Primary Cement Debris After Total Knee Arthroplasty

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Abstract

Polyethylene wear is accelerated by third body cement debris and contributes to aseptic loosening after knee arthroplasty. Saline irrigation with pulse lavage is expected to render the joint free of such particles. The purpose of this study is to qualitatively characterize such primary cement debris remaining in the knee joint after cemented total knee arthroplasty and briefly discuss ways to decrease it further.

Introduction

Polyethylene wear and cement disease contribute significantly to aseptic loosening after total knee arthroplasty (TKA)¹. Material wear follows adhesion, abrasion, fatigue, corrosion or third body inclusions². Third body wear occurs when hard particles like cement debris and bone get trapped between a moving couple. This accelerates abrasive wear of polyethylene (PE) and can also affect the hard bearing surface³. Soft debris such as cancellous bone can cause significant abrasive wear due to elevated hydrostatic and electrodynamic stresses under lubricated conditions.⁴ Generation of debris is inevitable during cemented TKA and consists of bone, blood clots, cartilage and Polymethyl methacrylate (PMMA) bone cement. Copious irrigation with pulse lavage is expected to render the joint free of such particles. The purpose of this study is a qualitative distribution analysis of primary cement debris present in the joint at the beginning of the functional life of a cemented TKA. We have used the term "primary cement debris" to differentiate it from the more common association of the term with joints that fail over the long term.

Materials And Methods

From June - December 2020, 13 consecutive samples were collected at the end of cemented TKA performed for osteoarthritis. Sample size was estimated using epi infoTM (CDC sample size calculator)⁵. Institutional ethical clearance and written informed consent was obtained. Inclusion criteria were patients with osteoarthritis undergoing primary TKA. Revision surgery, bilateral primary TKA, rheumatoid arthritis, post traumatic arthritis were excluded.

All patients underwent standard cemented TKA using Genesis II (Smith & Nephew Inc., Memphis, TN, USA) or Vanguard[™] (Biomet, Warsaw, IN) prosthesis under tourniquet. Bone cuts were done with company specific commercial jigs and recommended saw blades. No patella was resurfaced. Thorough wash was given with 1.5 liters normal saline using pulse lavage before implantation. Both components were cemented using PALACOS[®] G 40 high viscosity bone cement (Biomet, Warsaw, USA). Tourniquet was released, hemostasis achieved and PE insert locked in. Final joint lavage was done with 3 liters of normal saline using a generic pulse lavage system.

Sampling

After inserting a drain and water tight closure of the arthrotomy, 50ml normal saline was injected retrograde thorough the drain tube into the joint. The knee was cycled repetitively and 15ml of the midstream outflow was collected from the drain outflow. In the lab this fluid was centrifuged at 1800 rpm for 30 minutes. The resulting sediment was cytopinned for 10 minutes using a conventional filter card and 5 smears prepared. These slides were processed in a routine manner with hematoxylin and eosin (H & E) stain. The cement particles were characterized under a microscope with 10x magnification. A higher magnification (x400) was used to estimate

size relative to nearby RBCs which were readily visible. The number and largest diameter of particles per slide was charted. They were subdivided in to 3 groups of $< 100\mu$, $100-500\mu$ and $> 500\mu$ (Table 1). We then averaged the number of particles from the 5 slides of each patient. Using the method and formula described by Hilson et al ⁶, this average number of particles was converted to number of particles per cubic mm. A summary of the published technique described by them is presented below.

Table 1
Tabulation for Debris (N = 13)

Sl.no	Name/age/ sex	Particle size, in μ	Slide 1	Slide 2	Slide 3	Slide 4	Slide 5	Sub total no of particles	Total no of particles	Total no of particles/ Cu mm
1	Ws/59/m	< 100	2	0	3	0	0	5	16	80
		100– 500	1	0	7	0	0	8		
		> 500	0	0	3	0	0	3		
2	Lt/59/m	< 100	0	0	1	0	0	1	2	10
		100– 500	1	0	0	0	0	1		
		> 500	0	0	0	0	0	0		
3	Sa /66/f	< 100	2	0	1	0	0	3	3	15
		100– 500	0	0	0	0	0	0		
		> 500	0	0	0	0	0	0		
4	Sd/66/f	< 100	0	0	1	0	0	1	5	25
		100– 500	0	2	1	0	0	3		
		> 500	0	1	0	0	0	1		
5	Sh/57/f	< 100	0	1	1	0	0	2	8	40
		100– 500	3	2	1	0	0	6		
		> 500	0	0	0	0	0	0		
6	Wa/80/m	< 100	1	1	1	0	0	3	11	55
		100– 500	3	4	1	0	0	8		
		> 500	0	0	0	0	0	0		
7	Am/62/f	< 100	3	0	0	0	0	3	5	25
		100– 500	1	1	0	0	0	2		
		> 500	0	0	0	0	0	0		
8	Mo/57/m	< 100	0	4	6	3	0	13	18	90
		100– 500	3	0	0	0	2	5		
		> 500	0	0	0	0	0	0		

Sl.no	Name/age/ sex	Particle size , in μ	Slide 1	Slide 2	Slide 3	Slide 4	Slide 5	Sub total no of particles	Total no of particles	Total no of particles/ Cu mm
9	Ja/59/f	< 100	7	0	0	0	0	7	7	35
		100– 500	0	0	0	0	0	0		
		> 500	0	0	0	0	0	0		
10	Ra/58/f	< 100	0	0	0	3	0	3	15	6
		100– 500	2	0	1	0	0	3	15	
		> 500	0	0	0	0	0	0	0	
11	Go/58/f	< 100	2	0	0	0	0	3	15	5
		100– 500	2	0	0	0	0	2	10	
		> 500	0	0	0	0	0	0	0	
12	So/73/m	< 100	1	4	1	2	10	18	90	35
		100– 500	6	3	0	0	3	12	60	
		> 500	0	1	2	1	1	5	25	
13	Sar/68/f	< 100	2	1	0	0	0	3	15	3
		100– 500	0	0	0	0	0	0	0	
		> 500	0	0	0	0	0	0	0	

Summary (Hilson et al)⁶

The construction and use of a disposable cell-counting chamber is described. The technique is intended primarily for the assessment of the cell content of urine. The chamber is made from an ordinary microscope slide and three coverslips. Used in conjunction with a microscope calibrated by a simple method, it permits the estimation of urinary cell concentrations in terms of number of cells per cubic millimeter. The accuracy of the results obtained in this way is comparable to that achieved with conventional haemocytometers, and is adequate for the purposes described.

Results

(Statistical evaluation with IBM SPSS Statistics for Windows, Version 25.0., IBM Corp., Chicago, IL.)

There were eight female and five male patients. All 13 patients, across age and sex, showed primary cement debris. However, on aggregate 29 of 65 slides (44.6%) had no particles. Distribution of micro-cement particles across the size ranges was not uniform. Smaller particles were more prevalent than larger ones. Figures 1, 2 and 3 illustrate some of the debris appearance and size in insets. The plot in Fig. 4 shows declining number of particles measuring more than 500µm in the samples. It also shows that particles measuring 100µm or less were seen more frequently. This suggests that pulse lavage tends to wash out larger particles more effectively than smaller ones. We have desisted from applying classic statistical analysis of particles to lay emphasis instead on qualitative distribution, trends and interpretation. We have tried to focus not so much on the actual number and size but their collective presence and distribution pattern with the limited goal of answering the question of whether the joint is free of debris at closure.

Discussion

At arthroplasty the replaced knee is optimally reconstructed and aligned. The mechanical wash effect of pulsatile lavage clears the joint of bone, cartilage and cement particles generated during the operation. We analysed fluid obtained from the joint cavity after final saline lavage and retinacular closure. This fluid contains cement and non-cement particles that persist in the joint and likely contribute to early third body wear. These third body inclusions of cement happen early, much before the commonly described combination of PE and PMMA debris accumulates after wear. Non-cement particles like bone and cartilage were excluded.

In our results cement debris was seen across all patients in the study. However almost half the samples showed no cement particles suggesting that smaller particles at the nano scale are not visible under the light microscope. The generation of debris is inevitable at surgery but their residual numbers at closure should ideally be zero. Current surgical techniques are not able to achieve that despite impressive relief of pain and improvement of function in the medium to long term. The variable shape and surface geometry of primary cement debris suggests that it may get entrapped in the synovial lining and initiate an early synovial inflammatory response. Studies have demonstrated the number, size and shape of particulate debris to influence the inflammatory biological reaction that leads to periprosthetic osteolysis.^{7,8,9} Small particles in the range of 0.3–10 µm are more biologically active eliciting a marked inflammatory response. Some of these could be the cause of persistent synovitis in the early postoperative period and a cause of unexplained pain. Our study shows that smaller particles are present in larger numbers at closure. In the long term a sustained inflammatory cellular cascade at the bone-implant interface leads to loosening.¹⁰

Cement particles can function as a third body between the moving couple, get embedded in the PE insert leading to accelerated wear. Scratching and pitting from hard third body inclusions is seen in retrieved PE inserts of both fixed and mobile bearing articulations¹¹. However these are joints that have failed over the medium to long term and the inclusions are a combination of PE wear and cement that is presumed to have migrated from the bone – implant interface. It is likely, as our study suggests, that some of these third body complexes are the result of an inability to render the joint free of hard, primary cement debris. Such debris can also scratch and affect the metal component early.

It is therefore essential that ways to decrease smaller particles that escape lavage are further investigated.

Pulsed lavage is widely believed to lower the risk of infection.^{12,13} Lavage also lowers free debris consisting of blood clots, cartilage, hard and soft bone and cement. Additional lavage does not dislodge all particles was shown by Yasuo Niki et al.¹³ In their in vitro study, volumetric particulate count became static after 9 liters of wash. Addition of antibiotics and other bactericidal agents such as betadine to saline aim to lower infection not debris. Addition of solvents to improve wash characteristics has not made progress.

Modifications in the method of cementation could decrease the number of free particles in the joint cavity. Incising the extruded cement sharply at the implant interface when doughy and removing it only after it has fully polymerised and hardened will prevent fragmentation and increase of cement debris. Preventing extrusion of cement beyond the edges of the implant by incorporating a disposable restrictor is an unexplored possibility.

We are aware of inaccuracies in our estimation of both number and size of primary cement debris. This is in part related to using an older method first described in 1964 for urinary WBC cytology to quickly answer a clinical question of suspected urinary infection. The decision to treat was based on whether WBCs in sufficient numbers were present in urine rather than their absolute count (G. R. F. Hilson et al)⁶. Similarly the method when applied here provides a glimpse of primary cement debris density of the joint at closure. New counting technologies such as infra-red spectroscopy can be used to improve accuracy but we had no access to such methods¹⁵. We have estimated the size of cement particles in relation to the diameter of nearby RBCs visible in the stains and not used formulae to estimate their volume. Instead, we averaged the number of particles per smear and used the previously described method to convert it to particles/cu.mm. Also, the samples were obtained after release of tourniquet and some of the debris could be trapped within blood clots rendering them inaccessible to the drain. This could have introduced an error of under counting. The advantage has been simplicity of the procedure such that both number and size of particles could be qualitatively estimated from H & E stains commonly available in histopathology departments.

Conclusion

Primary micro cement particulate debris at closure in primary TKA varies in size and number. Pulsed lavage with 3 litres of saline does not clear all of it, particularly the smaller sizes. Increasing the volume of lavage fluid, better cementing and containment techniques could further decrease micro-debris, the potential for early third-body wear and synovial inflammation. Further work on cement containment and irrigation fluid characteristics is required.

Declarations

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Author Contributions

AY, MS Ortho: chief operating surgeon, manuscript writing, data collection and discussion.

MM, MS Ortho: manuscript writing, data collection, and statistics.

KAR, MS Ortho: chief operating surgeon, data discussion.

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Figures

Figure 1

Bone cement debris of size 100-500µm encircled in black (H&E , X 40), inset (X 400)

Figure 2

Bone cement debris encircled in black of sizes > 500m (center) and 100-500m (below) (H&E , X 40), inset center debris (X 400).

Figure 3

Bone cement debris encircled in black of size <100m (H&E , X 40). Inset (X 400) figuring that the size of the red blood cell is about 7.5 m , size of the debris can be estimated.

Figure 4

Distribution of number of debris per cu mm with debris size (N=13)