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Medical Instruments and Tools for Bone Cement Remove in Knee Revision Arthroplasty: A comparative Review

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ABSTRACT

Revision Total knee arthroplasty (rTKA) implies significant surgical difficulty and removal of cement is still considered one of the most technically-challenging elements. Retention of cement is associated with peri-prosthetic infection (PJI) which may be responsible in cases of bone wasting away and loosening of the implant. Modern methods of cement removal in rTKA are discussed with a critical approach, namely non-powered manual equipment; powered equipment such as high-speed burrs, flexible reamers, ultrasonic based equipment, endoscopy-assisted surgery, and surgical procedures such as cortical windows and bone episiotomies. The comparisons between the benefits and limitations of both of the methods are based on efficacy, bone preservation, the invasiveness of the method, and the possibility of complications. The following synthesis provides an insight that personalized intervention that considers patient anatomy, characteristics of cement and fixation of implants is vital to good results. The recent innovations in ultrasonic and endoscopic technologies present an effective way forward when it is safer and more effective in extracting cement during the future rTKA surgeries.

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1. INTRODUCTION

Total knee arthroplasty (TKA) belongs to the most popular yet effective joint replacement procedures with a high revision-free survival rate. TKA procedures demonstrate more than 90% success rates after ten years of existence but its revision-free survival spans from 85 to 90% starting from year eleven based on patient characteristics and implant system specifications. Surgical procedures involving rheumatoid arthritis and post-traumatic arthritis have increased frequency under improved medical care systems yet osteoarthritis remains the leading cause of total knee arthroplasty (TKA) [1,2]. Research reveals that patients with inflammatory arthritis experience greater rates of total knee arthroplasty (TKA) complications and both procedures failure and required redo after original TKA than individuals who have primary osteoarthritis [3]. Total revision TKA (rTKA) procedures continue to increase because of the growing number of primary TKAs. Future healthcare plans along with resource distribution must incorporate these upcoming developments [4]. Reoperation is required by 5 to 15 percent of patients who undergo primary TKA. Among more than 9,000 TKA surgeries evaluated comprehensively aseptic loosening reached 38% and infections reached 19% while periprosthetic fracture stood at 12% as the most common revision reasons [5]. The number of prosthetic joint infections causes up to 11% of all revision surgeries and ranges between 6% and 11%. Primary TKA revision success relies on several clinical and demographic risk factors that medical research has already identified [6]. The combination of being young and overweight or smoking habit significantly raises postoperative complications after undergoing primary total knee arthroplasty (TKA).Aside from these demographic considerations, incomplete initial fixed, mechanical fixation loss with time, and particle-induced osteolysis, commonly caused by polyethylene wear or metal-on-metal wear, are further potential causes of aseptic loosening. In addition to reducing implant longevity and increasing the risk of revision surgery, periprosthetic "fatigue" fractures can be produced by peri-articular osteolysis caused by polyethylene debris [7,8]. This review aims to discuss technical considerations for cement removal during rTKA. Some of the available options for cement removal during revisions include nonpowered instruments, ultra-sonic devices, powered instruments (drills, burrs and reamers), endoscopic-assisted techniques, bone episiotomies, and cortical windows. In performing rTKA, lower extremity surgeons need to carefully weigh the risks and benefits of each cement removal.

2. POLYMETHYL METHACRYLATE (PMMA) (BONE CEMENT)

Cementless revision total knee arthroplasty (rTKA) implants that have been authorised by the FDA are not yet available for purchase in the US. Accordingly, the major way to fixate the femoral and tibial components in TKA is using PMMA or bone cement. Studies evaluating total hip arthroplasty also contribute significantly to our knowledge of cementation techniques in total knee arthroplasty. The appropriate cement mantle thickness has been determined to be 2-5 mm and the ideal length to extend beyond the prosthesis tip is 2-4 cm, according to previous research on total hip arthroplasty. But there aren't many studies looking at this correlation in TKA [10]. For arthroplasty, a researcher and his colleagues classified cement mantle quality as good, borderline, or inadequate. Radiographic measurements informed their descriptions, which integrated the "length" of the radiolucency with the "position" of the cement mantle in relation to the prosthesis tip [11]. Another one used this quality criteria of cement mantle to determine which cement mantle traits were associated with premature failure. An increased risk of mechanical loosening and early revision surgery was linked to cement mantles that were shorter than 2 cm, as they observed in their study [12]. High rates of complications and the possibility of significant surgical morbidity characterise revision total knee arthroplasty (rTKA), which is still a technically demanding operation. When planning a primary or revision total knee arthroplasty, it is crucial to keep intraoperative fracture and nerve injury risks in mind [11]. A systematic review found that 26 percent of patients with nerve dysfunction and 23 percent had intraoperative fractures when undergoing initial total knee arthroplasty. There is an increased risk of intraoperative fracture in Rtka procedures when bone stock is compromised or when there has been prior bone loss from the main implant [13]. Nerve impairment following rTKA for infection was observed in 37% of patients. Peroneal nerve injury is a major worry during knee procedures, particularly during component removal and exposure, although radial nerve injury is not an issue with TKA [14]. The removal of cement, especially when setting well-fixed components, adds to the technical hurdles of rTKA [6]. A prior summary summed up the difficulties of removing well-fixed components during complete shoulder and hip arthroplasty. Removing a loose humeral component with "minimal force" during revision shoulder arthroplasty is typically achievable in fewer than 2% of cases. As with rTKA for prosthetic joint infection (PJI), cement removal is an essential part of the procedure since leaving cement in the canal raises the risk of recurrent and chronic infection by a factor of more than three [15]. Research studies indicate that avoiding complete cement mantle extension to the prosthetic tip may bring advantages to specific surgical conditions. During cement removal procedures for rTKA there is higher risk of PJI because this technique is complex and time-consuming. Minimizing operative duration while ensuring surgical safety during cement removal procedures presents an effective solution to lower both surgical complication rates and morbidity and operational times [16]. The surgical methods for cement removal in rTKA exist in various forms. The tools employed for cement extraction include manual osteotomes and curettes together with powered equipment that includes drills, burrs along with reamers. The list of alternatives for cement removal in rTKA consists of endoscopic procedures along with bone episiotomies and cortical windows and ultrasonic devices and bone episiotomies. surgeons select both surgical techniques and cement extraction depth based on personal choice as well as the unique requirements of each surgical instance [17]. Reduced operating time, surgical morbidity, and problems could result from a focus on safe and efficient surgical procedures for cement removal [18]. Technical considerations for cement removal during rTKA are the focus of this review. During revisions, you can remove cement using a variety of methods, including powered instruments (drills, burrs, and reamers), endoscopic techniques, bone episiotomies, cortical windows, and nonpowered instruments. Surgeons specialising in rTKA for the lower extremities must meticulously consider the pros and cons of each cement removal procedure.

2.1. Surgical Anatomy

The knee joint is the largest and one of the most complex joints in the human body. It functions primarily as a hinge joint, allowing flexion and extension, while also permitting a small degree of rotation. Structurally, it is formed by the articulation of three bones: the distal femur, the proximal tibia, and the patella [19]. The fibula lies adjacent to the tibia but does not form a direct part of the knee joint itself. Stability of the knee is maintained through an intricate network of ligaments [8]. The anterior cruciate ligament (ACL) prevents forward displacement of the tibia, while the posterior cruciate ligament (PCL) prevents backward displacement. Both ends of the knee contain important stabilizers including the medial collateral ligament which controls the inner part along with the lateral collateral ligament which maintains the outer section [20]. In surgical procedures such as primary and revision total knee arthroplasty (TKA), careful assessment of ligament integrity is crucial because damaged ligaments may require the use of more constrained implants [20].The muscular anatomy around the knee is also vital to surgical success. The quadriceps muscle group extends the knee through the patellar tendon, which connects the patella to the tibial tuberosity. Posteriorly, the hamstring muscles and the gastrocnemius muscle assist in knee flexion. Preservation of the extensor mechanism — consisting of the quadriceps, patella, and patellar tendon — is particularly important during revision surgeries to ensure postoperative mobility [21].

Neurovascular structures near the knee pose significant surgical risks if not properly protected. The popliteal artery and vein run directly behind the knee joint and are at risk during deep posterior dissections. Laterally, the common peroneal nerve winds around the fibular neck and is especially vulnerable during lateral exposures or tibial work; injury to this nerve can result in foot drop. The tibial nerve is positioned more centrally within the popliteal fossa [3, 22]. The knee joint itself is enclosed by a fibrous capsule lined with synovial membrane, which produces synovial fluid to lubricate the joint. In revision TKA, thickened scar tissue and inflamed synovium often need careful excision to allow proper visualization and implant positioning. The joint is also surrounded by several bursae, notably the suprapatellar bursa, which is often opened during surgical exposure [23]. When performing revision surgeries, attention must be given to previous incisions to preserve skin vascularity and reduce the risk of wound healing complications. Additionally, maintaining or restoring proper patellar tracking is critical to achieving a successful functional outcome. Bone defects are frequently encountered and may require specialized implants, augments, or bone grafting to reconstruct the joint surfaces adequately [9]. A comprehensive understanding of the knee's surgical anatomy is essential to minimize complications and optimize patient outcomes during both primary and revision total knee arthroplasty procedures.

2.2. Surgical Positioning

The correct positioning of patients before surgery remains essential because it provides both adequate surgical view and minimized complications which result in better treatment success. The operating table features a supine placement of the patient whose operative leg receives positioning for complete knee joint accessibility [24]. A tourniquet with proper padding is commonly placed on the upper thigh during procedures to create a bloodless working area but complex revision operations might not need tourniquet application to prevent complications such as thromboembolism or soft tissue damage [25]. Easy movement of the knee joint must be achievable during the surgical process. The surgical support devices featuring leg holders stabilize the thigh area for placement of the tourniquet to maintain bloodless surgical visualization. During implant exposure and placement, the surgeon can easily handle the knee by placing a padded bump under the thigh to maintain slight flexion of the knee [26]. The flexion position of the knee relaxes joint tissues mainly the extensor mechanism and collateral ligaments which improves component removal or implantation visibility [25]. Attention must be paid to protecting bony prominences and soft tissue structures during positioning to prevent pressure injuries or nerve palsies, especially during long revision surgeries. When necessary, a sterile tourniquet system and a draped foot holder may be used to allow dynamic adjustment of the knee position during surgery.The entire lower extremity, from the mid-thigh down to the foot, is typically prepped and draped into the sterile field to allow complete freedom of movement and access during the procedure [27].In certain complex revision cases where extensive posterior exposure is needed — such as in managing significant bone loss or implant removal — the operating table can be slightly tilted or rotated to optimize visualization. Although the lateral decubitus (side-lying) position is extremely rare for knee surgeries, it may be considered in highly specific situations, although it is much more common in hip or elbow procedures [28].Finally, intraoperative fluoroscopy (C-arm imaging) may be employed, especially in complex revisions involving stems, metaphyseal sleeves, or cones. Thus, the surgical setup must allow space for imaging equipment access from the contralateral side of the table [29].Overall, proper surgical positioning of the knee joint ensures the operative site is fully exposed, the surgeon has a complete range of motion during the procedure, and the patient's neurovascular structures are well protected throughout the surgery.

2.3. Surgical Exposure

Surgical exposure of the knee joint is a crucial step in total knee arthroplasty (TKA) and revision knee surgeries, as it directly impacts the surgeon's ability to visualize, access, and correctly prepare the joint surfaces. The most commonly used approach is the midline skin incision, typically centered over the patella and extending from approximately 5 to 10 centimeters above the patella down to below the tibial tuberosity. This incision aims to provide a straight, easily extendable path that respects previous incisions when possible, minimizing the risk of skin necrosis and wound healing complications [28]. Once the skin and subcutaneous tissues are dissected, attention turns to the deep exposure. The medial parapatellar arthrotomy is the traditional and most frequently used method. In this technique, the joint is entered by making an incision along the medial border of the patella and patellar tendon, allowing the surgeon to evert or subluxate the patella laterally. This maneuver improves visualization of the distal femur, proximal tibia, and posterior structures, and it is particularly helpful in tight or stiff knees [26]. In cases where the patella cannot be safely everted, alternative exposures such as the midvastus or subvastus approaches can be considered. The midvastus approach splits the fibers of the vastus medialis obliquus muscle, while the subvastus approach works beneath it, preserving the extensor mechanism more fully and potentially leading to faster recovery of quadriceps function postoperatively. However, these techniques can be more technically demanding, especially in revision surgeries where scarring and fibrosis are common [29].Surgical exposure of the knee joint is a crucial step in total knee arthroplasty (TKA) and revision knee surgeries, as it directly impacts the surgeon's ability to visualize, access, and correctly prepare the joint surfaces. The most commonly used approach is the midline skin incision, typically centered over the patella and extending from approximately 5 to 10 centimeters above the patella down to below the tibial tuberosity. This incision aims to provide a straight, easily extendable path that respects previous incisions when possible, minimizing the risk of skin necrosis and wound healing complications [28]. Once the skin and subcutaneous tissues are dissected, attention turns to the deep exposure. The medial parapatellar arthrotomy is the traditional and most frequently used method. In this technique, the joint is entered by making an incision along the medial border of the patella and patellar tendon, allowing the surgeon to evert or subluxate the patella laterally. This maneuver improves visualization of the distal femur, proximal tibia, and posterior structures, and it is particularly helpful in tight or stiff knees [26]. In cases where the patella cannot be safely everted, alternative exposures such as the midvastus or subvastus approaches can be considered. The midvastus approach splits the fibers of the vastus medialis obliquus muscle, while the subvastus approach works beneath it, preserving the extensor mechanism more fully and potentially leading to faster recovery of quadriceps function postoperatively. However, these techniques can be more technically demanding, especially in revision surgeries where scarring and fibrosis are common [29]. Additional techniques are used in complex revision settings to obtain adequate exposure when treating well-fixed implants and dealing with extensive bone loss. Therapeutic quadriceps snips combined with V-Y turndowns represent one option among tibial tubercle osteotomies when surgeons require extended exposure to extensor structures. These operative strategies should only be used targeting specific indications because they create risks including extensor lag that requires delayed healing at the osteotomy site [30]. The protection of collateral ligaments together with posterior capsule and neurovascular bundle located in the popliteal fossa should be a priority during all exposure stages. The repair of tissue viability and optimal healing demands intraoperative steps which combine gentle tissue retraction with frequent irrigation in addition to minimizing traumatic soft tissue events [31].The surgical access to the knee joint requires skillful preparation and execution of the chosen procedure which matches the particular needs of either standard total knee arthroplasty or complicated revision surgery. The surgical exposure helps doctors execute precise bone preparations while placing implants correctly and simultaneously reduces complications risk and leads to better postoperative results [30].

2.4. Considerations Prior to Cement Removal

A surgeon needs to assess multiple essential aspects before starting cement removal in revision total knee arthroplasty (TKA). The surgical assessment requires examination of three main factors such as the state of both femur and tibia bone stock and the dimensions and quality of cement along with the implant fixation condition. Medical imaging procedures such as X-rays help surgeons determine bone defects before surgery because the findings guide cement extraction decisions [14]. The surgical planning process should direct implant experts due to the increased fragile nature of thin cortices with osteolytic defects during the removal process [31]. The surgical challenge related to cement removal increases when cement extends farther than the implant settles beyond its margins and when cements become thick. It becomes difficult to extract thick cement mantle segments which reach extended distances beyond the implant stem tip when working without direct observation. The removal of cement requires flexible reamers in conjunction with ultrasonic devices along with cortical windows to achieve proper cement access at a safer level [32]. The implementation strategy of implant fixation maintains important significance for the procedure. Components that are loose permit simpler extraction with basic technical requirements despite the obstacles of firmly embedded implants deep within bone structures. Proper techniques should minimize bone tissue damage throughout hard-to-remove procedures because bone preservation remains crucial for effective future prosthesis installation [33]. The removal of all remaining cement materials stands as a vital requirement in PJI management to lower the chances of ongoing and repeated infections. Preoperative evaluation and deliberately planned procedures offer essential components for the safe execution of cement removal procedures in knee revision arthroplasty [32].

3. TECHNIQUES FOR CEMENT REMOVAL

The successful outcome of revision total knee arthroplasty (TKA) heavily depends on proper cement removal which constitutes a challenging technical element. Experts have developed multiple techniques to manage well-fixed polymethyl methacrylate (PMMA) bone cement extraction without causing harm to neighboring bone tissue, as shown in figure (1) [34]. Cement extraction in revision total knee arthroplasty requires medical practitioners to use manual instruments including thin osteotomes and curettes with specialized cement extraction tools. Specialized tools that fit between bone and cement permit precision chipping of cement material to prepare it for extraction. A controlled procedure through this method requires extensive effort yet high pressure on the bone has the potential to create cracks during extraction [35]. The use of powered instruments remains a common procedure to enhance the efficiency of cement removal. Standard-powered high-speed cutting tools and flexible reamers and ultrasonic equipment effectively break cement down into pieces without harming the underlying bone structure. Ultrasonic tools generate vibration energy to break down cement structures in order to remove it with smaller forces acting on the bone [36]. In complex cases, surgeons may create a cortical window a small opening in the bone shaft to directly access and remove deeply embedded cement. Although effective, creating a cortical window carries a risk of weakening the bone and requires meticulous repair afterward [37]. Flexible reamers are another valuable tool, especially for removing cement from the medullary canals of the femur or tibia. These reamers can adapt to the natural curvature of the bone and help remove cement mantles that extend beyond the tip of the original implant stem [38]. In cases where cement fragments are difficult to visualize or access, intraoperative fluoroscopy (real-time X-ray imaging) can assist in guiding the removal process, ensuring that no cement debris is left behind [37]. Regardless of the method used, thorough and complete cement removal is essential, particularly when revision is being performed for infection. Retained cement can harbor bacteria or interfere with the stability and positioning of the new prosthesis. Therefore, a careful, methodical approach tailored to the patient's bone quality, the amount of remaining cement, and the complexity of the case is necessary to optimize outcomes [38].

3.1. Non-Powered Instruments

Non-powered instruments remain a fundamental approach for cement removal during revision total knee arthroplasty (TKA). These traditional techniques are often preferred when precision is critical, and when preserving bone stock is a primary concern. Using manual tools allows the surgeon to carefully and tactically separate the cement mantle from the bone without relying on high-speed mechanical devices, reducing the risk of accidental bone injury, as shown in figure (2) [39].Common non-powered instruments include thin osteotomes, curettes, flexible chisels, small gouges, rongeurs, and cement hooks. Surgeons use these instruments to gradually disrupt the interface between the bone and the cement. Thin, sharp osteotomes are particularly valuable for sliding along the cement-bone boundary, lifting and fracturing the cement into removable fragments [40]. Curettes allow the surgeon to scrape out small pieces of cement, especially in difficult-to-reach areas like the medullary canal or tight spaces around the femoral and tibial components. Flexible chisels can follow the contour of the bone more easily, making them useful when cement extends into curved regions of the canal. Rongeurs and forceps are used to grasp and extract larger cement pieces once they have been loosened [41]. The non-powered technique relies heavily on direct visualization, careful tactile feedback, and patient handling. Surgeons must take great care to avoid applying excessive force, which could fracture the thin cortical bone, particularly in patients with osteopenia or osteoporosis. In challenging cases where cement mantles are thick or extend deep into the canal, additional methods, such as cortical windows or flexible reamers, may be combined with non-powered removal techniques, as shown in Table (1) [42]. While non-powered instruments are slower compared to powered devices, they are highly valuable in cases were preserving as much native bone as possible is essential for the success of the revision implant. Non-powered cement removal techniques continue to be an important and reliable method, especially when used by experienced surgeons with a meticulous and patient approach [43].

3.2. Powered Instruments

Powered instruments have significantly advanced the process of cement removal during revision total knee arthroplasty (TKA), providing surgeons with greater efficiency, precision, and control. Compared to traditional manual techniques, powered tools can help reduce operative time, minimize surgeon fatigue, and in many cases, better protect the surrounding bone from excessive mechanical stress [21]. Common powered instruments used for cement removal include high-speed burrs [44], flexible reamers [45], and ultrasonic devices [46]:

- High-Speed Burrs: These are rotary cutting tools that can precisely drill and grind away cement without exerting heavy force on the bone. Burrs are particularly effective for removing well-fixed cement mantles from flat surfaces, irregular contours, or around implant interfaces. They allow the surgeon to selectively target the cement while preserving the adjacent bone, as shown in figure (3) [44].

- Flexible Reamers: Flexible reamers are particularly useful for accessing and removing cement from the intramedullary canals of the femur or tibia. Their flexible shafts allow them to follow the natural curvature of the bone canal, which can be critical for removing cement that extends deep within the medullary cavity. Flexible reamers can break up and extract cement in long, narrow, or curved bone tunnels [45].
- Ultrasonic Devices: These instruments use ultrasonic vibrations to break the bond between the cement and the bone. Ultrasonic energy can fragment the cement with minimal heat generation and without mechanically traumatizing the bone. This technique is especially helpful when dealing with very well-fixed cement or in patients with poor bone quality where excessive mechanical force must be avoided [46].

Using powered instruments requires careful technique and constant irrigation to prevent overheating of the bone, which could otherwise lead to thermal injury and compromise bone viability. Surgeons must also be attentive to the depth and direction of cutting to avoid inadvertently thinning or penetrating the cortex [47]. Despite these risks, when used properly, powered instruments significantly enhance the surgeon's ability to completely and safely remove cement a critical factor for successful implant reimplantation, especially in cases of infection or mechanical failure [48].

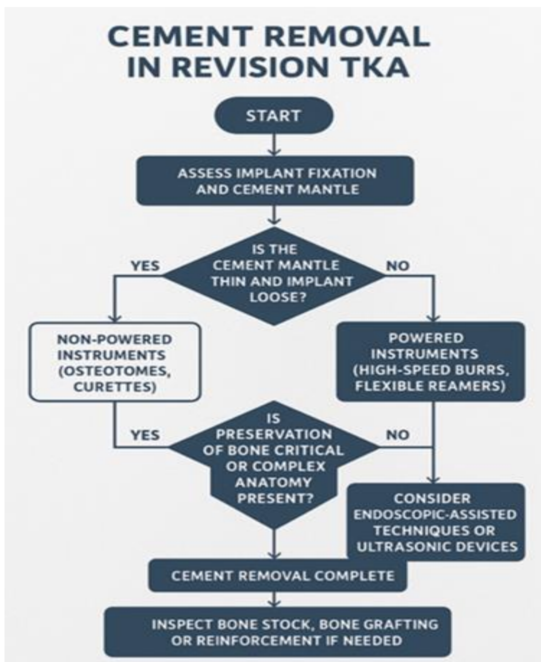
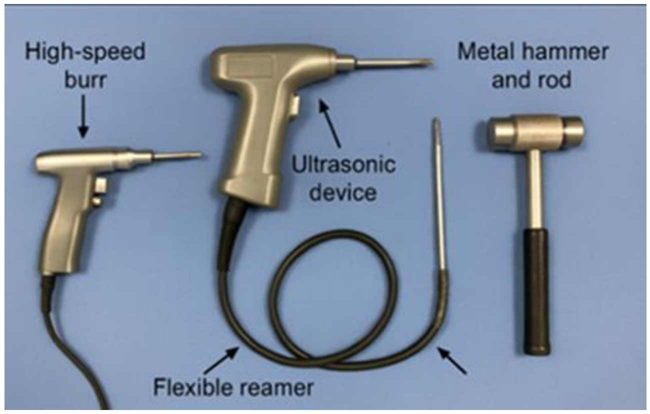


Figure 1. Diagram for knee arthroplasty cement removal techniques.

Figure 2. Diagram Non powered instruments utilized for cement removal including (from Left to Right) large reverse curette (Top), rongeur, Kerrison rongeur, cement gouge, artist chisel, thin flexible osteotome, mallet, straight curette, small curved curette, synovial rongeur, and large rongeur [39].



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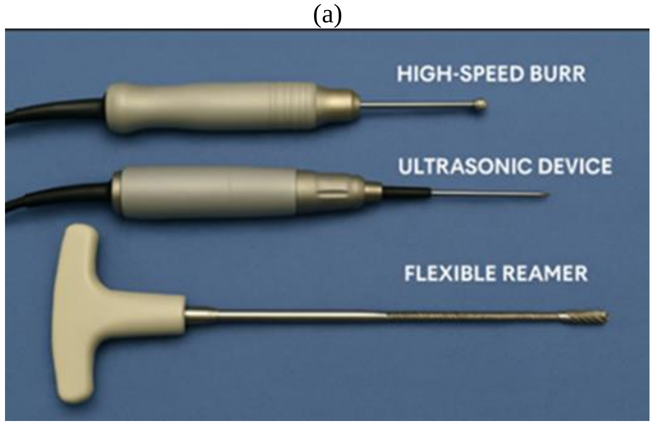

(b)

Figure 3. Powered instruments utilized for cement removal [44].

Table 1. Comparison between Non-Powered and Powered cement removal techniques used in revision knee arthroplasty [42].

Feature	Non-Powered Instruments	Powered Instruments
Examples	Osteotomes, curettes, gouges	High-speed burrs, flexible reamers, drills
Power Source	Manual (hand-driven)	Electrical or pneumatic motors
Control and Precision	High tactile feedback, precise control	Requires careful handling; less tactile feedback
Bone Preservation	Better bone preservation with careful technique	Risk of inadvertent bone loss if not cautious
Efficiency (Speed)	Slower, more labor-intensive	Faster, especially for hard, well-fixed cement
Risk of Thermal Injury	None	Possible (due to heat generation from friction)
Ease of Use for Thick Cement	Difficult and time-consuming	Easier to remove large volumes or hard cement
Cost	Low (basic surgical tools)	Higher (powered equipment required)
Common Complications	Incomplete removal, surgeon fatigue	Bone perforation, thermal necrosis, overcutting
Ideal Situations	Thin cement mantles, loose implants	Thick, hard, or well-fixed cement mantles

3.3. Endoscopic-Assisted Techniques

Endoscopic-assisted techniques represent an innovative and minimally invasive approach to cement removal during revision total knee arthroplasty (TKA). These techniques use a small camera (endoscope) and specialized instruments to assist in the visualization and removal of cement, especially from deep or difficult-to-access regions such as the femoral or tibial canals [49].The main advantage of endoscopic-assisted cement removal is the direct visualization it offers within confined spaces without needing extensive bone exposure or cortical windows. Using a small endoscope inserted into the medullary canal, the surgeon can clearly see cement fragments, assess the cement-bone interface, and guide the removal process with much greater precision. This real-time imaging reduces the risk of leaving residual cement behind, which is crucial for preventing mechanical failure or infection after reimplantation [50]. During the procedure, miniaturized tools such as flexible curettes, graspers, or burrs are introduced alongside the endoscope, as shown in figure (4) [51]. Cement pieces are identified under direct vision, fragmented if necessary, and carefully extracted. Surgeons can also assess the condition of the native bone, identifying areas of osteolysis or bone defects that may not be visible otherwise [52].

Endoscopic-assisted cement removal is particularly beneficial in cases where [50]:

- Cement extends far beyond the implant tip.
- Previous revisions have altered the bone anatomy.
- The surgeon aims to minimize further damage to compromised bone stock.
- The use of large cortical windows would be risky or undesirable.

However, this technique requires specific training and familiarity with endoscopic equipment. It can also be technically demanding, and there is a learning curve associated with navigating small instruments in a tight, curved space while maintaining continuous visualization [52].Overall, endoscopic-assisted techniques offer a minimally invasive, bone-preserving, and highly controlled method for cement removal, helping to improve outcomes in complex knee revision surgeries [53].

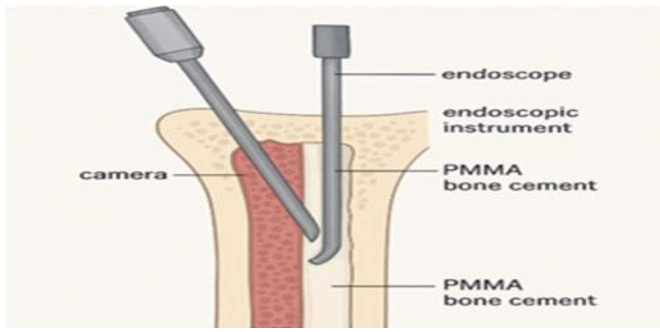

Figure 4. Simple diagram explains how the endoscope and instruments work together inside the bone [51].

3.4. Ultrasonic Devices for Cement Removal

Ultrasonic devices were initially introduced into hip and knee revision arthroplasty in the late 1990s and early 2000s, gaining popularity for cement removal due to their ability to selectively remove cement while preserving the surrounding bone [34]. These devices operate based on heat exchange that occurs when friction between the device, the bone, and the cement is created. The mechanical energy generated by the device is converted into thermal energy, which is absorbed primarily by the polymethyl methacrylate (PMMA) cement. This localized heating softens the cement, making it easier to fragment and extract without damaging the host bone [54]. Studies in knee arthroplasty have demonstrated that ultrasonic removal techniques significantly reduce the rates of cortical perforations compared to manual cement extraction. Reported perforation rates with ultrasonic methods are between 0 and 4%, compared to around 13% with manual techniques available at the time. However, there are concerns regarding the potential for iatrogenic injury, particularly thermal injury to nearby soft tissues such as the collateral ligaments or neurovascular structures [55].

Several strategies have been proposed to minimize heat generation during ultrasonic cement removal in the knee joint. These include continuous irrigation to cool the working area and slow, controlled advancement of the ultrasonic probe through the cement mantle. By reducing thermal buildup, surgeons can lower the risk of tissue injury. Despite these advancements, there are relatively few studies dedicated to specifically assessing the rates of nerve injury or other complications related to ultrasonic use in knee revision surgeries [56].Overall, ultrasonic devices represent a highly effective and bone-sparing option for cement removal during revision total knee arthroplasty (TKA), particularly when careful technique is employed to minimize thermal injury, as shown in table (2) [57].

Table 2. Ultrasonic Devices properties in knee revision arthroplasty [57].

Aspect	Advantages	Disadvantages
Bone Preservation	Selectively removes cement, spares native bone	Risk of bone perforation if misused
Precision	High precision with controlled application	Requires skilled technique
Thermal Injury	Minimal if properly used	Potential thermal injury to soft tissues
Efficiency	Facilitates removal of well-fixed cement	Slower than mechanical powered tools sometimes
Soft Tissue Safety	Less trauma compared to mechanical methods	Risk of nerve injury if close to neural structures
Cost	Can reduce OR time and revision difficulty	Expensive equipment and maintenance

3.5. Bone Episiotomy and Cortical Windows for Cement Removal

Bone episiotomy is a technique sometimes used during revision total knee arthroplasty (TKA) to aid in the removal of difficult-to-access cement. Originally described for shoulder arthroplasty, this method involves making a longitudinal cortical osteotomy in the distal femur or proximal tibia. When using an episiotomy approach in the knee, the osteotomy is made unidirectionally and vertically, typically along the diaphysis [39]. The goal is to disrupt the mechanical "hoop stresses" that stabilize the implant-cement-bone interface, allowing easier extraction of the cement and prosthesis. This technique often requires stabilization with cerclage wires, cables, or heavy sutures after cement removal [58]. However, one important risk of episiotomy is distal fracture propagation beyond the intended cut, which emphasizes the need for meticulous surgical technique. Cortical windows are another important method used to access and remove cement in knee revision surgery. A carefully made opening in cortical femur or tibial bone enables surgeons to visually inspect implant stems and cement mantle material. Creating cortical openings needs to match implant stem width and occupy between 1-2 cortical diameters because this ensures adequate visibility while maintaining bone structural strength [37]. Small hand tools enable practitioners to carefully make an orderly rectangular bone flap for the window before removing it for cement extraction and finally restoring the window afterward. According to literature the surgical cuts need oblique angles to achieve stability during surgical closure [59]. Medical personnel restore the mechanical stability of the femur or tibia through heavy absorbable sutures or alternative fixation solutions after implant removal and cement extraction of the cortical window [60]. Endoscopic and ultrasonic methods prove challenging to use in well-fixed cement mantles while this procedure provides effective access alternatives. The combination of cortical windows and proper repair techniques offers excellent stability and reliable outcomes in complex knee revision surgeries [61].

3.6.Comparison between TKA Cement Removal Techniques

Table (3) demonstrate the description, advantages and disadvantages for each cement removal technique.

Table 3. TKA arthroplastic cement removal techniques

Technique	Description	Advantages	Disadvantages
Non-Powered Instruments	Manual tools like osteotomes, curettes, gouges, flexible chisels	Simple, low-cost, preserves bone if used carefully	Time-consuming, physically demanding, risk of fracture [34]
Powered Instruments	High-speed burrs, flexible reamers, drills	Efficient, faster removal, good for dense cement	Potential for bone loss, overheating, nerve injury risk [46]
Endoscopic-Assisted Techniques	Arthroscopic or small-incision camera-assisted cement removal	Better visualization, minimally invasive	Technically demanding, requires special equipment [50]
Ultrasonic Devices	Heat/friction-based devices that soften and break up PMMA cement	Selective cement removal, preserves bone integrity	Risk of thermal injury if not properly managed [55]
Bone Episiotomy	Vertical osteotomy made along femur/tibia diaphysis to release hoop stresses	Facilitates removal of well-fixed implants and cement	Risk of fracture propagation, requires careful fixation [58]
Cortical Windows	Controlled rectangular opening in femur/tibia cortex for direct access	Direct visualization, effective for thick mantles	Requires bone repair post-removal, potential weakening of bone temporarily [60]

4. CONCLUSION

Revision total knee Arthroplasty (rTKA) is still a rather technically challenging surgery and cement removal is the key to success. Poor removal of cement mantles that have been well fixed may greatly precondition reinfection, mechanical failure and defective integration of the implant. It is highlighted in this review that there is no one-fit method that is superior to others; however, each technique, manual, powered, ultrasonic, and endoscopic, has its own indications, advantages, and disadvantages. Manual tools are more precise, time, and labor-intensive. Although powered burrs and reamers enhance efficiency there is a greater risk of thermal trauma or overcutting. Ultrasonic instruments are selective in destroying cement but spare bones, having to be managed in a careful thermal fashion. Endoscopic-guided procedures facilitate better visualization by minimising invasiveness though they require special training and equipment. The difficult cases may be achieved with surgical techniques such as cortical windows and bone episiotomies that allow direct access, however; require careful planning and reconstruction. Recommendation to Clinical Practice and Research:

- The type of cement removal method to be used needs to be selected by the surgeon who has consideration on the amount that has been cement fixed and the health of the bones plus the possibility of complications.
- Surgical curricula must be trained in high technology (e.g. endoscopic, ultrasonic).
- Subsequent research must look into the comparative results of techniques in the perspective of surgical time, bone preservation, reinfection rate and recovery of the patients.
- The next step in research could be development of decision-support algorithms that could allow customizing the techniques to patient-specific and implant-specific cases.
- Finally, proper and thorough cement extraction increases the success of reimplantation, salvages native bone, and improves the long-term outcomes in rTKA. The best practice to improve the outcome of revision knee arthroplasty is through the use of a multidisciplinary and evidence-based model.

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