increase stability. In the early years, a threaded acetabular cup was made to maintain the initial fixation only mechanically without surface coating, and this led to failure like in femoral components. Later on, threaded and expansion cups with grit-blasted surfaces were used. Although short and mid-term clinical outcomes were favorable, long-term failure rates were relatively high. A hemispherical acetabular cup with a porous-coated surface is currently the most frequently used design<sup>25</sup>. This design is better in obtaining biological fixation by providing greater contact surface area between the bone and the component. Although grit-blasted and HA-

coated surfaces designs were also attempted, unsatisfying results were observed unlike in the femoral stem. So, the porous coating design was applied and mainly used to induce bone ingrowth for acetabular component<sup>26-28</sup>. To achieve initial stable fixation, compression by inserting a cup bigger than the reaming diameter of the acetabular bone is used. The author of this study also uses a cup 2 mm larger than the reaming diameter in compression. Screw fixation through a hole in the metal cup is typically used in additional fixation.

Cementless stem design has been developed taking a 'fit and fill' approach in the intramedullary canal to maximize stability as increasing the contact surface between bone and stem as much as possible, and is a current standard femoral component design. Besides the 'fit and fill' concept in the evolution of cementless femoral stem designs, there are a variety of design concepts to obtain initial stability. One popular design concept is proximal fixation in the metaphysis and a distally tapered design to reduce stress shielding caused by high modulus of elasticity of metal. Also, there is distal diaphyseal scratch-fit design such as AML (Anatomic Medullary Locking, Depuy) stem, which has the problem of stress-shielded bone loss proximally. The press-fit concept is designed to provide strong rotational stability. To ensure strong initial press-fit fixation, a stem with rectangular cross section or a wedge-shape is fixed at metaphyseal-diaphyseal junction with a strong press fit. The CLS (Cementless Spotorno, Zimmer) or Zweymüller (Zimmer) stem is most commonly used and has shown good clinical results in a long-term follow-up<sup>29,30</sup>. In many cases, these stems have blasted surfaces made by spraying metal or ceramic powders at a high pressure to create rough surfaces<sup>31</sup>.

Titanium alloys with low modulus of elasticity are preferred materials instead of Co-Cr alloys. Cobalt-chrome stem surfaces (Trilock, PCA, and AML) are commonly coated with sintered beads, while titanium stem surfaces are roughened with meshing, plasma spraying and grit blasting for osseointegration. A circumferentially coated stem exhibits substantially lower osteolysis than a patch-coated stem, this stem prevents distal migration of polyethylene wear debris and has a lower incidence of loosening. Consequently, the cementless stem without circumferential coating at the proximal extent is no longer used. Furthermore, though HA-coated stems have displayed good outcomes in terms of bone ongrowth, the use of this stem design is

gradually decreasing due to debonding, coating absorption or other problems.

In summary, the use of a porous-coated hemispherical acetabular cup is found to be the best option to induce bone ingrowth. Additional screw fixation is optional. The femoral stem designs vary widely according to different concepts, but identifying the best option remains controversial. In choosing hip prostheses, surgeons should prepare for surgery with a full understanding of each implant design to achieve sufficient initial stability and minimize complication by adequate techniques.

## RESURFACING ARTHROPLASTY

Surface replacement arthroplasty, also known as cup arthroplasty, was first introduced by Charnley in the 1950s prior to low-friction arthroplasty. The femoral head was covered with a cup of Teflon, and the acetabulum was lined with another layer of Teflon. However, he abandoned it because of unsatisfactory results. Since the late 1970s, Gerard, Paltinieri, Trentani, Furuya, Freeman, Capello, Amstutz, Wagner and others reported varying results using improved implant designs and modified surgical techniques. Most of them used plastic cup and larger metal head resurfacing fixed with bone cement. In very short time after introduction of surface replacement, the use of this technique gradually decreased due to early failure and severe osteolysis of the acetabular component. However, surface replacement arthroplasty has been consistently explored by some groups using improved bearing surface tolerances of MoM bearing, such as BHR (Birmingham Hip Resurfacing, Smith & Nephew) by Derek McMinn<sup>32</sup>. These implants were developed to determine the precise center of hip rotation and improved with materials and fixation for acetabular components. Moreover, the advantage of these implants is revision of the femoral component only without replacement of the acetabular component in failed cases of hip resurfacing. Amstutz and Le Duff<sup>33</sup> suggested that the 5-year survival rate was 95.2%, and this could be improved by modifying surgical methods and choosing surgical indications, and other previous studies reached comparable conclusions<sup>34,35</sup>. However, metal ion release from MoM bearings, pseudo tumor and early loosening have emerged as serious problems and these implants are rarely used at present after ASR (Articular Surface Replacement/Resurfacing, Depuy) hip implant system was recalled.



## THE NEW BEARINGS

Along with recent breakthroughs and much progress in materials, surface-coating methods and designs in hip-replacement surgery, a variety of implants have demonstrated good clinical results. The development and improvement of new bearing materials are expected to overcome problems such as osteolysis, loosening and dislocation and extend the longevity of hip joint replacements. However, other new problems have emerged.

### 1. Highly Cross-linked Polyethylene

A critical factor for determining the long-term lifespan of THA is bearing, and high density polyethylene as a bearing material is the leading cause of osteolysis and loosening by releasing polyethylene debris<sup>36</sup>. Free radicals produced during irradiation are identified as facilitators of this process. As solutions, cross-linked polyethylene was designed to improve wear resistance through irradiation crosslinking of polyethylene by gamma or electron beam rays. Furthermore, second-generation cross-linked polyethylene was developed through blending of vitamin E, changing irradiation or annealing process for the reduction of free radicals<sup>37</sup>. This highly cross-linked polyethylene (HXLPE) has been successful in dramatically reducing wear rates and osteolysis<sup>37,38</sup>. The combined use of a HXLPE cup with a ceramic femoral head has revealed good clinical results<sup>39,40</sup>. This material is the most commonly used bearing surface in THA in the United States. On the other hand, resistance against fatigue fracture is reduced as wear-resistant improves, and failure has emerged as a problem due to reduced liner thickness and repeated impingement resulted from a recent trend towards increasing femoral head size<sup>41</sup>. Furthermore, damaged femoral bearing surface and third body rather lead to an increase in wear rates<sup>42</sup>, and more small wear particles could speed up the process of osteolysis.

According to a U.S. market research report in 2015, ceramic-on-HXLPE accounted for 50%, metal on HXLPE for 42% thus HXLPE acetabular liner for more than 90%<sup>43</sup>. These statistics appears to be attributed from concerns about ceramic fracture or squeaking in ceramic-on-ceramic (CoC) bearings. Considering Improvements in polyethylene properties and a low coefficient of friction with ceramic, ceramic-on-HXLPE

bearings are anticipated to significantly decrease osteolysis and loosening in the long term<sup>44,45</sup>. However, long-term clinical outcomes have to be carefully monitored to confirm that ceramic-on-HXLPE is the best choice as a wear-resistant material.

### 2. Metal-on-Metal Bearings

MoM bearings have drawn increasingly more attention as the problem of polyethylene debris-induced osteolysis has been raised. MoM bearings were introduced about 40 years ago by McKee & Farrar and Ring in England, and by Haboush, Urist, and McBride in the United States. While the use of these prostheses gave surgeons further experience with what had become known as THA, the results were not entirely satisfactory because of problems with loosening of the components and wear between the opposing metal surfaces. That was the reason why Charnley prosthesis took the place of MoM bearing prosthesis. The leading cause of failure was aseptic loosening, and other causes were rough bearing surfaces, not fully rounded shape and too small clearance<sup>32,46</sup>. Subsequently, manufacturers introduced the Metasul<sup>TM</sup> as second-generation MoM prosthesis by modifying first-generation MoM hip prosthesis in several aspects, and the Metasul<sup>TM</sup> was approved by the U.S. Food and Drug Administration (FDA) in 1999. The benefits of MoM bearing are that the volume of wear debris released by MoM bearings is about 100 to 200 times lower than that of polyethylene gamma sterilized in air, and hip stability can be enhanced by having the ability to use large femoral heads<sup>47</sup>. On the contrary, potential problems with metal bearing surfaces are metal hypersensitivity and adverse local tissue reactions (ALTRs) such as pseudo tumor. Although the clinical symptoms of ALTRs occur in a small number of patients, ALTRs are suspected to shorten the life expectancy of hip arthroplasty by incurring severe osteolysis<sup>48,49</sup>. In addition, Co-Cr used for MoM bearing surfaces may generate genetic mutations as long-term biological reaction, and act as an oncogenic material through ionization<sup>50</sup>. According to the data from the Australian Orthopaedic Association National Joint Replacement Registry, the revision rate of arthroplasties involving the ASR XL was 9.3% and ASR resurfacing was 10.9% at 5-year follow up<sup>51</sup>. According to the National Joint Registry of England and Wales (2012), the revision rate was 3.59% and high failure rates for

MoM hip replacements were shown particularly in young women implanted with large diameter heads<sup>52</sup>. DePuy issued a voluntary recall of ASR devices in 2010, and the FDA has required post-marketing studies since 2011. The Korea Food and Drug Administration (KFDA) also took similar measures in 2012 and this bearing system is rarely used.

### 3. Ceramic-on-Ceramic Bearings

CoC bearings can be an optimal option for hip-bearing material due to their many advantages (e.g., hardness, high wear resistance, no metal ion release, enhanced lubrication with chemical inertness and hydrophilic properties and the ability to use of larger femoral head)<sup>53</sup>. First-generation CoC hip prosthesis introduced 30 years ago showed inadequate clinical performance due to wear and fracture. Second-generation CoC hip prostheses were released in 1977 by improving several weaknesses, but the Mittelmeier system, once momentarily popular, became a failed design due to neck-socket impingement, ceramic fracture and loosening. Third-generation alumina ceramic bearing (BioloX Forte) was introduced in 1994. The grain size in third-generation ceramics was less than 1.8 micrometer, and fracture incidence was lowered to less than 0.02% by meeting strength specifications<sup>54</sup>. The volume of wear debris released by alumina-alumina bearings is comparable to that of debris from MoM bearings, but not ionized in the body. The FDA approved alumina-on-alumina bearing hip implants in 2003 after clinical trials performed in the 1990s. BioloX Delta, introduced in 2000, is composed of 82% alumina and 17% zirconia, and according to the manufacturer, this alumina composite was anticipated to remarkably reduce the incidence of ceramic fractures. The use of BioloX Delta ceramic has reduced the rate of femoral head fractures to 0.003% compared to 0.021% for alumina-on-alumina; however the fracture rate of liners has not been reduced, and remained at approximately 0.03%<sup>54</sup>. The problem of early CoC bearing was initial acetabular fixation, thus CoC bearings have become tremendously popularized by newly developed CoC that employ modular design with metal acetabular shell in the early 2000s. The most important current concerns about CoC bearings are ceramic fracture and squeaking<sup>55</sup>. Ceramic fracture may occur when excessive load is partially applied. First, incorrect component positioning of the acetabular cup and the femoral stem may generate

fracture by incurring impingement. Fractures may also be caused by mismatched geometry between the taper and ceramic head, damaged taper and jamming when a liner is placed into the cup in the wrong direction. Squeaking is a phenomenon which could occur when using hard-on-hard bearings. The reported clinical incidence of squeaking with CoC bearings varies between 0.7% and 20.9%<sup>56</sup>. Although the exact cause has not been clarified, squeaking appears to be associated with a specific stem design, a short neck length, anteversion of the acetabular cup and others<sup>57,58</sup>. Squeaking requires revision when a patient complains of discomfort to noises, since this symptom persists permanently without spontaneous remission<sup>59</sup>. Despite such problem, CoC bearings have demonstrated favorable clinical results at long-term follow-up<sup>39,60-63</sup>.

CoC bearings are widely used in Korea, but this is different from the U.S. market where ceramic-on-HXLPE is used at a considerably high rate. Demand for ceramic heads is gradually increasing in most markets worldwide<sup>43</sup>.

### 4. Big Head Concept

The normal range of motion for hip flexion is 135°, but artificial hip joints were designed to accommodate maximal flexion up to 120°. Even though the current designs of prostheses are dramatically improved, impingement between the femoral head and the acetabular liner is unavoidable. In particular, impingement frequently occurs in 22-mm and 28-mm diameter heads, and can be easily checked in revision surgery due to wear of the polyethylene liner. However, this cannot happen in a ceramic or metal liner; therefore impingement can potentially lead to dislodgement or ceramic fracture and others. However, femoral head sizes could not exceed 28 mm on polyethylene due to wear, but the use of larger size femoral heads are allowed after wear has been resolved to a certain degree in cross-linked polyethylene, ceramic or metal materials. Therefore, the risk of impingement can be reduced by using larger heads<sup>64</sup>. Head sizes have gradually increased up to 32 mm, 36 mm and 40 mm. In the United States, the most commonly used head sizes are 36 mm (51%), followed by 32 mm (28%)<sup>23</sup>. The use of larger femoral heads has attracted much attention because larger head size gives proportionally greater range of motion and lowers impingement or dislocation rates.

With increasing head sizes, new problems have been

manifested including bursitis of the iliopsoas tendon and others. According to one study, head diameters greater than 32 mm were essential to minimize component to component impingement, but the range of motion no longer increased by using femoral heads greater than 38 mm. Because the impingement in further range of motion is caused by bone-to-bone impingement<sup>65</sup>, the use of head sizes larger than 36 mm seems to be meaningless.

## OTHER ISSUES ON TOTAL HIP ARTHROPLASTY

### 1. Minimally Invasive Total Hip Arthroplasty

Minimally invasive surgery has drawn much attention worldwide as it has achieved clinical outcomes equivalent to standard surgical approaches, and this trend continues in the field of orthopedics. Minimally invasive procedures such as arthroscopic surgery or endoscopic spinal surgery have been popularized as their outstanding efficacy and benefits have been proved in THA. Minimally invasive hip replacement, in fact, is not a single type of surgery but rather is a family of operations designed to allow total hip replacement to be completed through smaller incisions, potentially with less soft-tissue disruption. The three main methods involve; i) a combination of a small incision and a posterior approach to the hip, ii) a combination of a small incision and an anterior approach to the hip, or iii) two small incisions performed using the Smith-Peterson interval for acetabular placement and the approach usually used for femoral intramedullary nailing for femoral component insertion. However, clinical results for these approaches still remain controversial. Some studies have suggested that minimally invasive surgery is similar to traditional surgical methods<sup>66,67</sup>, while previous studies have reported higher rates of adverse effects including inadequate fixation of implants, extended opening hours, technical challenges, increased risk of neurovascular injuries, and fracture caused by insufficient dissection of soft tissues during prosthesis insertion due to difficulty in obtaining a surgical view and excessive or insufficient reaming<sup>68,69</sup>. In addition, other limitations include the lack of long-term follow-up studies and other scientific information. However, many problems can be solved by using navigation systems<sup>70</sup>.

Intense focus on improving initial problems is demanding in THA which requires long-term monitoring, and there

are limitations to overcome complications at present.

### 2. Computer Navigation and Robot Surgery

Correct positioning of the acetabular or femoral component during THA results in good clinical outcomes, but not all operations yield desirable results. (Malposition of the acetabular component during hip arthroplasty increases the occurrence of impingement, reduces range of motion, and increases the risk of dislocation and long-term wear.) Although surgeons have acquired surgical techniques to insert implants at correct position, different surgeons have different limitations. Along with scientific development, surgical intervention using computer-assisted navigation enables the remote tracking of human anatomical structures and surgical instruments. To determine accurate orientation of surgical instruments and patient's anatomical locations spatially, provided views are used as virtual reference data using three non-collinear points coordinated by the camera system. There are three types of surgical planning: i) volumetric image-based navigation, which makes use of volumetric images such as computed tomography, magnetic resonance imaging, or ultrasound echography; ii) fluoroscopic navigation, which makes use of intraoperative fluoroscopic images; and iii) imageless navigation, which makes use of kinetic information about joints or morphometric information about the target bones obtained intraoperatively<sup>71</sup>. This navigation system is increasingly used as an alternative measure to prevent possible incorrect positioning of the acetabular cup in minimally invasive surgery<sup>72,73</sup>. However, the navigation system is too expensive to be commercialized and its efficacy still has a lot of controversial issues.

Robot-assisted THA is further elaborated computer-assisted orthopedic surgery where a hip prosthesis is designed to fill the medullary canal is custom-made through three-dimensional visualization of computed tomography-image data, and then the shape of the medullary canal is carved using a high-speed burr or rasp. Subsequently, the designed implant is inserted to accurately fit the medullary canal with a computed tomography-based navigation system. However, this technique is used sparingly because filling the medullary canal to the maximum degree does not guarantee favorable results, and it is still in the trial stage due to the lack of long-term data, cost-related problems and insufficient studies to clarify safety<sup>74</sup>. This field appears

to have unlimited potential for development along with future scientific advances.

## CONCLUSION

Hip replacement is a remarkable medical innovation that allows humans to walk without pain by reconstructing badly damaged hip joints. Today, hip replacement procedures have advanced dramatically through failures and successes over many years. The introduction of a new hip prosthesis does not always mean better performance compared to traditional hip implants nor does it assure good clinical outcomes. The best professional approach for surgeons will be performing surgery using standard hip replacement prostheses when fully understanding the concepts, principles, benefits and risks of currently established approaches.

## CONFLICT OF INTEREST

The author declare that there is no potential conflict of interest relevant to this article.

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