Acta Orthop. Belg., 2004, **70**, 534-539

ORIGINAL STUDY

How close does an uncemented hip stem match the final rasp position ?

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During total hip arthroplasty the final clinical position of the cementless CLS stem (Centerpulse) is not always identical to the position of the final rasp with which a successful trial reduction was performed. Therefore, the rasp-stem correspondence of CLS system (Centerpulse) was investigated in a laboratory study and compared to the CBC-T system (Mathys). Both systems showed an average rasp-stem mismatch below 2 mm in three orthogonal directions. It was found that this mismatch related to geometric differences at the corners between rasp and stem. The measured mismatch is not expected to have adverse clinical consequences.

INTRODUCTION

Malposition of a femoral hip stem may lead to leg length discrepancy, impingement, tension problems, increased risk of luxation and even increased polyethylene wear and subsequent early loosening. Using a collarless cemented stem, possible malposition can be adjusted as long as the bone cement is viscous. This is not possible with an uncemented stem. In uncemented hip arthroplasty, the surgeon trusts that the uncemented femoral stem adopts the same position in the femur as the final rasp used during a successful trial reduction. This position of the rasp is, ideally, the position that was planned pre-operatively. That reality is sometimes not ideal, was shown by Hozack *et al.* (3). They performed 100 cementless total hip arthroplasties with the modular Taperloc prosthesis (Biomet, Warsaw, IN). In 19 cases they had to use different modular components than was determined during trial reduction : 8 required a longer neck length and 11 required a shorter neck length. What are the consequences, if the position of the uncemented femoral stem is different from the position of the final rasp ? If the problem is realised during surgery,

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Although none of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but are directed solely to a research fund, foundation, educational institution, or other non-profit organization with one or more of the authors are associated. Funds were received in total or partial support of the research or clinical study presented in this article. The funding source was a grant from the Dr Robert Mathys Foundation, Bettlach, Switzerland and Mathys Ltd, Bettlach, Switzerland.

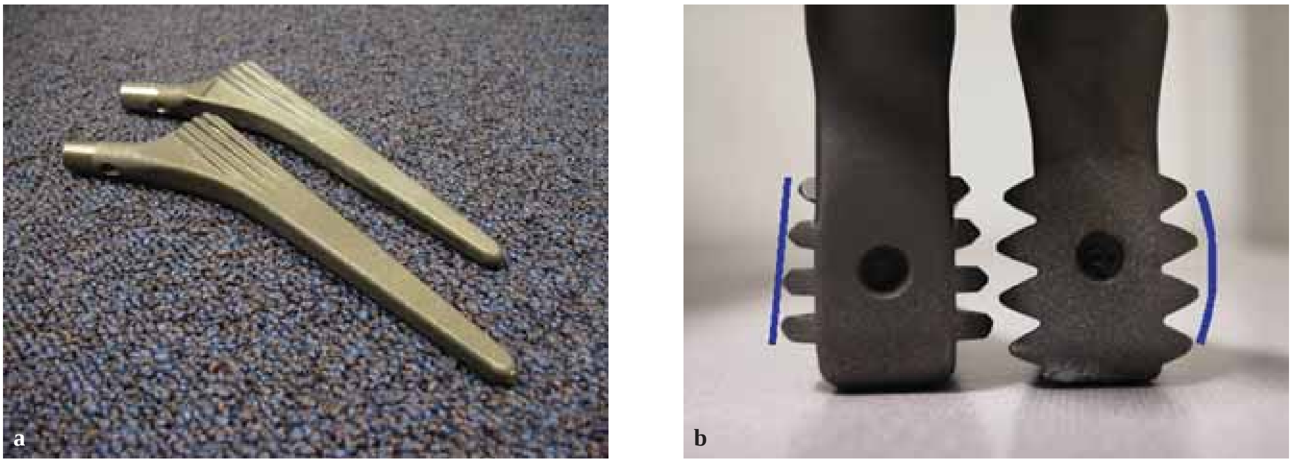

Fig. 1. — **a.** CBC-T (right, background) and CLS (left, foreground) uncemented hip stem. **b.** cross-section (top view in longitudinal direction) of CBC-T (right) and CLS (left) stem.

some degree of femoral malposition can still be corrected, especially in a modular hip system in which the offset of the prosthetic head can be adjusted. To solve a problem with a mono-block system might be difficult or even impossible. If, on the other hand, the problem is not realised during surgery, or its extent is underestimated, the patient probably ends up with a leg-length discrepancy or an unstable joint. Leg-length inequality is said to be the leading cause for litigation following total hip arthroplasty (*2*). It should be noted that leg-length inequality is not only caused by a malposition of the femoral stem, but by a combination of the position of both femoral stem and acetabular cup. Nevertheless, the acetabular cup is already in situ during the trial reduction, which was considered to be successful. Therefore, the difference which is experienced after surgery must have been caused by malpositioning of the femoral component.

Small differences in position between the final rasp and the stem will not be of much clinical significance. These small differences will not always be experienced during surgery and even post-operatively. However, a mismatch is never desired and an increase in mismatch will increase the occurrence of clinical problems. A correctly placed stem always remains the preferable situation.

In their daily clinical practice, the authors sometimes experienced a difference in trial- and final reduction with the CLS Spotorno system (Centerpulse, Baar, Switzerland). The CLS Spotorno (fig 1a : left foreground) is a straight tri-tapered stem with tapered fins. Since its introduction in 1984, it has become one of the most widely used cementless hip stems in the world, with good long term results (*1, 5, 6*). The CBC-T (Mathys Ltd, Bettlach, Switzerland) is a comparable, but relatively new, cementless hip system (fig 1a : right background). It is a straight double-tapered stem with prism shaped ribs, instead of tapered fins. For both stems, the cross section of the shaft is rectangular. In combination with the fins or ribs, the cross section of the CLS shows a wedge shape, as the cross section of the CBC-T shows an oval shape (fig 1b). The fins of the CLS are all almost equal in length (the front fin is slightly shorter) and therefore end at the same height. The central rib of the CBC-T extends more distally, which is thought to facilitate positioning of the prosthesis and prevent the stem from tipping into varus or valgus. The differences are not only limited to the stems, the rasps of both systems also show principle differences. The rasps of the CLS system have an actual saw-tooth appearance, and the rasps of the CBC-T system use a cheese rasp design.

What is the explanation for the experienced difference in trial- and final reduction for the CLS Spotorno system ? The purpose of this study was to

Fig. 2. — Rasp shape and surface contours of CBC-T stem

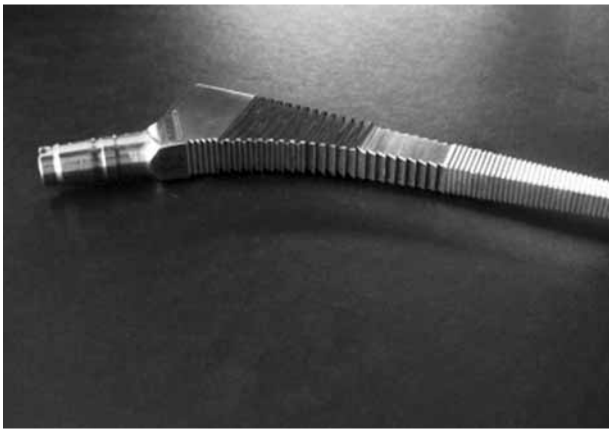

Fig. 3. — Rasp shape and surface contours of CLS stem

quantify and to explain the difference in rasp- and stem position for the CLS Spotorno system and compare these results with those of the CBC-T system. The questions in this study were : Is there a difference in placement mismatch between both uncemented stems, what is the order of magnitude of this mismatch, and can possible differences be explained by differences in rasp and stem design of both systems ?

MATERIALS AND METHODS

Five CBC-T (Size 12.5) hip stems (fig 1a : right background) and five CLS (CLS Spotorno, size 12) stems (fig 1a : left foreground) were implanted in ten composite femora (type 3306, Pacific Research Laboratories, Vashon, WA, USA). Furthermore, five CBC-T hip stems and five CLS stems were implanted in the right and left side of paired human cadaver femora, respectively. Preplanning, preparation and implantation was done according to the instructions of the manufacturers, by an experienced orthopaedic surgeon (MS) who was familiar with both systems. The femora were prepared for implantation of the stems with their original rasp sets (fig 2 and 3).

The composite femora mimic left adult femora. Cortical bone is represented with a mixture of short fibers and pressure-injected epoxy resin. A cellular rigid polyurethane foam simulates trabecular bone.

The center of rotation of both rasp and prosthesis was used as the landmark for the measurements. The difference between the two positions was considered as the mismatch of the prosthetic system. The centers of rotation were determined using RSA (Roentgen Stereophotogrammetric Analysis) (*4, 7, 8, 9*). This technique allows a measurement of the three-dimensional marker positions with an accuracy of about 40 microns using stereo radiographs.

We defined the center of a trial reduction head, which was fixed to the cones of both rasp and prosthesis, as the center of rotation of both rasp and implant. To determine the center of the trial reduction head, eight markers were glued to its surface. The positions of these 8 markers were calculated with RSA. Then, a sphere was fitted through these 8 points. The center of this sphere was defined as the center of rotation. The precision of this method was determined by double examinations and was about 0.04 mm. We used the trial reduction head, with 8 RSA markers, instead of a metal femoral head as we found the method with 8 RSA markers to be more accurate than a method that uses the stereo projection of a metal femoral head.

In addition to the 8 head markers, 9 markers were attached to the femora, to allow calculation of the position of the center of rotation relative to the bone. By comparing the position of the center of rotation, obtained for the rasp and the stem, rasp-stem mismatch could be calculated.

Two-way ANOVA was applied to the mismatch data of the implantations in composite femora. A paired t-test was applied to the mismatch data in the paired cadaver femora. Rasp-stem position mismatches were considered as build-in systemic errors if a zero-mismatch was not captured in the 95% confidence interval (see also fig 4).

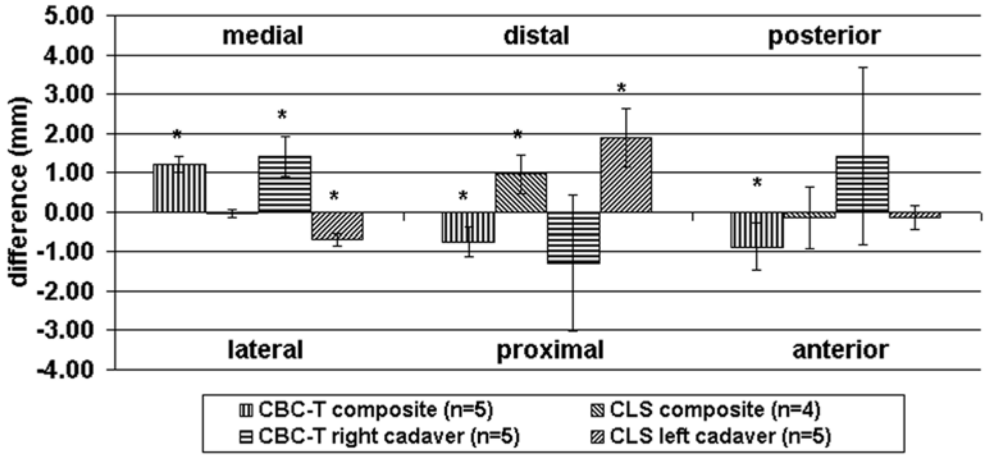

Fig. 4. — Difference between rasp- and stem position. Bars marked with * represent values significantly different from zero.

Finally, in an attempt to explain rasp-stem mismatches, the three-dimensional shape of both the rasp and stem was digitised. These measurements were performed with a CNC 3D coordinate measuring machine (BHN-305, Mitutoyo). Over- or under sizing of the prosthesis relative to the rasp was calculated by determining the maximum antero-posterior width and maximum medio-lateral width at 5 mm intervals along the length of the prosthesis or rasp. The reconstructed models of prosthesis and rasp were superimposed to compare the overall geometry. In this way, over- or under sizing of the rasp relative to the prosthesis could be visualized.

RESULTS

The average rasp-stem mismatch of the CBC-T and CLS systems was within 2 mm for the medio-lateral, proximo-distal and antero-posterior direction, respectively (fig 4). With the CBC-T stem implanted in composite femora, system errors were found in the medial, proximal and anterior directions. These errors were found in the cadaveric bones in the medial and proximal directions only : instead of an anterior, a posterior mismatch was found.

The CLS stem produced a systemic error only in the distal direction with the composite femurs and in distal and lateral directions with the cadaver bones. Hence, the mismatch results obtained with composite and cadaver femora were in good agreement. In general, the mismatch found with cadaver femora showed larger mean values compared to the mismatch found with composite femora. One should note that the proximo-distal mismatch was opposite for the CBC-T stem (stem placed too proximally) as compared to the CLS system (stem placed too distally).

The calculated antero-posterior and medio-lateral stem-rasp oversizing did show considerable differences. The CLS system had a little more prosthetic oversizing at the proximal side than the CBC-T stem (fig 5). Hence, this would suggest that the CLS stem would be placed higher (more proximal) than the CBC-T stem relative to their final rasp positions. However the contrary was found. When the mismatch in the corner areas was considered, it appeared that the CBC-T stem was slightly oversized at these locations relative to its rasp geometry, whereas the CLS stem was slightly undersized at the corners (fig 5). This difference was caused by geometrical differences of the two rasp systems. The cross sectional shape of the rasp of the CLS system was rectangular with sharp corners, whereas the shape of the CBC-T rasp had more rounded corners.

DISCUSSION

In this study the rasp-stem correspondence of two cementless hip systems was experimentally determined. The rasp-stem mismatch, found for the

Fig. 5. — Overlay of rasp (grey) and stem (black) geometry, for CBC-T (left) and CLS stem (right). Note that the mid-shaft area of the CLS stem shows stem oversize because of the absence of teeth on the rasp (see also Figure 2).

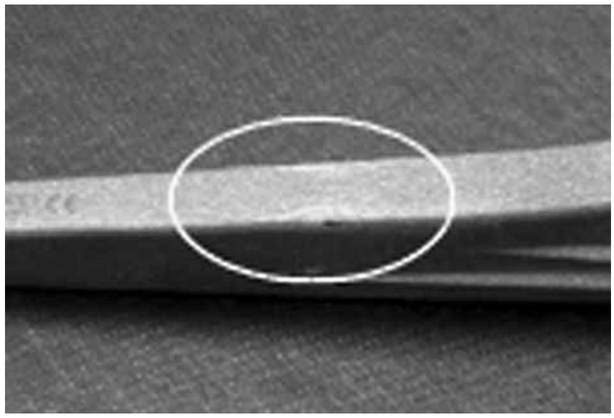

Fig. 6. — Burnishing marks on an extracted CBC-T stem, after tests on cadaver femurs (it might be observed in both CBC-T and CLS stems).

two uncemented hip stems, was similar in order of magnitude but opposite in direction. The CBC-T stem was placed slightly too proximally, whereas the CLS stem was placed slightly too distally. The difference in these mismatch directions can possibly be related to differences in corner geometry between rasp and stem. This suggestion is supported by the burnishing marks which were found at the corners of stems that were extracted after the experiments (fig 6). These burnishing marks indicate the area of stem/bone contact.

There is also a difference in rasp principle between both systems. The CBC-T rasp has a cheese rasp appearance and the rasp surface of the CLS stem has a saw-tooth appearance (figs 2 & 3). There may be a difference between both rasp principles in the ratio of removed material and impacted material. It is unlikely, however, that this actually influences the placement mismatch, as it influences the placement of both final rasp and stem in the same way. In composite femora, it is questionable whether this possible difference in ratio of removed and impacted material is functional after all. Rasping of trabecular material in composite femora results merely in removal of material instead of the impaction which is experienced in cadaver material. Therefore, the idea of impacting or compacting bone does not work with composite femora, as it does in cadaver femora. Nevertheless, the composite femora still showed a similar placement mismatch in comparison to the cadaver femora. This seems to indicate that there is no functional difference in rasp principle between the two systems.

Measured deviations between rasp and stem of less than 2 mm may be considered as of very low clinical relevance. This is supported by the fact that the modular CLS stem has good long term results in the Swedish Hip Arthroplasty Register (99.4% survival after 7 years (n = 276) (*5*)), and in other studies (*1, 6*). Still, a rasp-stem mismatch is not advantageous. Ideally, there should be no difference between the position of the center of rotation after the trial reduction and the position of the center of rotation after placement of the prosthesis. Any mismatch from the planned (and tested) position is undesirable and forms a potential source of clinical problems.

A difference in trial and final reduction as experienced during general clinical practice was not reproduced in this study. During the experiments, we were not aware of visual differences in placement between the final rasp and the prosthesis, which is underlined by the small differences which were measured. Therefore, a clinically experienced mismatch in position between the final rasp and the prosthesis has to be caused by a more complex interaction between different factors, and not only by differences in rasp and stem geometry. The current study was limited, as it was a laboratory study, which focused on an instrument related factor. The clinically experienced mismatch seems to be caused by a complex interaction between instrument, prosthetic, patient and surgeon related factors. One system may, of course, always be more susceptible to misplacement, in comparison to others.

One could argue that early subsidence may neutralise a stem placed too proximally. A stem which is placed slightly more proximally will also enhance stability as the capsule and muscles are stretched accordingly. A similar effect is obtained with a longer neck, a larger head (*3*), or a stem with a lateral offset. The only difference is that a stem with a lateral offset will not increase leg length. A stem which is placed slightly more distally, on the contrary, will enhance instability. In that respect the CBC-T systemic error may be of less concern than the error of the CLS system.

In conclusion, the authors found a relatively small mismatch in rasp-stem positions for both the CBC-T and the CLS prosthetic system. Although the mismatch was in the same order of magnitude (< 2 mm), it was in different directions. This difference of the placement mismatch in proximo-distal direction could be explained by small stem-rasp oversize or undersize at the corners along the shaft. As the CLS stem performs clinically well, we conclude that the small rasp-stem deviations of both systems are not of clinical relevance.

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