

Cementless knee arthroplasty

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Summary. Total knee replacement is a common treatment for advanced knee osteoarthritis. The most common and widespread method is cemented arthroplasty. As in the prosthetic hip a gradual transition from cemented to uncemented fixation techniques occurred over time, increasing interest is growing also around cementless knee fixation, with the theoretical advantages of preserving the bone stock and obtaining a biological fixation avoiding cement fragmentation. On the basis of the actual knowledge, the uncemented knee prosthesis represents an interesting alternative especially for the patient under 65 years of age, with viable bone quality, in which a biological bone-prosthesis fixation is desirable, while avoiding the drawbacks of cement fragmentation and of the possible future revision of a cemented implant. However the weak link remains the tibial fixation, so that technical tips are important to avoid micromovements with subsequent lack of osteointegration. In our experience, gap balancing, mobile bearings and no haemostatic tourniquet well combine with this kind of implant. (www.actabiomedica.it)

Key words: cementless, knee, arthroplasty, gap balancing, mobile bearing, tourniquet

Introduction

Total knee replacement is a common treatment for advanced knee osteoarthritis. The goals of arthroplasty are restoring the mobility and alignment, stability during standing, and the elimination of pain. Overall, the long-term results of this procedure are good in about 90% of cases (1, 2).

The fixation of tibial and femoral components, however, is still a debated topic, and although the cemented fixation is the most widely accepted and practiced (3), the advantages and disadvantages of cemented and uncemented implants seem to be equivalent, as well as clinical outcomes.

As in the prosthetic hip a gradual transition from cemented to uncemented fixation techniques occurred over time, similar process is also occurring around the knee prosthesis, thanks to the evolution of materials.

The use of cement in fact has advantages and disadvantages. The advantages reside in the immediate fixation, in the possibility to compensate for inaccurate

cuts, in the presence of a local antibiotic dose and in the hemostatic effect on bone bleeding. The disadvantages are the possible third-body wear for cement fragments and the increased bone loss at the time of the review.

The theoretical advantages of cementless prostheses are to preserve the bone stock and obtaining a biological fixation avoiding cement fragmentation. Given the decrease in the average age of the patients operated for arthroplasty, it's interesting for the surgeon to achieve biological bone-prosthesis fixation. In 2013, the UK register reported a 6.1% of uncemented or hybrid implants.

Implant design

The non-cemented femoral component still provides a good primary stability, as to be used also in hybrid implants.

The tibial component represents the weak link (4, 5), since it is more difficult to get a reliable fixation.

The presence of a keel allows axial compressive forces to act on a wider surface and to be transmitted through the cancellous bone to the more robust metaphyseal cortical. The cancellous bone of the proximal part of the tibia is bypassed in this way from the loading forces, creating areas of stress-shielding and consequent radiolucent lines.

For this reason it seems appropriate to search for a good correspondence between the tibial component and the dimensions of the tibia, to obtain a circumferential cortical support. However, it was shown that the proximal part of the tibia is not in possession of a real cortical, which is only present in the posterior side. This predisposes to the risk of front sinking and rear lifting. The presence of the taproot in addition to the keel approaches the component to the inner surface of the posterior cortex, preventing sinking and lifting.

The addition of lateral pegs increases the rotational stability of the tibia providing optimal fixation.

For the femoral component it is preferable to have not a hard grip to the front and rear cuts, so that the axial load is transmitted on the distal surface of the femur, stimulating osteointegration.

The cementless patellar components are those which created the most problems, even if the results are improved by eliminating the metal back and the thin polyethylene edges (6).

The coating material can be either hydroxyapatite or trabecular titanium. This must be present on the entire surface of the components, not to allow the synovial fluid of creep between the prosthesis and bone, thus interfering with the osteointegration process. Porous materials allow the migration of mesenchymal cells and osteoblasts to colonize the prosthetic surface. The initial implant stability, implemented by the roughness of the coating materials, is crucial in avoiding micro-movements that would compromise the osteointegrative potential.

The long-term results of total knee prostheses have gradually improved compared to the first experiences in the 80s, together with the evolution of prosthetic design and materials. The fixation systems of the first installations, such as for example screws, the use of which was related to the appearance of osteolytic lesions (4,7), have been abandoned. Today it is recog-

nized that the keel, taproot and pegs are sufficient to guarantee a reliable primary fixation (8).

The non-cemented components, given the attention to design and materials, are more expensive. But it should also be considered the savings linked to the lack of cement (together with the cementation kit and washing systems), as well as shorter surgical times: these elements are to offset the higher cost (9).

Surgical technique

The creation of an identical extension and flexion joint gaps is at the base of the articular mobility and stability of the implant. The key point of this correspondence is the rotation of the femoral component, which can be obtained through the bone references or ligament balance.

The usable bone references, as we know, are three:

- *Trans-epicondylar axis*

The trans-epicondylar axis (TEA) is the line that connects the external epicondyle to the groove immediately below the internal epicondyle. Several studies have shown that it is not so easy to identify with precision the TEA. An error $> 5^\circ$ is in fact demonstrable in 56% of cases with this technique (10).

- *Antero-posterior axis*

The Whiteside line combines the lowest point in femoral trochlea to the middle of the intercondylar notch at the point of insertion of the PCL. This line is easy to find and is perpendicular to the TEA. However, it is altered in the case of bone deformities, and in particular leads to an error in external rotation in the case of trochlear dysplasia and in case of varus knee OA (11).

- *Posterior condylar axis*

In the normal knee the posterior condylar axis is internal rotated $3-4^\circ$ with respect to the TEA, whereby an external rotation of $3-4^\circ$ with respect to the posterior condyles provides a good rotational alignment. However in the valgus knee osteoarthritis there is a misleading hypoplasia of the external condyle. In varus knee instead, the ACL deficiency leads to erosion of the rear part of the medial femoral condyle.

In conclusion, it was demonstrated that an accurate rotation is obtainable in 34% of cases with the

TEA, in 62% of cases with the Whiteside line, and only in 26% of cases with the Whiteside line (12).

The gap balancing technique is instead independent from bone anatomy and its possible alterations (13). This technique is based on the ligamentous release performed before the bony resections, until a correctable deformity can be obtained. It's important to remove the osteophytes to avoid tension on the ligaments. Usually it starts with the tibial cut, then the knee is tensioned in flexion: the tibial cut is parallel to the TEA, which can be used to control the alignment (Fig. 1). The cut of the distal femur is performed so as to reproduce in the same extension gap (13).

On the basis of these considerations, we believe that the non-cemented prosthesis must necessarily be implanted with a gap balancing technique, to minimize stress on uncemented components, which may result in micro-movements and alteration of the osteointegrative potential, particularly at the tibial level.

Another key point of the prosthetic knee is the balance between stability and mobility. In fact, excessive congruence leads to a high stress on the components, predisposing to mobilization, while excessive mobility creates excessive cutting forces that lead to wear of the polyethylene. The fixed low congruence

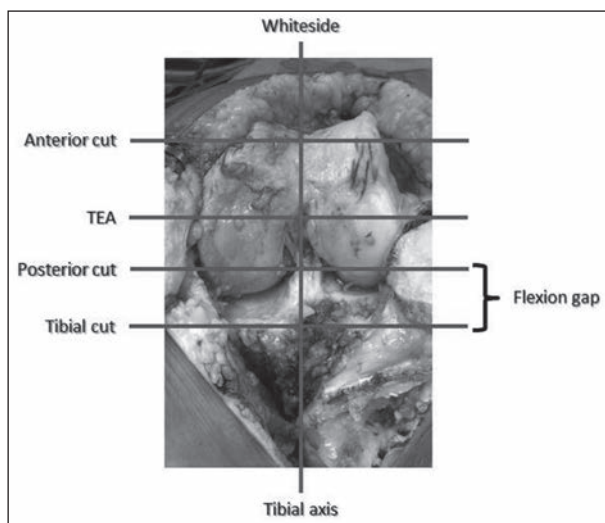


Figure 1. The figure shows the basics of flexion gap balancing: through the ligamentous tension a posterior resection parallel to the tibial cut is obtained, which is parallel to the TEA. These are perpendicular to the tibial axis which is in continuous with the Whiteside line

inserts remain a good compromise between matching and stability, but the failures are frequently attributable to the low congruence with polyethylene wear and subsequent mobilization. An ultracongruent (UC) insert instead must be mobile not to introduce an excessive constraint: the concept of LCS (Low Contact Stress) introduced by Buechel in 1977 (14) was based on this consideration. The high congruence distributes the load over a large surface, while the mobility of the insert prevents excessive stress on the components and ensures high mobility. The mobile inserts also have the advantage of “forgive” small rotational misalignment of the tibial component.

A complication of the LCS mobile inserts is the rate of early dislocation of the insert, described in 3.5% of cases, which has been correlated to the discrepancy between gap in flexion and extension (15). This suggests the need to associate the UC mobile inserts to a gap balancing technique.

When implanting UC inserts, this guarantees the anterior-posterior stability, avoiding the problems related to conservation and balancing of the PCL, and at the same time avoiding the bone loss for the creation of the femoral box for PS inserts, as well as the possible wear at the level of the polyethylene cam.

Comparative studies have not shown differences in clinical outcomes or longevity between fixed and mobile insert. However it is believed that a mobile insert is more suitable for younger patients for the lower polyethylene wear rate (16). Cementless prostheses and mobile inserts are well combining both for the reduction of stress on the tibial component, and for the indication in young patients.

Results

Several studies showed long-term results comparable with those of cemented prostheses (Tab. 1) (8, 17-19).

In 2012 the Australian registry reported a failure rate of 6.3% at 10 years for uncemented implants, of 5.3% for cemented and 5.0% for hybrids.

The uncemented implants have proven reliable in young patients (20, 21) and elderly (22), in patients with rheumatic disease (23, 24), in obese patients (25,

Table 1. Literature results of cementless knee arthroplasty

Author	Publication	Implant	Number	Follow-up	Survivorship %
Buechel	2001	New Jersey LCS TKR (DePuy)	140	16	100
Hofmann	2001	Natural-Knee (Zimmer)	300	12	95.1
Buechel	2002	LCS Rotating Platform (DePuy)	169	20	99.4
Watanabe	2004	Osteonics 3000 (Omnifit, Stryker)	76	10	96.7
Cross	2005	Active (Australian Surgical Design and Manufacture)	1000	9	99.14
Hardeman	2006	Profix (Smith & Nephew)	115	8-10	97.1
Whiteside	2007	Profix (Smith & Nephew)	1556	7	100
Epinette	2007	HA Omnifit Knee Prosthesis (Stryker)	146	11	98.14
Chana	2008	Duracon (Stryker)	186	8	98.6
Eriksen	2009	AGC 2000 (Biomet)	114	20	85
Ritter	2010	AGC (Biomet)	73	20	98.3
Kamath	2011	NexGen (Zimmer)	100	5	100
Cossetto	2011	AMK DuoFix (DePuy)	175	5.5	98.8
Choy	2014	LCS Rotating Platform (DePuy)	82	8-11	100

26). The results were consistent with the use of fixed and mobile inserts, in conservation or substitution of the posterior cruciate ligament (8).

Radiostereometric analysis (RSA) demonstrated that the non-cemented prosthesis undergo an average of 1 mm migration of the tibial component, which develops mainly in the first three months and then stabilize around the year from the implant (27). This migration is related to bone density, so osteoporotic patients have higher migration rates (28). A migration that continues to two years after implantation is predictive of mobilization (29). It should be noted that some studies have shown similar migration rates even in the cemented prosthesis (30).

With regard to the “stress-shielding” in the proximal tibial, one study has shown that this is greater in cemented prostheses (31), while another study found no difference between cemented and uncemented implants (32), with the “stress-shielding” dependent only on age, sex and BMI.

Haemostasis

Some authors have shown an increased blood loss after uncemented implants, because the cement would

act as a bone haemostatic (33-35). However it is a hotly debated topic, and other studies did not confirm this hypothesis (36). Indeed, it was also considered that the non-cemented prosthesis allows the release of the tourniquet prior to implantation, with more accurate haemostasis, given the best visibility on the posterior capsule.

Indeed it is possible to perform the entire operation without tourniquet, curing hemostasis during surgery. This procedure also has the advantage of avoiding the muscular tension associated with the use of the tourniquet, which represents a considerable advantage if using a gap balancing technique, which will be more accurate.

A study on the use of the tourniquet in knee replacement has shown that this causes most of the knee swelling and bruising in the post-operative period, with slower articular recovery and transient loss of ability to elevate the extended leg (37). Another study has linked the use of the tourniquet to the higher incidence of DVT and pulmonary embolism, problems of the surgical wound, bruises and paralysis of the sciatic (38). Some authors have for these reasons reduced the use of the tourniquet to the only time of cementing, however without showing real benefits (39).

For these reasons we believe that the joint replacement should be performed without a tourniquet

and that the uncemented procedure combines well with this kind of philosophy.

Discussion

As described in the text, the non-cemented prosthesis requires an effective osteointegration process, and it is therefore essential to obtain a stable fixation of the components, which is less simple to tibial level. Today, the combined use of the keel, taproot and pegs allows a good primary fixation in the presence of trophic bone. For this reason, we have adopted the INNEX prosthesis (Zimmer), which responds to the characteristics described, unlike the classic LCS (DePuy) which did not contain the pegs and had thus a lower rotational tibial stability (Fig. 2).

The trabecular titanium porous coating is uniformly present on the lower surface of the tibia, not allowing the synovial fluid to creep at the bone-prosthesis interface (Fig. 2). The movable meniscus decreases the rotational stress on the tibial component, and given the UC insert, the PCL is sacrificed, avoiding the problems associated with PCL balancing.

Another factor affecting implant stability, as demonstrated by radiostereometric analysis (RSA), is bone quality. In fact, we prefer to use the classic cement-



Figure 2. The figure illustrates the characteristics of the INNEX (Zimmer) tibial plateau. The setting is based on a taproot with a small keel and two pegs. The porous coating is present on the entire lower surface of the component

ed implant in case of osteoporotic patients (T-score <-2.5).

We should also pay attention to the state of collateral ligaments to correctly perform a gap balancing technique: severe deformities with ligamentous imbalance are not suitable for this type of implants.

Usually we don't resurface the patella, which would still require a cementation and therefore a hybrid plant.

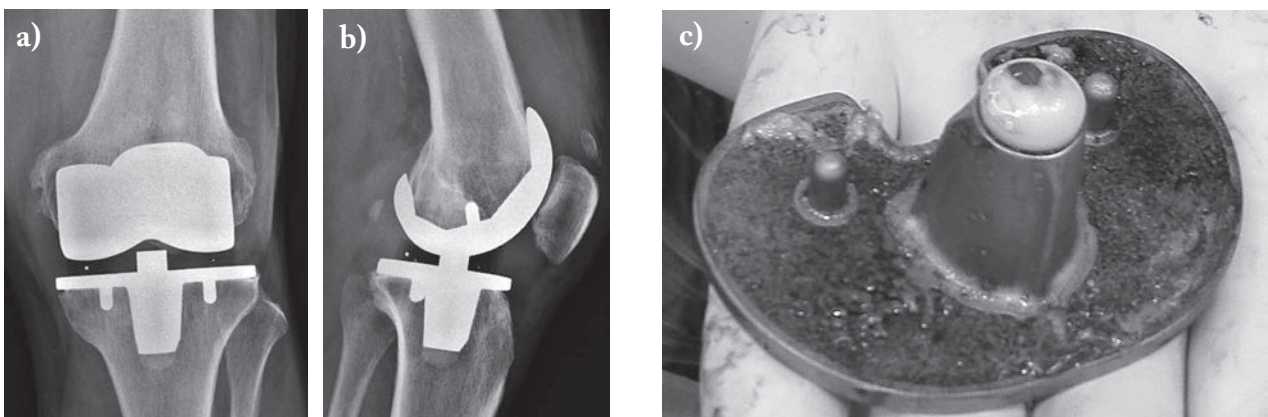


Figure 3. 65 year old man, operated by two years of bicompartamental non-cemented prosthesis. After one year, the persistence of pain and arthrosynovitis, a synovectomy was performed with histological analysis (negative for rheumatic disease) and culture (negative for infection). The allergy tests were negative. The following year it was operated for revision: a) Pre-operative X-rays showed the proper positioning of the implant and the absence of mobilization, albeit with a slight radiolucency below the tibial plateau; b) Pre-operative lateral view; c) The tibial plateau has been explanted with extreme ease and its lower surface showed incomplete and patchy osteointegration;

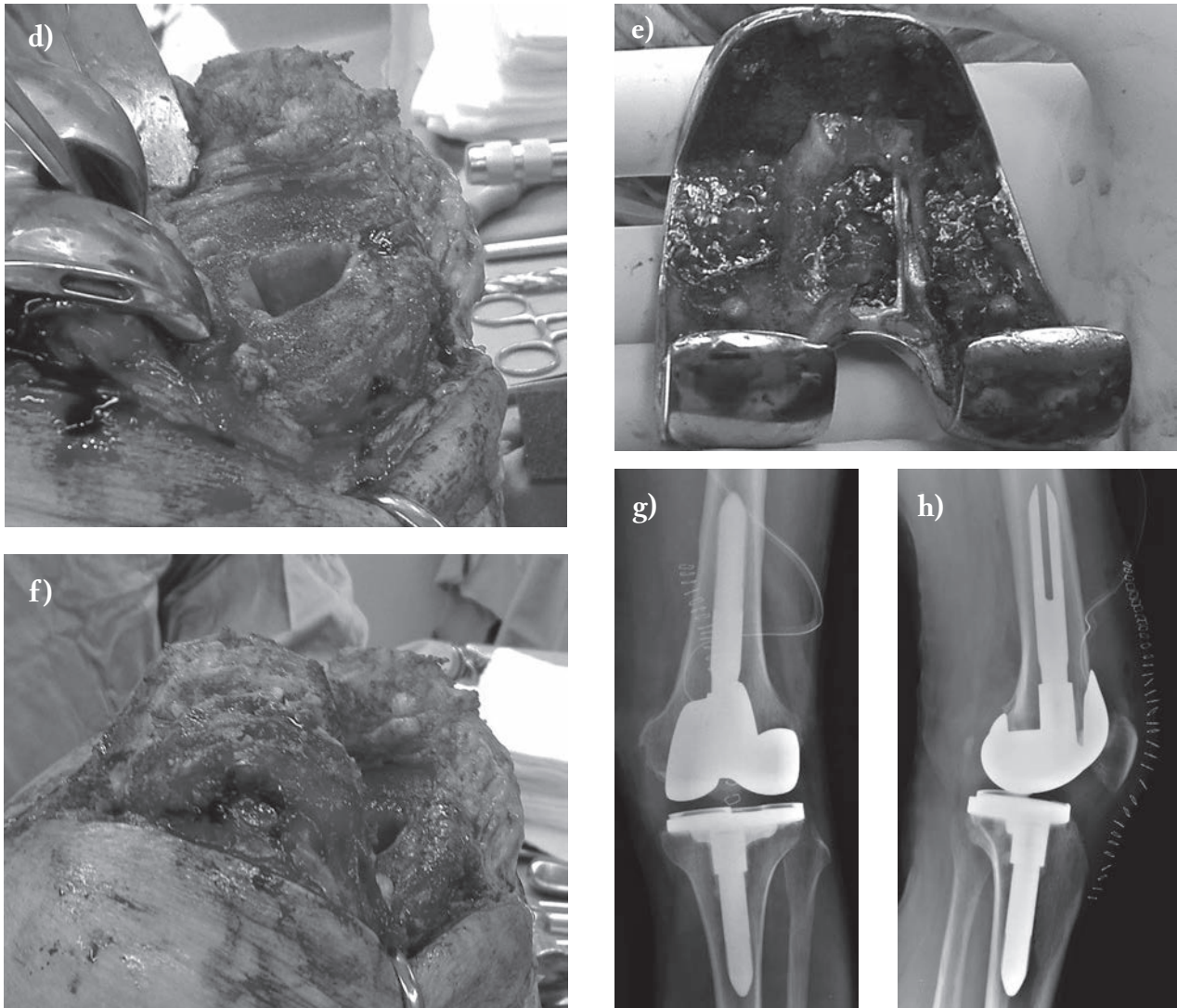


Figure 3. 65 year old man, operated by two years of bicompartamental non-cemented prosthesis. After one year, the persistence of pain and arthrosynovitis, a synovectomy was performed with histological analysis (negative for rheumatic disease) and culture (negative for infection). The allergy tests were negative. The following year it was operated for revision: d) The tibial surface after explantation was regular, with no bone loss as result of the explant; e) The explanted femoral shield showed more complete and widespread osteointegration; f) The femoral surface after explant showed areas of bone loss; g) Post-operative X-rays after cemented implant with Oxinium surfaces; h) Post-operative lateral view

This type of system provides excellent results in terms of mobility and stability. Compared to cemented implants, in our experience the post-operative period is burdened by slightly greater pain, possibly related to the time of osteointegration. We also found cases of persistent knee pain despite correct implantation, with no signs of osteolysis or loosening. In these cases, a revision surgery is necessary after more than a year from the first operation, and the common finding is

the lack of osseointegration in tibial level, with the need for a revision to a cemented prosthesis (Fig. 3). In planning these kind of revisions we must also take into consideration other differential diagnosis such as the slow infection and metal allergies.

In conclusion, the uncemented knee prosthesis represents an interesting alternative especially for the patient under 65 years of age, in which a biological bone-prosthesis fixation is desirable, while avoiding

the drawbacks of cement fragmentation and of the possible future revision of a cemented implant. However we have to be prepared on the most appropriate implant technique for cementless implant, to know the indications and limitations, and the potential complications.

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