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Patellar component stability improves with pulsatile lavage in total knee arthroplasty

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Abstract In a cadaver study, we prepared 37 fresh frozen human patella pairs to determine the efficacy of jet lavage in comparison to syringe lavage with respect to cement penetration and stability of the polyethylene patellar component after patellar resurfacing. For 12 patella pairs, sagittal sections were obtained at predefined levels using a diamond saw. Cement penetration was significantly greater ($P<0.0001$) in the jet lavage specimens compared to the syringe lavage specimens. For the remaining 25 patella pairs, pullout tests were performed on patellar components using a traction-compression device. The maximum force required to cause mechanical failure was significantly greater ($P<0.0001$) in jet lavage specimens compared to syringe lavage specimens. Our results support the routine use of jet lavage for cleansing the patellar bed prior to cement application in cemented patellar resurfacing.

Résumé Dans une étude cadavérique, nous avons préparé 37 paires de rotules humaines fraîches congelées pour déterminer l'efficacité du lavage au jet par rapport au lavage à la seringue en ce qui concerne la pénétration du ciment et la stabilité du composant en polyéthylène après resurfaçage rotulien. Pour 12 paires de rotule les sections sagittales ont été obtenues à des niveaux prédéfinis en utilisant une scie-diamant. La pénétration du ciment était nettement plus grande ($P<0.0001$) dans les spécimens avec lavage au jet comparés aux spécimens avec lavage à la seringue. Pour les 25 paires restantes des épreuves d'arrachement ont été exécutées avec un appareil de traction-compression. La force maximale nécessaire pour causer l'échec mécanique était considérablement plus grande ($P<0.0001$) dans les spécimens à lavage du jet comparés aux spécimens à lavage à la seringue. Nos ré-

sultats montrent que les lavages au jet pour nettoyer le lit rotulien avant l'application du ciment doivent être utilisés en routine dans le resurfaçage rotulien cimenté.

Introduction

The incidence of patellofemoral complications after total knee arthroplasty (TKA) has been reported to range from 2% to 24% [9, 10, 11]. These complications include patellar fracture; patellar subluxation or dislocation; extensor mechanism disruption; and component wear, loosening, or dissociation [2]. The lowest complication rate was obtained with all-polyethylene dome-shaped patellar components implanted with cement [10]. To improve long-term survival of cemented components in TKA, it is necessary to achieve an adequate bone-cement and cement-prosthesis bond at the time of surgery [18]. The preparation of cancellous bone surface [7, 8, 12, 16], the method of cement application [8, 12, 16], the quantity of bone interdigitation with cement [17], and the depth of penetration of cement into bone [14, 17], are important factors influencing the shear strength of the bone-cement interface.

Pulse lavage of cancellous bone has been identified as a significant factor with regard to improved cement penetration [6] and consequently improved shear strength. Despite these facts, national surveys in the United Kingdom [19] and Germany [5] have shown a low prevalence of pressurized jet lavage in cemented TKA and total hip arthroplasty (THA). Syringe lavage is often used as an alternative.

Our study was designed to compare the effectiveness of jet lavage versus syringe lavage with regard to cement penetration and stability of the polyethylene component in retropatellar resurfacing in TKA.

Material and methods

Thirty-seven paired fresh frozen human cadaver patellae were retrieved for this study. Radiographs were taken of all pairs to ensure stereometrically equal patellar configuration. Bone cement and lavage systems commonly used in Germany were employed,

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Fig. 1 Microradiograph of patellar sagittal section with regional definitions used in image analysis

including Palacos R (Biomet-Merck). We used polyethylene replicas of single-pack patellar components (P.F.C. Sigma, Johnson and Johnson, New Brunswick, New Jersey, USA), which were modified at the patellar dome. A screw was placed in this modified, elevated dome for pullout testing after implantation. The patellar component was 25 mm in diameter. Articular resection was performed at the subchondral bone level using an oscillating saw and a patellar cutting clamp. Care was taken to ensure identical levels of resection of left and right specimens. After osteotomy, patella thickness was checked with a caliper. With a 25 mm drill bit, the patellar bed was then prepared. In a paired comparison, all bone beds were irrigated using either 200 ml jet lavage (Pulse Lavage model L31, Tava Surgical Instruments) or 200 ml syringe lavage (using a bladder syringe) after randomized allocation into the two groups. The specimens were then placed in specially designed plastic pots and imbedded in plaster of Paris so that the osteotomy was level with the plaster of Paris. After the plaster of Paris set, the exposed cancellous bone surface was hand-dried with a swab. The cementation process was standardized. Prechilled Palacos R cement was hand mixed for 30 s and applied after a further 60 s while still in a relatively low-viscosity phase to the patella. No pressure was applied during the cement insertion.

Study A

For the first 12 paired patellae, the polyethylene component was implanted using a traction-compression device (Material-Pruefmaschine Z005/TN2S, Zwick GmbH Ulm) with 200 N for 14 min. Before application, the component was coated with Klingerflon spray (Rich. Klinger GmbH, Idstein/Taunus) to ensure that the polyethylene could be removed easily after compression without disrupting the cement layer. After storage of the pots for 48 h at room temperature, the specimens were retrieved and standardized sagittal sections were obtained from the cemented area using a diamond saw. The reference section was first taken through the middle of the cemented area. Further sections (2 mm) were taken to the left and right of the reference. Care was taken to obtain 2-mm slices from the patella pairs that corresponded to each other, i.e., mirror images of left and right. Microradiographs were obtained using a Faxitron F machine (model 43855C, Rhode and Schwartz). The radiographs were digitized using a scanner and analyzed using image analysis software (Kontron KKS 300, Elektronik GmbH, Zeiss GmbH). The entire section area (As), the cross-sectional area of the region of cancellous bone filled with cement (Ac), and the cross-sectional area of the region of cancellous bone not containing cement (Anc) were determined (Fig. 1). From these measurements, the following parameters were deter-

Fig. 2 Maximum pullout force to induce mechanical failure in patella pair (number 14) with jet and syringe lavage

mined and statistically analyzed: (1) $CP (\%) = Ac/As \times 100$, where CP is defined as cement penetration into cancellous bone; (2) $Rcb (\%) = Ac/Anc \times 100$, where Rcb is the ratio of the region of supported cancellous bone to unsupported cancellous bone.

Study B

In a second experiment, we used 25 human paired cadaver patellae. The specimen preparation protocol was identical to Study A. After the pots had been stored for 48 h at room temperature, the traction-compression device was used to pull out the polyethylene component with a test speed of 7 mm/min. When the threshold value of 50% of the maximum force was reached, the experiment was automatically stopped and failure of the component was defined (Fig. 2).

All analysis was done using Statistical Analysis Systems (SAS, Version 8 for Windows). The means were compared using a two-tailed Student's *t*-test. The global significance level was fixed at $\alpha = 0.05$. The experiments' α levels were adjusted according to the Bonferroni-Holm method.

Fig. 3 Mean cement penetration (CP) as a percent for jet lavage and syringe lavage sections for all 12 patella pairs. CP increased in all jet lavage patellae ($P<0.0001$)

Fig. 4 Maximum pullout force in newtons for jet and syringe lavage in all 25 patella pairs. Stability was greater in all specimens after jet lavage ($P<0.0001$)

Results

In the first experiment (Study A), statistical analysis revealed that mean cement penetration was significantly ($P<0.0001$) greater in the jet lavage specimens (23.46% ; $SD\pm 6.50\%$) compared to the syringe lavage specimens (10.21% ; $SD\pm 6.26\%$). A pairwise comparison of lavage type among sections taken from the patella pairs showed that with jet lavage the mean cement penetration increased in all 12 patella pairs (Fig. 3). In another analysis, we took the section with maximum cement penetration from each jet lavage patella and compared it to the corresponding syringe lavage section. Cement penetration in the jet lavage group (mean 36.42% ; $SD\pm 9.67\%$) was significantly greater ($P<0.0001$) than in the syringe lavage group (mean 9.70% ; $SD\pm 8.27\%$). When choosing the maximum cement penetration from the syringe lavage sections as reference, there was still a significant difference ($P<0.0158$) in favor of the jet lavage specimens (mean 25.27% ; $SD\pm 12.40\%$) in comparison to the syringe lavage specimens (mean 18.37% ; $SD\pm 11.24\%$). Rcb was also significantly greater ($P<0.0001$) in the jet lavage specimens (mean 33.26% ; $SD\pm 1269\%$) compared to the syringe lavage specimens (mean 12.46% ; $SD\pm 9.36\%$).

In the second experiment (Study B), statistical analysis showed that the maximum pullout force required to cause mechanical failure was significantly greater ($P<0.0001$) in the jet lavage specimens (mean 1208.69 N; $SD\pm 222.62$ N) compared to the syringe lavage specimens (mean 784.12 N; $SD\pm 278.75$ N). A pairwise comparison showed improved component stability in each of the 25 patellae irrigated with jet lavage (Fig. 4). In the jet lavage group, failure occurred at the component-cement interface, whereas in the syringe lavage group, failure occurred at the bone-cement interface.

Discussion

Component design and surgical technique both influence patellar tracking and are major factors to achieve a successful TKA. Bindelglass and Dorr [3] emphasized that surgical technique is of greater importance than design factors. In the study of Boyd et al. [4], the overall rate of patellar component complications was 4% (16/396 knees). There was loosening of the patellar component in five knees, patellar subluxation in four, patellar fracture in three, patellar tendon rupture in three, and chronic peripatellar pain in one. Healy et al. [10] showed in 211 TKAs a patellofemoral complication rate of 12.8%. Patellar component failure, patellar component loosening, and patellar fracture could be found among these complications. Scuderi et al. [21] reported the incidence of loosening of non-metal-backed patellar components to range from 1% to 3%. If loosening occurs, treatment options include observation, arthroscopic excision, reimplantation, or patellectomy. Though patella component loosening is a rare problem, it represents a significant complication, which can lead to patellar fracture, failure, and ultimately to revision surgery. Data from the Swedish Knee Arthroplasty Registry showed that patella-related complications commonly are the reason for early revision, occurring in 44% of knees with a primary tricompartmental procedure [13].

Modern cementing techniques result in improved cement penetration into cancellous bone and improve long-term outcome of cemented components in TKA. Numerous experimental studies have confirmed the benefit of bone lavage with regard to cement penetration [6, 8, 12, 14, 16]. Krause et al. [12] observed in human tibiae that the depth of bone cleansing using lavage had a tendency to limit the depth of cement penetration. Bannister and Miles [1] also found improved cement penetration and

increased interface strength when bone lavage was used. Maistrelli et al. [15] compared jet lavage with syringe lavage in human resected tibial plateaus obtained at TKA and found significantly better cement penetration in the jet lavage group; however, they did not comment on the amount of irrigation used. Using identical volumes of irrigation, jet lavage was found to significantly improve cement penetration in the femur in a pairwise study [6]. The same impact was demonstrated clinically by Ritter et al. [20]. Proper preparation of cancellous bone with high-volume, high-pressure lavage and pressure injection of low-viscosity cement reduced the initial occurrence of radiolucent line in TKA, which has a positive effect on survival of at least the tibial component.

Our results show that, in contrast to jet lavage, syringe lavage is significantly less effective with regard to cleansing capacity of cancellous bone as measured by cement penetration and stability of the polyethylene component in patellar resurfacing. Cement penetration into the intertrabecular spaces of the patella is important to ensure a durable interface, thus a lower mechanical failure rate of cemented patellar components can be expected. We conclude that the use of high-volume, pressurized, jet lavage for cleansing of the retropatellar bed before cement application should be used routinely in cemented TKA to reduce patellofemoral complications.

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