Highlighting the advantages and benefits of cementless total knee arthroplasty (Review)

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Abstract. In the field of orthopedic surgery, cemented total knee arthroplasty (TKA) is considered to be one of the gold standards. However, there are categories of patients (i.e., obese and morbidly obese patients, younger than 65 years old) among whom cemented TKA has however a high failure rate. Moreover, the frequency of using uncemented TKA is increasing due to the potential benefits of long-term biological fixation, being an innovative field that addresses a new generation orthopedic surgical treatment which is more suitable for young patients who have good bone quality (good to very good, in terms of density). The survival rates and functional results of the latest generation of cementless TKAs may be similar to functional results and survival rates of cemented prosthesis. In conclusion, this review-type article can be considered a powerful database, extremely informative, dense, and focused on the topic mentioned above, in the interest of all medical professionals and all interested individuals.

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Contents

1. Introduction

The most frequently used procedure in the management of end-stage knee osteoarthritis (OA) is total knee arthroplasty (TKA), that can also be mentioned as relevant for other various underlying manifestations [dysplasia, inflammatory arthritis, malignancy and fracture (deformity and/or post-traumatic OA)] (1,2). With the increased request for TKA operations, so does the variety of the individuals choosing to have the surgical procedure. Previously, TKA was considered a surgical operation for elderly people affected by end-stage arthritis causing persistent knee pain. In recent decades, the number of younger patients and a patient population with greater complexity (from the medical point of view) that undergo TKA has increased considerably (3,4). After the operation, compared to older adults, a critically increased number of younger patients report lower contentment with their functional potential (5,6).

Uncemented knee implants have lately gained further attention due to advanced design processes and manufacturing technologies such as the implementation of an additional coating layer that improves biological adherence and strengthening, as

well as implant component pattern (7-10). The Miller-Galante II knee, that has remedied the increased incidence of previously observed patellofemoral complications, through improving the implant structure, can be considered an example (11,12). Another reason for the enhanced attention towards cementless fixation is represented by the age of patients subjected to TKA. Younger patients (<65 years), having increased activity levels after the surgery, as well as a greater life expectancy, that need firm, long-lasting fixation techniques increasingly undergo TKA. As the cement mantle does not have remodeling properties such as biologically osseo integrated parts, it is subjected to increased pressure having as a result a greater incidence of aseptic loosening (10,13).

This review refers to a more special topic, namely cementless knee arthroplasty, in terms of the advantages and benefits it offers. This topic was chosen because it is an innovative field that addresses a new generation orthopedic surgical treatment which is more suitable for young patients with bone quality (good to very good, in terms of density). The novelty/special character of this research consists precisely in the exhaustive approach of the numerous aspects related to the cementless TKA.

2. Bibliography selection methodology

In order to carry out this review study, the most important databases were researched, of which the richest and most important was PubMed. The search was performed using the key words mentioned at the beginning of the paper, and the articles found were selected based on clear and well-established criteria (English language known by the authors, relevance of the topic addressed, informative nature, scope/novelty of information).

3. Cementless knee arthroplasty

Surgical aspects. Following anesthesia, the incision is made on the front part of the knee, to make possible access to the joint. The cutting guide, which is a positioning instrument, is used to perform correct angle bone cutting, preserving the functionality of the joint. Afterwards, the articulating area of the patella is eliminated. The prosthesis elements are pressed to fit on the previously prepared bone surfaces. A metal tray is fixed on the tibia with screws. The screws are kept in place being necessary to fix the implant until enough bone ingrowth develops. To the metal tray is added a plastic spacer that hinders the friction of prosthesis parts. A patellar element is fixed in the rear of the patella, and then the soft tissues are put back into place and sewn. Staples are used to close the skin incision. Obtaining similar flexion and extension joint gaps represents the basis of the articular stability and mobility of the implant. The rotation of the femoral element, that can be attained by ligament balance or bone landmarks, is a key element for this similarity.

There are three bone landmarks that may be used. The trans-epicondylar axis (TEA) represents the link between the groove and the external epicondyle, just under the internal epicondyle. Precisely identifying the TEA is quite difficult, as revealed by many studies (14-16). Using this method indicates an error >5˚ in 56% of cases (14). The middle of the intercondylar notch is connected to the lowest point in the femoral trochlea at the posterior cruciate ligament (PCL) insertion point by the Whiteside line. It is easily detectable, being perpendicular to the TEA. Bone irregularities modify this line, leading to external rotation flaw in trochlear dysplasia or varus knee osteoarthritis (OA) (15). The posterior condylar axis internally rotated with 3-4˚ related to TEA in the normal knee, while a 3-4˚ external rotation related to the posterior condyle ensures proper rotational alignment. In valgus knee OA, a confusing hypoplasia of the external condyle is present. On the contrary, in varus knee, anterior cruciate ligament (ACL) deficiency determines the erosion of the medial femoral condyle rear section. To conclude, an exact rotation is achievable in 34% cases with TEA, in 62% of cases with posterior condylar axis and in 26% of cases with Whiteside line (16). The gap balancing method is rather distinct from bone structure and the possible changes. This method implies performing ligamentous release prior to bony resections until an adjustable deformity is obtained. Removing osteophytes is recommendable in order to release tension on the ligaments. The procedure begins with the tibial cut, tensioning the knee in flexion, the tibial cut being parallel to the TEA, that can be used to adjust the alignment. Distal femur cutting is carried out so that the same extension gap is generated (17). Based on these facts, it is considered that the non-cemented prosthesis has to be based on a gap balancing method, reducing stress on uncemented elements, that may trigger micro-movements and changes in the osteointegrative potential, especially at the tibial level (18).

Implant coating material. Among several bioactive coatings that can be used, hydroxyapatite (HA) is applied on the metal substrate of the cementless TKA to improve fixation and transform fibrous tissue into bone (19,20). HA has been demonstrated to lower the tibial component micromotion and improve femoral and tibial element fixation (21). Cross and Parish presented in 2005 the results of a study carried out on 1,000 patients with HA-coated cementless TKA with a 9-year survey (22). The final evaluation revealed 0.5% revision rate for aseptic loosening and the 10-year survivorship of the prosthesis of 99.14% [95% confidence interval (CI) 92.5 to 99.8] (22). A study by Epinette and Manley demonstrated 98.14% survivorship after an 11.2-year survey of a group of patients (146 primary TKA) with HA-coated cementless prosthesis, considering mechanical failure as end-point (23). The meta-analysis of 926 arthroplasties carried out by Voigt and Mosier revealed that HA-coated devices ensure increased durability compared to other forms of fixation or cemented TKA (24).

A new biomaterial made of tantalum is trabecular metal (Zimmer Biomet) having mechanical characteristics and porosity similar to original trabecular bone (25). Predictable ingrowth of a trabecular metal implant in the surfaces (26) and bone mineral density (BMD) preservation were indicated after ingrowth (27). Increased ratio of early failure for a trabecular metal monoblock tibia was presented by several studies (28,29) including the study of Meneghini and de Beaubien (28), while other studies (30,31) showed positive results, as those of the randomized clinical trial (RCT) performed by Pulido *et al* on 389 patients monitored for at least 2 years (2 to 9 with a mean 5 years) or until death; 128 patients had highly porous metal

cemented tibia, revealing great bone ingrowth given by the trabecular metal (32).

Uncemented implants have been gradually improved with additional newer concepts. Among these is BIOFOAM (Microport Orthopedics, Inc.) one of the many titanium foams produced by several manufacturers. The foams can be produced with variable porosity and strength of the elements as to be consistent with the bone (up to 80% porosity) (33). Additional products using electron beam melting (EBM) also known as '3D implants' are other complete orthopaedic implants. This method provides porous metal implant accurate execution. Being able to change porosity and density, these metal parts offer the possibility of improving their biocompatibility. Due to the fact that this method is at the beginning stage, no clinical results are available to date (34).

Benefits. The benefits of cementless implant fixation in knee arthroplasty include: better component fixation directly integrating the bone with the implant covering, genuine bone stock preservation, better surgical efficacy and reduced systemic side effects connected with debris wear and cement impaction (7,35). Cementless implants reduce the incidence of radiological radiolucent lines (RLL) that help increase implant lifespan and decrease the control rates compared to cemented implants for TKA and unicompartmental knee arthroplasty (UKA) (36). These benefits have determined the emergence of high-volume centers selecting cementless over cemented UKA with good outcome reported by patients and over 97% implant lifespan for at least 10 years of study. The improvement of materials and implant models have determined for TKA a similar evolution with UKA, in the last decade (37).

New improvements in implant models, materials and surgical techniques have enhanced the implant survival rates in contrast to earlier models, reaching a survival rate of 96-100% after 10-15 years (38,39). For cemented as well as cementless procedures, UKA has demonstrated better functional results as compared to TKA (40). Conservation of bone stock, maintenance of natural kinematics of the knee, decreased blood loss, preservation of soft tissue anatomy as well as decreased surgical time are among the advantages of UKA (41). There is a significant amount of studies sustaining the mobile bearing unicompartmental implant that was demonstrated to have extremely good functional results with cementless fixation (42,43).

Reviewing the results of several prospective cohort studies on 2,218 cementless UKA, van der List *et al* presented the component survival at 5, 10 and 15 years to be 96.4, 92.9 and 89.3%, respectively. For 10,309 cementless TKAs, the registered outcomes were 97.7, 95.4 and 93%, respectively (44). However, in spite of the tendency to register data, there are obvious differences between the registered data and the increased implant survival indicated in studies on large groups. However, there is a general favorable tendency of increased implant survival in cementless UKA compared to the cemented alternatives (44-47).

The possibility to obtain durable biological attachment of the implant to the bone, preserving bone stock and preventing cement debris, are theoretically considered advantages of cementless TKA. Loosening may only occur due to lysis or sepsis, being improbable to happen after osseointegration. As a greater number of young and active subjects prefer TKA, a more physiological connection is required (35).

To favor bone formation, cementless implants require roughened or porous surfaces, mesenchymal cells and osteoblasts moving towards the implant (48). The micro-mobility is reduced by the porous surface that ensures a mechanical interlock. Long-term fixation is induced by the initial stability achieved during the operation, being important as micromotion endangers the osseointegration process (49).

4. Cementless vs. cemented knee arthroplasty

Cementless prostheses provide advantages such as biological fixation without fragmentation and conservation of the bone stock. Biological fixation of bone prosthesis is desirable due to the lower average age of the patients that undergo arthroplasty (50). Registered data from the UK (51), Sweden (52), Australia (53) and New Zealand (54) have revealed increased use of cemented fixation compared to non-cemented fixation and decreased failure rates. Improved functional results and lower revision rates for cemented TKAs were also presented by several trials (55,56).

Non-cemented fixation is associated with greater damage probability (as the cementless metal-backed element has a thin polyethylene layer) as well as a greater incidence of patellofemoral complications. Combining the evidence from registered data with the results of prospective randomized studies and meta-analyses, Ranawat *et al* sustain the advantage of cemented fixation in TKAs (57). A meta-analysis conducted by Pijls *et al* revealed the highest migration for uncoated Interax elements as well as the greatest revision rate for aseptic loosening (58).

Different types of fixations (cemented, uncemented porous HA and uncemented porous fixation) were compared in a study conducted by Carlsson *et al* who concluded that tibial element cementing provides stabile bone-implant contact for a period of 5 years in comparison with uncemented fixation. Augmenting a porous surface using HA could imply decreased mobility of the implant and bone in the first year after the operation, a fact obvious when uncemented elements are used (59).

Recently, Mont *et al* identified and reviewed 37 research studies (2,940 patients and 3,568 TKAs) that compared cemented vs. uncemented TKA. A fixed-effect meta-analysis of cemented and cementless TKA as well as cementless TKA with or without screw fixation was used to compare implant survivorship. Implant survivorship of cementless TKA was similar to cemented TKA [odds ratio (OR), 1.1; 95% confidence interval (CI), 0.62-2.00]. Cementless TKA had an average survivorship at 10 years of 95.6% while cemented TKA had an average survivorship of 95.3%. Implant survival rate at 20-year revision decreased to 76 and 71%, respectively. There was no difference detected in fixation with or without screws (OR, 1.1; 95% CI, 0.16-7.5). Cementless TKA implant survival was similar to that of cemented TKAs, the current gold standard (60).

The efficiency of hybrid TKA implants with cementless femoral and cemented tibial elements was evaluated by Lass *et al* in comparison with titanium-coated cemented implants. A control evaluation of 120 TKAs, 60 hybrid

cemented and 60 cementless TKAs was conducted by the authors. Clinical and radiographic results as well as the survival rate of the implant at a minimum observation for 5 years were analyzed. The 5-year evaluation was accomplished by 90 patients that were subjected to TKA. Both groups recorded considerably raised Knee Society Scores (P<0.001). Two patients in both groups needed revision because of aseptic tibial element loosening, the implant survivorship being 96%. Considerably reduced radiolucent lines around the tibial baseplate were detected by radiographs in the cementless group (n=12) compared with the cemented group (n=26) (P=0.009). Taking into account postoperative complications, as well as clinical and functional outcome at a 6-year mean evaluation, there was no considerable discrepancy between cementless and hybrid cemented tibial elements in TKA. Considerably reduced number of radiolucent lines in the cementless group indicated initial stability and the increased fixation durability of TKA (36).

A randomized clinical trial performed on 81 subjects with primary TKA before the age of 70 was conducted by Beaupré *et al*. The patients were randomly subjected to cemented tibial fixation or cementless tibial fixation. They were evaluated before operation, then at 6 months, 1 year and 5 years after the operation. The 5-year evaluation was completed by 70 subjects (86%). The RAND-36 and WOMAC scores revealed insignificantly increased pain reported at 6 months in the HA group; 1 year after the operation there were no differences. There were also no differences in radiographic results, complications or function. During the clinical trial, no revision of the tibial prosthesis was necessary. There was no discrepancy between cemented tibial fixation and cementless tibial fixation with HA at 5 years after the operation concerning postoperative complications, health-related quality of life, radiographic, function or self-reported pain (61).

In a study conducted by Bercovy *et al* on 291 patients, for the ROCC Rotating Platform total knee replacement, the results of 164 cemented elements and 157 HA-coated tibial elements were comparatively analyzed. The average revision was at 7.6 years (range, 5.2-11.0 years). Two revisions were performed for loosening: for cemented tibial element and for an HA-coated tibial element. The HA-coated femoral elements presented no radiolucent lines at the radiological examination. Radiolucent lines were detected at three months after the operation for three HA-coated tibial elements but disappeared after using protective weight-bearing for three more months. In the case of the HA-coated elements, the time for operation was reduced (P<0.006), the tibial interface radiological evaluation being more stable (P<0.01). The survivorship at 9 years was 99.1% for both groups of patients. Similar results were revealed by the findings for cemented elements and HA-coated elements comparable with the results of studies on porous-coated knee replacements or cemented replacements pointing out HA fixation as a good option for initial total knee replacement (62).

A group of 100 TKA subjects randomly distributed to cementless and cemented fixation groups were registered in a study conducted by Fricka *et al*. The Oxford scores, the KSS functional scores, self-reported satisfaction, better function and reduced pain at 2 years were comparable but increased KSS clinical scores (96.4 vs. 92.3, P=0.03) were observed in the cemented group. The cementless knee presented more radiolucencies (P<0.001). One revision was performed for instability in the cementless group and one for infection in the cemented group. A similar survival rate was indicated for cemented TKA and cementless TKA (revision for any reason as the endpoint) at this interval (63).

Comparable results concerning clinical results, migration and survivorship were revealed by Gao *et al*. The authors used radiostereometric analysis in an RCT performed on 41 young subjects (<60 years) that underwent TKAs for knee replacement (NexGen, Zimmer Biomet): 19 patients that had hybrid fixated implants and 22 patients having totally cemented implants (64).

Another study carried out by Duffy *et al* evaluated 55 cementless TKAs compared with 51 cemented TKAs with a 10-year surveillance. Functional knee and pain scores increased in the first group from 50 and 33 before the operation to 60 and 93 after operation. After 10 years from operation, the survivorship was 72% and the revision rate for osteolysis or femoral or tibial aseptic loosening was 18.1% (65).

A systematic review performed by Nakama *et al* revealed decreased dislocation of the cemented tibial element compared to cementless fixation, in studies performed on patients with rheumatoid arthritis and osteoarthritis that had initial total knee prosthesis, after a surveillance of 2 years; increased risk of aseptic loosening after operation was demonstrated in case of cemented fixation compared to cementless fixation (66).

For subjects >65 years, HA-coated tibial implant was found to offer better durability compared to other tibial fixations, a fact revealed by a meta-analysis and systematic review by Voigt and Mosier (24).

The clinical efficacy as well as the reliability of cemented and cementless fixations in primary TKA have been comparatively evaluated in many reviews. The meta-analysis and systematic review performed by Wang *et al* targeted to use highest-level available evidence to reveal the clinical reliability and functional results of cementless elements compared with the same items for standard cemented elements in young subjects that underwent primary TKA. This meta-analysis was the first research to evaluate cementless compared to cemented TKA in young subjects. The study found cementless fixation as having a better outcome in functional recovery after operation in cases of primary TKA in these patients. RCTs comprising increased quality evidence bases for further use of cementless fixation, providing clinical basis to improve cementless prosthesis were the only ones taken into account for the study (67).

A systematic review of RCTs and a meta-analysis comparatively evaluating the results of cementless and cemented fixation in primary TKA were carried out by Prasad *et al*. The revision rate was the first evaluated result followed by postoperative functional result scores. Cemented fixation use was found to be similar to cementless fixation use in TKA. The performed research did not reveal a considerable difference in post-operation results, comprising knee function and revision rate of any cause up to 16.6 years. Extended surveillance was recommended based on some evidence, as potential aseptic loosening was revealed in the case of some cementless prosthesis. Because of biological fixation, high post-operation immediate pain, for some patients, was reported with cementless prosthesis (68). A study of 778 subjects under 55 years

of age with a mean surveillance of 14 years, performed by Gioe *et al* revealed superior survivorship in the group with cemented TKA. The significance of this result was more illustrative for the cemented group, as a higher number of cemented prosthesis was studied (738 vs. 40 cementless) (69). A retrospective study by Mont *et al* revealed no clinical discrepancies in the cemented and cementless groups of young subjects at an average surveillance of 7 years. Being more physically active, the subjects under 65 years of age had greater expectations and exerted greater pressure on the implants (70).

Encouraging long-term outcomes of different cementless devices in comparison with the results of cemented TKA were revealed by many studies (71,72). For 73 Anatomic Graduated Component (AGC, Biomet, Inc.) knees a 20-year survival rate was demonstrated, with 10 year minimal revision and no subject lost, in a study performed by Ritter and Meneghini (73). The study revealed survival rates of 100% for the cementless femoral elements and survival rates of 96.8% for the cementless tibial elements when patellar failures were not taken into account (65). A series of 300 consecutive knees arthroplasties were studied by Hofmann *et al* for 238 patients with a 12-year average evaluation following cementless TKA. In 141 subjects, 176 knees arthroplasties were available for evaluation. Implant survival was 93.4% (95% CI 90.1-96.7), at the final evaluation, regardless of polyethylene liner changes and infection. The patellar element survival rate, in the mentioned series was 95.1% (95% CI 92.3-98.0) (74).

A rotating platform device was used for treating 169 subjects as reported by Buechel. At 10 and 18 years, the survival rate was 98.3%, with the ending point of evaluation, and 99.4% survival rate at final evaluation of the cementless patellar elements (71). A total of 255 cementless cruciate-retaining TKAs with unresurfaced patellae were investigated by Whiteside. After surveillance for 15 to 18 years, exceptional Knee Society Scores were reported at final evaluation (75). A prospective research of 76 cementless TKAs performed on 54 patients was conducted by Watanabe *et al*. The authors reporting a 100% implant survival rate at 10 years and a 96.7 survival rate at 13 years (76).

5. Clinical/therapeutic dilemmas, future directions, and conclusions

The survival rates and functional results of the latest generation of cementless TKAs may be similar to the functional results and survival rates of cemented prosthesis. The novel variants of implants with HA bioactive coatings or of highly porous metals ensure better fixation than other implants as demonstrated by radio-stereographic studies. Due to these technologies, using press-fit stems has become a better option for TKAs for young patients. In order to decide whether to recommend it for large-scale use in TKA, detailed cost analyses are needed. Long-term fixation and biologically active osseointegration are ensured by cementless fixation in TKA. In the first cementless TKA models, failure was observed especially of the tibial and patellar elements. The development of early models, especially in porous metal technology and enhanced biomechanical stability, made cementless TKA important in the last two decades. Compared to the cemented variant, the operation method of cementless TKA is more demanding, emphasizing indications, component alignment as well as accurate resection. Novel cementless TKA models have ensured good early- and mid-term survival rates similar to cemented TKA. Further long-term research is required to look into this issue. Despite the higher costs of cementless implant models, clear evidence shows the lower total cost of cementless elements due to reduced operation time and cement-associated supply costs. There is an increasing interest in cementless implants as the patients requiring TKA are younger and more active. Cementless implant models have been improved in regards to sizing, the metal used and surface adherence. Cemented and cementless elements have been improved with the new results in polyethylene and kinematic topographies. Bone preparation accuracy is possible with an inprovement in instrumentation. Initial implant stability has gained importance.

The acquired information makes way for better results of cementless TKA, needing further research to confirm it. Reliable scientific data sustain the cemented TKA as a reference standard. Cementless TKA is more and more attractive due to the preferences of the patients that require TKA modifications. To assess the correct influence of cementless TKA, further research is required. In the case of subjects with end-stage knee OA, cementless TKA represents a possible fixation alternative even though various studies have questioned the durability of these implants compared to the usual standard cemented TKA. Modern cementless TKA is demonstrated by recent research to have similar results with cemented TKA at the same intervals of surveillance. However, in order to identify the differences between these fixation alternatives more prospective studies and randomized trials are necessary to be carried out.

The current literature offers no evidence in sustaining a particular method of fixation. The extensive use of cemented implants is motivated by the clinical experience obtained in time. Therefore, a comparison between standard cemented implants and ingrowth surface cementless fixation is necessary to be performed using randomized clinical trials. The cemented fixation is unlikely to offer proper long-time results because of fixation failure, due to the ever-increasing demand for TKA and the decreasing age of the OA population. The use of cementless TKA has increased and numerous developments have been made. Modern cementless TKA has similar survival rates and functional results as cemented prostheses, a fact demonstrated by short-term recent trials. Yet, further research is necessary to establish and clarify the discrepancy of these two fixation alternatives.

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BU, CMV, DMT, OM, TAM and CH searched and selected articles from scientific databases. ACN, TB, FLAC, JMP and SB made substantial contributions to the conception of the work; also, they drafted the manuscript and were major contributors in writing the manuscript. All authors read and approved the final manuscript to be published. All the authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

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Competing interests

The authors declare that they have no competing interests.

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