Original Article

Tibial cleaning method for cemented total knee arthroplasty: An experimental study

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Abstract

Background: The survival rate of cemented knee prosthesis depends among other factors on optimal cement-bone contact, nevertheless no standard exists for cementing technique of tibial components. The aim of this study was to determine which tibial surface preparation technique leads to the best bone-cement contact.

Materials and Methods: Human tibial plateau specimens were cleaned in four different ways before cementing: a) no cleaning, b) manual syringe irrigation, c) fracture brush cleaning, and d) pulsatile jet-lavage. The specimens were cut into transverse sections and the bone cement contact distance was calculated for every 10 mm and the cement penetration depth was measured. Both values were statistically analyzed (ANOVA).

Results: The longest bone-cement contact (62 mm) was seen after PJL, the shortest (10.6 mm) after no cleaning at all. The deepest cement penetration (4.1 mm) again was seen after PJL, the least (0.7 mm) after no cleaning. Statistically, PJL yielded the longest bone-cement contact and deepest cement penetration.

Conclusion: The results supports the use of pulsatile jet-lavage before cementing tibial components in knee arthroplasty.

Key words: Bone preparation, cemented total knee arthroplasty, cementing technique, pulsatile jet-lavage

Introduction

The goal of knee arthroplasty is to achieve a satisfactory level of pain-free mobility, restore the anatomical tibial axis with balanced ligament tension, and ensure the long service life of the prosthesis. The long term anchorage of the tibial component is an important predictor of outcome.[1] Having achieved varying outcomes with cementless application,[2] cement fixation of the tibial component has currently become routine procedure for most knee prosthesis and offers more reliable anchorage with good long term outcomes[1,3] depending on the type of prosthesis, the implantation technique and the resultant mechanical axis. Cementation technique is especially important for other reasons apart from the question of whether surface cementation alone is sufficient or whether additional cementation of the tibial stem leads to better clinical outcomes.[4] In the context of cemented hip arthroplasty cementation technique using jet-lavage leads to a reduction in fat embolism.[5] In addition, a number of investigations have shown that jet-lavage leads to improved cement penetration into the proximal femur,[6-8] therefore, jet-lavage can be regarded as the gold standard in terms of femoral cementation technique for hip prosthesis. It seems that no clear standard exists for cementation technique of the tibial component in knee replacement.[9] Ritter *et al.*[10] were able to demonstrate the advantage of jet-lavage as early as 1994 in relation to radiolucent zones at the tibia, but it seems that a generally accepted method did not arise as a result of this evidence.[9] Comparison with cemented hip prosthesis is not entirely relevant because of the structural differences between the proximal femur and the tibial plateau and the desired penetration depth at the tibial resection surface. For these reasons, direct transfer of experimental results from femoral investigation to the tibial situation does not seem justifiable. Investigation and clinical application of numerous different cleaning methods and suction techniques to improve cement penetration depth at the tibia have been reported in the literature with various outcomes.[10-17] The aim of this study was to identify the optimal cleaning method in terms of cement-bone contact at the tibial resection surface.

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Materials and Methods

After approval by the relevant ethics committee and informed patient consent, the tibial plateau specimens obtained during surgery for knee resurfacing arthroplasty were taken for experimentation. The tibial plateau specimens were taken because the bone structure on the resection side is just the same as on the remainig side of tibia in the patient and therefore was seen as a reproduction of the clinical setting. A total of 20 tibial plateau specimens were acquired and deep frozen. Later, some specimens had to be rejected because the resection surface was asymmetrical with visible cancellous bone trabeculae from medial to lateral. This means that on one side there was a sclerotic zone with no possible cement penetration. In the clinical situation the surgeon can drill holes in the sclerotic bone to achieve a penetration, in the experimental setting we excluded these specimen. After slow thawing a total of 12 complete and viable specimens were available for preparation. Three specimens were subjected to one of four different cleaning methods for four minutes each. The methods were manual syringe irrigation (MSI) with a 0.9 × 40 mm^2 cannula and 20 ml syringe with maximal manual pressure (MSI), fracture brush cleaning (FBC), pulsatile jet-lavage (Stryker, Duisburg Germany) (PJL) with direct application of the jet-lavage device to the bone just as in the clinical situation and no cleaning as a control (NC). Palacos R® (Heraeus Medical, Wehrheim/Ts. Germany) was then mixed according to the manufacturer's instructions and spread on each specimen. This was followed by application of a polyethylene plate, which was hammered six times to the cement with a 300 g hammer and then pressed into the specimen at maximal manual force until the cement had hardened. This experimental setup was choosen to simulate the clinical situation.[18] After each impaction of the polyethylene plate with the 300g hammer, a break was implemented, to prevent exhaustion of the simulated surgeon. A polyethylene plate was chosen for experimental reasons since it can easily be separated from the cement and specimen processing can continue. After complete hardening all specimens were cut at 90° to the cement surface into four sections. The six cut surfaces per specimen were then scanned in an optical scanner with size reference. The scanned images were captured using the DICOM program Osirix 3.8.1 (Pixmeo Sarl, Bernex Switzerland). The bone-cement contact distance was then measured at three different (not overlapping) places per cut for every 10 mm of cement surface and the mean of these three measurments was built [Figure 1]. After that the cement penetration depth was measured in five places per cut and again the mean was built.

Statistical evaluation was performed with ANOVA. Level of significance was set at $P < 0.05$. Eighteen surfaces were available for analysis for each cleaning method, that is, 76 sections were captured and the bone-cement distance and penetration depth measured at several places and then averaged for each surface.

Results

The longest bone-cement contact distance was found for PJL at 62 mm per 10 mm cement. The least was found for NC at only 10.6 mm per 10 mm. The cement penetration again was found deepest after PJL (4.1mm) and least (0.7mm) after NC. The average bone cement distance was longest for PJL at 31.8 mm (cement penetration 2.99mm) and least NC at 13.8 mm (cement penetration 1.25) [Tables 1 and 2]. The bone-cement contact distance and cement penetration depth were significantly longer after jet-lavage than for any other cleaning method ($P < 0.001$ and $P < 0.001$). Compared to all other methods the bone-cement contact distance and cement penetration depth after no cleaning was significantly shorter (FBC bone

Table 1: Evaluation of bone-cement contact distance

Cleaning methods	Average bone-cement contact [mm] and standard deviation	Maximal bone-cement contact [mm]	Minimal bone-cement contact [mm]
Pulsatile jet-lavage	31.82±11.55	62	18.50
Brush cleaning	20.60±3.86	27.5	15.00
Syringe irrigation	19.92±4.92	30	14.00
No cleaning	13.82±2.12	17.50	10.60

Table 2: Evaluation of cement penetration

Cleaning methods	Average cement penetration [mm] and standard deviation	Maximal cement penetration [mm]	Minimal cement penetration [mm]
Pulsatile jet-lavage	2.99±0.61	4.1	2.0
Brush cleaning	1.75±0.39	2.9	1.2
Syringe irrigation	1.94±0.38	2.7	1.4
No cleaning	1.25±0.26	1.6	0.7

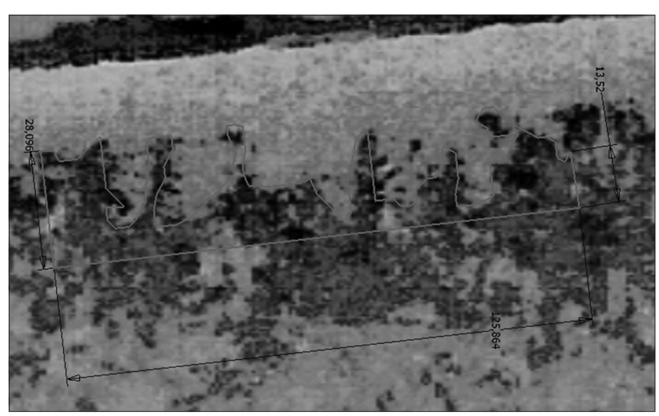

Figure 1: Bone-cement contact distance per 10 mm measurement

cement distance $P = 0.013$/cement penetration $P = 0,003$, MSI $P = 0.032/P < 0.001$, PJL $P < 0.001/P < 0.001$). The results after @@FBC and MSI did not differ significantly ($P = 0.989/P = 0,574$) [Figures 2 and 3].

Discussion

The long term stability of a knee prosthesis depends on a number of different variables. Apart from those factors that are beyond the reach of the surgeon, such as patient activity or body weight, factors that can be influenced by the surgeon need to be addressed. So far there is no evidence for the superiority of cementless fixation in the tibia. A study by Carlsson *et al*.[19] found a more stable bone-cement contact for the cemented tibial plateau compared to hydroxyapatite coated or porous surfaces after 5 years.

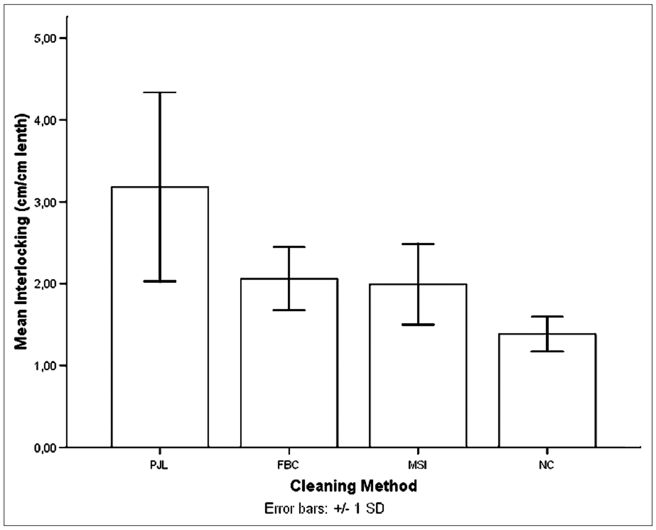

Figure 2: Bar diagram showing average bone cement contact values in relation to the cleaning method

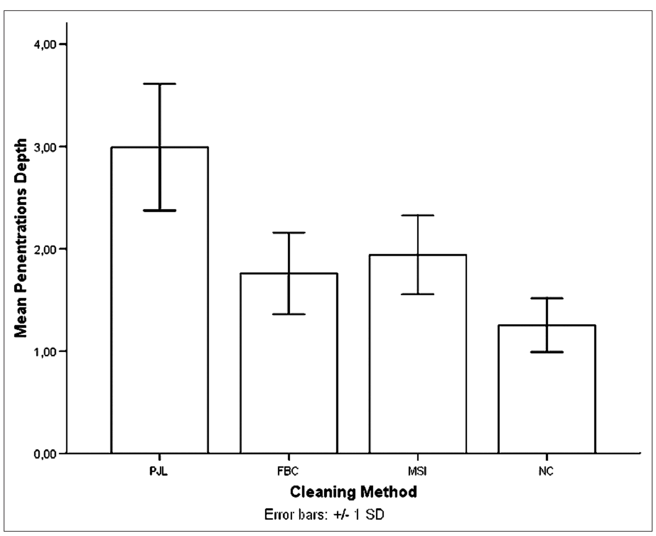

Figure 3: Bar diagram showing average cement penetration depth in mm in relation to the cleaning method

The study by Carlson *et al*. however showed different petterns of micromotions of cemented versus uncemented implants. The cemented implants showed very little initial micromotions whereas the uncemented coated showed initial micromotion and then stabilizing over time. This is confirmed by studies of Nelisson[20] and Henricson.[21] All three studies demonstrated very little micromotions over the period of 2-5 years in cemented implants with the use of PJL. With this research in mind, optimization of cementation technique takes on a particular importance. Ritter *et al*.[10] in 1994 already demonstrated a relationship between the occurrence of radiologically visible translucent zones at the bone cement margins after jet-lavage. Despite these results there is no common consensus how to prepare the tibial plateau in the clinical day to day work.[9] In many countries, it is accepted that pulsatile jet lavage is of advantage in implanting cemented tibial components, this is in contrast to the fact that in numerous publications evaluating long term outcome of cemented TKA, the cleaning method of the tibial plateau surface is not described in the materials and methods section.[3,22-25] This means that despite the opinion of many surgeons that the jet lavage is beneficial, there is little attention to this in the current literature. Vanlommel *et al*. demonstrated in a recent study in a sawbone model the importance of the preparation of the cement on the implant and the bone cut, finding out that applying the cement to the implant surface and the bone gives the best results.[26] To the best of our knowledge no experimental investigation of the bone cleaning effect in relation to the cement penetration and bone-cement contact over the tibial plateau has so far been undertaken. Clarius *et al*.[11] recently published their results investigating the effect of jet-lavage in the special situation of implanting an unicompartimental prosthesis in a minimal invasive technique and found better cement penetration in this special situation with the use of jet-lavage. Since this was a specialized technique the results may not be converted fully to the situation in TKA. Nevertheless, this study also supports the use of PJL. Krause *et al*.[27] investigated in an experimental study the mechanical strength of the cement-cancellous bone interlock, with respect to the bone surface preparation. Schlegel *et al*.[17] again focused in their recently published study on the pull out strength after two different cement preparing techniques and found out the higher pull out forces after PJL and deeper cement penetration. In the present study, we could demonstrate that the cement penetration and the cement-bone contact are valid parameters to measure the cleaning method of bone in order to fix a cemented tibial implant since the cement penetration was already used to measure this and is widely accepted.[8,12,16,26,27] In the study presented here, it was possible to show that cleaning by jet-lavage led to a significantly better cement-bone contact and cement penetration into the bone than syringe irrigation or brush cleaning. This is in discrepance to the results of Krause *et al*.[27] as they found no difference between jet lavage and brush cleaning regarding the mechanical strength. The clinical concordance of these results were not shown up to now. The experimental procedure aimed to mimick the situation with tourniquet. It remains unclear to what extent further improvement of the cement – bone contact, e.g. by application of bone suction beneath the resection surface as in the study by Banwart *et al*.,[12] will result in an improvement of the long term stability of a knee prosthesis. Various clinical studies[13,15] are reported to have shown that the so-called irrigation technique improves penetration depth to 3 to 5 mm. Whether this leads to further improvement in long term stability was not proven by either of these studies. Deep penetration of cement may even be a disadvantage as there is a risk of thermal bone necrosis, an effect described by Huiskes and Sloof for a penetration depth greater than 10 mm.[28] The maximal penetration depth in our study was only 4.1mm and therefore not critical to a thermal effect. Ungethuem *et al*.[29] investigated proximal femoral cementation in an animal model but did not find any significant effects for femoral irrigation.

The quality of tibial fixation depends not only on the cementation technique but also on the implant structure. Vertullo and Davey[14] showed that a so-called tibial baseplate lip improved cement penetration around the peripheral margins of the implant. In another experimental study Marx *et al*.[30] found that SiOx coating of the tibial implant surface interfacing with the cement led to less fissure formation in the cement.

The results of the present study accord with those of Breusch[7,8] who investigated the optimization of cement penetration in the proximal femur in the context of total hip arthroplasty. In that study no differences were found between the different bone cements. This is conclusive since all three types were moderately viscous bone cements but they did not differ in terms of penetration depth. The effects of different currently available bone cements are probably of a long term nature and probably attributable to properties such as fatigue strength. With regard to tibial migration Adalberth *et al*.[31] found no differences for different types of cement over a period of 2 years. Therefore, it is not necessary to test diffferent bone cements in order to test the cleaning method.

The relatively large variations in cement – bone contact distance and penetration depth for each cleaning method in our experiment derives from the interindividual differences between the tibial plateau specimens due to variability of the cancellous bone that is one of the limitiations of the study. Another limitation of the present study is the limited processing of each tibial plateau with a total of only six cut surfaces. However, the study approach did permit valid comparison of the different cleaning methods since the evaluation procedure was the same throughout.

In summary, the results of this experimental study support the use of pulsatile jet-lavage before cementing the tibial component in total knee arthroplasty.

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