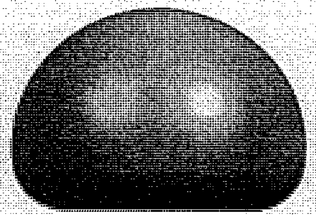
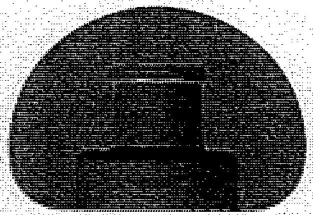
ORTHODYNAMICS

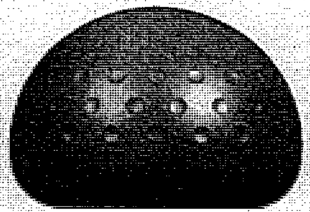
Overview of different Bionik System components

Metal Head
Silver "BS"

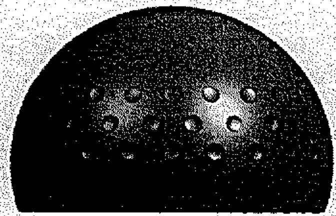


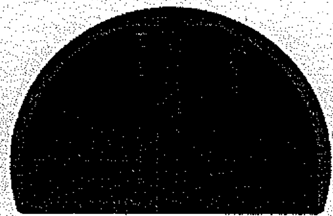


Metal Head
Biosurf Silver "BS"

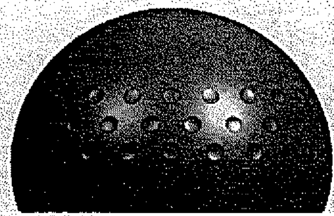


Femoral Head Shell, cem.
Biosurf Silver "BS"

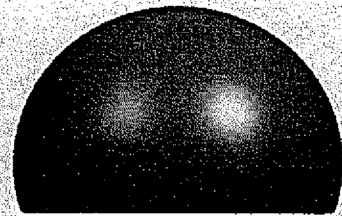


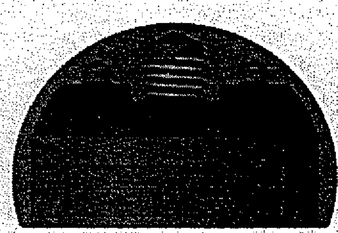


Hip Surf.Repl., cem.
Biosurf Silver "BS"

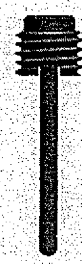


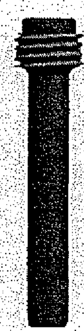
Hip Surf.Repl., cem.
Silver "BS"





Nail "BS"





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Type of Presentation: Podium

First Abstract Category: Hip/Knee

Second Abstract Category: Sports Medicine/Arthroscopy

Third Abstract Category: Rehabilitation Medicine

Has this information been presented or published at the national level? No

1. **Was there an intervention or interaction with a living person that would not have occurred or would have occurred in some other fashion if not for this research?** Yes
2. **Was identifiable private information/data obtained for this research in a form associable with an individual?** Yes
3. **Does this research involve existing data or specimens that are publicly available?** No
4. **Was this research approved by an Institutional Review Board (IRB) or Ethics Committee?** Yes
5. **Number of subjects** 208
6. **Type of Investigation** Prospective
7. **Randomization** non Randomized
8. **Control Group** Yes

FDA Status: NOT Approved

Title:
The onlay hip resurfacing – a controlled prospective study – mid term results

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Key Words:

Hip/Knee Osteoarthritis Miscellaneous

Introduction: Recently used hip resurfacing systems remove bone and reduce biomechanical properties of the femoral neck and ignore the individual joint congruency and position. As much bone was removed from the head as much the biomechanical properties decrease. The Onlay Resurfacing technique preserve complete bone stock and individual anatomy without any change in Offset or leg length.

Methods:

104 patient with primary osteoarthritis underwent hip onlay resurfacing. Men aged 51 yr, BMI 27,2. An onlay resurfacing system was used for resurfacing with a cemented femoral and a modular cementless acetabular component was used. The control group (n:104) got a standard cementless THA. All procedures were performed by one surgeon, minimal invasive antero lateral approach was used, same post Op treatment in both groups

Results:

In the Onlay Resurfacing group the HHS improved 6 weeks, 6 month and 3 years after surgery from 46 to 89, to 98 and 98 after 3 years. Compared to resurfacing the THA improved

from 42 to 85, to 92 and 93 after 3 years. At 6 month and 3 years the SF12 score (mental and physical) improved to normal in both groups.
One neck fracture occurred in the Onlay resurfacing group, one DVT an 1 dislocation in the standard group. No implant failure in both groups. Blood loss was significant less after Onlay Resurfacing.

Discussion and Conclusion:

Hip onlay resurfacing preserves maximal bone stock and provides excellent functional outcome. The outcome was better in the Onlay resurfacing group compared to standard THA. Combined with minimal invasive surgery patients will be able to shorten the rehab phase significantly. Side effects as luxation, instability, length differences were expected to appear less frequently.

oben beschriebenen erweiterten dorsalen Zugang stabilisiert, oder wir verwendeten zusätzlich zur dorsalen medialen Inzision einen separaten posterolateralen Zugang.

In unserem Patientenkollektiv trat postoperativ eine tiefe Beinvenenthrombose auf, welche zunächst mit Heparin therapiert wurde. Nach 14 Tagen wurde auf eine orale Marcumar-Medikation umgestellt. Bei einem Patienten mit postoperativem Hämatom und einem Patienten mit postoperativem Frühinfekt war jeweils eine Revisionsoperation mit Spülung und Débridement erforderlich. Der weitere Verlauf war bei beiden Patienten unauffällig. In zwei Fällen wurde aufgrund einer Arthrofibrose mit Streckdefizit des Kniegelenks eine Arthrolyse durchgeführt. Im ersten Fall gelang dies 6 Monate postoperativ in arthroskopischer Technik, im zweiten Fall war 12 Monate postoperativ eine offene posteromediale Kapsulotomie notwendig.

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Artikel für Operative Orthopädie und Traumatologie
Neben den Artikeln zu Operationstechniken werden in der Zeitschrift auch Artikel zu „Das besondere Instrument" oder „Tipps und Tricks" veröffentlicht. Die Autorenhinweise sowie Manuskriptvorlagen finden Sie im Internet auf **www.oot.at/ueber/autoren richtlinien**. Die Manuskripte sollen möglichst online eingereicht werden unter **www.editorialmanager.com/ootr**.

The Minimally Invasive Anterolateral Approach Combined with Hip Onlay Resurfacing

Ludger Gerdesmeyer[1,2], Hans Gollwitzer[2], Peter Diehl[3], Björn Buttgereit[4], Maximilian Rudert[1]

Abstract

Objective
Minimally invasive anterolateral approach in hip resurfacing with complete preservation of muscular integrity.

Indications
Primary or secondary osteoarthritis of the hip.

Contraindications
Approach:
- None.

Onlay implant:
- Females > 55 years with osteoporosis.
- Males > 60 years with osteoporosis.
- Severe varus deformity (CCD [collodiaphyseal] angle < 100°).
- History of metal allergy.
- Clinically relevant renal insufficiency.
- Radiologic appearance of avascular necrosis stage 3 and 4 according to Ficat.
- Femoral head cysts > 1 cm in diameter.

Surgical Technique
Supine position with possible overextension of the hip, longitudinal incision along the intermuscular septum and blunt intermuscular dissection between gluteus medius and tensor fasciae latae, partial resection of the anterior capsule and anterior dislocation of the hip with complete proximal release of the capsule. Dislocation of the femoral head and dorsal positioning, reaming of the acetabulum to implant the cementless acetabular component, exposition and reaming of the femoral head in extension/adduction and external rotation, implantation of the cemented onlay endoprosthesis.

Postoperative Management
Prophylaxis of thromboembolism and periarticular ossification. Rehabilitation with weight bearing as tolerated starting on the day of surgery, ergometer training from day 4 after surgery.

Results
31 patients with osteoarthritis underwent onlay resurfacing via a minimally invasive approach. The Harris Hip Score improved from 43.9 to 97.1 at 12 months after surgery. Adverse events such as fracture, dislocation, nerve or muscle lesions did not occur, and clinically significant thromboembolism or infection was not observed.

Key Words
Minimally invasive · Hip · Approach · Onlay · Prosthesis · Osteoarthritis · Resurfacing

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Der minimalinvasive anterolaterale Zugang zur Implantation einer Hüftoberflächenprothese

Zusammenfassung

Operationsziel
Implantation einer Hüftonlay-Femurkappenendoprothese über einen minimalinvasiven anterolateralen Zugang mit komplettem Erhalt der muskulären Integrität.

Indikationen
Primäre und sekundäre Koxarthrose.

Kontraindikationen
Zugang:
- Keine.

Onlay-Femurkappenendoprothese:
- Frauen > 55 Jahre mit Osteoporose.
- Männer > 60 Jahre mit Osteoporose.
- Schwere Coxa vara (CCD-[Centrum-Collum-Diaphysen-] Winkel < 100°).
- Metallallergie.
- Klinisch relevante Niereninsuffizienz.
- Hüftkopfnekrose Stadium 3 und 4 nach Ficat.
- Femurkopfzysten > 1 cm im Durchmesser.

Operationstechnik
Rückenlagerung mit der Möglichkeit, durch Aufklappen des Operationstischs das Hüftgelenk zu extendieren, gerader Hautschnitt entlang dem Septum intermusculare und stumpfe digitale Präparation der Muskellücke zwischen Musculus gluteus medius und Musculus tensor fasciae latae, partielle Resektion der vorderen Gelenkkapsel, Luxatic des Femurkopfes nach ventral und komplettes Kapselrelease am Azetabulum. Luxation des Kopfes in die dorsale Luxationsstellung, Fräsen des Azetabulums für die zemen lose Implantation der modularen azetabulären Komponer te. In Extension/Adduktion und Außenrotation Darstellun des Femurkopfes und Formfräsen des Kopfes, Implantatio der zementierten femoralen Komponente.

Weiterbehandlung
Prophylaxe einer Thrombose und periartikulärer Ossifikationen. Beginn der Mobilisation am Operationstag mit schmerzadaptierter Belastung, Ergometertraining ab dem 4. postoperativen Tag.

Ergebnisse
31 Patienten mit einer Koxarthrose wurden über einen mir malinvasiven anterolateralen Zugang mit einer Hüftonlay Femurkappenendoprothese versorgt. Der Harris-Hip-Score verbesserte sich 12 Monate postoperativ von 43,9 auf 97,1 Punkte. Es traten weder Komplikationen wie Fraktur, Luxation, Nerven- oder Muskelschäden noch Thrombosen oder Infekte auf.

Schlüsselwörter
Minimalinvasiv · Hüfte · Zugang · Onlay · Prothese Arthrose · Oberflächenersatz

Introductory Remarks

Resurfacing in total hip arthroplasty experiences a revival in modern orthopedics and becomes more and more popular. The concept itself has first been established in the 1980s [7]. Wagner described a bone-preserving technique already in the mid 1970s, which is still well known as the Wagner cup arthroplasty [8]. The approach was excellent, but poor tribological properties and failures of the polyethylene (PE) used as monoblock acetabular component resulted in a high early failure rate. Furthermore, small cement particles were generated due to significant deformation of the very thin PE acetabular components during weight bearing, and these cement particles initiated third body wear and consecutive failure [3, 4]. Improved technical knowledge and usage of advanced materials with better tribological properties have significantly increased survival rates and initiated a revival of hip resurfacing. All current implants used for resurfacing commonly require substantial bone resection at the femoral head, with lo of subchondral sclerotic bone [1, 2, 7]. Resection of su chondral bone – which shows the best biomechanic properties – is contradictory to the original concept resurfacing. By contrast, the onlay resurfacing tec nique avoids bone resection, enables improved biom chanical properties, more anatomic relations of tl femoral head, and an improved head/neck ratio. Wi the Biosurf surface topography of the femoral implar a significant reduction of wear and metal debris can l achieved as well. High modularity of the componen guarantees better options in the case of revision. Ho ever, complete preservation of the femoral head is aut matically followed by a minimized intraoperative sitι An appropriate surgical approach is therefore mand tory. By using guidance systems such as Kirschner wir or templates, the approach has to be increased in siz Therefore, the dorsal approach has been used most fr quently, which is associated with a high risk of avascul necrosis as a result of cutting the perfusing vessels of the medial femoral circumflex artery [1, 7]. On the other hand, if the standard anterolateral approach, first described by Watson Jones, is used, the preserved femoral head prevents adequate exposure and preparation of the acetabulum and correct insertion of the acetabular component [5]. Suboptimal placement is often due to increased anteversion and inclination, leading to a significant increase of metal wear [6]. To prevent these approach-related side effects, we have developed a modified anterolateral approach to be described in this study. This new approach is characterized by excellent exposure of femoral head and acetabulum, prevention of avascular necrosis caused by vessel damages and complete preservation of bone and muscle, which makes fast-track rehabilitation feasible.

Surgical Principles and Objective

Resurfacing of the femoral head by using a modified anterolateral approach with minimally invasive surgical technique. Excellent exposure of the acetabulum and femoral head with complete preservation of surrounding muscles. Resurfacing without bone resection, but with reconstruction of the individual anatomic structures and relations.

Advantages

- Surgery is possible in supine position.
- Excellent exposure of the acetabulum und femoral head.
- No guidance system (Kirschner wire, navigation, X-ray) required.
- Protection and preservation of muscle insertions to the femur.
- Preservation of the anatomic head/neck ratio.
- Extension of surgical approach easy to perform.
- Preservation of the individual anatomy.

Disadvantages

- Extensive soft-tissue preparation.
- High learning curve compared to standard approach.
- No long-term follow-up data.
- Extended duration of surgery.
- Technically demanding in muscular patients.

Indications

- Primary and secondary osteoarthritis of the hip.

Contraindications

Modified Approach

- Obesity 3° according to the WHO classification.
- Previous surgery via anterolateral approach.

Onlay Resurfacing

- Females > 55 years with osteoporosis proven by bone mass measurement.
- Males > 60 years with osteoporosis proven by bone mass measurement.
- Severe varus deformity (CCD [collodiaphyseal] angle < 100°).
- Severe coxa vara epiphysaria so that roundness cannot be restored by reaming the head and the femoral component is seated without full bony contact.
- History of metal allergy.
- Clinically relevant renal insufficiency because of increased metal ion concentration due to wear.
- Avascular necrosis of the femoral head stage 3 and 4 (Ficat).
- Femoral cyst > 1 cm in diameter.

Patient Information

- General surgical risks, e.g., thromboembolism, infection, bleeding, delayed/complicated wound healing, dislocation, nerve lesions.
- Loosening of the implants.
- Implant without long-term follow-up data.
- Ectopic ossifications.
- Intraoperative change of the surgical strategy to another implant, if indicated.
- Metal wear.
- Induction of metal allergy possible.
- Fracture of femoral neck.
- Painful hematoma.

Preoperative Work Up

- Physiotherapy to improve range of motion and reduce contracture which facilitates the surgical procedure.
- Physical exercising.
- Reduction of weight.
- X-ray: anteroposterior and lateral according to Lauenstein.
- Presurgical peripheral catheter nerve block.
- Perioperative antibiotic prophylaxis with second- or third-generation cephalosporin i.v., single dose; in case of surgery duration > 2 h, second application of antibiotics is recommended.

Surgical Instruments and Implants
- Standard instruments for hip replacement.
- Specific instruments and implants for onlay hip resurfacing (ESKA Implants, Grapengießerstraße 34, 23556 Lübeck, Germany).
- Specific retractor set (MIOS, provided by Aesculap, Am-Aesculap-Platz, 78532 Tuttlingen, Germany) used for minimally invasive procedures in total hip arthroplasty with smooth and broad design, and curvatures from 30° to 90° to protect muscles.
- Minimized acetabular reaming system (optional).
- Jet-lavage system.
- Largely curved insertion instrument, minimally invasive socket impactor (ESKA Implants).

Anesthesia and Positioning
- Combination of general anesthesia with femora nerve block is recommended.
- Patient-controlled analgesia [9].
- Supine position on operating table allowing 30° hi extension by bending the operating table.
- Contralateral stabilization of the patient with operat ing table fixation tools.
- Fixation of the contralateral leg.
- Disinfection and draping of the leg allowing full rang of motion.

Surgical Technique

Figures 1 to 21

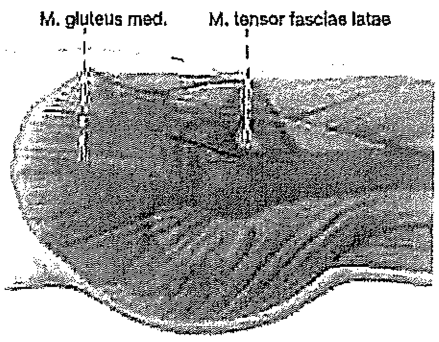


Figure 1
Patient placed in supine position allowing to hyperextend the hip up to 30° on the operating table. 10 cm skin incision between the tip of the greater trochanter and the anterior superior iliac spine, just above the intermuscular septum between the gluteus medius and the tensor fasciae latae.

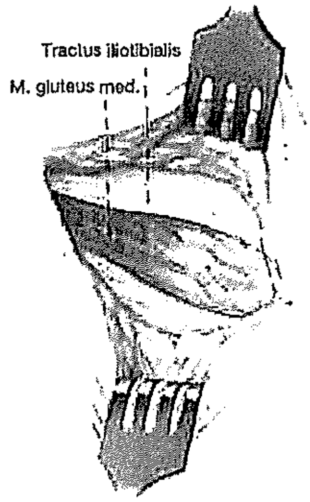


Figure 2
Incision of the fascia within the anterior aspect of the iliotibi. band.

Figure 3
Dorsal retraction of the gluteus medius and gluteus minimus by a 60° curved Hohmann retractor. A blunt and broad retractor is placed medially of the femoral neck to retract the tensor fasciae latae anteriorly. A 90° retractor is placed close to the anterior rim of the acetabulum providing good exposure of the capsule.

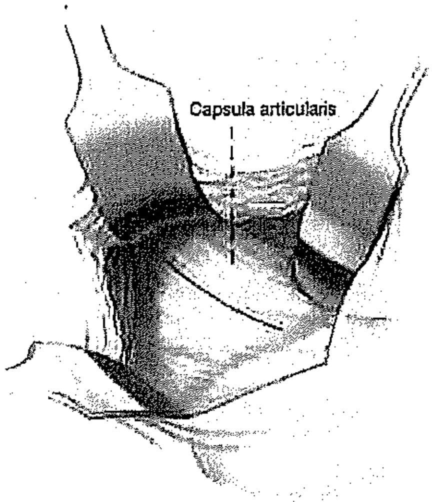


Figure 4
Incision of the capsule is performed in longitudinal direction of the femoral neck. Another incision is placed perpendicular along the anterior rim of the acetabulum to release the capsule as much as possible. Complete capsulotomy is essential for adequate exposure and to continue resurfacing.

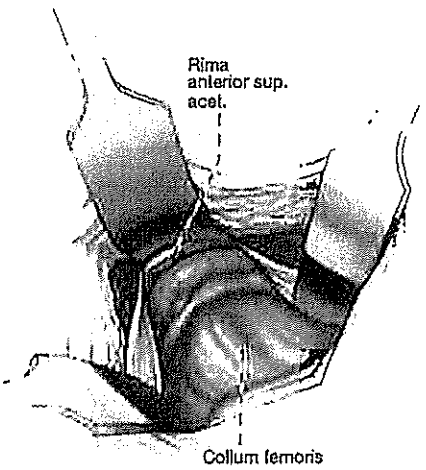
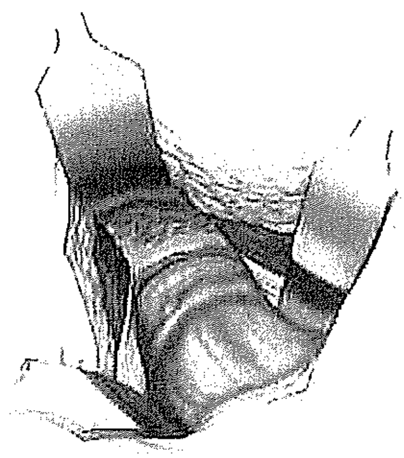
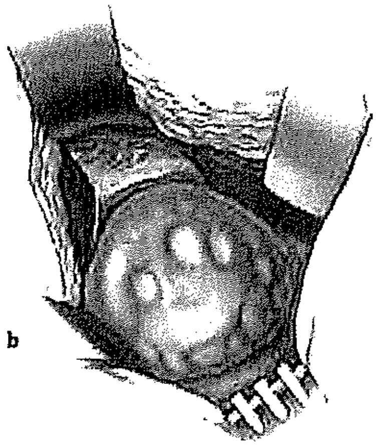


Figure 5
The gluteus medius and gluteus minimus are gently released from the lateral aspect of the pelvis. Abduction facilitates the detachment to create a dorsal muscular pouch for dislocation of the femoral head from anterior dislocation position to dorsal. This important step should be done digitally and gently to avoid muscle lesions.



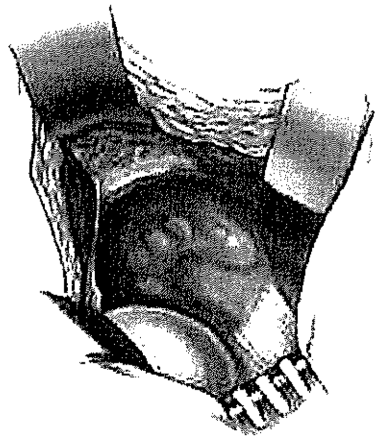
Figures 6a and 6b
Dislocation of the femoral head to an anterior position is achieved by adduction and external rotation (a). Resection of surrounding osteophytes is required, if luxation is not possible (b).

a

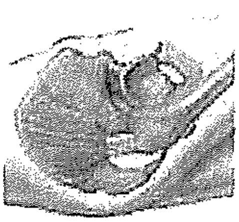


b

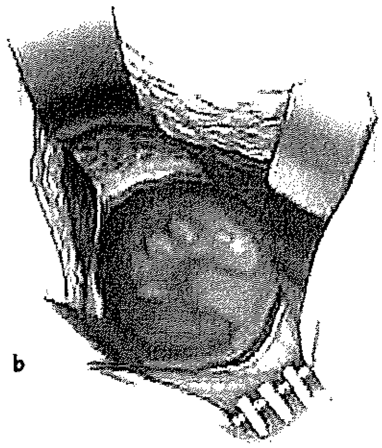
Figure 7
The transfer of the femoral head between gluteus medius, gluteus minimus and the ilium from anterior to the dorsal dislocation position has to be done very gently by flexion and simultaneous rotations until the final dorsal dislocation position is reached. Then, the release of the capsule has to be completed to provide better mobilization of the femoral head. The release should be done very close to acetabular bone, completing a circumferential capsular release of 360°. If release is done within a wider distance to the bone, bleeding can occur.



Figures 8a und 8b
After capsular release has been finished, the femoral head is dislocated into the dorsal muscular pouch (a) allowing excellent exposure of the acetabulum (b).



a



b

Figure 9
After complete exposure of the acetabulum has been achieved, reaming is started with the smallest size until the teardrop position is reached. Further reaming is done with size increasing in 2-mm steps until the size of the smallest possible implant is reached. The first reaming phase of the acetabulum ends with this step.

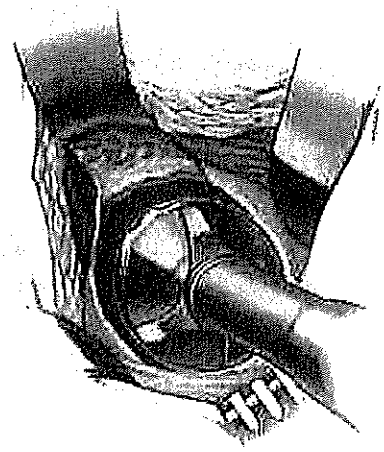


Figure 10
Repositioning of the femoral head into anterior dislocation by gentle abduction and external rotation. Extension of the hip is achieved, if the operation table is bent up to 30°; exposure of the head is much easier now due to relaxation of the gluteus medius and gluteus minimus in this position. Two 30° retractors are placed around the neck for complete exposure of the femoral head.

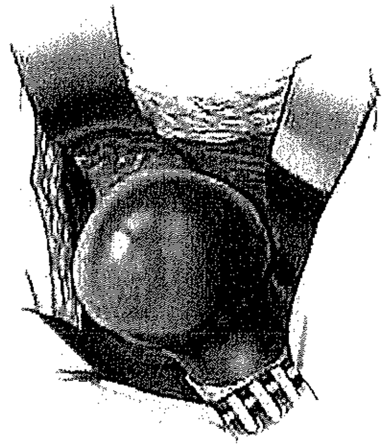


Figure 11
The reamer that fits the femoral head loosely has to be chosen first to start reaming until the osteophytes are removed and the head appears round.
After all osteophytes have been removed and the head is rounded, the next smaller reamer should be used to start final head reaming by 2-mm steps until all cartilage is removed. The last measured reamer corresponds to the largest size that can be implanted. Weakening of the subchondral bone stock occurs after extended or asymmetric reaming of the femoral head. If the femoral reamer is used in very close bone contact and reaming load is light, the subchondral bone is kept in excellent and unaffected condition.

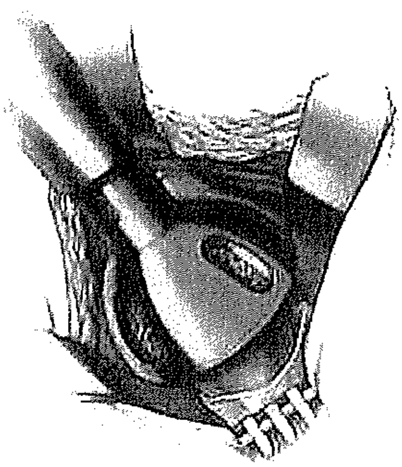


Figure 12
A trial implant is placed on the femoral head in press-fit technique to verify the reaming size. The trial implant is left in place while the femoral head is transferred back to the dorsal dislocation position for final reaming of the acetabulum.

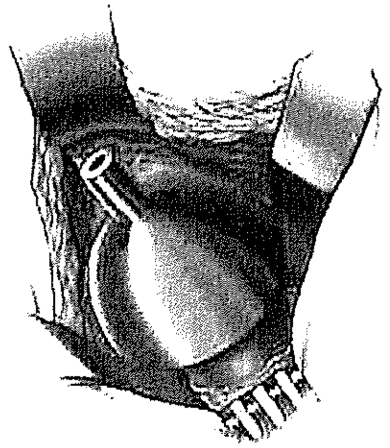


Figure 13
The second reaming phase starts with the reamer used before until the correct acetabular size is reamed (6 mm larger in diameter than the femur). The correct size is determined by the femoral size (femoral head reamer + 6 mm = correct acetabular reamer).
At the end of acetabular reaming, the subchondral cancellous structure is reached and subchondral sclerosis is opened to allow osseous integration of the implant.
If the acetabulum was overreamed while femoral head was decreased in size, a mismatch of the components could result because a specific femoral component needs to fit a specific corresponding socket and inlay. To avoid mismatch, we recommend to start reaming of the acetabulum first until the smallest socket which could be implanted is determined, followed by reaming of the femoral head to the largest size that fits the head. Then, the surgeon can easily continue reaming the acetabulum to the appropriated size.

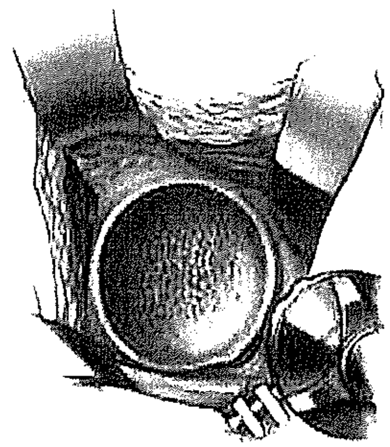
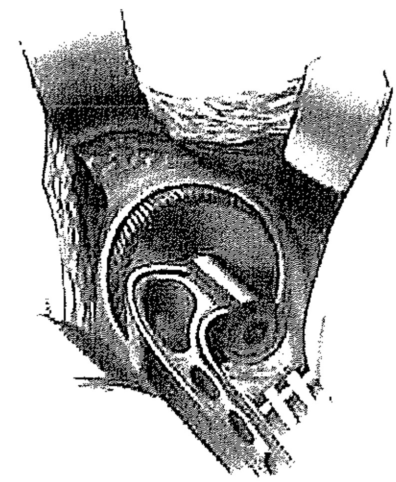
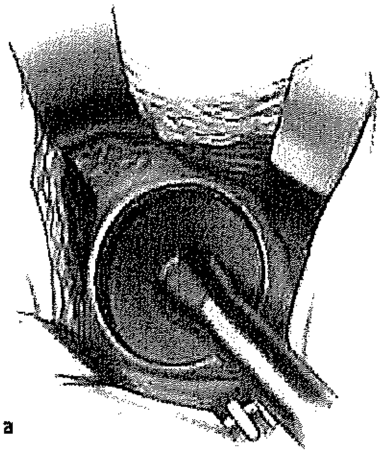


Figure 14
The acetabular implant is fixed on the curved impactor. Acetabular implant size = femoral implant size + 8 mm. The acetabulum has to be underreamed with the implant being oversized by 2 mm compared to the final acetabular reamer (socket size = femoral size + 8 mm). Malpositioning of the implants occurs, if exposition of the acetabulum is not completed. Large soft-tissue layers prevent exact positioning of the socket. Inadequate position commonly appears as increased inclination or anteversion or even both. A complete release of the capsule decreases the risk of malpositioning. Specific navigation systems could be an option to reduce the malpositioning risk.



Figures 15a and 15b
A disposable PE inserter has to be used to impact the acetabular implant (a) until correct positioning and depth of the socket are achieved (b). Eccentric impact leads to nonvisible deformities that induce peak load and increased debris rate and, thus, has to be avoided. If the final acetabular implant is seated (b) and correction of the implant is needed, an asymmetric impaction on the rim of the socket is not allowed. If any correction is needed, the socket-inserting instrument has to be used. Asymmetric impaction leads to a relevant deformation of the implant and the cone junction between inlay and socket is not possible anymore. If the inlay has been inserted in a deformed socket, the fixation of the inlay is no longer cone-based. Therefore, the specific impactor tools have to be used.


a

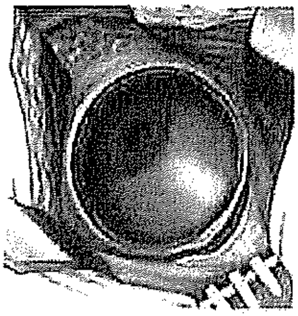

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Figure 16
The insert should be inserted manually to avoid tilting followed by impacting the insert with the single-use PE impactor. Tilting of the insert must be avoided to guarantee an easy removal of the insert in case of revision.

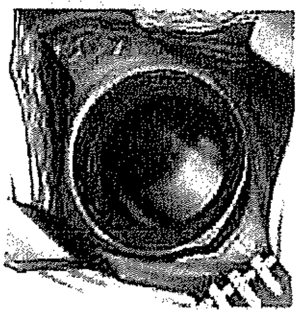


Figure 17
Repositioning of the femoral head into anterior dislocation for final reaming. To finalize reaming, the soft reamer is recommended. The size is determined by the acetabular implant (size of acetabular implant – 8 mm = reamer size to finalize the head).

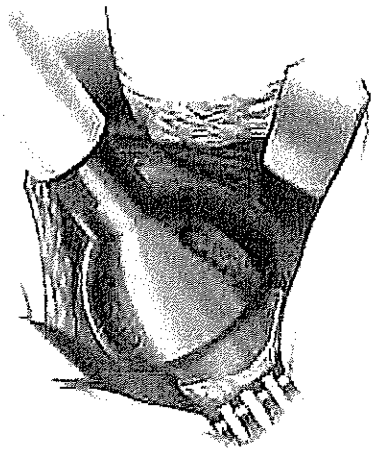


Figure 18
The trial implant is placed again in anatomically correct position guided by the individual neck-head junction. Then, the guiding hole is drilled and widened to facilitate and guarantee fast and reproducible implantation of the femoral component.

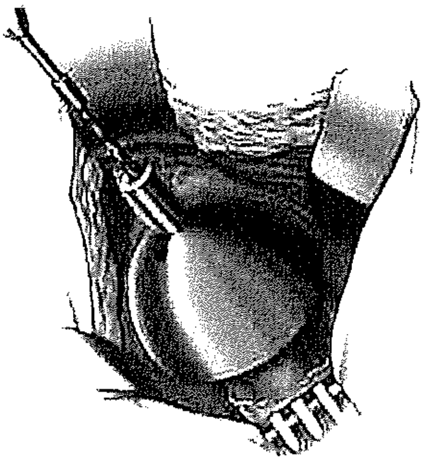
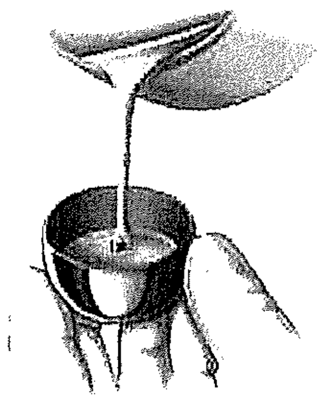


Figure 19
Jet lavage of the femoral head and preparation of the low-viscosity bone cement (Heraeus LV cement, Philipp-Reis-Straße 8/13, 61273 Wehrheim/Taunus, Germany). The cup has to be filled until 2 mm of the guiding pin are still visible. When the cement starts to be pasty, the onlay implant has to be placed on the femoral head.



Figures 20a and 20b
The implant has to be seated with permanent pressure and gentle hammer impaction (a), cleaning of the head, jet lavage, and repositioning followed by examination of the range of motion (b). Femoroacetabular impingement must be avoided. Check for impingement by flexion and internal rotation of the hip. Femoroacetabular impingement is caused by osteophytes, located at the anterior aspect of the head-neck junction or the corresponding aspect of the acetabulum. If the osteophytes are removed, recheck for impingement before wound closure.

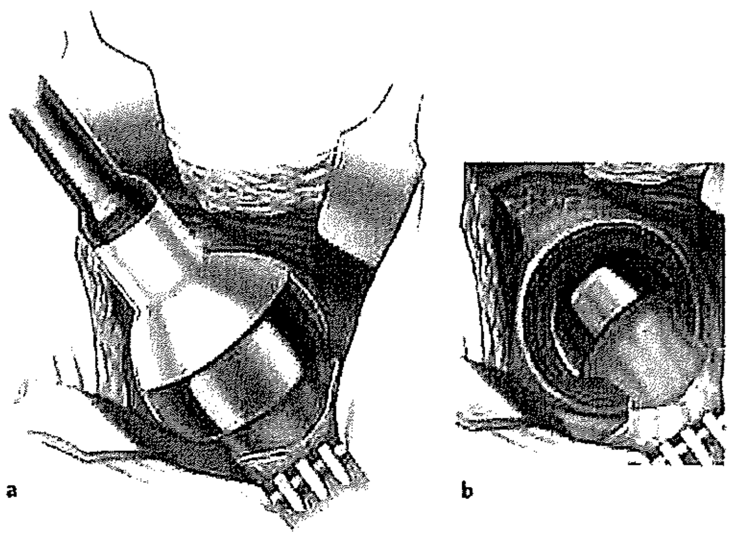
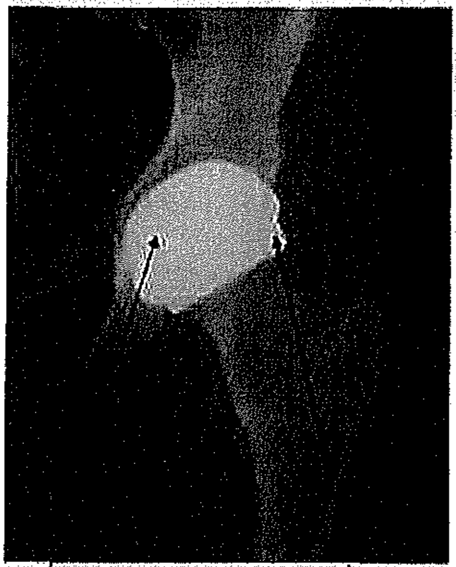

a b

Figure 21
Removal of all instruments. Now, the position of the implants can easily be verified by fluoroscopy. If correction of the implants is required, the specific impactor tools have to be used. Insertion of one drain and wound closure. Sterile dressing. X-ray control.



Postoperative Management

- Continuous passive motion starts on the 1st day after surgery and is continued until full range of motion is achieved and soft-tissue swelling has disappeared marking the start of the outpatient phase.
- Nonsteroidal anti-inflammatory drugs and metamizole as basic analgesics.
- Vital parameters observed continuously on the day of surgery.
- Mobilization with two crutches from the day of surgery with weight bearing as tolerated, increase of weight bearing up to full weight bearing as tolerated.
- We remove the drain on day 2 after surgery.
- Prophylaxis of thromboembolism until full weight bearing is achieved.
- Initiation of early rehabilitation on day 4 after surgery with 3 × 15 min of cycling on an ergometer (maximum 50 W, 80 rpm).
- Suture removal 12 days after surgery.

Errors, Hazards, Complications

- Bony defects of the acetabulum can occur, if reaming is not performed precisely in the central part of the acetabulum. Primary instability of the components results, if bony integrity of the acetabulum is lost: additional screw fixation is recommended.
- Transient disturbance of the femoral nerve, if retractors are placed at the anterior aspect of the acetabular rim: the retractors should be placed with bony contact to the anterior acetabulum.
- Lesions of small vessels of the gluteal region cause minor hematoma because the femoral head has to pass the interval between the dorsolateral aspect of the acetabulum and the gluteal muscles. These minor bleedings are difficult to coagulate because of the minimally invasive approach: the resulting hematoma is clinically of no relevance and resorbed spontaneously without any specific treatment. If preparation and luxation of the femoral head are done gently, bleeding risk can be reduced.
- Mismatch of the components, if the acetabulum was overreamed while femoral head was decreased in size: start reaming of the acetabulum first until the smallest socket which could be implanted is determined, followed by reaming of the femoral head to the largest size that fits the head. The femoral size determines the size of the socket. If both components cannot be adapted, the onlay procedure cannot be performed and surgery has to be changed to a standard resurfacing.
- Femoroacetabular impingement: resection of the osteophytes located at the anterior aspect of the head-neck junction or the corresponding aspect of the acetabulum.
- Neck fracture after surgery; resurfacing implants are associated with neck fractures known as peripros-

thetic fractures: conversion to a standard total hip. Due to the modularity of the acetabular component, the socket stays in situ and the inlay is only changed if necessary.
- Loosening of the femoral component: the head is resected, a short stem or standard femoral stem is implanted, and the inlay has to be changed to fit the new femoral component.
- Loosening of the socket: the socket should be removed and exchanged for a larger one that provides primary stability. A new specific inlay has to be implanted that fits the femoral component; otherwise, the femoral component has to be exchanged for a standard system to fit the new acetabular size.

Results

From December 2005 to June 2006, 31 patients (19 males, twelve females; mean age at the time of surgery 55 years [29–66 years]; mean body mass index 29.2 kg/m^2 [26.9–30.3 kg/m^2]) underwent hip onlay resurfacing via a minimally invasive anterolateral approach using the ESKA onlay implant in all cases. 17 operations were performed on the right and 14 on the left side. Resurfacing was indicated because of primary or secondary osteoarthritis of the hip. Patients with ongoing osteoporosis were excluded. The primary outcome criterion was defined as a change at follow-up compared to baseline in regard of the Harris hip scoring system 12 months after surgery. The change in pain perception measured on a 10-scale visual analog rating system (VAS), the percentage of fractures and loosening were used as secondary criteria. 18 out of the 31 patients suffered from primary and 13 from secondary osteoarthritis (eight cases of dysplasia, three cases of posttraumatic osteoarthritis, and two cases of systemic rheumatoid arthritis). Mean duration of surgery was 81 min (54–145 min). Operating time was significantly longer (up to 145 min) in the first ten cases; mean blood loss was measured at 280 cm^3 (140–510 cm^3). Cell saving was performed in all cases. Autologous blood sampling was not required prior to surgery. To prevent heterotopic ossification, ibuprofen 600 mg was administered three times a day over a period of 10 days and standard thromboembolism prophylaxis was done until full weight bearing was achieved. Patients stayed in hospital for a mean of 7 (± 3) days, followed by 3 weeks of rehabilitation. Rehabilitation consisted of pain-adapted weight bearing within the full range of motion and ergometer training at a load of up to 50 W and a frequency of 80 rpm. Cycling was allowed from postoperative day 4, if no secretion was noted. The ergometer training done three times a day to a total of 45 min and hi accepted by the patients.

12 months after resurfacing, functional outcome wa cellent. The Harris Hip Score improved to 97.1 p compared to 43.9 points at baseline and subjective sensation was scored at 0.6 points on the VAS compar 8.5 points at baseline. Severe side effects such as frac nerve or musculoskeletal lesions, thromboembolism c fection and approach-related side effects like del wound healing, limping or muscle insufficiency were observed. Two patients showed relevant hematoma load-related pain while cycling and walking withou need for revision or another specific treatment followe spontaneous resorption.

Implant-related adverse events such as loosening lengthening or dislocation were not found. All X-ra aminations 3, 6, and 12 months after surgery showe change regarding positioning and loosening. Neithe nal dysfunction nor metal-related allergic reaction seen within 12 months after surgery.

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Der Oberflächenersatz am Hüftgelenk

Die endoprothetische Versorgung des Hüftgelenkes gehört nach wie vor zu den erfolgreichsten orthopädischen Eingriffen. Standzeiten der Implantate von über 90% nach 10 Jahren sind die Regel beim älteren Patienten [17]. Erhalten jüngere Patienten unter 55 Jahre eine Hüftprothese sinkt die Überlebensrate der Implantate laut schwedischem Endoprothesenregister auf unter 80% nach 10 Jahren. Es werden aber auch durchaus längere Standzeiten bei jungen Patienten mit konventionellen Hüftendoprothesen beschrieben. Als mögliche Ursache für ein frühes Versagen wird v. a. die hohe Aktivität junger Patienten diskutiert. Andererseits ist auch die längere Lebensphase des jungen Patienten, in der eine Lockerung der Prothese erlebt werden kann, von Bedeutung. So erscheint es sinnvoll, einen Gelenkersatz zu entwickeln, der möglichst wenig eigene Knochensubstanz zerstört und dadurch eine spätere Wechseloperation erleichtert. Folgerichtig wurde eine Form des Oberflächenersatzes entwickelt, die im angloamerikanischen Raum auch als sog. Hip-Resurfacing bezeichnet wird.

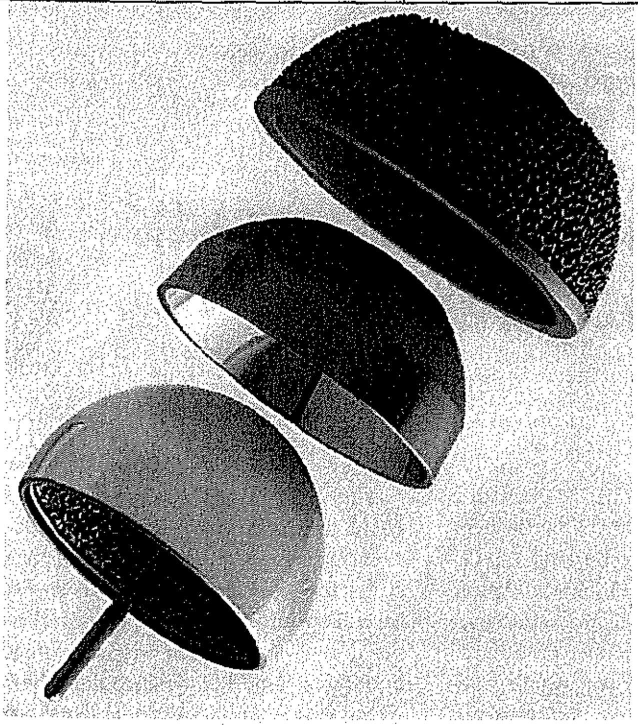
Historische Entwicklung

Das Konzept des Gelenkersatzes der Hüfte in Form des Oberflächenersatzes ist nicht neu. Eine erste Form des Oberflächenersatzes wurde von Charnley in den 1950er Jahren eingeführt. Er verwendete Teflonschalen, die mit einem frühen Verschleiß einhergingen und sich als nicht brauchbar erwiesen [4]. Wagner begann Mitte der 1970er Jahre mit der Implantation eines nach ihm benannten Oberflächenersatzes aus Metall oder Keramik am Femur und Polyethylen (PE) an der Pfanne [31]. Diese Form des Gelenkersatzes wurde wegen vielversprechender Frühergebnisse in Europa häufig angewandt. Später wurden aber hohe Lockerungsraten festgestellt, was zu einem weitreichenden Misserfolg und Verruf dieser Art des Gelenkflächenersatzes führte. In einer Schadensanalyse von insgesamt 124 an unserer Klinik zwischen 1977 und 1984 implantierten Wagner-Doppelcups konnten Rechl et al. [24] 85% der Patienten klinisch und radiologisch nachuntersuchen. Bei einer durchschnittlichen Nachuntersuchungszeit von 107 Monaten traten bei 104 Doppelcups insgesamt 53 Lockerungen auf. Die dünnwandige Polyethylenpfanne war dabei häufiger betroffen als die Femurkomponente. Die Pfanne verformte sich unter Belastung und führte dadurch in Verbindung mit der großen Artikulationsfläche zum erhöhten Abrieb. Dieser wurde für zum Teil sehr große Defekte im Pfannenbereich verantwortlich gemacht, die spezielle Revisionsimplantate und Knochentransplantationen notwendig machten. Der starke Abrieb erzeugte zum Teil Granulationsgewebe, das nach Osteolyse bis zum bindegewebigen Umbau des gesamten Femurkopfs geführt hat. Obwohl es sich bei diesen Lockerungsvorgängen um ein multifaktorielles Problem handelt, standen die ungünstigen Materialeigenschaften im Vordergrund. Salzer [25] verwendete zur gleichen Zeit eine zementlos implantierte Keramik-Keramik-Gleitpaarung, die jedoch wegen hoher Lockerungsraten ebenfalls früh wieder aufgegeben wurde.

Nur wenige Zentren arbeiteten konsequent an der Entwicklung eines Oberflächenersatzes weiter. Amstutz implantierte später modulare Systeme, die aus einem Metallkopf und einer Metallpfanne mit einer dünnen Polyethylenzwischenschicht bestanden. Eine Renaissance des Oberflächenersatzes am Hüftgelenk entstand nach der erneuten Einführung der Metall-Metall-Gleitpaarung durch bessere Fertigungstechniken. Geschmiedete oder gegossene Komponenten aus Chrom-Kobalt-Legierungen mit hohem Karbidgehalt wiesen exzellente Verschleißeigenschaften auf [22, 33]. Zu Beginn der 1990er Jahre entwickelten Wagner [32] in Deutschland, Amstutz [26] in den U.S.A. und McMinn [18] in England Prothesensysteme, die auf dieser Technologie basierten. Von diesen wurden nur wenige Modelle implantiert und ständig Änderungen an Design und Verankerungstechnik vorgenommen, da Frühlockerungen immer noch häufig beobachtet wurden. Erst eine Hybridfixierung mit zementfreier Pfanne und zementierter femoraler Komponente in Kombination mit der bereits genannten Metall-Metall-Gleitpaarung setzte sich im neuen Jahrtausend durch.

Aktueller Stand der Entwicklung

Heute bieten praktisch alle großen Prothesenhersteller ein System für den sog. Oberflächenersatz am Hüftgelenk an. Allen gemeinsam ist eine Metall-Metall-Gleitpaarung mit hohem Karbidanteil, eine zementlose Fixierung der Pfanne und eine meist zementierte Fixierung der Femurkomponente. Dennoch bestehen Unterschiede, die nicht nur die tribologischen Eigenschaften bestimmen.



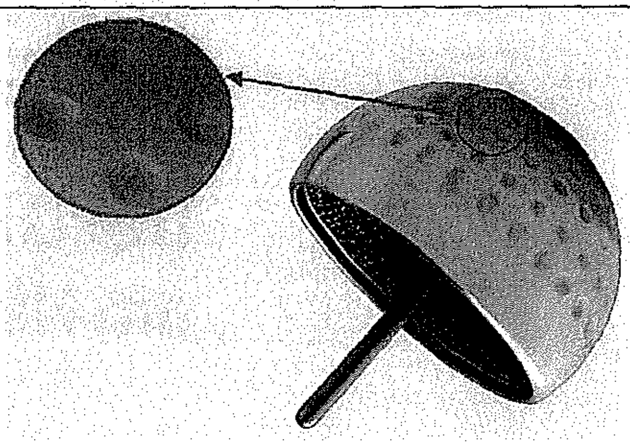


Abb. 2 ▲ Femurkappe eines Oberflächenersatzes. In der Vergrößerung sind die Vertiefungen in der Oberfläche gut sichtbar, die als Reservoire für die Schmierflüssigkeit zwischen den Gelenkpartnern dienen

Abb. 1 ◄ Modularer Oberflächenersatz für das Hüftgelenk mit zementfreier Verankerung und austauschbarem Metallinlay (CL-Kappe „BS", CL-Sockel „BS", Metallinlay; *CL:* cementless, *BS:* Bionic System; Firma ESKA-Implants, Lübeck)

In Simulatorversuchen wurde ein deutlich niedrigerer Verschleiß bei Metall-Metall-Paarungen mit <0,3 mm³/Jahr nach der Einlaufphase im Vergleich zu Metall-Polyethylen-Gleitpaarungen mit einem Abrieb von 30–100 mm³/Jahr nachgewiesen [27]. Nach einer gewissen Einlaufphase nimmt der Verschleiß bei den Metall-Metall-Paarungen ab. Gleiches soll für die Situation gelten, wenn ein Wechsel der Femurkomponente erfolgt, die Pfanne jedoch in situ verbleibt. Ob dies ein Problem bei der Kombination von „eingelaufenen" Pfannen und neuen Großköpfen darstellt, ist bisher noch nicht bekannt. Es muss davon ausgegangen werden, dass die Kombination aus einem neuen Kopf und einer eingelaufenen Pfanne eine veränderte Clearance ergibt, die wiederum einen Einfluss auf den Schmierfilm zwischen den Gelenkpartnern hat. Einzelne Hersteller bieten deshalb die Pfannenkomponente mit Metallinlay an, was einen späteren Wechsel der artikulierenden Flächen durch völlig neue Komponenten ermöglicht (■ Abb. 1).

Welche Rolle die Größe und Morphologie der Partikel spielen, ist bis heute noch nicht ganz klar. Plitz [8, 23] geht davon aus, dass zwar ein geringeres Partikelvolumen im Vergleich zu Metall-PE-Gleitpaarungen entsteht, bei geringerer Größe der Partikel aber eine höhere Gesamtzahl von Abriebpartikeln vorliegt. Bereits in den 1970er Jahren wurde eine erhöhte Serumkonzentration von Metallionen (Chrom und Kobalt) bei Metall-Metall-Paarungen nachgewiesen [5]. Eine weitere Erhöhung der Ionenkonzentration in Serum und Urin ließ sich beim Oberflächenersatz mit großem Durchmesser der artikulierenden Komponenten im Vergleich zum herkömmlichen totalen Hüftgelenkersatz mit Metall-Metall-Gleitpaarung nicht erkennen [14].

Da Chrom- und Kobaltionen in der Niere über glomeruläre Filtration ausgeschieden werden, sollten Patienten mit Niereninsuffizienz von einer solchen Gleitpaarung ausgenommen werden. Gleiches gilt für Patienten mit evidenter Metallallergie. Sowohl für die erhöhte Konzentration der Metallionen selbst als auch für das Vorliegen von allergischen Reaktionen auf diese gibt es bisher allerdings keine nachweisbaren Daten. Es müssen deshalb weitere Beobachtungen abgewartet werden, um hier eindeutige Empfehlungen aussprechen zu können. Ähnliches gilt für die Implantation von Metall-Metall-Gleitpaarungen im gebärfähigen Alter. Brodner [3] konnte bei Schwangeren mit dieser Gleitpaarung zwar erhöhte Konzentrationen der Metallionen im peripheren Blut, jedoch keine erhöhten Konzentrationen im Nabelschnurblut nachweisen. Unklar ist ebenfalls, ob es im Verlauf durch die erhöhten Metallkonzentrationen z. B. zu einer Hypersensitivität kommen kann und ob eine erhöhte Gefahr für die Entwicklung von sekundären Entartungen besteht.

Der Abrieb der Paarung hängt von der Makrogeometrie (Größe der Komponenten, Passform), der Mikrogeometrie (Oberfläche) und der Schmierung zwischen den Komponenten ab. Je größer die Komponenten bei gleichen übrigen Parametern sind, desto geringer ist der Abrieb [9, 29]. Dass größere Durchmesser der Komponenten auch zu einem größeren Bewegungsausmaß führen, ist so jedoch nicht korrekt. Das Bewegungsausmaß ist entscheidend von dem Verhältnis zwischen Femurkopf- und Halsdurchmesser geprägt [2]. Die großen femoralen Komponenten senken dennoch die Luxationsneigung des Gelenks deutlich. Auch soll die Verwendung von großen Komponenten eher zu einer Kinematik führen, die dem gesunden Hüftgelenk im Vergleich zum konventionellen Gelenkersatz ähnlicher ist [20]. Die Autoren der Studie räumen jedoch ein, dass die Ergebnisse durch ein gewisses Bias in der Patientenwahl beeinflusst sein könnten.

Um die Schmierung der Komponenten durch einen Flüssigkeitsfilm zu erhöhen, sind große Komponenten mit möglichst glatter Oberfläche von Nutzen [30]. Ein anderer Weg ist die Veränderung der Oberfläche durch gezielte Vertiefungen, die als Flüssigkeitsreservoire im Gelenkspalt dienen, die die Menge an Schmierfilm konstant halten sollen, um damit den Abrieb auf ein Minimum zu reduzieren (■ Abb. 2).

Je größer die femorale Komponente, umso größer wird der Knochenverlust bei der Implantation der passenden Pfanne. Dieser Sachverhalt erscheint logisch. Er trifft v. a. im Vergleich zur konventionellen totalen Hüftendoprothetik zu [16].

Ein großer Unterschied besteht momentan in der Fixierung der einzelnen Komponenten und ihrer Oberflächen. Plasma gesprayte Oberflächen, Chrom-Kobalt-Kugeln und dreidimensional offenzellige Spongiosametalloberflächen werden derzeit vornehmlich implantiert. Bisher werden bei keiner Verankerung Schrauben angewandt, da es sich bis auf die von der Firma ESKA hergestellten Pfannen nicht um modulare Systeme handelt und Löcher für Schraubenköpfe in der Oberfläche des empfindlichen Gleitflächensystems offensichtlich zum erhöhten Verschleiß führen würden. Ob die Bearbeitung der Oberflächen die langfristigen Abriebeigenschaften der artikulierenden Flächen beeinflusst, bleibt abzuwarten. Gleiches gilt für das unterschiedliche Spiel oder den Spielraum zwischen den Komponenten (im angloamerikanischen Raum als Clearance bezeichnet). Ein gewisses Maß an Spiel ist notwendig, um einen konstanten Schmierfilm zwischen den Gleitpartnern zu erlauben. Moderne Fertigungstechniken gewährleisten einen reproduzierbaren Spielraum, der messbar ist und für den Oberflächenersatz im Mikrometerbereich liegt. Bei der Implantation von dünnwandigen Pfannen kann es aber zur Veränderung dieses Spielraumes und damit auch des Abriebs kommen. Der im Simulatorversuch gemessene Verschleiß der Komponenten muss daher immer als Idealfall betrachtet werden.

Femoralseitig spielen der Zugang zum Hüftgelenk, die Zurichtung des Hüfkopfes respektive Platzierung der Komponente und die Verankerung eine besondere Rolle. Für die Durchblutung des Hüftkopfes ist der Zugang zur

Zusammenfassung · Abstract

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M. Rudert · L. Gerdesmeyer · H. Rechl · P. Jühnke · R. Gradinger

Der Oberflächenersatz am Hüftgelenk

Zusammenfassung

Der moderne Oberflächenersatz gilt als attraktives Verfahren, um gerade beim jungen Patienten ein degenerativ verändertes Hüftgelenk zu ersetzten. Die hohen Erwartungen, die in diese Form des Gelenkersatzes gesetzt werden, müssen allerdings erst noch erfüllt werden. Frühere Implantate mit ähnlichen Formen des Oberflächenersatzes haben zu hohen Revisionsraten durch vorzeitige aseptische Lockerungen in Verbindung mit hohem Materialverschleiß und zu Schenkelhalsfrakturen geführt. Heute ermöglichen neue Fertigungstechniken der Metall-Metall-Gleitpaarung die Verwendung eines Oberflächenersatzes mit minimiertem Abrieb, was ein langfristiges Überleben der Prothese theoretisch möglich macht. Nach wie vor stehen Langzeitergebnisse der neuen Generation des Oberflächenersatzes aus. Schenkelhalsfrakturen und ein femoroazetabuläres Impingement erweisen sich als mögliche Frühkomplikationen. Die Implantation dieser Systeme ist technisch anspruchsvoll und erfordert ein hohes Maß an Erfahrung vom Operateur. Eine zugangsbedingte Traumatisierung der Muskulatur und Gefährdung der Blutgefäßversorgung des Femurkopfs steht dem positiven Effekt der Erhaltung von Knochensubstanz am Oberschenkel und einer verbesserten Revisionsmöglichkeit im Versagensfall gegenüber. Wir werden erst in der Zukunft sehen, ob gerade der junge Patient mit seiner höheren Aktivität von einem Oberflächenersatz tatsächlich profitiert.

Schlüsselwörter

Hüftgelenk Arthrose · Endoprothese · Oberflächenersatz · Metall-Metall-Gleitpaarung

Resurfacing arthroplasty of the hip

Abstract

Resurfacing arthroplasty is regarded as an attractive method, especially for the young patient who needs a hip replacement. However, the high expectations regarding this new technique in THR must first be met. Earlier experiences with similar forms of surface replacement have led to high revision rates with early aseptic wear induced component loosening and neck fractures. Technical progresses in production techniques for metal-on-metal articulations with minimized wear have enabled the introduction of new surface replacements for the hip joint. Long-term results of these resurfacing arthroplasties are still due. Femoral neck fractures and femoroacetabular impingement are possible early complications which require revision. The implantation of these systems requires a high degree of operative skill and experience on the part of the surgeon. Approach dependent trauma to the musculature and endangering of the blood supply to the femoral head is balanced with the positive effect of the preservation of femoral bone stock and better options in case of revision. Whether the younger patient with a higher activity profile and an increased chance of implant loosening actually profits from the resurfacing arthroplasty will be determined in the future.

Keywords

Hip arthritis · Endoprosthesis · Resurfacing arthroplasty · Metal-on-metal bearing

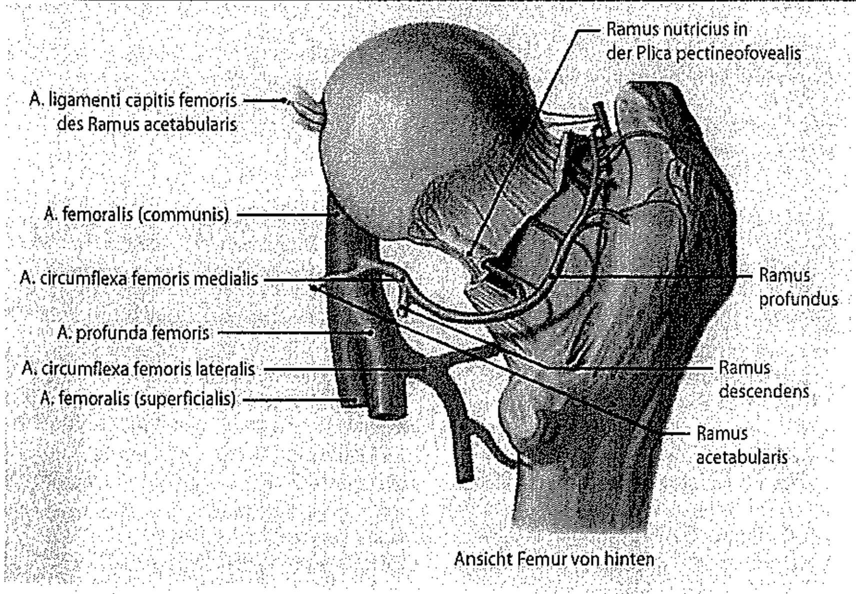

Abb. 3 ▲ Anatomische Darstellung der dorsolateralen Region eines rechten Femur mit R. profundus und Aufteilung der Rr. nutritii, deren Arkadenbildung deutlich erkennbar ist. (Modifiziert nach Tillmann (2005) Atlas der Anatomie des Menschen. Springer, Heidelberg)

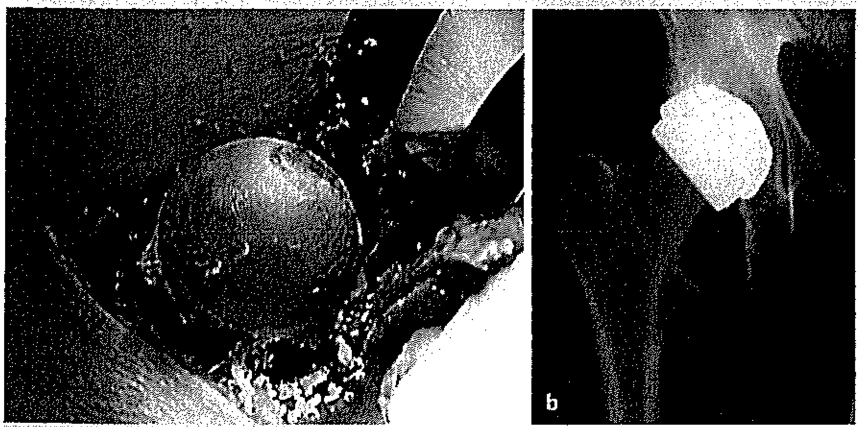

Abb. 4 ▲ **a** Hüftkopf, bei dem lediglich die Knorpeloberfläche bis auf die Kortikalis entfernt wurde, um eine möglichst physiologische Krafteinleitung über eine zementierte Kappe zu erreichen. **b** Röntgenbild eines am rechten Hüftgelenk implantierten Oberflächenersatzes in der unter Abb. 4a beschriebenen Technik. Die Pfanne ist zementfrei verankert, die Kappe mit einem niedrigviskösen Zement fixiert (Onlay-Femurkopfschale)

Abb. 5 ▲ Konventioneller Oberflächenersatz in zementfreier Verankerungstechnik im Röntgenbild

Hüfte besonders interessant. So kann von der Kompromittierung der Hüftkopfdurchblutung bei einer Zerstörung des Ramus profundus der A. circumflexa femoris medialis ausgegangen werden (◘ Abb. 3). Dieser Ast ist besonders bei dem häufig verwendeten hinteren Zugang gefährdet, da er im Ansatzbereich der Außenrotatoren der Hüfte verläuft [10]. Er liegt unterhalb der Sehne des M. obturator externus. Wir bevorzugen deshalb den anterolateralen Zugang zum Hüftgelenk, auch wenn dieser die Exposition des Schenkelhalses zeitweise erschwert. Im Vergleich zur konventionellen endoprothetischen Versorgung der Hüfte ist eine erweiterte Lösung der Weichteile notwendig, um die Pfanne ausreichend darstellen zu können. Der Implantationsweg wird durch den erhaltenen Hüftkopf sonst zu stark verdeckt und eingeengt.

Die Zurichtung des Femurkopfes sollte möglichst eine Ausrichtung der Kappe auf das Zentrum des Schenkelhalses erlauben. Wenn dies nicht beachtet wird, ist das Bewegungsausmaß des Hüftgelenks in vielen Fällen noch mehr eingeschränkt, als dies durch die ungünstigere Relation zwischen Schenkelhals- und Kopfdurchmesser bereits vorgegeben ist. Ein Beispiel hierfür ist die Coxa vara epiphysarea, die mit einer exzentrischen Lage des Hüftkopfs auf dem Schenkelhals einhergeht. Wird dieses Missverhältnis bei der Implantation beibehalten, kommt es postoperativ häufiger zum femoroazetabulären Impingement, was zur Notwendigkeit der frühzeitigen Revision führen kann. Liegt aber ein konzentrischer Verschleiß bei physiologischer Gelenkstellung vor, sehen wir momentan die Indikation für einen neu entwickelten Oberflächenersatz, bei dem lediglich der femorale Knorpel bis auf die Kortikalis abgetragen und eine Kappe ohne Stiel auf diesen zementiert wird (◘ Abb. 4). Die femorale Fixierung erfolgt üblicherweise durch niedrigviskösen Zement. Die Viskosität und die Dicke des Zementmantels werden dabei kontrovers diskutiert. Die exzessive Penetration des Zements in die Trabekel kann zu einer Nekrose des Knochens in diesem Bereich führen. Stress-Shielding kann hier ebenfalls eine Rolle spielen und in Verbindung mit einem kurzen Schaft, der bei der Krafteinleitung ins Femur teilnehmen kann, zu einer Osteolyse und konsekutiver Fraktur des Schenkelhalses führen. So sind die Schenkelhalsfraktur und das Impingement momentan hauptsächlich für die implantatassoziierten Frühkomplikationen verantwortlich.

Ergebnisse

Im eigenen Krankengut wurden zwischen Dezember 2003 und Februar 2005 bei strenger Indikationsstellung 16 Patienten (mittleres Alter 41 Jahre) mit 20 Oberflächenersatzprothesen (ESKA-Bionik-System) versorgt (◘ Abb. 5). Das System wird im Vergleich zu den Implantaten anderer Hersteller völlig zementfrei implantiert. Spongiosametall bildet den Kontakt sowohl zum Beckenknochen als auch zum Schenkelhals. Ein Inlay aus geschmiedetem Metall wird modular in den Sockel eingesetzt und kann im Fall einer Wechselsituation ausgetauscht werden. Hier bietet sich die Möglichkeit sowohl ein Inlay für eine Großkopfartikulation, als auch ein Inlay für eine Standardartikulation aus Keramik gegen Polyethylen oder Metall-Metall mit geringeren Kopfdurchmessern zu wählen. Bei unserem Patientengut wurde bei einer durchschnittlichen Nachuntersuchungszeit von 18 Monaten keine Infektion oder aseptische Lockerung beobachtet. Der Harris-Hip-Score stieg im Mittel von 52 Punkten präoperativ auf 92 Punkte postoperativ. Es wurden eine Schenkelhalsfraktur und eine Pfannendislokation im Beobachtungszeitraum festgehalten. Damit lag die Revisionsrate bei unseren ersten Oberflächenersatzsystemen bei etwa 10% [15].

In der Literatur werden Revisionsraten zwischen 2 und 17% angegeben [15]. Shimmin et al. [28] berichten über das nationale Australische Prothesenregister mit 3497 Birmingham-Cups mit einer durchschnittlichen Nachuntersuchungszeit von 36 Monaten. Es traten dabei 50 Schenkelhalsfrakturen, 12 aseptische Pfannenlockerungen, 4 aseptische femorale Cuplockerungen und 2 Infektionen auf. Die Revisionsrate lag insgesamt bei 2%. Witzleb berichtete über zufrieden stellende Ergebnisse nach 420 Oberflächenersätzen (Birmingham-Hip und Durom-Cup). 238 Patienten wurden nach durchschnittlich 2 Jahren nachuntersucht. Die Revisionsrate betrug 2,2%. Patienten, die mit einer Dysplasiepfanne versorgt worden waren, wiesen ein gleichermaßen gutes Ergebnis auf wie die Patienten, die eine Standardpfanne erhalten hatten.

Amstutz et al. [1] publizierten die Ergebnisse von 400 Hybridoberflächenersätzen („Conserve Plus") bei 355 Patienten mit einem mittleren Alter von 48 Jahren nach einer mittleren Nachuntersuchungszeit von 3,5 Jahren. Nach 4 Jahren waren noch 94,4% ohne Wechseloperation verblieben. Der mittlere Harris-Hip-Score betrug 93,5 Punkte. 12 Hüften waren in konventionelle totale Hüftprothesen gewechselt worden. Bei 3 Patienten kam es zur Luxation der Hüfte. Heterotope Ossifikationen (Brooker III-IV) traten in 10% der Fälle auf.

Tab. 1 Vor- und Nachteile des Oberflächenersatzes am Hüftgelenk

Vorteile	Nachteile
Knochensparende Technik am Femur	Leicht erhöhter Knochenverlust am Azetabulum
Geringere Luxationshäufigkeit	Gefahr der Schenkelhalsfraktur
Bessere Revisionsmöglichkeit am Femur	Fehlende Langzeitergebnisse und Erfahrungen mit Revisionen
Gelenkersatz auch bei subkapitalen oder diaphysären Deformitäten des Femurs möglich	Metallabrieb und Metallionen im Organismus
Seltener Beinlängendifferenzen	Keine Rekonstruktion des Offsets

Gregoris [11] berichtet über 200 konsekutive Oberflächenersätze (Durom-System) mit guten Ergebnissen. Das mittlere Alter der Patienten betrug 48 Jahre, die Nachuntersuchungszeit 2,2 Jahre. Es traten keine Luxationen, Infektionen oder Lockerungen auf. Ähnlich gute Resultate wurden von De Smet [7] über 200 Patienten publiziert, die ein Birmingham-Hip-Resurfacing erhalten hatten. Lediglich eine Schenkelhalsfraktur wurde im Mittel 1,1 Jahre nach der Implantation verzeichnet. Über die besten Resultate berichten Daniel et al. [6], die 446 Patienten mit einem Alter unter 55 Jahren mit einem Birmingham Oberflächenersatz versorgt haben. Die mittlere Nachuntersuchungszeit betrug 3,3 Jahre. Die Nachuntersuchung erfolgte am Telefon und über Fragebögen. Eine klinische oder radiologische Kontrolle wurde nicht durchgeführt.

Schlussfolgerungen

Die frühen und mittelfristigen Ergebnisse des modernen Oberflächenersatzes lassen hoffen, dass die langfristigen Resultate ebenfalls positiv ausfallen. Momentan sind die klinischen Ergebnisse noch nicht mit denen des konventionellen Gelenkersatzes am Hüftgelenk vergleichbar. Auch die Komplikationsrate ist im Vergleich zu diesem weiterhin erhöht. Primäre Fehlerursachen sind Schenkelhalsfrakturen und aseptische Lockerung der femoralen Komponente sowie aus unserer Sicht das femoroazetabuläre Impingement. Kritisch erscheinen hier die korrekte Positionierung der Pfanne und die korrekte Ausrichtung der Kappe auf dem Schenkelhals bzw. die Deformität von Schenkelhals und Hüftkopf. Eine äußerst kritische Indikationsstellung und sehr genaue Operationstechnik sind erforderlich, um den Erfolg des Implantats zu gewährleisten. Vor- und Nachteile des Oberflächenersatzes sind in ◘ Tab. 1 zur Übersicht dargestellt.

Frühe Fehler können durch die Implantationstechnik verursacht werden, was zu Mikrofrakturen mit späteren Pseudarthrosen unter dem femoralen Implantat im Schenkelhals führen kann [21]. Ein weiterer Risikofaktor für die Schenkelhalsfraktur ist die Unterdimensionierung der Femurkappe. Sie führt zum Einkerben des Schenkelhalses und damit zu einer Sollbruchstelle mit fraglichem Langzeitresultat. Mont [19] empfiehlt die Implantation des Oberflächenersatzes daher nur Operateuren, die hierfür ein spezielles Training durchlaufen haben. Als mögliche Hilfestellung, um die evidente Lernkurve zu verkürzen, könnte die Navigation in Zukunft eine größere Rolle spielen.

Durch den großen Durchmesser des Schenkelhalses liegt ein ungünstiges Verhältnis vom Kopf-Hals-Durchmesser vor. Dadurch kommt es zu einer Reduktion des Bewegungsausmaßes [2]. Kommt es zum Anschlagen vom Schenkelhals an die Pfanne oder den randständigen Knochen, wird es neben Schmerzen für den Patienten zu Subluxationsphänomenen der Kappe in der Pfanne kommen. Diese können so ausgeprägt sein, dass ein Wechsel der Femurkomponente erforderlich wird.

Die neuen Generationen der Metall-Metall-Gleitpaarungen mit großem

Durchmesser weisen äußerst gute Verschleißeigenschaften auf. Diese Verschleißeigenschaften kommen aber nur dann zum Tragen, wenn die Komponenten optimal implantiert wurden und keine Randbelastungen auftreten, was den Verschleiß um das bis zu 500fache erhöhen kann [21]. Je größer der Kopfdurchmesser wird, desto größer wird jedoch auch der Pfannendurchmesser [16], was wiederum dem Ziel eines möglichst knochensparenden Eingriffs entgegensteht. Ist eine Revision aufgrund des Versagens auf der femoralen Seite notwendig, wird die Pfanne gerade bei großen Dimensionen natürlich nicht gewechselt werden. Die meisten Systeme zum Oberflächenersatz am Hüftgelenk weisen eine Monoblockpfanne auf, deren Oberfläche z. B. aufgrund eines erhöhten Verschleißes nicht ausgetauscht werden kann. In Simulatorversuchen hat sich dies zwar als wenig problematisch erwiesen [12], es soll aber zu einer Erhöhung der Ionenkonzentration kommen, die indirekt auf einen erhöhten Abrieb hinweist. Wir geben deshalb einem modularen System den Vorzug, das auch im Revisionsfall die Möglichkeit bietet, die Pfanne mit einem neuen Inlay zu versorgen.

Fazit für die Praxis

Der Oberflächenersatz am Hüftgelenk bleibt weiterhin eine reizvolle Alternative zur sehr erfolgreichen Standardendoprothetik. Zunehmende Erfahrungen und Informationen über die Fehlermechanismen, die bei diesen Systemen eine Rolle spielen, werden helfen, die Implantate weiter zu optimieren und die Implantationstechnik zu verbessern.

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29

Modes of Implant Failure After Hip Resurfacing: Morphological and Wear Analysis of 267 Retrieval Specimens

By Michael M. Morlock, PhD, Nick Bishop, Dipl-Ing, Jozef Zustin, MD, Michael Hahn, Dipl-Ing, Wolfgang Rüther, MD, and Michael Amling, MD

Background: Resurfacing of the hip joint is experiencing a revival due to improvements in materials, design, and manufacturing techniques. Despite good midterm outcomes, the high early rate of failure and concerns about metal debris require a detailed morphological and wear analysis of retrieved resurfacing implants in order to understand failure mechanisms.

Methods: A worldwide collection of hip resurfacing revision devices was initiated, and 267 components were received. Devices were analyzed by patient demographics, radiographic positioning, and wear, as well as morphologically and histologically. Specimens were grouped into four different failure types. They were also stratified into rim-loaded or non-rim-loaded groups. Failures were also assessed by surgeon learning-curve effects.

Results: Time to failure was significantly different between the four revision-type groups: Specimens with fractures involving the implant rim were most common (46%) and failed earliest after surgery (mean of ninety-nine days), followed by fractures inside the femoral head (20%, 262 days) and loose cups (9%, 423 days). Revisions not due to fractures or cup loosening (25%) occurred at a mean of 722 days after surgery. Rim-loaded implants exhibited an average twenty-one to twenty-sevenfold higher wear rate than implants without rim-loading. Rim-loaded implants also showed a steeper mean cup inclination than their non-rim-loaded counterparts (59° compared with 50°). Most failures occurred during the learning curve of the surgeon (the first fifty to 100 implantations).

Conclusions: Failures on the femoral side usually occur within the first nine months after surgery and appear to be most directly related to the implantation technique or patient selection. Later failures are observed mainly due to acetabular problems, either due to dramatically increased wear or poor cup anchorage. Improper cup anteversion may be similar to or more important than cup inclination in producing excessive wear.

Clinical Relevance: Femoral neck fractures are the main reason for early hip resurfacing failure. Insufficient cup fixation and positioning can cause later failure and thus, patients at risk of increased wear should be carefully monitored in order to prevent excessive exposure to metal ions. Appropriate education is required to reduce the length of the surgeon learning curve.

The short-term and midterm outcomes of metal-on-metal hip resurfacing are encouraging, particularly in younger and more active patients[1-5]. This has resulted in rapid acceptance of the technique, which is demonstrated by a 7.8% rate of resurfacing among all Australian total hip arthroplasties in 2007[6]. However, the Australian hip registry also clearly demonstrates an increased risk of revision within the first six to twelve months for hip resurfacing. After this initial period, the number of revisions does not differ from that associated with conventional total hip arthroplasties[6]. The high early revision rates are speculated to be related to the difficult implantation technique, which requires careful sizing of implants as well as reaming, positioning, and cementation of the femoral head[7-10]. Positioning of the joint components, with an emphasis on the cup, has been shown to be crucial for decreasing wear[11]. Patient selection and surgeon operative expe-

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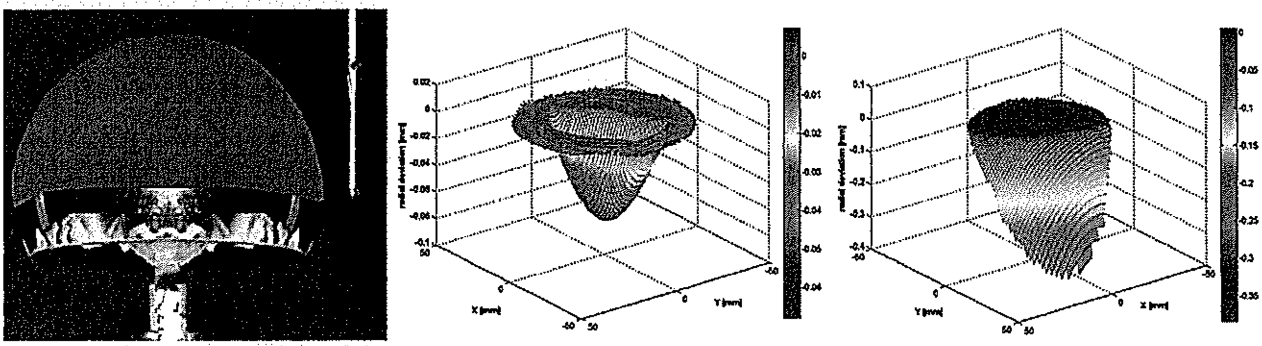

Fig. 1
Left: Determination of the surface geometry of the retrievals with use of a coordinate measurement system. The measured area is highlighted in red. *Middle:* Wear pattern of a rim-loaded resurfacing head (radial deviation from a perfect sphere). *Right:* Wear pattern of the respective acetabular cup (radial deviation from a perfect spherical cup).

rience also appear to play important roles in success rates[12,13]. These factors have been investigated in a previous study by us in a sample of fifty-five retrieved failed implants[14]. Currently, the number of available retrievals has increased to more than 267.

The previous study focused on the biomechanical, morphological, and, in particular, tribological aspects related to failure. With respect to the effect of wear debris, it is accepted that a reduction in metal ion concentration by a reduction in joint wear is highly desirable to avoid ion side effects[15-18]. The purpose of the present study was to identify the main reasons for revision surgery and to analyze the influence of component alignment on total joint wear by investigating complete revisions (head and cup couples of the same joint).

Materials and Methods

The implants in this study were obtained from an international retrieval program, which was initiated in 2004. This study gives surgeons the opportunity to submit implants retrieved at revision for a detailed biomechanical, morpho-

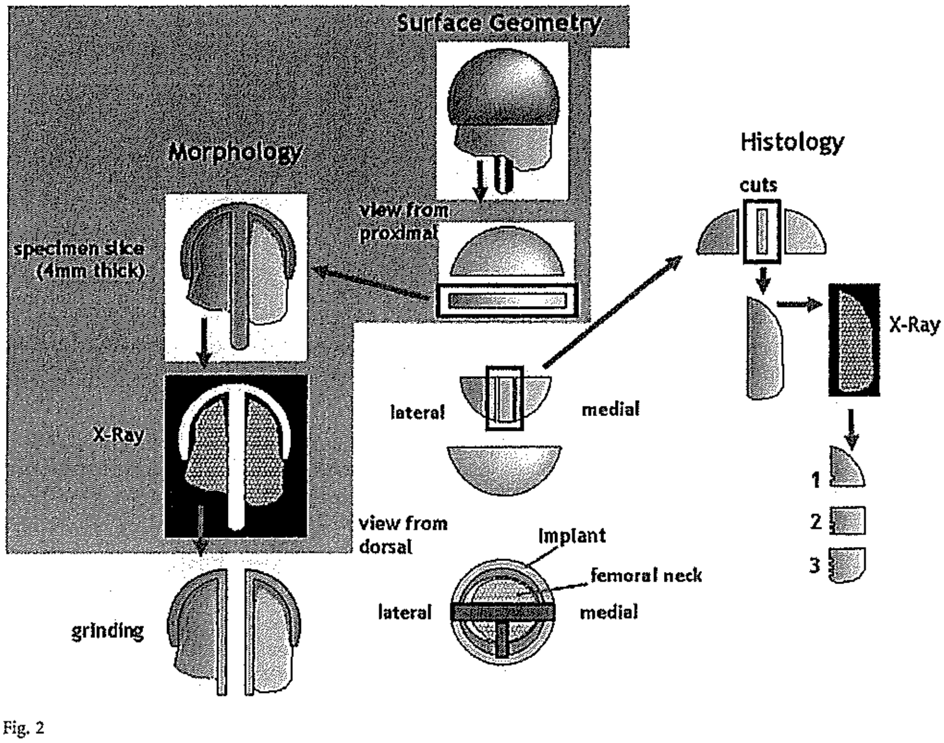

Fig. 2
Schematics of the preparation of a retrieval head for the biomechanical, morphological, and histological analysis. This study concentrates on the results of the surface and morphology analysis.

logical, and histological analysis, thereby permitting a better understanding of the reasons for failure. The analysis of the combined individual reports should yield a realistic cross section of the present situation in hip resurfacing. It could give a reasonable estimate of the situation for an arbitrary patient outside a controlled clinical study. Implants from sixteen different countries were included in this study. We did not distinguish between implants from different manufacturers, since almost identical early failure patterns were observed for all implant designs analyzed[14].

Patient Data

Attempts were made to obtain complete sets of patient data and medical records, including radiographic documentation and descriptions of the implantation and cementing technique. Due to the nature of the study, the availability of complete data sets could not be guaranteed. The number of available cases used in each analysis will be described.

Wear Measurement

The surface geometry of each retrieved implant was determined with use of a coordinate measurement machine (Mitutoyo BHN 805, Tokyo, Japan). For the heads, sixteen sets of planar data were collected from the equator to the equator through the pole, rotated consecutively by 11.5° around the polar axis, with a coordinate measured every 5 mm using a 1-mm diameter ruby probe. The same method was applied to the acetabular cups but starting 2 mm below the cup rim.

A sphere was fitted to the point data in a manner that excluded the worn regions and included only the assumed original unworn implant surface. The distance of each area of the triangulated points to the unworn spherical surface was calculated as radial deviation and used for the estimation of wear volume. Only deviations greater than the 3 μm accuracy of the measurement machine were considered for the wear estimation (Fig. 1). This method has been described in detail previously[14].

Morphological Analysis

After determination of the surface geometry, implants were analyzed morphologically and histologically. A 4-mm slice was cut from the polar section of the head using a diamond saw (EXAKT 310, Oklahoma City, Oklahoma), and then radiographed and photographed (Fig. 2). We attempted to orient sections to lie in the plane of the femoral neck, although this was sometimes difficult to assess in cases of fracture within the head or when the neck had been cut high. Some variation in the cutting plane occurred.

Cup Inclination, Edge Wear, and Reason for Revision

The cup inclination angle was determined from the anteroposterior radiograph. The antetorsion angle of the cup could not be determined with confidence since no standardized lateral radiographs were available. The cup inclination alone, however, gives no reliable indication of the loading situation of the implant in situ; therefore, edge-wear pattern, as determined from the surface topography measurements was chosen as an indicator for the rim-loading situation in the patient. This categorization was not based on the magnitude of wear (which is highly dependent on the implantation period), but rather on the wear pattern itself. Patterns demonstrating a clear demarcation between regions of low and high wear of the implant were considered a clear indication of edge wear (Fig. 1).

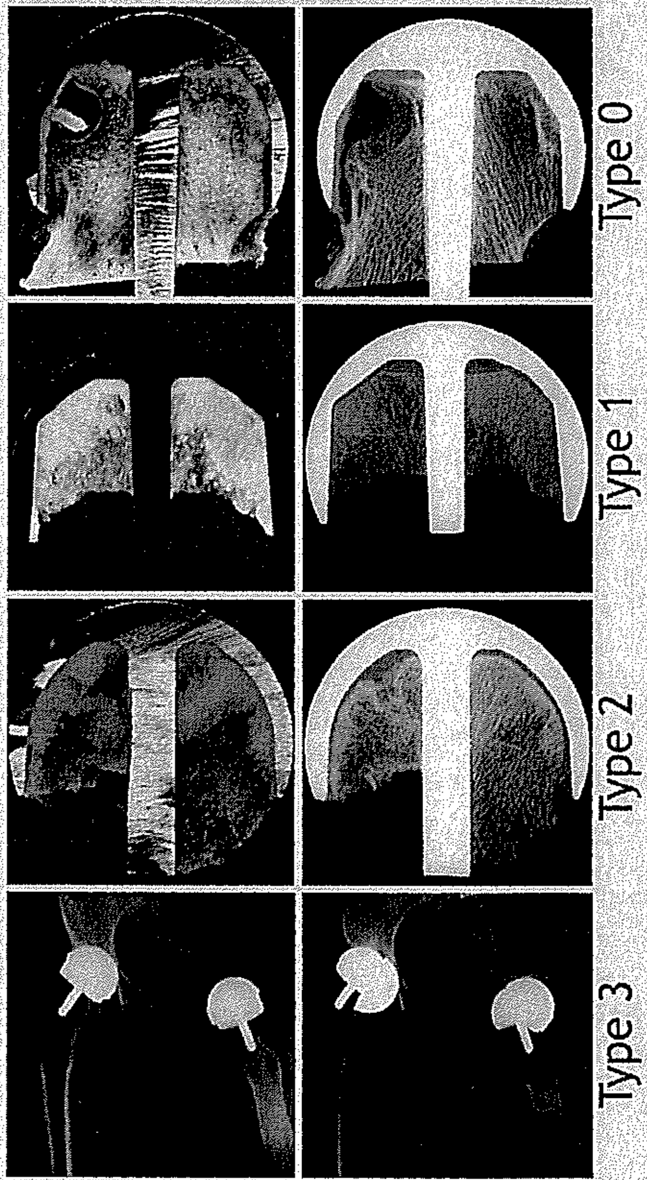

Fig. 3

The four groups of revision types and the mode of fracture. Type 0: failures without an acute fracture; Type 1: failures with acute fractures completely inside the resurfacing head; Type 2: failures with acute fractures involving the rim of the resurfacing head; Type 3: loosening of the acetabular cup.

On the basis of the images of the central slices of the femoral head and the information sent by the surgeon, the implants were allocated to four revision failure-mode groups (Fig. 3). Implantations with no indication of an acute fracture as a

TABLE I Wear Rate and Implant Inclination for the Two Components of the Implant Pairs with and without Rim-Loading*

	Number of Implants	Mean*	Median*	Standard Deviation*	Minimum*	Maximum*
Wear Rate						
Rim-Loading†						
No						
Cup	17	0.0016	0.0001	0.0038	0.0000	0.0134
Head	12	0.0011	0.0000	0.0016	0.0000	0.0038
Total	12	0.0030	0.0009	0.0046	0.0000	0.0143
Yes						
Cup	15	0.0435	0.0335	0.0441	0.0019	0.1639
Head	14	0.0238	0.0256	0.0148	0.0038	0.0613
Total	14	0.0716	0.0768	0.0526	0.0057	0.1941
Inclination‡						
Rim-Loading						
No						
Cup	17	49.8	50.5	5.7	42.0	61.5
Head	12	50.8	50.5	5.6	45.0	61.5
Yes						
Cup	15	58.5	57.8	10.3	45.0	75.0
Head	14	58.1	63.0	11.2	41.0	75.0

*The values for the wear rate are given in mm^3/day, and the values for inclination are given in degrees. †The difference in wear rates between the implants with and without rim-loading was significant for the cup ($p = 0.003$), the head ($p < 0.001$), and the total joint ($p = 0.001$) (power = 0.99). ‡The inclination angle specified for the head represents the inclination angle for the respective cup. The difference in cup inclination angle between the implants with and without rim-loading was significant ($p = 0.011$) (power = 0.56).

revision reason were Type 0. If there was cup loosening, they were categorized as Type 3. Implants demonstrating an acute fracture were allocated, depending on the fracture morphology, to Type 1 (fracture entirely within the head) or Type 2 (fracture outside the edge of the implant). Other fracture modes were not identified. These groups are redefinitions of the five groups defined in an earlier paper and reflect the further information gained from the analysis of 200 additional retrievals[14].

Statistical Analysis

Statistical analyses were performed with use of one-way analysis of variance (fracture type), two-way analysis of variance (edge loading, implant type), and linear regression (inclination angle compared with wear rate). The Tukey B (equal variance) and Tamhane T2 (unequal variance) post hoc comparison tests were used. The probability of a type-I error was set at 5% ($\alpha = 0.05$) for all analyses. The standard deviation was used throughout to describe the spread around average values. Test power was reported, where applicable.

Results

A total of 267 specimens were available for analysis. Of these, the femoral head component was the most common (84%). The main indication for surface replacement was primary osteoarthritis (75%), followed by hip dysplasia (11%), osteonecrosis (6%), posttraumatic arthritis (5%), and rheumatoid arthritis (4%). The proportion of implants from female patients was 49.5%.

A total of thirty-seven implant couples (head and cup of the same joint) were received. Wear results are presented only for the implant pairs in order to address the wear rate of the total joint. Rim-loading with edge wear was observed in 54% of the pairs (Table I). The daily volumetric wear rate was significantly higher for edge-loaded implants by a factor of twenty-two to twenty-seven (Table I). The cup wear rate showed a trend to be larger than the head wear rate ($p = 0.160$, Table I). There was also a trend for rim-loading to affect cup wear more than head wear ($p = 0.183$). The cup inclination angle was higher for implants with edge wear by a mean of 8.7° (Table I). The variation in cup inclination was about two times greater for implants with edge wear. A significant correlation between cup inclination angle and volumetric wear rate across all implant pairs was found ($r^2 = 0.28$, $p = 0.019$).

Approximately two-thirds of the implants were revised due to fracture (66.5%, Table II). A large variation in implantation period was observed, with a peak in the first fifty days postoperatively. Rim fractures occurred at a mean of ninety-nine days after implantation, and head fractures occurred at a mean of 262 days (Table II). Revisions for cup loosening occurred in 9% of the implants at a mean of 423 days, and revisions without fracture or cup loosening occurred in 25% of the implants at a mean of 722 days (Table II).

The learning curve of the surgeon is blamed frequently as the cause for the high early failure rates. This is supported by the current data: 39% of the failures occurred in the first fifty

TABLE II Time to Revision for the Different Groups According to Reason for Revision

					P Value§			
Type	Reason for Revision	Number of Implants*	Valid Number†	Time to Revision‡ (days)	Compared with Type 2	Compared with Type 1	Compared with Type 3	Compared with Type 0
2	Rim fracture	98 (46.2%)	72	99.1 ± 96.3				
1	Head fracture	43 (20.3%)	37	262.4 ± 249.3	0.002		0.485	
3	Loose cup	19 (9.0%)	14	423.4 ± 319.2	0.013	0.485		0.098
0	No acute fracture	52 (24.5%)	33	722.15 ± 479.9	<0.001		0.098	

*The values represent the total number of specimens with the respective reason for revision. The total number of implants does not add to 267 because implant pairs were only counted once and the final pathologic assessment for some of the last implants was not yet available at the time of publication. †The values represent the number of specimens with complete data sets used for analysis. ‡The values are given as the mean and the standard deviation. §The p values pertain to the pairwise comparisons between types (power = 1.00).

implantations of a respective surgeon. After approximately 100 procedures, this tendency decreased[12-14].

Discussion

Since the present study is not a controlled clinical trial, we cannot give an indication of the actual rate of failure of hip surface replacement procedures. Such information is available elsewhere in the literature. In Australia, the rate of revision is currently 4.4% within five years[6]. The present study, however, can provide an impression of the actual clinical situation, and it would be anticipated that the samples submitted represent a random sample of the total population of hip-resurfacing failures. Along with the well-documented problems of femoral neck fracture, it was found in this study that 33.5% of the revisions occurred without an acute fracture due to cup loosening or other nontraumatic reasons. While fractures occur mostly within the first nine months, revision for other reasons can be expected to occur after more than one year (cup loosening) or two years (other reasons). In general, early failures are mostly associated with the femoral component, whereas later failures tend to be associated with problems on the acetabular side. Acetabular problems include poor primary stability of the cup and inadequate cup positioning.

The positioning of implants has had a large effect on the function of large diameter metal-on-metal bearings. The good wear characteristics of these bearings are based on the generation of a fluid-film layer. Anything that disturbs this film will severely increase wear. As the contact zone between cup and head approaches the rim of the cup (edge-loading), the effective contact area is reduced, thereby increasing stresses and disrupting the fluid layer. This can lead to a dramatic increase in metal wear (in this study, the maximum total wear rate for an implant pair amounted to 71 mm^3/yr).

The mean cup inclination angle for implants without edge-loading was 50°, which is at the border of the "safe zone" of 40° ± 10° that is advocated by Lewinnek et al.[19]. The implants demonstrating edge-loading had a mean inclination angle far outside the safe zone (59°). The difference of 8.7° between instances of edge-loading and normal wear is significant, but at a rather low level. This suggests that another parameter, namely anteversion, may be as important, or even more so, for edge-loading[20]. Unfortunately the anteversion angle could not be determined in this study. Massive metal wear is also suspected to be sometimes involved in the development of pseudotumors[21]. Reducing metal wear by optimizing design, materials, manufacturing, and component placement should only lead to positive side effects because a dose-effect relation between metal ion concentration and negative side effects is present[22]. High metal wear due to inappropriate component placement has to be prevented by all means[11]. A recent clinical study investigating metal ion concentrations showed very similar results with respect to critical inclination of the cup[23].

During revision of fractured heads, the cups can frequently be left in situ. This is considered as one of the advantages of hip resurfacing. A new bedding-in phase occurs, mainly on the new head, and the wear that occurs during this phase is markedly lower than the wear that takes place during the bedding-in phase after primary implantation[24]. This reduction in bedding-in wear after revision is due to the optimized contact situation on the cup side since bedding-in of the cup has already taken place. However, it is important that the new head be an identical replacement with regard to size and orientation. In situations in which a malpositioned cup has caused heavy wear, it must be noted that revision of the head alone does not solve the problem. Should signs of heavy wear be observed at revision, the cup should also be replaced.

The low wear of modern, correctly positioned hip-resurfacing components fulfills the predictions of simulator studies, despite the greater number of cycles physiologically than the 1 million per year per leg that is taken as the testing norm[5,25,26]. The wear rates for the third and fourth-generation surface replacements that are being studied are clearly lower than those for first-generation metal-on-metal joints

(6 mm^3/yr)[27]. For preclinical testing in the future, more stringent testing conditions should be imposed on implants, which are designed for younger and more active patients.

With regard to the question of cause of failure, the explanations have to be viewed as somewhat speculative at this point in time. Revisions without an acute fracture due to excessive wear can often be attributed to the positioning of the cup. The cup loosenings we observed should not be attributed to surface replacement itself but rather to the more difficult task of seating monobloc cups. Monobloc cups have no screw holes and consequently provide no view of the acetabular floor. Furthermore, large metal-on-metal bearings exhibit high start-up moments, which must be counteracted by their anchorage capacity in the bone[28]. Continuous impingement can also be a reason for cup loosening.

Regarding fractures of the femoral neck, the reasons are less clear. The situation becomes simpler if the fractures are separated into the two types defined in this study. Rim fractures can arise from *notching* (cutting the femoral neck during reaming), high implantation forces[29] (in-house measurements have even indicated peak impaction forces up to 20 kN), or cysts, all of which can lead to stress concentrations and local overloading of the bone, increasing the risk of fracture[13]. The second fracture type observed involved fractures inside the head. These occurred later than the rim fractures (Table II). The reasons for this could be initial microfractures underneath the implant (e.g., due to high implantation forces) and consequent osteonecrosis of the bone proximal to these fracture zones, leading to failure at the transition to the necrotic zone[30].

In this report, the problems of patient selection or cementing technique, which can generally be blamed for high implantation forces, were not addressed. These factors also play an important role in the failure scenario. A first analysis showed that a cement mantle thickness outside the desired corridor of 1 to 5 mm was present in 91.4% of the implants[31]. These results, together with a detailed histological analysis, will be presented in a later report.

There is evidence from clinical studies that hip-resurfacing implants provide a valuable addition to the traditional designs of hip prostheses. Due to the technology available to date, nearly all of the implant-related problems of the first and second generation of hip resurfacings have been resolved. However, it must be recognized that resurfacing is challenging to the surgeon and requires extremely accurate and precise planning and surgery. Deviations can lead to early failures at a higher rate than is seen in other types of established hip prostheses. From a biomechanical perspective, this is not surprising: the shorter the implant, the smaller the margin of error. The superior wear characteristics of large hard-hard bearing couples, in comparison with those of traditional polyethylene bearings, come with the trade-off of greater sensitivity to cup malpositioning. The wear increase caused by malpositioning does not occur in a gradual way but rather in a sudden dramatic way. Finally, it should be reiterated that, in percentage terms, most of the failures occur at the start of the learning curve. This is unacceptable for the patient. Increased efforts, such as compulsory educational and assessment schemes, should be undertaken to minimize technical errors and malpositioning of the components during surgery. ■

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Winner of the Rand Award

Cementless Femoral Components in Young Patients

Review and Meta-Analysis of Total Hip Arthroplasty and Hip Resurfacing

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Abstract: The study purpose was to analyze current results of modern cementless femoral components in young patients having total hip arthroplasty (THA) or hip resurfacing. Twenty-two studies (n = 5907; hips = 6408) evaluating modern cementless THA in young patients and 15 studies evaluating hip resurfacing (n = 3002; hips = 3269) were included. Meta-analysis techniques were used to pool failure rates. The pooled failure rate for THA using femoral revision for mechanical failure as an end point was 1.3% (95% confidence interval [CI], 1.0%-1.7%) at a mean 8.4 years of follow-up. At a mean of 3.9 years of follow-up, the pooled mechanical failure rate of the femoral component for hip resurfacing was 2.6% (95% CI, 2.0-3.4). In conclusion, the enthusiasm for hip resurfacing should be tempered by these data. Longer follow-up and direct comparison trials are required to confirm these findings. **Keywords:** hip resurfacing, cementless, femoral component, total hip arthroplasty, meta-analysis.

There are several perceived advantages to hip resurfacing when compared to total hip arthroplasty (THA). These include improved range of motion with decreased risk of dislocation, more normal proprioception, preserved proximal femoral bone stock, and easy conversion to THA should failure occur [1,2]. Advocates of resurfacing often cite the high rate of failure of THA in young patients as justification for its use. These reports however often contain an older generation of hip arthroplasties with poor design and bearing surfaces that led to high failure rates [3,4].

There has been concern with regard to the short-term and long-term durability of the femoral component in hip resurfacing. Femoral neck fractures and failure of fixation (aseptic loosening) of the femoral component secondary to poor cement technique, avascular necrosis, or aseptic loosening are common modes of failure [5,6]. In addition, the lack of current long-term outcomes, proper patient selection, and technical factors (learning curve) make a widespread adoption of the procedure concerning [7].

The purpose of our study was to analyze failure rates of modern femoral components in young patients having THA or hip resurfacing. Meta-analysis techniques were used to analyze the current available literature with regard to pooled failure rates, the proportion of femoral component failures to overall failures and survival rates. Our hypothesis was that modern cementless femoral components in THA in young patients may in fact be more durable with a lower mechanical failure rate than those associated with hip resurfacing.

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Methods

Search Strategy

Medline, PubMed, and Cinahl were systematically searched from their inception date to March 31, 2008, to identify relevant studies. Reference lists from review articles and potentially relevant studies were hand

Table 1. Baseline Characteristics

Characteristic	HRA Studies	THA Studies
No. of studies	15	22
No. of hips (patients)	3269 (3002)	6408 (5907)
Average age, y (SD; range)	46.6 (6.1; 34.2-56.8)	41.4 (6.1; 32.0-55.4)*
Average of mean length of follow-up, y (SD; range)	3.9 (2.1; 8.7-0.56)†	8.5 (2.4; 13.5-4.8)‡
Bearing surface (no. of studies)		
MOM	15	2
MOP	0	17
COP	0	1
COM	0	1
Multiple	0	1
Diagnosis§		
Osteoarthritis	1853	3709
Avascular necrosis	207	892
Developmental dysplasia	181	446
Rheumatoid arthritis	24	200
Childhood disorder	42	66
Other	113	130

MOM indicates metal on metal; MOP, metal on poly; COP, ceramic on poly; COM, ceramic on metal; multiple, multiple types of bearing surfaces studied.

* McLaughlin, 2000; Aldinger 2003; and Eskelinen, 2006, did not record a mean age of study participants.

† Treacy 2005 did not provide an average length of follow-up for study participants.

‡ Eskelinen 2006 did not provide an average length of follow-up for study participants.

§ Not all studies listed specific numbers for diagnosis.

searched to identify additional studies. The search was restricted to English language studies.

Selection Criteria

Inclusion criteria for studies were established a priori. Studies were included in the systematic review if they met each of the following: (i) study design was a randomized controlled trial or observational, (ii) study participants were young adults (mean age, <55 years) undergoing THA with modern cementless components or hip resurfacing arthroplasty (HRA), (iii) the study either compared THA and HRA groups or reported on a single cohort of either THA or HRA patients, and (iv) study reported at least one of the predefined primary end points of femoral failure due to any reason, femoral failure due to revision, and femoral failure due to mechanical reasons.

Validity Assessment

Methodological quality assessment was performed by a single reviewer by assigning nonrandomized studies a Methodological Index for NonRandomized Studies score.

Data Abstraction

All variables intended for data abstraction were established a priori and included the following: baseline participant demographics, interventions (THA and HRA information), and outcome variables. Two reviewers independently abstracted outcome data from the included studies, and disagreements were solved through consensus. The remaining variables were extracted by a single reviewer.

Analysis

Event and survival rates were respectively calculated and recorded from included studies. Where possible, rates from single-arm THA or HRA studies were pooled, and forest plots were constructed. Pooled rates were displayed with their respective 95% confidence intervals (CIs). For comparison studies, odds ratios (ORs) and 95% CIs were calculated for dichotomous end points. Where possible,

Table 2. Total Hip Arthroplasty Studies Included in Meta-Analysis

Author	Journal (y)	Average Follow-Up	Average age (y)	No. of Hips
Aldinger et al [8]	Acta Orthop Scan (2003)	12 y	47	154
Capello et al [9]	J Bone Joint Surg (2003)	11.2 y	39	111
Chiu et al [10]	J Arthroplasty (2001)	7.6 y	33	61
D'Antonio et al [11]	Clin Orthop (1997)	6.8 y	38.4	155
Dowdy et al [12]	J Arthroplasty (1997)	5.3 y	42	41
Ellison et al [13]	J Arthroplasty (2006)	92.6 mo	34.7	249
Eskelinen et al [14]	Acta Orthop Scan (2006)	10 y	<55	5607
Fye et al [15]	J Arthroplasty (1998)	84 mo	37	72
Giannikas et al [16]	J Arthroplasty (2002)	4.8 y	55	71
Glassman et al [17]	Orth Tran (1996)	8 y	39.1	242
Jacobsen et al [18]	Acta Orthop Scan (2003)	7.6 y	50	97
Kearns et al [19]	Clin Orthop (2006)	8.4 y	41.1	299
Kim et al [20]	J Bone Joint Surg (2004)	7 y	37	68
Kim et al [21]	J Bone Joint Surg (2003)	9.8 y	46.8	118
Kronick et al [22]	Clin Orthop (1997)	8.3 y	37.6	174
McAuley et al [23]	Clin Orthop (2004)	6.92 y	40	561
McLaughlin et al [24]	Clin Ortho (2000)	10.2 y	37	100
Migaud et al [24]	J Arthroplasty (2004)	68.7 mo	39.8	78
Nercessian et al [25]	J Arthroplasty (2001)	10.5 y	48.3	52
Olcott et al [26]	Orth Tran (1996)	12.5 y	48	46
Petsatodes et al [27]	J Arthroplasty (2005)	13.5 y	47.5	205
Piston et al [28]	J Bone Joint Surg (1994)	7.5 y	32	35

Table 3. Hip Resurfacing Studies Included in Meta-analysis

Author	Journal (y)	Average Follow-Up	Average Age	No. of Hips
Amstutz et al [29]	J Bone Joint Surg (2004)	3.5 y	48.2	400
Amstutz et al [30]	Ortho Clin N Am (2005)	4.7 y	38.1	25
Amstutz et al [31]	J Bone Joint Surg (2007)	6 y	43.7	59
Beaule et al [48]	Clin Orthop (2004)	3 y	34.2	94
Beaule et al [32]	J Arthroplasty (2004)	8.7 y	47.5	42
Daniel et al [33]	J Bone Joint Surg (2004)	3.3 y	48.3	446
De Smet et al [34]	Orth Clin N Am (2005)	2.8 y	49.7	252
Hing et al [50]	J Bone Joint Surg (2007)	5 y	52.1	230
Lilikakis et al [35]	Ortho Clin N Am (2005)	28.5 mo	51.5	70
Mont et al [36]	J Bone Joint Surg (2006)	38 mo	40	42
Revell et al [37]	J Bone Joint Surg (2006)	6.1 y	43	73
Schmalzried et al [38]	Clin Orthop (1996)	16 mo	42	21
Siebel et al [39]	J Mech Eng (2006)	202 d	56.8	300
Steffen et al [40]	J Bone Joint Surg (2008)	4.2 y	51.8	610
Treacy et al [41]	J Bone Joint Surg (2005)	24 mo	52.1	144

ORs were summarized using common ORs and their respective 95% CIs.

For each end point, the results of both the fixed and random effect models were displayed to provide opportunity to interpret the results of both models. Comprehensive Meta-analysis (version 2.0) software (Biostat, Englewood, NJ) was used to perform all statistical analyses.

Results

Baseline summary characteristics of all studies included in the meta-analysis are listed in Table 1. Twenty-two studies evaluating THA with a modern cementless femoral components in young patients were identified using the aforementioned search criteria. There were 5907 patients (6408 hips) with a mean average age of 41.4 years (range, 32-55.4 years). The mean average follow-up across all studies was 8.5 years (range, 4.8-13.5 years). Table 2 lists the studies included in the meta-analysis for THA.

Fifteen studies evaluating hip resurfacing were identified using the aforementioned search criteria. There were 3002 patients (3269 hips) with a mean average age of 46.6 years (range, 34.2-56.8 years). The mean average follow-up across all studies was 3.9 years (range, 0.56-8.7 years). Table 3 lists studies included in the meta-analysis for hip resurfacing. Table 4 lists the components evaluated in the meta-analysis for THA and HRA. All THA femoral components were cementless designs. All hip resurfacing components were of the hybrid type, with a cementless acetabular component and a cemented femoral component.

Table 4. Hip Resurfacing and Femoral Component (THA) Used in Studies

Hip Resurfacing Implant (Manufacturer)	Femoral Implant Hip Arthroplasty (Manufacturer)
ASR (Depuy, Warsaw, IN)	ABG (Stryker)
Birmingham (Smith and Nephew, Memphis, TN)	AML (Depuy)
Conserve (Wright Medical, Arlington, TN)	Autophor 900 (Osteo AG, Selzach, Switzerland)
Corin (Corin Medical, Cirencester, UK)	Bi-Metric (Biomet, Warsaw, IN)
Cormet (Stryker, Malwah, NJ)	CLS (Sulzer)
Durom (Zimmer, Warsaw, IN)	Mallory-Head (Biomet)
McMinn (Corin Medical)	Omnifit (Stryker)
Wagner (Sulzer, Hampshire, UK)	Profile (Depuy)
	SROM (Depuy)
	Taperloc (Biomet)
	Zweymuller (Sulzer)

Pooled Failure Rates

Table 5 lists the pooled failure rates for those studies reporting overall failure for any reason (revision + radiographic failure) for modern cementless THA (n = 19) and HRA (n = 13). Table 6 lists the acetabular failure rate for those studies reporting overall acetabular failure rate using failure for any reason (revision + radiographic failure) for modern cementless THA (n = 21) and HRA (n = 15).

The pooled failure rates of the femoral component in both THA and hip resurfacing with various end points are listed in Table 7. The pooled failure rate of the femoral component in THA using revision of the femoral component for any reason (aseptic loosening, infection, dislocation, fracture, osteolysis, and others) was 3.1% (95% CI, 2.7%-3.7%) at a mean average follow-up of 8.4 years. The pooled failure rate of the femoral component in hip resurfacing using revision of the femoral component for any reason (aseptic loosening, infection, dislocation, fracture, and others) was 2.7% (95% CI, 2.1%-3.5%) at a mean average follow-up of 3.9 years.

Table 5. Overall Failure Rates

	MA	HRA		THA	
End point	Model	n	% (95% CI)	n	% (95% CI)
Overall failure rate	Fixed	15	4.6 (3.7-5.6)	19	16.1 (14.9-17.3)
	Random	15	3.7 (2.0-6.5)	19	11.6 (7.5-17.4)

MA indicates meta-analysis.

Table 6. Acetabular Failure Rates

End point	MA Model	HRA n	HRA % (95% CI)	THA n	THA % (95% CI)
Cup failure rate due to any reason	Fixed	15	2.8 (2.0-3.9)	21	14.1 (13.1-15.2)
	Random	15	1.4 (0.5-3.4)	21	10.5 (7.0-15.4)

The *mechanical failure rate of the femoral component in THA,* defined as femoral revision for aseptic loosening, was 1.3% (95% CI, 1.0-1.7) at a mean average follow-up of 8.4 years. The *mechanical failure rate of the femoral component in HRA,* defined as femoral revision for aseptic loosening or femoral neck fracture, was 2.6% (95% CI, 2.0-3.4) at a mean average follow-up of 3.9 years.

Proportion of Femoral Component Failures

Femoral component failures requiring revision surgery any reason accounted for 70.7% (95% CI, 57.9-80.9) of all failures in HRA. In contrast, modern cementless femoral component failures requiring revision surgery for any reason in THA accounted for 14.7% (95% CI, 10.3-20.6) of all failures.

Discussion

The concept of hip resurfacing is not new. In fact, the procedure was first introduced in the 1930s and has spanned several decades of technological advancement [42]. Early results however were poor with unacceptably high rates of wear, osteolysis, and component loosening [43,44]. With the rising success of THA, the use of hip resurfacing diminished substantially in the United States. The advent of newer bearing surfaces, better fixation options, and improved surgical techniques have led to a resurgence of hip resurfacing. In Australia, hip resurfacing now represents 7.9% of all hip arthroplasties, and 46% of patients younger than 55 years undergoing arthroplasty in the United Kingdom had a resurfacing [45,46].

Proponents of hip resurfacing often cite poor results of THA in the young patient as justification for hip resurfacing. Many of these studies commonly cited, however, include an older generation of cementless stems, cemented stems, and the use of suboptimal bearing surfaces resulting in high rates of osteolysis and aseptic loosening [3,4]. Callaghan et al [3] reported the result of cemented and hybrid fixation in a group of patient younger than 50 years. The hybrid group had an 18% failure rate of the femoral component and 24% prevalence of radiographic loosening at 5-year to 10-year follow-up. This femoral component was ultimately abandoned due to concerns with surface finish and distal geometry. Interestingly, the cemented Charnley femoral stems in this group had a femoral component failure rate of only 5% at 20 years. Joshi et al [4], however, reported a 51% survivorship at 20 years in young patients (age, <40) with osteoarthritis. Both acetabular and femoral components were cemented.

The results of modern cementless THA in young patients are quite encouraging [8-28,47]. A meta-analysis of cementless femoral component survivorship in young patients (9 studies) in our study was 95% at 12 years. In addition, the mechanical failure rate of the femoral stem is extremely low, 1.3% at a mean average follow-up of 8.4 years. Petsatodes et al [27] reported on the results of 205 hips (195 patients) with an average age of 47 years. Survivorship at 17 years using a fully porous-coated stem was 98% using femoral revision for any reason as an end point. Only 2 stems were revised at 10 years for aseptic loosening. Ellison et al [13] reported on the results of 249 hips (201 patients) with an average age of 34.7 years using a proximally coated femoral component. The survivorship at 15 years using revision of the femoral component for aseptic loosening was 99.2%.

Presently, there are no long-term data available on the current designs of hip resurfacing. The short to intermediate-term data that are available, while as whole show acceptable results, is concerning the femoral component. In reviewing 15 current studies available on hip resurfacing, the overall pooled failure rate is low (4.6%) [29-41,48,49]. The femoral component failure rate was 2.7% at 3.9 years; however, it accounted for 70% of all the failures in resurfacing arthroplasty. The most common reasons are femoral neck fracture and aseptic loosening of the femoral component.

The 2007 Australian registry reports a cumulative percentage of revision rate for hip resurfacing of 3.8% [46]. For patients younger than 55 years, this 5-year cumulative revision rate was 2.8%. In comparison, the

Table 7. Femoral Failure Rates

End point	MA Model	HRA n	HRA % (95% CI)	THA n	THA % (95% CI)
Femoral failure rate due to revision surgery	Fixed	15	2.7 (2.1-3.5)	22	3.1* (2.7-3.7)
	Random	15	2.7 (1.8-4.0)	22	2.7* (2.1-3.5)
Femoral failure rate due to any reason (including radiographic failure)	Fixed	15	2.8 (2.1-3.5)	22	3.4* (2.9-4.0)
	Random	15	2.8 (2.0-4.0)	22	3.2* (2.4-4.2)
Femoral failure due to mechanical failure requiring revision surgery	Fixed	15	2.6 (2.0-3.4)	20	1.3* (1.0-1.7)
	Random	15	2.4 (1.5-3.8)	20	1.3* (1.0-1.7)

* Eskelinen et al [14] recorded femoral failure rates for modern and nonmodern femoral stems. In this analysis, outcomes associated with nonmodern femoral stems were excluded from the pooled femoral failure rate.

cumulative percentage of revision rate for THA (all components, all ages) was 2.8%. For cementless THA in patients younger than 55 years, the 5-year cumulative percentage of revision rate was 3.1%.

Steffen [40] recently reported on the results of 610 hip resurfacings done at an independent center. Overall survivorship at 7 years was 95%. There were 23 failures (3.7%) requiring revision. Of the 23 failures, 13 occurred in the first year after surgery and 57% of failures were on the femoral side. In addition, 30% of patients had radiographic evidence of femoral neck narrowing of uncertain clinical significance. Interestingly, the older age group had improved survivorship compared to a younger cohort of patients. Hing [49] also reported an independent review of their first 230 hip resurfacing. Survivorship for worst case scenario was 97.8% at 5 years. Radiographic review however revealed 6 patients with progressive radiolucent lines around the femoral component, and 18 femoral components (8%) had migrated into varus.

Young patients often require arthroplasty for disease other than primary osteoarthritis. Secondary arthritis due to avascular necrosis and dysplasia are common in this age group. Revell et al [37] and Mont et al [36] in separate studies reported survivorship of 93.2% at 6 years and 94.5% at 41 months, respectively, in group of young patients with avascular necrosis. Amstutz [31] reported a 10% failure rate of hip resurfacing in 59 patients with a diagnosis of dysplasia at 6 years.

With no long-term data available, it is difficult to predict what if any failure mechanisms may develop. Narrowing of the femoral neck has been reported but is of unknown clinical consequence at this point [50]. Beck et al [51] has reported that men lose 18% and women 25% of their bone mineral density in the femoral neck from age 30 to 70. Ritter et al [52] evaluated failure modes of an older generation resurfacing and found that the average time to failure was 9.7 years. All late femoral failures (>10 years) had shown evidence of narrowing of the femoral neck.

Most surgeons would agree that hip resurfacing is technically more demanding than primary THA. The surgeon's learning curve has been shown to be substantial and may require up to 55 to 60 cases to diminish the complications related to surgical technique [7]. The first 537 cases monitored in the Food and Drug Administration post market analysis of the Birmingham hip resurfacing in the United States shows a 7.4% adverse event rate and includes 9 nerve palsies and 9 dislocations. There were 14 reoperations (7.4%) within the first year and 10 for femoral neck fracture [53].

As with any procedure, patient selection is critical to the success of any procedure, and hip resurfacing may be particularly sensitive to patient selection [54]. Beaule et al [48] demonstrated a 12 times greater relative risk of early complications in hip resurfacing in patients in patients with a Surface Arthroplasty Index Score greater than 3. In addition, the ability to alter the biomechanics of the hip joint with regard to leg length and offset are limited with hip resurfacing [55,56]. In such instances, patients may be better optimized with THA.

We have shown in this meta-analysis of modern cementless femoral components a low rate of mechanical failure (1.3% at 8 years) of the femoral component in young patients undergoing THA. The femoral component in hip resurfacing likewise shows a low failure rate (2.7%) but only at short-term follow-up. In addition, many of the total hip studies analyzed implement poor bearing surfaces (non–cross-linked polyethylene) with high rates of osteolysis. The advent of modern bearing surfaces combined with these cementless stem designs is to be hoped to improve on the current results. The strength of this study includes the large number of patients analyzed with surgery performed by multiple surgeons and a variety of implants. Potential limitations are the retrospective review of the study, the limitations of each individual study, and the potential overlap of included patients who could be potentially reported twice in articles by the same author.

There is little doubt that hip resurfacing has an appropriate role in the arthroplasty arena, and the perceived benefits are appealing to both surgeons and patients. The preservation of proximal femoral bone stock in a young patient is advantageous and may yield to a potentially easy conversion to THA when failure occurs [57]. Surgeons and patients however should feel comfortable with the durability of modern cementless femoral component in this patient population. Our meta-analysis data show twice the mechanical failure rate of the femoral component in hip resurfacing with half the follow-up compared to modern cementless femoral components in THA. We believe that modern cementless femoral components should be used as the benchmark for comparison in hip resurfacing. Longer follow-up of resurfacing and prospective direct comparison trials are required to confirm these findings.

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