Review Article

Hip arthroplasty – All problems solved or still place for improvement?

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1. Actual results of total hip arthroplasty

Total hip arthroplasty was popularised by Sir Charnley since the late 1950s of the last century. Over the following decades, some evolutions had been made, one of them regarding the implant fixation, leading to a high rate of cementless implants since the 1970s. Today, in Germany and central Europe, the majority of total hips are fixed cementless. Another evolution was the increasing size of femoral heads, so that a 22 mm large head is only used in very small cup sizes these days in Europe. By this increasing head diameter, the problem of hip instability and dislocation could be reduced to numbers of less than 2–5%. Another part of improvement was related to the approach. By introducing different minimal invasive approaches, muscle damage became less and recovery faster.

With all those innovations, hip arthroplasty became extremely successful over the last years. For example, comparing total hips and total knees, hips deliver a far higher number of very happy patients; however, there are still some percentages for improvements left. The revision rate within the first year in Germany, for example, is still 4%. The reasons for early and for late revision are multiple. While predominantly infection and luxation are early failure modes, polyethylene wear and loosening are late failure reasons. Minor forms of instability may not lead to a complete luxation; however, it can lead to a bony or implant related impingement syndrome. This can finally accelerate polyethylene wear and by that loosening. Relevant parameters for hip biomechanics and by that also for a good clinical and functional outcome are leg length, lateral and posterior offset, cup and stem position. An increased inclination angle of the cup, as well as changes of the anteversion can cause

instability from the cup side. Therefore, Lewinnek defined the safe zone as goal for cup placement. Various studies could show that this zone is only reached in 26–57% of cases. An insufficient restoration of the lateral offset as well of the leg length can induce instability from the stem side. However, the overall offset is influenced by the cup position too.

The individual anatomy of the proximal femur can be influenced by the various hip pathologies (e.g. dysplasia, other secondary arthritis forms), also by previous surgeries and ethnic origin. It could be shown that pre-op planning and templating is mandatory to restore the anatomy. In these days, planning should be performed on digital X-rays (Fig. 1).

During this planning process, it sometimes becomes obvious that a standard implant might not fit into the femoral canal or that it is not possible to restore offset or CCD angle. Based on that data, the surgeon should decide pre-op how to solve the problem. After careful planning, a successful execution of the plan is next step. Mainly, fluoroscopy is used to control this part of the process; however, it is a 2D technique for a 3D problem and additional problems from visualisation can make it limited to use.

Although total hip arthroplasty leads to happy patients and good clinical outcome in a high percentage, restoration of joint biomechanics and implant position can still be challenging in some patients. In the following article, the value of individual implant design and of navigation for an improved treatment of those patients is discussed.

2. Role of individual stems in restoration of the biomechanics and results

2.1. Technical aspects

Conventional digital templating is a 2D technique that allows sufficient pre-op planning in majority of cases; however, in some

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Fig. 1. A standard AP X-ray of the pelvis including both hips. Positioning and sizing of cup and stem is performed with digital templates. Restoration of leg length and lateral offset is also planned.

hips with an increased antetorsion or a situation after derotational osteotomy, this technique comes to its limit. In those cases, a 3D planning using CT is preferable (Fig. 2). This 3D planning does not automatically mean that an individual stem is needed. The different standard stem designs can be templated and based on this information the final decision about the optimal fitting stem can be made.

Besides the fitting, the contact area and its stress areas are visualised in colour maps (Fig. 3). Based on that, potential intra-op problems like fissures or stem penetration can be prevented. Besides the planning of stem fit also, the position of the cup, and stem, cup and total offset as well as leg length can be planned accurately (Fig. 4).

After the planning, if necessary the order of the individual stem is performed. Production of the stem and its rasps take around 4 weeks and an additional 1–2 weeks is needed for shipping. For the surgical technique, it is important to mention that preparation of the bed for the stem is made with only 1 or 2 rasps. Those match the shape and the last the size of the individual implant. This technique can in some cases be a challenge.

2.2. Results

The technique of individual stems is available since the mid 1980s with different companies. Although the numbers of individual stems are relatively small, some papers with mid- and long-term results exist, all showing excellent clinical results.

Density on implants

Fig. 3. The colour-coded contact areas for stem and cup. Red means high contact stress while blue means low contact stress.

Pakos et al. (2015) reported recently a 95.4% survivorship after 10 years for stem and cup for any reason. For femoral loosening, he reported a survivorship of 98.1%.

3. Role of CAS in hip arthroplasty

3.1. Different CAS techniques

As mentioned above, planning is crucial for a good result in total hip arthroplasty. Execution of the plan is next step. Normally, the intra-op control is mainly based on clinical stability testing, conventional leg length measurements and fluoroscopy. Sometimes, a slight instability can be treated with a head extension; this, however, then can result in a lengthening of the leg. Controlling the lateral offset intra-op is even harder, but again important for good functional result and a stable joint. Therefore, navigation was introduced in the late 1990s.

Fig. 2. A typical CT planning. Left for the stem and right for head centre in all three planes.

Fig. 4. The coronal planes as well as the sagittal plane is demonstrated and offset and leg length are calculated.

Navigation could show that the numbers of outliers for cup position could be reduced. Dastane et al. could further show that with navigation, quantitative assessment of offset and leg length are possible. With that, a more precise reconstruction of those parameters could be proven in different studies. So far the midterm results, however, show no significant differences in clinical scores between navigated and non-navigated hips. Besides those advantages, also disadvantages of navigation need to be mentioned. In image-based system, the radiation is a shortcoming and due to that image-free systems became more popular. For all systems, palpation of defined anatomical landmarks are mandatory, the so-called surgeon defined anatomy. This can be problematic in particular in the pubis area in very obese patients. Another problem mentioned is the increased surgical time.

Davis et al. (2015) could show that a new technique without registration of the anterior pelvic plane delivers a high reproducibility. On the femoral side, a pin-free navigation has been introduced which showed comparable precision compared to the pin-based femoral navigation and further it could overcome the potential problems of pin infection and fracture.

Another new technique is the combined anteversion in femur first technique, in which the stem is implanted first and based on its anteversion then the anteversion of the cup is defined. Further on, an optimum for an impingement-free range of motion is calculated and the cup position is determined. First studies show

good results of this method; however, there are also some limitations. Therefore, long-term studies need to be awaited.

Another promising option is the combination of navigation with computed surgery. In a CT-based navigation, the cup is placed in terms of inclination and anteversion as well as depth as planned and finally after stem position, the leg length and offset are controlled.

4. Personal experience with CAS in hip arthroplasty

In order to execute the surgery as planned, we integrated CAS into our workflow since the last 2 years. So the following paragraphs describe our technique and short-term results; however, no long-term results are available at our institution so far.

Every hip is planned for stem and cup position as well as leg length and offset with digital templates. In the OR, the new navigation technique is added on all total hips except the neck fractures. In our hospital, the modified minimal invasive antero-lateral Watson Jones approach is used. For that, 2 pins are placed at the spine of the pelvis. For the femur, one cortical reference screw is introduced into the proximal femur and a pin-free marker is placed at the distal femur (Fig. 5).

After opening the joint and before the osteotomy is performed, the anatomical landmarks of the pelvis (spina iliaca superior both sides) and the screw of the femur are referenced. Then, the osteotomy is performed and hip head extracted. As a next step, the

Fig. 5. Typical set-up after pin insertion on the iliac crest and fixation of the pinless reference arrays on the femur.

Fig. 6. Position of cup impactor for inclination and anteversion.

Fig. 7. Monitor image is showing the leg length as well as the medial/lateral offset with the trial implant in place.

fovea and the cup surface are palpated. With this technique, the inclination and anteversion of the cup can be measured in real time (Fig. 6).

After cup implantation and trial stem placement, the hip is repositioned and finally leg length and offset are visualised (Fig. 7). At that point, adaptations to the planning can be made by changing stem position, neck adapters or head length. After this optimisation process, the original hip is finally referenced again and a protocol for the patient is produced at the end of surgery.

In a prospective study, we have looked at 50 navigated hips and 50 non-navigated hips and compared both groups for surgical time, cup positioning in the safe zone and leg length and offset. We found an increased surgical time of 4.5 min which was not significant. Regarding the precision, we were able to reduce the numbers of outliers for all different values. The number of patients with a cup in the safe zone could be increased from 88 to 94%, and the number of leg length difference within 5 mm from 74% to 80%. The offset changes of more than 5 mm could be reduced from 54% to 66%. The goal to reach all the parameters raised from 66 to 74%. All these changes were not significant. This is, however, comparable to results from previous studies. An increased BMI had no influence on the precision in our study. This is partially in contrast to studies with the older software in which the palpation of the pubis was necessary. The complication rate was not increased by introducing the navigation, again as in previous studies.

In summary, we use this new CAS technique as our standard because it helps to minimise the numbers of outliers without a significant increase of surgical time.

5. Conclusion

Hip arthroplasty has a long and successful history. However, some clinical relevant problems like leg length discrepancies and joint instability due to offset loss and/or malpositioned stem and cup exist in a higher percentage of cases.

Careful planning with digital templating is mandatory to avoid intraoperative problems. In some cases with severe anatomical deviations, an extended 3D planning can be necessary. Based on this 3D planning, sometimes an individual stem needs to be implanted in order to avoid the problems of fracture. In those cases, only with the help of those stems, the individual biomechanical parameters can be restored.

Navigation with its last developments can help to execute the plan in a higher percentage of cases than with the standard surgical technique. Whether both aspects will lead to an increased percentage of excellent results in the future need to be proven with long-term studies in the next years.

Conflicts of interest

The authors have none to declare.