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Pulse-lavage brushing followed by hydrogen peroxide–gauze packing for bone-bed preparation in cemented total hip arthroplasty: a bovine model

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ABSTRACT

Purpose. To compare the effectiveness of pulse-lavage brushing followed by hydrogen peroxide–gauze packing with either technique alone or normal-saline irrigation in bone-bed preparation for cemented total hip arthroplasty.
Methods. 44 fresh-frozen ox femoral canals were prepared for cemented total hip arthroplasty using 4 techniques: normal-saline irrigation, pulse-lavage brushing, hydrogen peroxide–soaked gauze packing, and a combination of the latter 2 techniques. The maximum tensile pull-out force required to separate the prosthesis from the femoral canal was measured as an indicator of the strength of the cement-bone interface.
Results. The mean pull-out force to separate the prosthesis from the femoral canal was significantly higher in specimens prepared with pulse-lavage brushing followed by hydrogen peroxide–soaked gauze packing or pulse-lavage brushing alone than those prepared with normal-saline irrigation or hydrogen peroxide–soaked gauze packing alone ($p<0.001$).
Conclusions. Pulse-lavage brushing is more effective at cleansing the femoral canal and increasing mechanical strength at the cement-bone interface than preparation with normal-saline irrigation or hydrogen peroxide–soaked gauze packing.

Key words: *arthroplasty, replacement, hip; bone cements; femur; hip prosthesis; hydrogen peroxide*

INTRODUCTION

The most common late complication following cemented joint replacement surgery is aseptic loosening of the prosthesis secondary to failure of the cement-bone interface.[1,2] Stable fixation of acrylic bone-cement to cancellous surfaces is achieved primarily by interdigitation of the cement into the microstructure trabeculae. Interdigitation increases the area for load transfer, reduces localised stresses, and enhances the shear strength at the cement-bone interface.[3,4] Many cementing techniques have been developed to remove debris (blood clots, fat, marrow) from the bone surface.[4–6] Aseptic loosening rates

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are significantly reduced when thorough bone-bed cleaning with pulse-lavage with distal and proximal seals are used.[7]

Hydrogen peroxide is used as an irrigating solution for bone-bed preparation as it has a haemostatic effect and facilitates debris removal.[8] In an *in vitro* tensile-loading study, the use of hydrogen peroxide yielded superior cement fixation, compared with normal saline and povidone iodine.[9] In a radiographic study, pulse- and brush-lavage preparations significantly increased cement interdigitation and penetration into cancellous bone, compared with syringe- or non-brush-lavage techniques.[10] These findings are consistent with studies on tensile and shear strength at the cement-bone interface.[11,12]

We compared the effectiveness of pulse-lavage brushing followed by hydrogen peroxide–gauze packing with either technique alone or normal-saline irrigation in bone-bed preparation of the femoral canal for cemented total hip arthroplasty.

MATERIALS AND METHODS

44 fresh-frozen ox femurs of similar size were selected. Bones were thawed at room temperature for 12 hours prior to implantation. The femoral neck was osteotomised and the femoral canal was broached for a size-8 stem (Osteonics Omnifit; Stryker Instruments, Kalamazoo [MI], US). As porosity of the cancellous bone may vary in direction and location, care was taken to ream to constant depth along the mid-shaft. The stem was collarless, hydroxyapetite plasma–sprayed, C-tapered, and made of cobalt chromium. Although it was a non-cemented implant, its roughened stem increased the likelihood of failure at the cement-bone interface.

Four types of bone-bed preparation were used: normal saline (1 litre) syringe irrigation, pulse-lavage brushing, hydrogen peroxide-soaked gauze packing, and a combination of the latter 2 techniques. The intramedullary canal was distally plugged with bone-cement using an injection gun, and the proximal end sealed. Simplex P acrylic bone-cement was mixed at room temperature for one minute, and then injected into the intramedullary canal 3 minutes after mixing. The stem was then inserted and the cement left to cure for a minimum of 30 minutes. To maintain constant pressure during injection, the injection gun trigger was instrumented with strain gauges and the calibrated strain output monitored in real time using a signal processing unit. The pressure level was based on the surgeon's preference.

The maximum tensile pull-out force was assessed using a servo-hydraulic material test system. The distal femur was secured in a bracket with a 15-mm pin passing through the epicondyles, whereas a 300x8 mm threaded steel rod was screwed into the proximal implant (Fig. 1). To ensure uni-axial tension, the specimen was aligned in the vertical position with the steel rod directly in line with the long axis of the femur. The distal femur was then displaced upward at a constant rate of 5 mm/min. The tension was recorded continuously at 20 Hz until separation. Only specimens with failure at the cement-bone interface were included for analysis; failure at the prosthesis-cement interface was indicated when the cement mantle remained in the femur (Fig. 2). The femur was then sawed in the transverse plane through the lesser trochanter. The cross-sectional area was measured using a digital camera, and the size of the surface area calculated.

To associate the pull-out force with cement penetration into the trabecular bone, microscopy was performed on the transverse sections of 2 intact specimens each prepared with normal-saline irrigation or pulse-lavage brushing. The positions of 4 evenly spaced cutting sites along the length of each stem were determined using radiographs (Fig. 3). The fingers of bone-cement interdigitation—or pedicles—were examined using a dissecting microscope (Fig. 4a). The mean pedicle length (in mm) of each section was determined using computerised image analysis (Fig. 4b).[13]

Figure 1 An Ox femur is mounted on the servo-hydraulic material test system.

Figure 2 Failure at the **(a)** prosthesis-cement and **(b)** cement-bone interfaces.

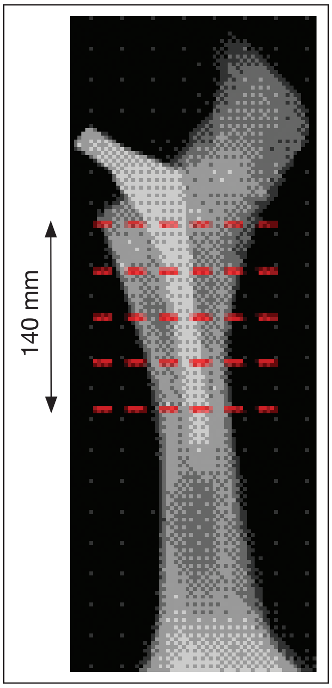

Figure 3 Radiograph of an ox femur with intact prosthesis: dashed lines represent the location of transverse sections taken for microscopy

The mean pull-out force (to separate the prosthesis from the femoral canal) in each preparation technique was compared using a single-way repeated-value analysis of variance (ANOVA). The mean pedicle lengths of the 2 intact specimens each prepared with normal-saline irrigation or pulse-lavage brushing were compared using pair-wise Fisher comparisons. A p value of <0.05 was considered statistically significant.

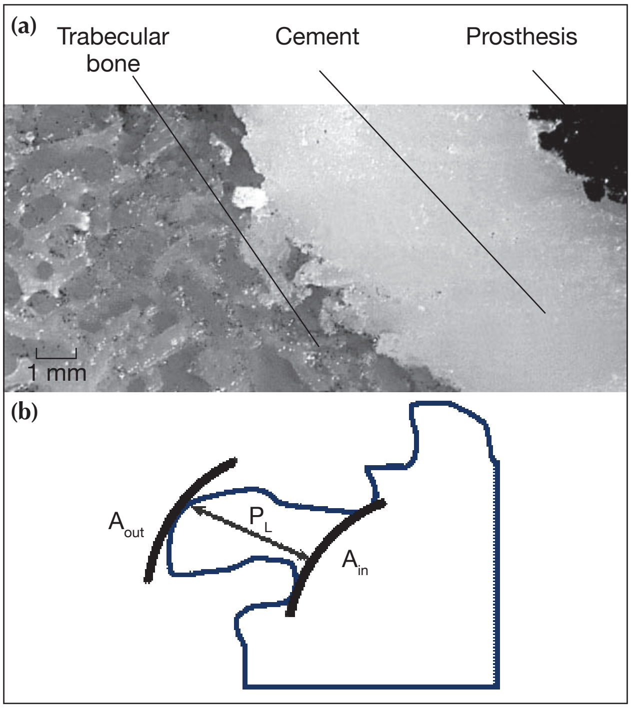

Figure 4 **(a)** Low-power photomicrograph of a cement pedicle in a transverse section prepared using pulse-lavage brushing; **(b)** schematic diagram illustrating cement penetration: the outer arc (A_{out}) is positioned at the maximum pedicle depth, whereas the inner arc (A_{in}) is positioned at the edges of the 2 adjacent pedicles. Pedicle length (P_L) is measured from the perpendicular distance between the 2 arcs.

RESULTS

Two specimens failed at the prosthesis-cement interface and were excluded. The size variation of the specimens was small; the mean (standard deviation) cross-sectional area at the lesser trochanter was 45.8 (2.5) cm^2.

The mean pull-out force to separate the prosthesis from the femoral canal was significantly higher in specimens prepared with pulse-lavage brushing followed by hydrogen peroxide–soaked gauze packing (8489.2±3634.3 N) or pulse-lavage brushing alone (8049.4±3557.8 N) than those prepared with hydrogen peroxide–soaked gauze packing alone (2017.9±1200.6 N) or normal-saline irrigation (947.1±862.9 N) [p<0.001, Table]. The difference was not significantly higher in those prepared with pulse-lavage brushing followed by hydrogen peroxide–soaked gauze packing versus pulse-lavage brushing alone (p>0.05), and in those prepared with hydrogen peroxide-soaked gauze packing versus normal-saline irrigation (p>0.05).

Table
Cement-bone failure strengths for each bone-bed preparation technique

Sample	Pull-out force (N)			
	Normal-saline irrigation	Hydrogen peroxide–soaked gauze packing	Pulse-lavage brushing	Pulse-lavage brushing + hydrogen peroxide–soaked gauze packing
1	218.4	306.3	4327.4	2491.6
2	290.4	944.4	4633.2	2983.3
3	373.8	1157.6	5047.0	6811.2
4	394.1	1279.3	5260.8	7904.3
5	395.8	1306.3	5612.1	8155.0
6	526.8	1835.0	6290.9	8292.8
7	537.5	2543.8	8540.8	9171.9
8	1015.0	2649.9	10852.2	9922.5
9	1870.2	2757.0	11256.0	10103.2
10	2137.5	2822.9	12944.8	12899.4
11	2658.2	4594.2	13778.0	14646.3
Mean (SD)	**947.1 (862.9)**	**2017.9 (1200.6)**	**8049.4 (3556.8)**	**8489.2 (3634.3)**

The mean pedicle length was significantly longer in specimens prepared with pulse-lavage brushing than normal-saline irrigation (3.5±2.1 vs 1.2±2.6 mm, $p<0.01$). Cement penetration into the trabecular bone was positively related to the pull-out force to separate the prosthesis from the femoral canal.

DISCUSSION

Hydrogen peroxide mechanically removes fat, blood, marrow, and other tissue debris from the surface interstices and bony microstructure, thereby increasing porosity at the bony trabeculae.[9] In our study, hydrogen peroxide–soaked gauze packing did not lead to a significantly higher pull-out force to separate the prosthesis from the femoral canal (compared with normal-saline irrigation). The same was true after pulse-lavage brushing followed by hydrogen peroxide–soaked gauze packing versus pulse-lavage brushing alone.[14] Part of the disparity may be associated with the use of purely tension-based load testing[9] versus predominantly shear-based testing (as in our study).

Pulsatile lavage combined with brushing of the femoral canal is a standard technique in cemented total hip arthroplasty, despite data showing no significant difference between continuous and pulsed pressurised lavage, and no significant benefit of brushing.[6] In our study, pulse-lavage brushing appeared to be significantly more effective in cleansing the bone-bed than hydrogen peroxide–soaked gauze packing or normal-saline irrigation. Combining larger lavage volumes with pressurising devices to contain cement may further increase cement pressurisation and penetration, but excessive preparation may lead to damage and loss of bony trabeculae.[15,16] In our study, the role of hydrogen peroxide in the management of blood flow was not investigated. Nonetheless, the clinical benefits associated with its haemostatic effects should not be overlooked.

Our study had several limitations. First, although the strength and porosity of the cancellous bone from ox and human femurs are comparable,[17,18] the bony architecture differs.[19] This may lead to variations in the strength of cement-bone fixation. However, bone composition was unlikely to affect bone-bed preparations because our specimens were of similar age and cross-sectional area. Although cement mantle and depth were not quantified, their variation should be small as our surgeries were performed for one implant type by one surgeon. Second, *in vivo* loading involves combinations of shear, compression, tension and torsion, but in our study only the uni-axial pull-out force was measured. Our study was not designed to emulate *in vivo* loading or failure magnitudes. Rather, it was used as a simple, repeatable protocol to assess the strength of the cement-bone interface. Third, in our *in vitro* study there was no blood flow into the femoral canal during bone-bed preparation and cement injection. Blood flow can compromise the integrity of the cement and the cement-bone interface.[20] Fourth, the strength of the cement-bone interface depends on the amount of cement penetration into the cancellous bone.[3,4] However, in our study the pull-out force (rather than cement penetration) was the primary measure of the effectiveness of bone-bed preparation.

REFERENCES

1. Jasty M, Maloney WJ, Bragdon CR, O'Connor DO, Haire T, Harris WH. The initiation of failure in cemented femoral components of hip arthroplasties. J Bone Joint Surg Br 1991;73:551–8.
2. Stauffer RN. Ten-year follow-up study of total hip replacement. J Bone Joint Surg Am 1982;64:983–90.
3. Graham J, Ries M, Pruitt L. Effect of bone porosity on the mechanical integrity of the bone-cement interface. J Bone Joint Surg Am 2003;85:1901–8.
4. Halawa M, Lee AJ, Ling RS, Vangala SS. The shear strength of trabecular bone from the femur, and some factors affecting the shear strength of the cement-bone interface. Arch Orthop Traum Surg 1978;92:19–30.
5. Lange DR. The mechanical bonding of methylmethacrylate to cancellous bone. Effect of a hemostatic agent. J Bone Joint Surg Am 1979;61:254–6.
6. Majkowski RS, Miles AW, Bannister GC, Perkins J, Taylor GJ. Bone surface preparation in cemented joint replacement. J Bone Joint Surg Br 1993;75:459–63.
7. Barrack RL, Mulroy RD Jr, Harris WH. Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty. A 12-year radiographic review. J Bone Joint Surg Br 1992;74:385–9.
8. Hankin FM, Campbell SE, Goldstein SA, Matthews LS. Hydrogen peroxide as a topical hemostatic agent. Clin Orthop Relat Res 1984;186:244–8.
9. Howells RJ, Salmon JM, McCullough KG. The effect of irrigating solutions on the strength of the cement-bone interface. Aust N Z J Surg 1992;62:215–8.
10. Breusch SJ, Norman TL, Schneider U, Reitzel T, Blaha JD, Lukoschek M. Lavage technique in total hip arthroplasty: jet lavage produces better cement penetration than syringe lavage in the proximal femur. J Arthroplasty 2000;15:921–7.
11. Krause WR, Krug W, Miller J. Strength of the cement-bone interface. Clin Orthop Relat Res 1982;163:290–9.
12. MacDonald W, Swarts E, Beaver R. Penetration and shear strength of cement-bone interfaces in vivo. Clin Orthop Relat Res 1993;286:283–8.
13. Maher SA, McCormack BA. Quantification of interdigitation at bone cement/cancellous bone interfaces in cemented femoral reconstructions. Proc Inst Mech Eng H 1999;213:347–54.
14. Guerin SR, MacNiochaill R, O'Reilly P, O'Byrne J, Kelly DJ. A comparative study of the effect of hydrogen peroxide versus normal saline on the strength of the bone-cement interface. Biomed Mater Eng 2007;17:379–86.
15. West BR, Nichter LS, Halpern DE, Nimni ME, Cheung DT, Zhou ZY. Ultrasound debridement of trabeculated bone: effective and atraumatic. Plast Reconstr Surg 1994;93:561–6.
16. Bhandari M, Adili A, Lachowski RJ. High pressure pulsatile lavage of contaminated human tibiae: an in vitro study. J Orthop Trauma 1998;12:479–84.
17. Rey RM Jr, Paiement GD, McGann WM, Jasty M, Harrigan TP, Burke DW, et al. A study of intrusion characteristics of low viscosity cement Simplex-P and Palacos cements in a bovine cancellous bone model. Clin Orthop Relat Res 1987;215:272–8.
18. Bannister GC, Miles AW. The influence of cementing technique and blood on the strength of the bone-cement interface. Eng Med 1988;17:131–3.
19. Currey JD. The mechanical adaptations of bones. Princeton: Princeton University Press; 1984:38–42
20. Benjamin JB, Gie GA, Lee AJ, Ling RS, Volz RG. Cementing technique and the effects of bleeding. J Bone Joint Surg Br 1987;69:620–4.