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# Improved Results with Use of a Rim Cutter in Cemented Hip Arthroplasty

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**Running title:**

**Use of a Rim Cutter in Cemented THA**

This work is part of on-going routine review of a cohort of patients and so is exempt from IRB approval.

**Conflict of Interest Statement:**

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## **Abstract**

*Background:* We report a technical innovation in cemented hip arthroplasty. The Rim Cutter™ was designed to improve fixation and positioning of cemented sockets. It prepares a rim around the bony bed with the aims of 1) enhancing pressurisation and cement penetration at the periphery of the socket during introduction of a flanged acetabular component and 2) improving the accuracy of placement of the prosthesis.

*Methods:* A retrospective clinical study was performed in order to assess the radiological result of the use of the device. Two consecutive groups of 45 patients undergoing a cemented THR with the Exeter Contemporary cup were compared; one using the device, the other without. Post-operative radiographs were analysed to compare anatomic measurements with regard to the centre of rotation of the socket; height and lateralisation of the centre of rotation from the teardrop, as well as width of the cement mantle compared with the normal contralateral hip and number of radiolucent lines.

*Results:* The Rim Cutter group showed improved radiological parameters. The device group were closer to the anatomical centre of rotation both vertically and horizontally ( $p < 0.001$ ) and had consistently thicker and more uniform cement mantles ( $p < 0.001$ ). There were 2 radiolucent lines in the control group and none in the device group although this was not statistically significant.

*Conclusions:* The introduction of this rim cutting device represents a progression in the technique for the preparation of the acetabulum in cemented hip arthroplasty.

**Key words:** total hip arthroplasty; cemented acetabulum; Rim Cutter; radiolucent line; loosening

## Introduction

The fate of a cemented acetabular component, in terms of mechanical loosening and subsequent migration, is determined primarily by the quality of the surgical technique used at the time of insertion. Many advances in cementing technique have increased the durability of a cemented socket including pressurisers, sucker aspirators and flanged acetabular components<sup>1-3</sup>. The introduction of the new “Rim Cutter™”<sup>4</sup> (Stryker Orthopedics, Mahwah, NJ) represents a further potential advance in the technique for the preparation of the acetabulum in cemented hip arthroplasty. It is a logical progression in surgical technique when a flanged socket is to be implanted. The device prepares an accurate rim around the margin of the bony acetabulum into which the flange of an acetabular implant sits. It fixes the orientation of the socket in terms of version and inclination, as well as the position of the centre of rotation of the component. By reducing the space for cement egress underneath the flange as the socket is seated, there is a sustained rise in cement injection pressure behind the socket during implantation<sup>4</sup>. The aim therefore, is to improve cement macro- and micro-interlock and create a congruent cement mantle with no radiolucencies at the cement-bone interface, especially in the highly predictive DeLee Charnley Zone 1<sup>5,6</sup>.

The aim of this study was to assess the radiological results of using the Rim Cutter compared to a control group where the device was not used to identify differences in 1) the position of the hip compared to a normal, contralateral hip, 2) the uniformity of the cement mantle and 3) the width of the cement mantle and the number of radiolucencies in the three DeLee Charnley acetabular zones.

## Patients and methods

A retrospective clinical study was performed in order to assess the radiological result of the use of the Rim Cutter (**Fig. 1**). Power analysis based on previous studies in our unit <sup>7</sup> for difference in height of the centre of rotation (mean 2mm, SD 3mm) indicated at least 37 cases were needed in each group. To allow for underestimation of these variables, a goal of 45 patients per group was set. Therefore, two groups of consecutive patients with 45 patients in each group were included in this study. In the study group, the device had been used as previously described <sup>4</sup>; in the control group, the acetabulum had been prepared without the use of the device. In all cases an Exeter Contemporary flanged cup and Exeter Universal stem (Stryker Orthopedics, Mahwah, NJ) were used. The operations were performed by 5 surgeons (two consultants and three fellows) using a standardized surgical technique. Exclusion criteria in the study were bilateral total hip replacements, a pre-existing THA or a dysplastic hip on the contralateral side, since a normal contralateral hip was required to define the optimal socket position. All cases were evaluated on post-operative radiographs using OrthoView™ (Orthochart™, Ortho-Graphics Inc., 807 E S Temple, Suite100, Salt Lake City, UT84102) software to record the anatomic measurements with regard to:

- i) centre of rotation of the socket, height of the centre of rotation from the teardrop and lateralisation of the centre of rotation from the teardrop,
- ii) width of the cement mantle in the three DeLee Charnley <sup>6</sup> acetabular zones and
- iii) radiolucent lines in any zone

The values defining the centre of rotation were compared with the equivalent measurements made for the normal contralateral hip.

The post-operative films were assessed using OrthoView, which is a digital x-ray templating system. This software is an orthopaedic planning and measurement tool for digital images, allowing surgeons to template images easily and accurately, prior to and following total joint arthroplasty. Post-operative x-rays were taken in a standardised fashion with the image source at the position of the pubis. The OrthoView wizards and tools were used to make all measurements. Initially the software was used to scale the implanted femoral head, which in these cases has a known diameter of 28mm. Subsequently, scaling allowed us to make an accurate measurement of other parameters.

The methodology used to make these measurements is illustrated in **Figure 2A**. Two circles from the software were projected onto the normal head of the femur and onto the prosthetic head. The sizes of these circles were adjusted to fit perfectly the femoral head and the implanted head, and thus to enable us to find the accurate centre of rotation. A line was drawn across the bottom of the obturator foramen (line 1). Another line, parallel to the first line, was drawn across the teardrops (line 2). The inter-teardrop line is the green line (**Fig. 2A**) joining each teardrop at the infero-medial position of the acetabulum. A box was positioned over the correct point on each hemi-pelvis. A vertical line was then drawn through the centre of the femoral heads (line 3). Then, a line (line 4) was drawn vertically down at the teardrops in both hips crossing line 2. The cup height in relation to the pelvis is given by the measurement from the centre of the femoral head to the horizontal inter-teardrop line (line 2). The lateralisation of the centre of rotation of the cup was calculated by measuring the distance between the vertical line in the teardrop (line 4) and the vertical

line at the centre of the femoral head (line 3) on both sides. The thickness of the cement mantle was measured in the three acetabular zones <sup>6</sup> by measuring the distance between the plastic end of the socket (not the wire) and the end of the cement.

### **Surgical technique**

A posterior approach was used for all hip replacements. The labrum is removed from around the periphery of the acetabulum, and the true medial wall of the acetabulum identified by using reamers or a long-handled gouge. The transverse ligament is located to ensure that the cup is inserted at the correct centre of rotation; the aim is to implant the acetabular component such that its inferior edge is at the level of the transverse ligament. Concentric reaming is started after removal of the medial osteophyte with the aim of achieving a good cancellous surface. Large peripheral osteophytes are removed prior to the use of the device. The size of the largest reamer determines the size of the acetabular component and device used (2mm less than the reamer size). The principle aim of this innovation is to cut a rim around the periphery of the acetabulum to a set depth (**Fig. 3**). The flange of the socket seats into this rim, thus controlling the orientation and depth of insertion of the socket. The device is attached to a power tool (**Fig. 4**) so that it will cut a groove in the periphery of the acetabulum of the appropriate diameter for the flange. The apical hemispherical guide (green plastic base) (**Fig. 5**) fits into the reamed base of the acetabulum, centralizing the cutter. The surgeon then compresses the device down onto the rim of the acetabulum. It is advanced to its fullest extent by exerting pressure against the spring between the dome and the cutting ring until it reaches an end-stop. This will ensure a congruent cement mantle of 4mm or more all the way around the acetabular component. The device incorporates an alignment rod (**Fig. 4**) to guide the surgeon with regards to

abduction and anteversion. If the handle is placed with the guide vertically, then the cutting edge is at an angle of 45° to the horizontal. The anteversion guide is then used to direct approximately 25° of anteversion in relation to the long axis of the patient. Any debris created, including the innermost fibres of the transverse ligament, is removed. The acetabular component (Exeter Contemporary flanged socket, (Stryker Orthopedics, Mahwah, NJ)) is then cut around the second line marking of the flange. This will ensure that the rim of the socket fits accurately within the rim cut (**Fig. 6**). The socket is usually stable enough for a trial reduction to be carried out, if desired, if the femur has already been prepared and a broach inserted.

Multiple keyholes are drilled in the acetabulum and bone graft reamings are impacted against the smooth cortical medial wall to improve cement fixation. Packing the bone chips onto the transverse ligament also serves to prevent extrusion of cement under that structure<sup>8</sup>. The socket is then thoroughly washed and dried. This is followed by the introduction of the cement which is then pressurised in the normal way using firm pressure. The iliac sucker is used in the wing of the acetabulum to enhance cement penetration and clear blood from the cement bone interface<sup>2,9-11</sup>.

The socket is then inserted at 5 to 7 mins after mixing (Simplex cement at 20°C) using the introducer and an axial pusher to drive the socket into the seated position. It requires significant force to seat the cup as the flange approaches the rim as the pressure rises within the cement behind the cup.

### **Statistical methods**

Descriptive statistics are reported as mean, standard deviation and 95% confidence intervals or median and interquartile range (IQR) as appropriate. Data were analysed using general



linear models with the absolute difference (between the anatomical and the implanted position of the COR) as the dependant variable and the group (study or control) as the fixed factor. All tests were 2-sided and the level of statistical significance was set at 5%.

Differences in cement mantle thickness in each zone were examined using the Mann-Whitney U-test as the data was non parametric in nature, and adjusted for multiple testing using Bonferroni's correction. The uniformity of the cement mantle was assessed using the chi-squared test, comparing the frequencies of uniformity in the 3 zones. The number of radiolucent lines in each group was compared using Fisher's exact test. Analyses were performed using SPSS for windows V16.0 (SPSS Inc, Chicago, IL).

## Results

The measurements (in mm) for lateralisation of the centre of rotation (COR) and the height of the COR in relation to the pelvis are shown in **Table 1**. The anatomical measurements are for a normal contralateral hip. In the study group the socket was placed closer to the normal centre of rotation (COR) compared to the control group. With regard to the superior implantation of the socket, in the study group the mean absolute difference of the height of the COR of the implanted acetabular component was 1.5mm (95% CI 1.2 to 1.8) compared to 3.7mm (95% CI 3.2 to 4.1) in the control group ( $p < 0.001$ ). Similarly, with regard to the lateralisation of the COR, the implants in the study group were significantly closer to the COR of the contralateral normal hip ( $p < 0.001$ ). In the study group, the mean absolute lateral distance was 1.8mm (95% CI 1.3 to 2.3) compared to the normal contralateral hip and 4.4mm, (95% CI 3.7 to 5.1) in the control group. In the study group, 49 % of the implanted sockets were lateralised (0.5-6.5 mm lateral difference from the normal hip) 11% were in the exact anatomical position (within 0.5mm difference) and 40% were medialised (0.5-6

mm medial difference from the normal hip). In the control group, 44% were lateralised (1-7.5 mm lateral difference from the normal hip) 56% were medialised (0.5-9 mm medial difference from the normal hip) and there was no socket at the exact anatomical medio-lateral position.

The uniformity of the cement mantle width in each group was tested using chi-squared. The cement mantle was found to be significantly more concentric in the study group (more patients had a similar width of cement mantle in all zones) than the control group ( $p < 0.001$ ) (**Table 2**). Two cases in the control group showed radiolucencies in Zone 1 compared to none in the device group, although this was not statistically significant ( $p = 0.49$ ). As far as the width of the cement mantle is concerned, this was significantly higher in the Rim Cutter group in all zones ( $p < 0.001$ ) (**Table 1**).

## **Discussion**

Although the published long term outcomes for cemented total hip replacements are good, as with all hip arthroplasties, the limiting factor for success is the acetabulum. We prospectively examined two groups of patients to compare the radiological outcomes when using a new device designed to improve fixation in the acetabulum. This device also aimed to more accurately restore the anatomy compared to the normal, contralateral hip, and to deliver a more uniform cement mantle. The study is limited by the fact that we have used the incidence of postoperative radiolucencies around the cement mantle as a short term indicator for the longer term survival of the acetabular component<sup>5</sup>, as the true survival will not be known for many years. However, post operative appearances have been shown to be predictive of the long term outcome and the results are encouraging regarding the initial improvements seen<sup>5</sup>. In addition, this study is a retrospective cohort study rather than a

prospective randomised controlled trial; we have however reported on two consecutive groups of patients which have similar demographics and selection criteria. Ideally, the radiological evaluations would be performed by more than one blinded reviewer with full inter and intra-observer analysis performed. Unfortunately for our study, only 1 independent observer performed the measurements.

The optimal placement of the cup has been highly debated in the literature. Improper cup angle has been associated with recurring dislocations in total hip arthroplasty and a safe zone of 35° - 45° has been suggested<sup>12</sup>. In order to maintain bony containment of the acetabular cup, Sarmiento<sup>13</sup> recommended an angle of greater than 45° and it was found that this bony containment was also correlated with reduced incidence of global radiolucencies and linear wear. Hirakawa<sup>14</sup> however suggested that an angle of less than 40° of inclination is preferable, having a lower risk of revision in his series. There remains ongoing debate as to the optimal socket orientation. An accurately machined rim around the periphery of the acetabulum allows the cup to be placed in to a pre-rehearsed position, helping to ensure that it is positioned within the desired “safe zone”<sup>12</sup>.

In addition to stability of the hip, cup position will also influence both prosthetic impingement and wear which, in theory at least, can be reduced by more accurate component positioning. Sandhu<sup>15</sup> showed that it is challenging to achieve consistency in placing the acetabular component in the correct centre of rotation, citing the difficulty of achieving both accurate positioning and simultaneous pressurisation. The difficulty of implanting the acetabular component at the correct centre of rotation was a consistent finding, regardless of the surgeons’ grade and experience. Our study has shown that the use of this rim cutting device helps to ensure that the cup is placed closer to the centre of the

rotation of the acetabulum and that there is less danger of superomedial placement compared with if the device is not used.

Another important issue with cemented acetabular components is the optimum width of the cement mantle. It has been suggested that a 2 to 5 mm depth of cement penetration is optimal<sup>11, 16-19</sup>. Thin or incomplete cement mantles should be avoided as they may result in cement fracture and increased polyethylene wear<sup>20</sup>. Kobayashi<sup>21</sup>, noted that a thin cement mantle in Zone 1 and a deficient mantle in Zone 2 were related to rapid polyethylene wear at 10 years. Conroy et al.<sup>22</sup>, also showed that use of the Rim Cutter improved cement penetration and mantle thickness in a reliable manner. They demonstrated a statistically significant improvement in cement penetration and cement mantle thickness in zones 2 and 3, with a reduced incidence of bottoming out of the socket. Cement mantle thicknesses greater than 8mm were achieved more consistently in the device group, something which is in accordance with our findings. As can be seen in Figure **2B**, with the use of the device, for all but the smallest cup size, a cement mantle of 4mm will be created around the socket. Sandhu<sup>15</sup> showed in his study that the vast majority of acetabular components are eccentric within their cement mantles. The device improved the uniformity of the cement mantle thickness ( $p < 0.001$ ) as well as the more accurate placement of the socket in the study group of patients.

It has been shown that the most important prognostic factor for the long term survival of the acetabular component is the absence of radiolucent lines (RLLs) especially in DeLee Charnley<sup>6</sup> Zone 1 on the immediate post-operative radiographs of the operated hip<sup>5, 16, 23</sup>. Cups with complete radiolucent lines on the initial postoperative radiographs would subsequently migrate, regardless of the thickness of the line. Ritter, in his series of Charnley

hip arthroplasties <sup>5</sup>, found that 28% of cases which exhibited Zone 1 radiolucency on the first post-operative radiograph would progress into a radiographically loose or surgically revised cup in the medium-term. Even minor demarcations in Zone 1 in the first year after surgery can lead to a 35% to 40% radiological loosening within ten years <sup>3,24</sup>. Kneif et al., in their study using radiostereometric analysis (RSA) reported that radiolucencies in Zone 3 on post-operative films are associated with migration, indicating potentially less stability for these implants <sup>25</sup>. Ritter <sup>26</sup> in his review of the results of cemented socket arthroplasty acknowledged the importance of the need to prevent Zone 1 radiolucency. Even when more advanced cementing techniques were used, surgeons had not been able to reduce rates of Zone 1 radiolucencies below 10%.

It is possible to reduce the risk of the occurrence of RLLs by drilling penetration holes for the cement, cleansing the bone bed of marrow and debris by pulsatile lavage <sup>27</sup>, minimising bleeding by the use of hypotensive anaesthesia, careful haemostasis with hydrogen peroxide solution <sup>28</sup> or adrenaline <sup>29</sup>, using a sucker aspirator <sup>10,30</sup> and the prolonged application of a proprietary pressuriser <sup>31</sup>. Charnley, in his observations of demarcation lines and histological studies of the cement bone interface in the acetabula of post-mortem specimens, stated that the injection pressure of the cement in the acetabulum, being lower than that in the femur, does not achieve the same inter-digitation that is possible in the latter. An important step forward was the introduction of flanged sockets. The flange has a beneficial effect on the radiological appearance of the cement–bone interface at the time of implantation, especially in Zone 1 <sup>3</sup>. This advantage is maintained at ten years, when 42.7% of flanged sockets still showed no evidence of radiological demarcation, as against 30.3% of an unflanged group. Flanged sockets, by increasing the cement injection pressure, improve

the cement-bone interface. In a laboratory model, Shelley et al.<sup>32</sup> used acetabulum shaped cavities with simulated cancellous bone. The authors found that flanged cups produced higher peak pressures as well as higher intruded cement volumes compared to unflanged cups.

The most important potential benefit from the introduction of the Rim Cutter is the opportunity to further reduce the problem of radiolucent lines in cemented sockets, especially in Zone 1. The flange rests accurately on the prepared rim and the space underneath the acetabular component is thereby sealed. Intra-operatively, greater pressures are generated underneath the cup as the implant is seated, including peripherally under the flange<sup>4</sup> and therefore better inter-digitation of the cement is achievable. A more congruent, thicker, cement mantle is also produced<sup>4</sup>. An additional function of the device is that it facilitates exposure of trabecular bone around the periphery of the acetabulum, which in turn may enhance fixation and micro-interlock in this important area.

Experimental tests in our institution with this device used in sawbone models showed that there was a statistically significant increase in peak pressure at both the apex (p-value = 0.039) and rim (p-value = 0.004) when this device was used and a flanged cup inserted<sup>4</sup>.

There was also a statistically significant increase in cement penetration under the rim of the cup when compared with both flanged and unflanged cups (p-value = 0.003). This may explain why we found fewer radiolucent lines in any zone in the immediate post-operative radiographs in the Rim Cutter group in our study.

## **Conclusion**

In this study we have shown that the use of a rim cutting device results in more accurate placement of the centre of rotation of a cemented prosthetic socket, and produces a thicker, more congruent cement mantle compared with when the device is not used. We also found fewer radiolucent lines. More clinical data will be required in order to demonstrate the value or otherwise of the device in the longer term, but we are hopeful that it will prove a positive contribution to cemented hip arthroplasty.

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**Tables:****TABLE 1:** Mean (mm) and 95% confidence intervals for height and lateralisation of centre of rotation (COR) from teardrop. Median and IQR cement mantle thickness in each zone.

| Variable   | Rim Cutter group        | Control group           |
|--|-------------------------|-------------------------|
| Number of subjects   | 45                      | 45                      |
| Height of COR from teardrop<br>-difference from anatomical         | 1.5 (95% CI 1.2 to 1.8) | 3.7 (95% CI 3.2 to 4.1) |
| Lateralization of COR from teardrop<br>-difference from anatomical | 1.8 (95% CI 1.3 to 2.3) | 4.4 (95% CI 3.7 to 5.1) |
| Cement mantle thickness  |                         |                         |
| - Zone 1   | 5.0 (1.0)               | 3.0 (0.5)               |
| - Zone 2   | 5.0 (1.5)               | 3.0 (2.0)               |
| - Zone 3   | 5.0 (1.0)               | 3.0 (1.8)               |

**TABLE 2:** Frequencies of uniformity of the cement mantles in Zones 1, 2 & 3.

| <b>Zone</b>                     | <b>Rim Cutter group</b> | <b>Control group</b> |
|---------------------------------|-------------------------|----------------------|
| All 3 zones the same thickness  | 31 (93.9%)              | 2 (6.1%)             |
| 2 of 3 zones the same thickness | 13 (38.2%)              | 21 (61.8%)           |
| All 3 zones different thickness | 1 (4.3%)                | 22 (95.7%)           |
| <b>Total</b>                    | <b>45</b>               | <b>45</b>            |

**Legends for figures:**

**Figure 1:** The Rim Cutter.

**Figure 2:** Measurements made using OrthoView™ tools (A). At minimum of a 4mm cement mantle is created as the flange of the socket “seats” on the rim cut (B).

**Figure 3:** Picture of the rim prepared around the acetabulum before implantation of the socket.

**Figure 4:** Picture showing the Rim Cutter device with the alignment rod, attached to a power tool.

**Figure 5:** The hemispherical guide (green plastic base) that centralizes the cutter.

**Figure 6:** The trimmed flanged socket rests on the rim, sealing the space underneath.

Figures:

Figure 1:



Figure 2:

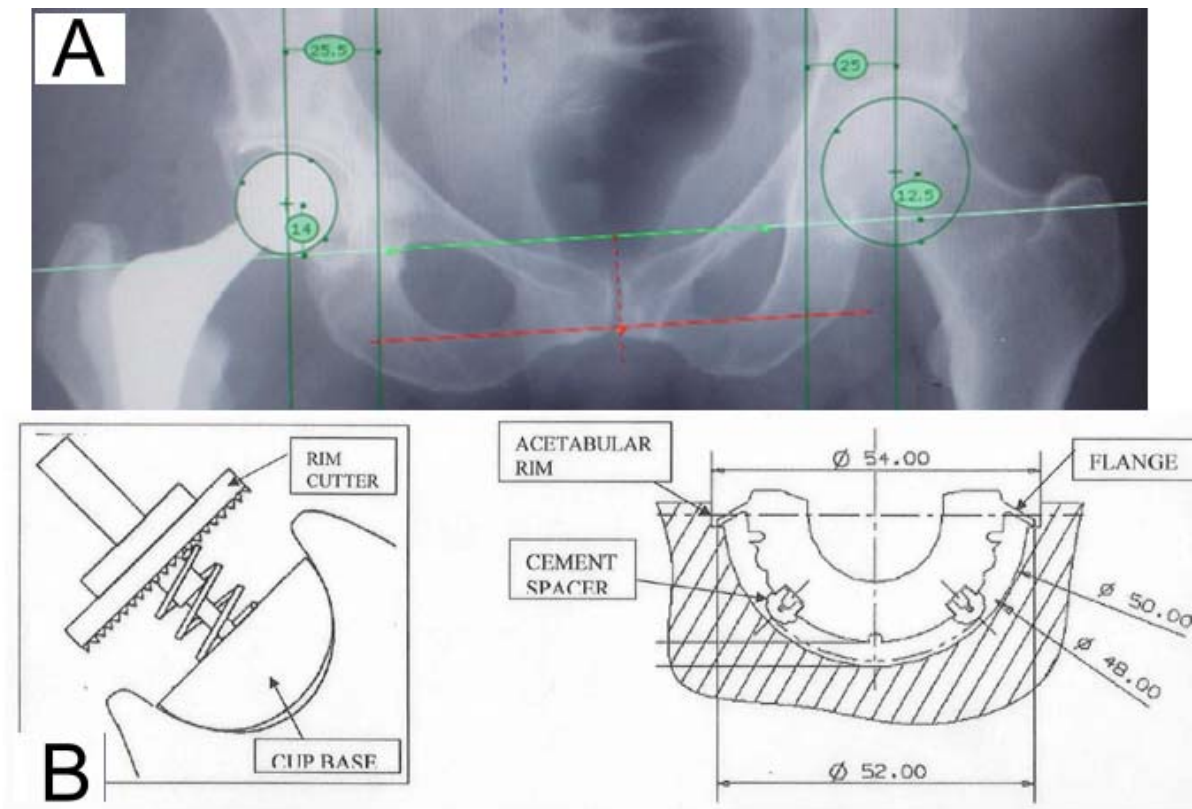


Figure 3:

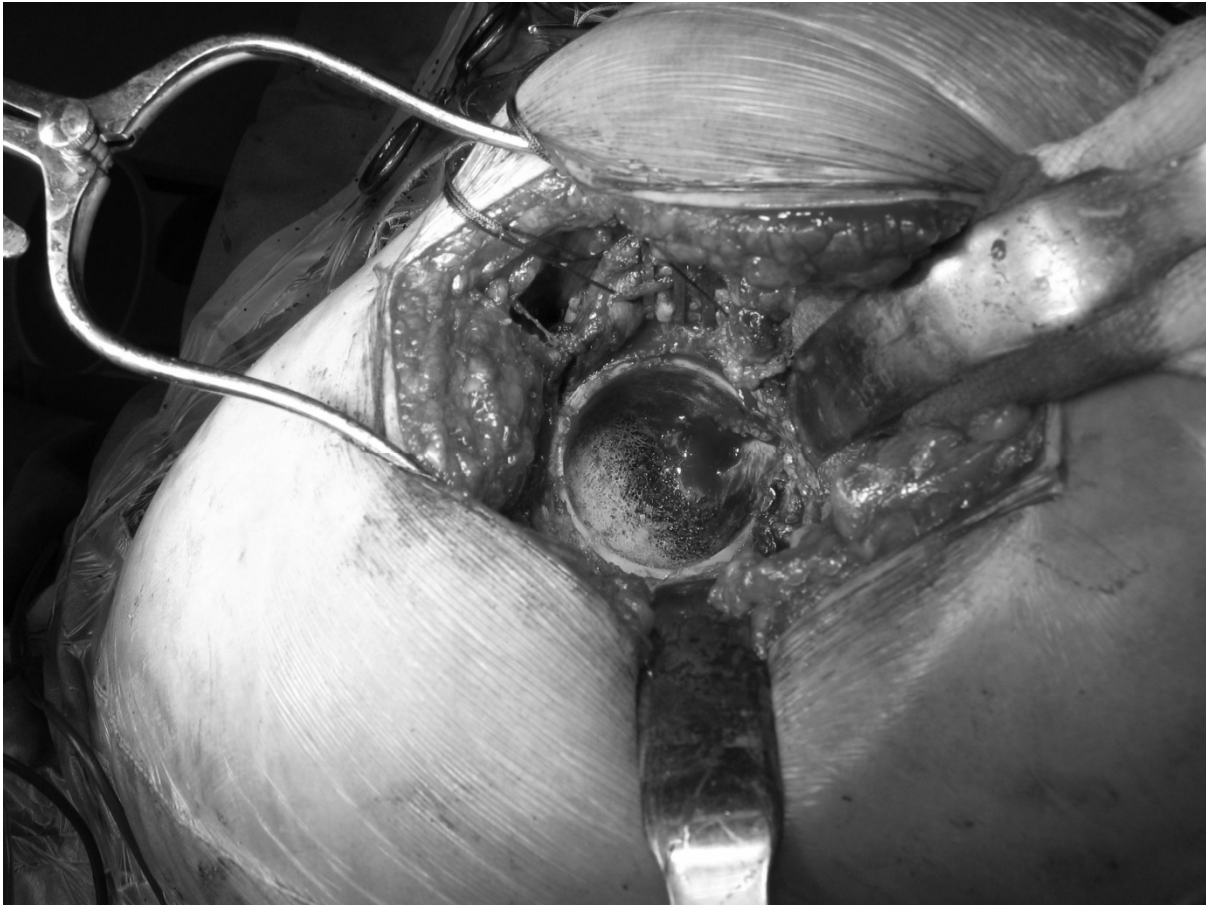




Figure 4:

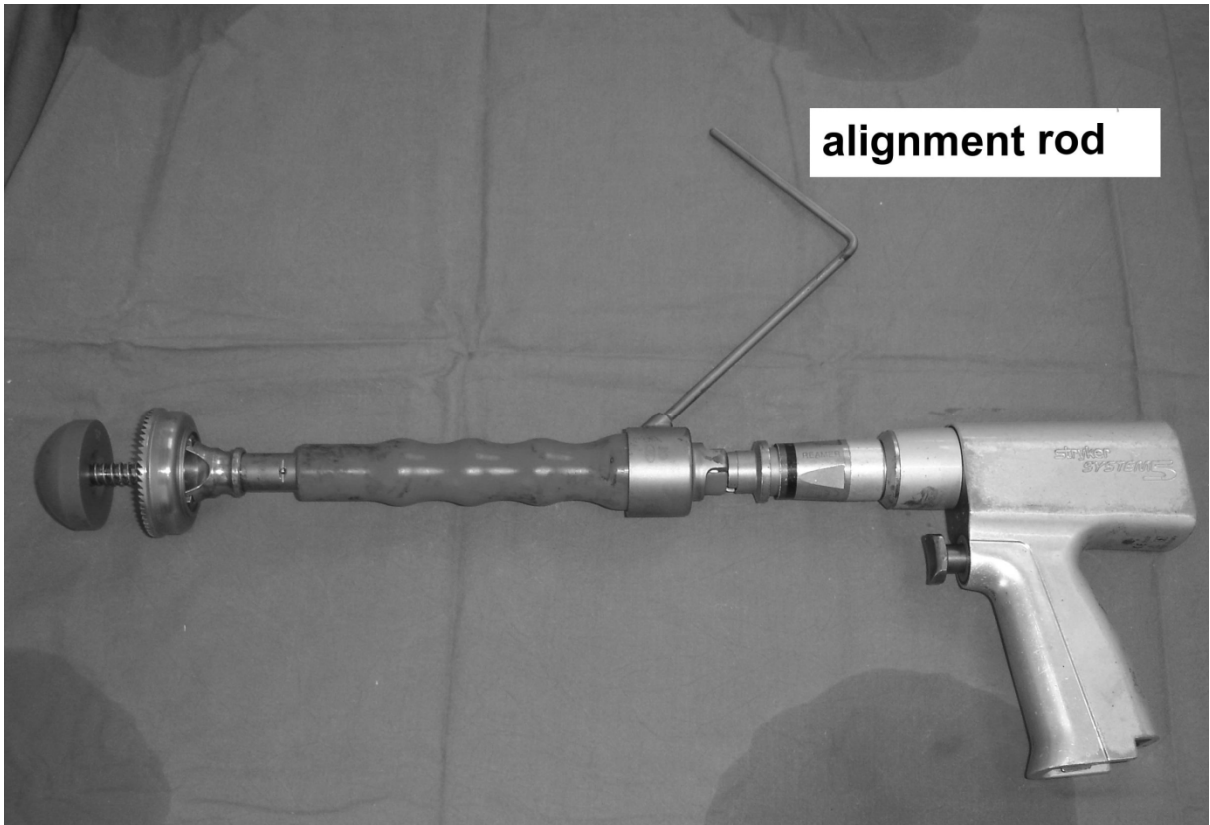


Figure 5:

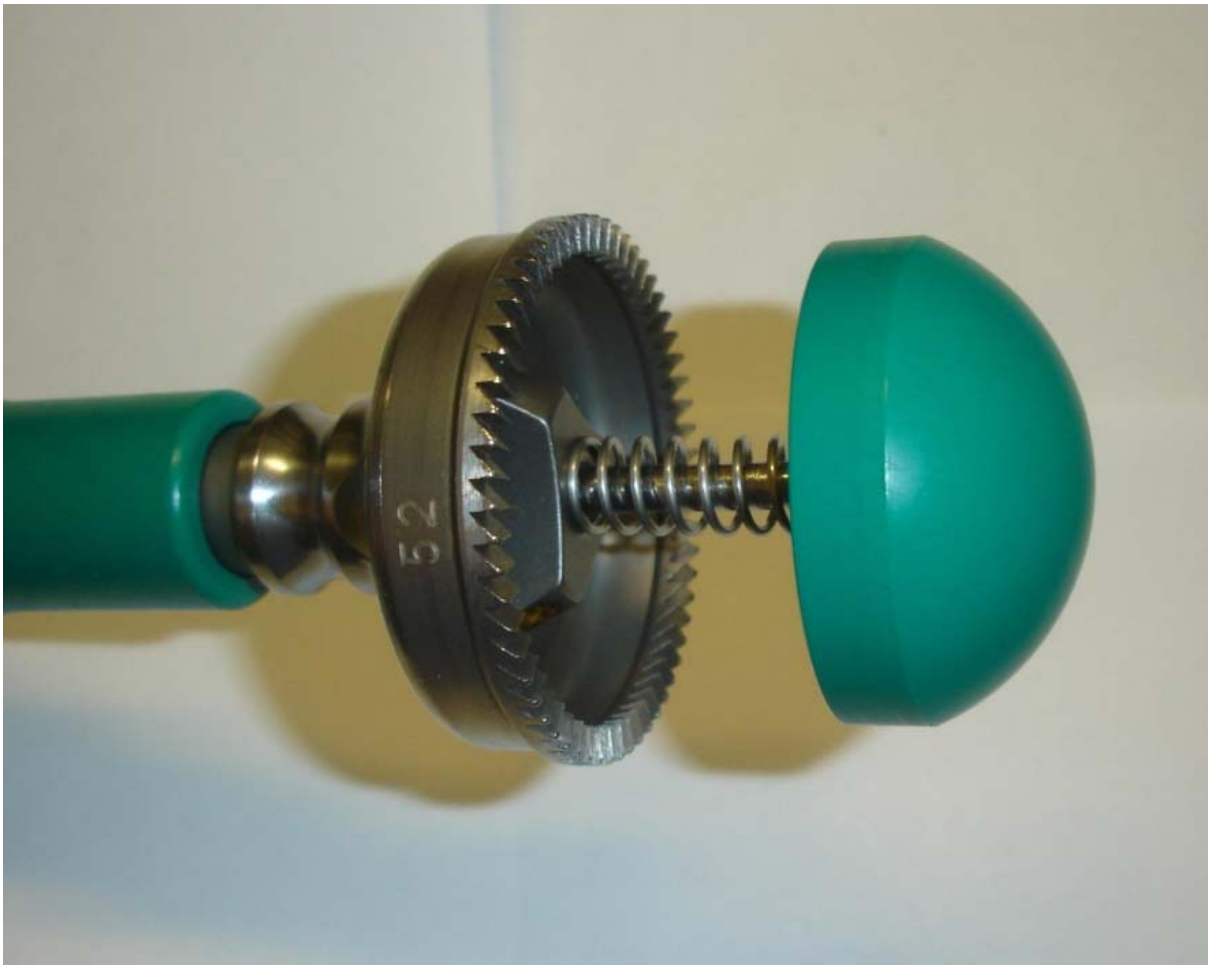


Figure 6:

