S. Glyn-Jones · J. Hicks · J. Alfaro-Adrian
H. S. Gill · P. McLardy-Smith · D. W. Murray

The influence of cement viscosity on the early migration of a tapered polished femoral stem

Accepted: 9 July 2003 / Published online: 12 August 2003
© Springer-Verlag 2003

Abstract It is unclear whether it is best to use high-viscosity or low-viscosity cement for fixation of total hip replacement (THR) femoral components. This study examines the influence of cement viscosity on the migration of the Exeter femoral component using roentgen stereophotogrammetric analysis (RSA). Simplex, CMW1 and CMW3 G cements were examined in a total of 46 patients over a 12-month period. The overall pattern of migration for all cohorts was one of subsidence and rotation into valgus. There was no significant difference in any aspect of migration between the groups. In vitro studies demonstrate that low-viscosity cement forms a more stable bone-cement interface. Several groups have examined the in vivo effect of cement viscosity on stem longevity with conflicting results. For a polished, tapered implant that is designed to subside, cement viscosity does not influence the 1-year migration, and it is therefore unlikely to affect long-term outcome.

Résumé Il n'est pas précisé actuellement s'il est meilleur ou non d'utiliser un ciment de basse ou haute viscosité pour la fixation des composants fémoraux des PTH. Cette étude examine l'influence de la viscosité du ciment sur la migration du composant fémoral de type Exeter, en utilisant le système RSA. Les ciments Simplex, CMW1 et CMW3 G ont été examinés dans un total de 46 malades sur une période de 12 mois. Le modèle de migration pour toutes les cohortes était une descente et rotation en valgus. Il n'y avait aucune différence notable dans l'aspect de migration entre les groupes. Les études in vitro démontrent que le ciment de basse viscosité forme une interface os-ciment plus stable. Plusieurs groupes ont examiné l'effet in vivo de la viscosité du ciment sur la longévité de la tige, avec des résultats discor-

dants. Pour un implant conique poli qui est conçu pour descendre, la viscosité du ciment n'influence pas la migration dans la première année et c'est peu probable que le résultat à long terme soit influencé.

Introduction

Traditional cements such as CMW (DePuy, Leeds, UK) and Simplex (Stryker, Newbury, UK) are high viscosity and were designed to be introduced by hand. More recently developed cements such as CMW3 (DePuy, Leeds, UK) have a lower viscosity during curing and are designed for retrograde application with a gun.

The bone-cement interface is integral to the stability of the femoral component in total hip replacement (THR). Lower viscosity cements have been shown to produce a more stable bone-cement interface in vitro [12, 13] through increased penetration of medullary bone; this gives a better mechanical interlock and consequently enhanced resistance to shearing forces. However, this in vitro finding has not been confirmed by in vivo survival studies [4, 5, 11]. The Norwegian Hip Registry has studied over 20,000 cemented THR using survival analysis, looking at four main types of cement. It showed significant differences in the revision rate depending on cement viscosity and suggested that the low-viscosity cements, CMW3 and Boneloc (Biomet Inc, Warsaw, USA), are associated with a higher revision rate. Data from the Swedish Hip Registry [10] also suggests that lower-viscosity cements are associated with a higher risk of revision. This data, like that of the Norwegian Hip Registry, includes many types of prostheses and various surgical approaches. This may introduce bias into the effect of a single factor.

Conversely, a roentgen stereophotogrammetric analysis (RSA) study [11] demonstrated that cement viscosity has no effect on any aspects of femoral component migration and therefore should not influence longevity. However, in that study there were 14 subjects, out of which only three showed significant movement; it is

S. Glyn-Jones · J. Hicks · J. Alfaro-Adrian · H. S. Gill (✉)
P. McLardy-Smith · D. W. Murray
Oxford Orthopaedic Engineering Centre,
Nuffield Orthopaedic Centre,
Windmill Road, Headington, Oxford, OX3 7LD, UK
e-mail: richie.gill@ndos.ox.ac.uk
Tel.: +44-1865-227457, Fax: +44-1865-742348

Table 1 Patient distribution in study groups

	Cement type		
	Simplex	CMW1	CMW3
Gender (M:F)	1:1.8	1:2.8	1:2
Age: mean (range)	70 (54–85)	68 (47–79)	68 (49–80)
Surgical approach (lateral:posterior)	1:1.2	1:1	1:1
Offset allocation (mean)	44	44	44
Size allocation (mean)	2	2	2

likely the study was underpowered. It therefore cannot conclusively answer the question: “Does cement viscosity affect femoral component migration and hence longevity?”

We have undertaken an RSA study of 46 patients to determine whether cement type influences femoral component migration for a polished, tapered femoral component.

Material and methods

We studied 46 patients, each having received an Exeter femoral stem (Stryker, Newbury, UK) with a Charnley Elite cemented cup (DePuy, Leeds, UK). Three surgeons were involved. Three types of cement were used: 18 subjects had Simplex (Stryker, Newbury, UK), 16 had CMW3 and 12 had CMW1 (DePuy, Leeds, UK). Exeter cement restrictors were used and the cement was pressurised in all cases. Patients were included in the study if they were fit and had been fully consented. Subjects with disabling systemic illness or bone disease other than osteoarthritis were excluded. Distribution of patients in terms of gender, age, surgical approach and sizing was approximately equal over the three groups (Table 1). All patients had 0.8 mm tantalum marker balls implanted at standardised points on the femur [1].

RSA was used to measure implant migration. The Oxford technique has been previously described [1] and can measure movements with a clinical precision of 0.3 mm. RSA X-ray stereopairs were made post-operatively and then at intervals of 3, 6, and 12 months. From the RSA stereopairs the three-dimensional (3D) positions of the prosthesis and host bone were reconstructed. Using the immediate post-operative measurement as a baseline, the RSA measurements gave the stem migration at 3, 6, and 12 months.

The data was examined for distribution prior to analysis. A multivariate ANOVA was used to determine significant differences between groups. For those aspects of migration in which group differences approached significance, an independent group *t*-test was used as a more sensitive indicator of significance. All calculations were performed in SPSS 10 (SPSS Inc, Woking, Surrey, UK).

Results

The migration data was found to be normally distributed. The overall pattern of migration for all cohorts was one of subsidence (Fig. 1) and rotation into valgus (Fig. 2), which is typical for the Exeter stem. In addition, the implants tended to internally rotate within the femur, indicated by posterior-head migration (Fig. 3). The largest movement in all groups was subsidence; this amounted to about 1 mm in the first year. Head subsidence was 1.15 ± 0.17 mm [mean $\pm$ standard error of the mean,

Fig. 1 Subsidence of Exeter stem for Simplex, CMW1 and CMW3 cements over first year post-operation. Mean and standard errors are presented

Fig. 2 Medial tip migration of Exeter stem for Simplex, CMW1 and CMW3 cements over first year post-operation. Mean and standard errors are presented

(SEM)] for the Simplex group, 0.86 ± 0.37 mm for the CMW1 group and 0.93 ± 0.23 mm for the CMW3G group (Fig. 1 and Table 2). The largest amount of medial-tip migration was observed for the CMW1 group— 1.47 ± 0.56 mm, compared to 0.45 ± 0.25 mm and 0.16 ± 0.34 mm for the Simplex and CMW3G groups respectively (Fig. 2 and Table 2). Simplex cement showed

Table 2 One-year stem migration in millimetres for each cement type. Component migration is given along anatomical planes for the head, shoulder and tip of the femoral stem. *SEM* standard error of the mean

		Simplex		CMW1		CMW3	
		Mean	SEM	Mean	SEM	Mean	SEM
Head	Distal	1.15	0.17	0.86	0.37	0.93	0.23
	Posterior	0.66	0.19	0.56	0.43	0.59	0.27
	Medial	0.02	0.08	-0.26	0.18	-0.18	0.11
Shoulder	Distal	1.1	0.15	1.18	0.35	0.94	0.22
	Posterior	-0.21	0.36	-0.13	0.82	-0.42	0.51
	Medial	0.01	0.11	-0.22	0.24	-0.14	0.15
Tip	Distal	1.07	0.18	1.26	0.38	1.0	0.24
	Posterior	0.11	0.05	-0.06	0.11	0.10	0.07
	Medial	0.45	0.25	1.47	0.56	0.16	0.34

Fig. 3 Posterior head migration of Exeter stem for Simplex, CMW1 and CMW3 over first year post-operation. Mean and standard errors are presented

the largest amount of posterior head migration— 0.66 ± 0.19 mm compared to 0.56 ± 0.43 mm and 0.59 ± 0.27 mm for CMW1 and CMW3G respectively.

The results of the multivariate ANOVA showed that there was no significant difference in migration between any of the types of cement ($p=0.56$) at any time point. As the difference in medial-tip migration between CMW1 and Simplex appeared to be approaching significance (Table 2 and Fig. 2), the independent samples *t*-test was used. This confirmed the MANOVA results, which showed no significant difference ($p=0.11$). A retrospective power calculation was performed using Altman's nomogram [3], which showed that the study was of adequate power with a minimum of ten subjects required in each group to detect significance (difference of interest = 0.3 mm, standard deviation (SD) = 0.25, $\alpha = 0.1$, $\beta = 0.9$). A difference of interest of 0.3 mm was chosen as previous studies [7] have suggested that migrations of more than 0.4 mm are likely to be significant.

Discussion

Our study suggests that cement viscosity has no influence on the first-year migration behaviour of the Exeter femoral component. Importantly, we demonstrate that the viscosity of a cement has no influence on the components of migration that are thought to be associated with premature failure, namely posterior-head migration [1] and subsidence [6].

Lower-viscosity cements are claimed to better penetrate medullary bone than higher-viscosity compounds, resulting in a bone-cement interface that has an increased resistance to shearing. Critics of low-viscosity cement claim that larger volumes are injected into the bone when cementing the femur. This in turn is claimed to increase endosteal damage due to heat [11, 14]. Thanner [16] and others [15] question this and have demonstrated that thermal osteonecrosis is only seen in 10% of cemented prostheses.

Mjoberg [11], using RSA, found that cement viscosity had no effect on prosthesis migration. His study, using the Scan prosthesis with Osteopal G and Palacos R, looked at only 14 femoral components, three of which migrated. It is difficult to extrapolate his findings to the Exeter stem given the different prosthesis used and the relatively small numbers. Conversely, both the Norwegian and the Swedish Hip Registries show that stems implanted using low-viscosity cement are more likely to fail. However, it is suggested that these findings may be due to a lack of experience with the low-viscosity cementing technique. In addition, these studies did not standardise for implant type and considered both polished and matt stems of differing design. These findings may therefore not apply to devices like the Exeter that are designed to subside, and hence do little to clarify the issue.

We believe our study provides strong RSA evidence demonstrating that cement viscosity before curing is relatively unimportant in determining the longevity of the Exeter femoral component. Our RSA findings appear to differ with what might be expected when the *in vitro* properties and dynamics of the cement are considered—that is, that low-viscosity cements should be associated

with a lower revision rate. There are a number of factors that may explain these differences. In vitro, the lower viscosity allows greater bone penetration and therefore a better mechanical interlock. Surgeons may apply the cement in vivo when they deem the consistency is correct. As a result, the later application of a lower-viscosity cement will effectively produce a high viscosity cement, so the mechanical interlock will be similar. The cements used in this study have similar cured properties [8, 9]. They all have similar compressive and bending strengths and, in addition, they display similar bending moduli and fatigue strengths. These cured properties probably account for the similarity in observed migration patterns.

In this study we have looked at the Exeter and demonstrated that it subsides within the cement mantle, as in previous studies [1]. With other stems, such as the Elite [2], we have demonstrated that significant movement also occurs at the bone-cement interface. In these cases where the cement mantle subsides as well, viscosity may have an important effect on migration and subsequent implant longevity.

This study demonstrates that cement viscosity has no effect on prosthesis migration for an Exeter-type stem and therefore probably has no effect on longevity.

References

1. Alfaro-Adrian J, Gill HS, Murray DW (1999) Cement migration after THR. A comparison of Charnley elite and Exeter femoral stems using RSA. *J Bone Joint Surg [Br]* 81:130–134
2. Alfaro-Adrian J, Gill HS, Murray DW (2001) Should total hip arthroplasty femoral components be designed to subside? A radiostereometric analysis study of the Charnley elite and Exeter stems. *J Arthroplasty* 16:598–606
3. Altman D (1999) Practical statistics for medical research. Chapman and Hall, London
4. Havelin LI, Espehaug B, Vollset E, Engesaeter LB (1995) The effect of the type of cement on early revision of Charnley total hip prosthesis. *J Bone Joint Surg [Am]* 77:1543–1550
5. Havelin LI, Engesaeter LB, Espehaug B, Furnes O, Lie SA, Vollset E (2000) The Norwegian Arthroplasty Register. *Acta Orthop Scand* 71:337–353
6. Karrholm J, Herberts P, Hultmark P, Malchau H, Nivbrant B, Thanner J (1997) Radiostereometry of hip prostheses. Review of methodology and clinical results. *Clin Orthop* 344:94–110
7. Kobayashi A, Donnelly WJ, Scott G, Freeman MA (1997) Early radiological observations may predict the long-term survival of femoral hip prostheses. *J Bone Joint Surg [Br]* 79:583–589
8. Kühn KD, Specht R, Ege W, Kock HJ (2001) Mechanical properties of bone cement. In: Walenkamp G, Murray DW (eds) *Bone cements and cementing technique*. Springer-Verlag, Berlin Heidelberg New York
9. Lewis G (1997) Properties of acrylic bone cement: state of the art review. *J Biomed Mater Res* 38:155–182
10. Malchau H, Herberts P, Söderman P, Odén A (2000) Prognosis of total hip replacement. Update and validation of results from the Swedish National Hip Arthroplasty Registry 1979–1998. In: 67th AAOS; 2000; Orlando, USA
11. Mjoberg B (1986) Loosening of the cemented hip prosthesis. The importance of heat injury. *Acta Orthop Scand Suppl* 221:1–40
12. Reading AD, McCaskie AW, Barnes MR, Gregg PJ (2000) A comparison of 2 modern femoral cementing techniques: analysis by cement-bone interface measurements, computerized image analysis, and static mechanical testing. *J Arthroplasty* 15:479–487
13. Stone JJ, Rand JA, Chiu EK, Grabowski JJ, An KN (1996) Cement viscosity affects the bone-cement interface in total hip arthroplasty. *J Orthop Res* 14:834–837
14. Sturup J, Madsen J, Tondervold E, Jensen JS (1990) Decreased blood perfusion in canine tibial diaphysis after filling with acrylic bone cement compared with inert bone wax. *Acta Orthop Scand* 61:143–147
15. Sturup J, Nimb L, Kramhoft, Jensen, JS (1994) Effects of polymerization heat and monomers from acrylic cement on canine bone. *Acta Orthop Scand* 65:20–23
16. Thanner J, Freij Larsson C, Kärrholm J, Malchau H, Wesslen B (1995) Evaluation of Boneloc. Chemical and mechanical properties, and a randomized clinical study of 30 total hip arthroplasties. *Acta Orthop Scand* 66:207–214