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Plug migration and cement mantle assessment in total hip replacement

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Abstract We reviewed a series of consecutive total hip replacements with cemented femoral components. Modern cementing techniques were followed in all cases, but two different medullary plugs were used—one was polyethylene and the other bioabsorbable gelatin. Cement mantle quality and plug migration were assessed by three different observers (X, Y, and Z); their findings did not agree. This was particularly evident when the cement mantles were assessed. There was a better cement mantle grading and less distal migration with polyethylene plugs, although there was no significant statistical difference between the two groups.

Résumé Nous avons étudié une série de prothèses totales de hanche consécutives avec un composant fémoral cimenté. Les techniques modernes de cimentage ont été utilisées dans tous les cas avec une obturation médullaire par un bouchon de polyéthylène ou par un bouchon de gélatine bio—absorbable. La qualité du manchon cimenté et la migration du bouchon ont été évaluées par trois observateurs différents. Pour l'évaluation du manchon de ciment la concordance inter observateur a été mauvaise. Dans les cas avec obturateur en polyéthylène un manchon de ciment de meilleure qualité et une moindre mi-

gration distale du bouchon ont été notés, sans signification statistique cependant.

Introduction

The use of uncemented, press-fit, acetabular components combined with cemented femoral stems is considered by many to be the current “gold standard” for total hip replacement [14]. The development of so-called second- and third-generation cementing techniques is intended to improve the introduction of cement into the cancellous bone bed. Any void in the cement mantle is thus decreased, and the stem is centralized within the cement mantle in order to avoid loosening of the femoral component [9]. These techniques require some or all of the following: plugging of the medullary canal, pulsatile lavage of the bone bed, retrograde filling of the canal with cement, pressurization of the cement within the canal, porosity reduction of the bone cement, the use of a stem centralizer on the distal part of the femoral stem, and proximal pressurizers [1].

The two critical features that determine the passage of cement into the bone are its viscosity and the pressure used during delivery. This pressurization is best done in a retrograde fashion using a cement gun and an adequate femoral seal [4]. The medullary plug seals the medullary canal below the tip of the stem and thus should obstruct any cement flow beyond this level. It should also be fixed firmly to the endosteal cancellous bone in order to prevent plug migration during pressurization, as this would result in less “cement pressure” on the medullary cancellous bone proximal to the plug. This in turn would produce less cement penetration and allow excessive cement migration distal to the stem tip [2, 12].

There are only a few reports of comparative in vivo studies of different medullary plug design stability. Thomsen compared three polyethylene plug designs [16], and Bulstra tested a biodegradable polylactic model with a polyethylene plug [3].

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The purpose of our study of a series of consecutive cemented or hybrid total hip replacements was to assess retrospectively the cement mantle quality of the cemented femoral prosthesis when combined with the use of two different medullary plugs.

Material and methods

Between January and November 2002, 72 primary total hip replacements in 72 patients were performed at our institution. A cemented stem was used in 25, and three were excluded from the series because of a lack of relevant radiographs. Thus, the series contained 22 patients. In eight, a cemented total hip replacement was introduced and in 14 a hybrid total hip replacement was used. There were 19 women and three men. The mean age of the women was 65 years with a range of 44–80 (σ 9.8) and the men averaged 70 years with a range of 64–76 (σ 6.1). There were nine left hips and 13 right hips. Eighteen patients had osteoarthritis, two rheumatoid arthritis, one avascular necrosis, and one a femoral neck fracture. The mean age for the cemented total hip group was 70 (σ 8.9), and there were six women and two men. For the hybrid total hip group, the mean age was 63.8 years (σ 10) and there were 13 women and one man.

The same cementing technique was used in all patients and was combined with femoral canal broaching and reaming, medullary canal lavage and cleaning with a peroxide-soaked sponge, retrograde filling with distal plugging using a proximal femoral seal, and low viscosity cement with vacuum mixing. Two different designs of medullary plugs were used: The Biostop plug (Bioland, Toulouse, France) is made of bioabsorbable gelatin and is available in sizes 8–20 mm with increments every 2 mm; the canal was measured to determine the appropriate size, and an introducer was used to position the plug 20 mm distal to the tip of the stem. The Cemex Prepackit plug (Tegres S.p.A. Verona, Italy) is made of polyethylene, is available in two sizes (small and large), and is supplied with a canal preparation kit. The proper level of insertion is 2 cm distal to the stem tip; the smaller plug is inserted first, and if this is a loose fit then it is exchanged for the larger size (Fig. 1).

Three different observers examined the A-P postoperative pelvic X-rays and the cement mantle was assessed using Barrack's [1] system that divides the quality of the cement mantle into four categories. In all categories, the cement mantle was measured distal to the lesser trochanter, and this examination was continued distally to 1 cm below the stem tip. An A grade represents complete filling of the medullary cavity by bone cement with no radiolucencies between the cement mantle and bone. In grade B

Fig. 1 A gelatin bioabsorbable Biostop plug is shown on the left and a polyethylene Cemex plug on the right

Fig. 2 Hybrid total hip replacement. The cement mantle was graded B. A gelatin bioabsorbable plug was used and it is located 30 mm distal to the stem tip. The centralizer can be seen at the stem tip. The void in the cement mantle is not considered because it is below the stem

Fig. 3 Cemented total hip replacement with a Charnley flanged stem. The cement mantle was graded A or B by different observers. A polyethylene plug was used and is located 30 mm below the stem tip

there is up to 50% of radiolucency at the cement/bone interface. Grade C presents radiolucencies in 50–99% of the cement/bone interface, and if any void or deficiency is present in the cement mantle, the result is recorded as type C. Type D cement mantles have 100% radiolucency or no cement distal to the stem tip (Figs. 2 and 3).

Distal migration of the medullary plug was also measured and was recorded in millimeters from the stem tip. A data collection sheet was used and included each patient's file number, together with Barrack's classification of cement mantle grading. A specific space for each grade of Barrack's classification was available in front of each patient's file number, along with a space for noting the number of millimeters of plug migration.

Statistical analysis

A descriptive statistical analysis (ANOVA) was used to compare the observations of the three observers for distal plug migration. The interrater agreement of Barrack's scoring system between the three observers was done with the kappa statistic measure. We used the Landis and Koch [11] interpretation, and Student's *t* test was used to compare the differences between the two groups.

Results

Ten bioabsorbable and 12 polyethylene plugs were used; nine (90%) bioabsorbable plugs were used in women patients and one (10%) in one man. Ten polyethylene plugs were used in the women (83%) and two (17%) in the men. Patients with the bioabsorbable plug had a mean age of 64 years (σ 11.3) and patients with the polyethylene plug a mean age of 67.8 years (σ 8.6). There was no statistical difference in age between the two groups ($p=0.38$).

Cement mantle grading

According to Barrack's classification system, observer X determined that 11 cement mantles belonged to the grade A group, which included seven polyethylene and four bioabsorbable plugs. There were nine grade B mantles, of which five had a bioabsorbable and four a polyethylene plug. There were two with C cement mantles, one with a bioabsorbable and the other a polyethylene plug. No D cement mantles were described by X who reported eleven polyethylene and nine bioabsorbable plugs with an excellent (grade A mantle) or good (grade B mantle) result.

Observer Y noted that there were three grade A cement mantles, and all were associated with polyethylene plugs. The B grade cement mantle group consisted of 17 patients, of whom ten had a bioabsorbable and seven a polyethylene plug. Y noted two examples of grade C cement mantle, and one of each type of plug was used in these. No examples of type D cement mantle were recorded by Y, though he did note ten examples of each plug group with an excellent or good cement mantle but only the polyethylene group was in the excellent cement mantle grade.

Observer Z found three examples of grade A cement mantle, two with a polyethylene plug and one with a bio-

Fig. 4 Cemented total hip replacement with a Charnley CDH stem. The cement mantle was graded A, but there is a 90 mm distal migration of the gelatin bioabsorbable plug

absorbable plug. Eleven patients were in the grade B cement mantle, seven with a polyethylene plug and four with a bioabsorbable plug. There were eight grade C cement mantles, of which five had a bioabsorbable and three a polyethylene plug. Z noted 14 patients with good or excellent cement mantles, of which nine had a polyethylene plug and five a bioabsorbable plug.

Overall there were 30 excellent or good cement mantles in the group with a polyethylene plug and 24 excellent or good in the group with a bioabsorbable plug.

The kappa test for interobserver concordance showed that between X and Y there was an agreement factor of 0.25 and between X and Z a factor of 0.27, both of which are considered fair. Between Y and Z the agreement factor was 0.191, which is considered slight.

Plug migration

For plug migration, X reported 38.3 mm (σ 24.6) of mean distal migration for the whole series with a range of 10–85 mm (Fig. 4).

In the bioabsorbable plug group, X noted the mean distal migration to be 48.3 mm (σ 28.3) with a range of 15–85 mm. In the polyethylene plug group, X reported a mean migration of 30 mm (σ 18) with a range of 15–85 mm. Thus, there was no statistically significant difference between the distal migration of the two types of plug according to X ($p>0.08$, Student's *t* test).

The overall migration for Y was of 45.5 mm (σ 22.6) with a range of 10–90 mm. In the bioabsorbable plug group, the mean distal migration was 54 mm (σ 27) with a range 20–96. In the polyethylene plug group, the mean distal migration was of 38.3 mm (σ 15.97) with a range of 28–86 mm. Thus, there was no statistically significant difference between the distal migration of the two plugs according to Y ($p>0.10$, Student's *t* test).

The overall migration according to Z was of 35 mm (σ 22.6) with a range of 9–85 mm. In the bioabsorbable plug group, the mean distal migration observed by Z was 45.5 mm (σ 26.3) with a range of 9–85 mm. In the polyethylene plug group, the mean distal migration was 27.8 mm (σ 15.9) with a range of 16–75 mm. Thus, there was no statistically significant difference between the distal migration of the two types of plug according to Z ($p>0.06$, Student's *t* test).

In addition, there was no statistically significant difference when comparing the mean plug migration between all three observers with the ANOVA test ($p>0.37$).

Discussion

The importance of good cementing technique in the long-term results of total hip replacement has been reported [6, 13, 15]. This technique demands an adequate cement mantle, which is achieved by filling the medullary canal around the stem allowing no radiolucencies at the implant/cement interface or at the cement/bone interface. There should be no voids or defects within the cement mantle, but there should be the presence of bone beyond the tip of the stem [5, 7].

When considering the role of the cement mantle in producing good long-term results with total hip replacement, the description and analysis of the resulting cement mantle of the cemented stem is important. However, various studies using the cement mantle grading method of Barrack et al [1] have shown that there is a large interobserver variation when this method is used [8, 10]. In our study, we found that the interobserver agreement was inadequate when using the Barrack grading method and only resulted in fair or slight interobserver concordance. However, our observers received no training in classifying these cement mantles before assessing the X-rays. In fact, the classification was first presented to them printed on the data-collecting sheet, and this fact may well have influenced the large variation of their grading. It also shows that Barrack's grading system is neither simple to use nor reliable. The greatest differences were detected between the A and B categories, while there was more agreement in the C group. Most of our hips were placed within the groups A or B, and there were none in group D. This might be a result of the use of modern cementing techniques.

While the good long-term studies of large series of patients with long follow-ups and where cemented femoral implants with the use of modern cementing tech-

niques were used do not classify or grade the type of cement mantles, we can probably assume that D cement mantles were rare [6, 13, 15]. When we compared the two different designs of medullary plugs used with the cement mantle, the best results were with the polyethylene plug.

Distal migration of the cement plug may result in less cement pressure and less insertion of cement into the endosteal cortex of the femoral medullary canal [12]. This also results in the need for more cement in order to fill the canal, which in turn will render more difficult any subsequent surgical procedures. In our study, we measured distal migration of the two types of medullary plug inside the femoral canal. We found that the polyethylene plug as compared with the bioabsorbable plug moved less, but this difference was not statistically significant. The small number of patients in our series may explain this, although the trend suggested that the polyethylene plug might be associated with the achievement of a more adequate cement mantle. Study of a larger series of patients might confirm this supposition.

We have confirmed the need for a better method of grading the cement mantle but have been unable to find any relevant references. We know that distal migration of the medullary plug represents a potential problem, and in our hands the polyethylene Cemexmedullary plug proved to be more reliable, perhaps because it is supplied in different sizes. The concept of a bioabsorbable plug is attractive, particularly if any revision surgery is going to be needed.

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