Preliminary Report

Comparison of Caulking Gun and Standard Cement Gun using for Femoral Cementation

Anuwat Pongkunakorn MD*,
Nuttawut Pengkong MD*, Wachara Maneeratroj MD*

** Department of Orthopaedic Surgery, Lampang Hospital and Medical Education Center, Lampang*

Background: *Currently the standard femoral cementing technique requires cement injection gun to deliver bone cement into the femoral canal. The standard cement gun is expensive and must be imported. There is no previous study about the use of a household caulking gun for femoral cementation.*
Objective: *To compare the radiographic quality of cementing technique in proximal femur between using standard cement gun and caulking gun.*
Material and Method: *Experimental study was performed on ten pairs of adult bovine femora. After the proximal femoral canal was prepared for cementation, each pair of bovine femora was randomly selected to be injected with bone cement with a standard cement gun in one side. The other side was injected with a caulking gun and the authors' invented kit. The prosthesis was inserted and radiographs were taken. Radiographic quality of cement interdigitation was evaluated by the modified Barrack's cement grading score. Cement distribution was categorized into 14 zones of Gruen. The data was statistically analyzed by Wilcoxon matched pairs signed-rank test. The inter-observer and intra-observer agreement was analyzed by Kappa analysis.*
Results: *Radiographic quality score of femoral cementation in the group using the caulking gun was not statistically different from in the group using the standard gun in all 14 Gruen zones ($p > 0.05$). Intra-observer and inter-observer agreement were moderate (Kappa = 0.71 and 0.59 respectively).*
Conclusion: *The radiographic quality of femoral cementation using the caulking gun was not significantly different from the standard cement gun. The caulking gun and invented kit could be applied in clinical use and save the operative cost.*

Keywords: *Femoral cementation, Cementing technique, Caulking gun, Cement gun, Invented, Hip replacement surgery*

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Hip replacement surgery is an important orthopaedic procedure. Hip hemiarthroplasty offers a successful form of treatment for the majority of patients with intra-capsular hip fracture[1]. Whereas, total hip replacement (THR) is the most commonly performed adult reconstructive hip procedure and can predictably relieve pain and improve function of patients with painful arthritic hips[2,3]. Furthermore, THR is proven to be one of the most cost-effective medical interventions known[4].

Correspondence to : Pongkunakorn A, Department of Orthopaedic Surgery, Lampang Hospital and Medical Education Center, 280 Paholyothin Rd, Muang, Lampang 52000, Thailand. Phone: 054-223-623 ext. 5121, Fax: 054-219-270, E-mail:dranuwat@gmail.com

During hip replacement surgery in elderly patients who have poor bone quality, it is very helpful to use the polymethylmethacrylate (PMMA) cement to fix the prosthesis securely in bone. PMMA bone cement distributes loads evenly from the surface of the prosthesis to the bone surface, thereby reducing stress in the supporting bone[5]. Good interdigitation between the bone and cement is essential for minimizing early loosening of the prosthetic component[6]. The conventional cementing method initially advocated by Charnley, known as first-generation technique, resulted in radiographic loosening of femoral components in 20% of cases at five-year follow-up and increased to 40% at ten years[7]. The second-generation method for cementing femoral component is to improve the first-

generation technique by using a retrograde cement gun instead of manual impaction[8,9]. While cement is delivered into the femoral canal and pressurized, the likelihood of entrapping blood and air, commonly encountered during finger packing, is diminished[6]. Improved cementing technique in second-generation could increase intrusion of cement into trabecular bone[10] and substantially reduce the incidence of femoral loosening[7,11].

Currently the standard femoral cementing technique requires an injection guns for filling cement into the proximal femur. The cost of commercially available cement injection gun in Thailand is about 2,000 Baht (58 US$), difficult for retrieval and must be imported. The authors invented the more economical cement injection kit using a household caulking gun (SL Home Products, Bangkok), a 50-mL disposable syringe (Terumo, Tokyo), a 1" PVC internal threaded cap and a piece of 3/8" clear polyethylene tube (Thai Pipe, Bangkok). All materials were safe to use with the patient (Fig.2). The invented kit cost about 100 Baht (3 US$). It is expected to be applicable in clinical use and save on operational costs. Moreover, to the authors' knowledge, there is no previous publication about the use of a household caulking gun for femoral cementation.

The purpose of the present study was to compare the efficacious use of a caulking gun and the commercially standard cement gun for femoral prosthetic fixation in terms of radiographic cementation quality.

Fig. 1 Miller bone cement injector and front loading cartridge kit (Zimmer, USA)

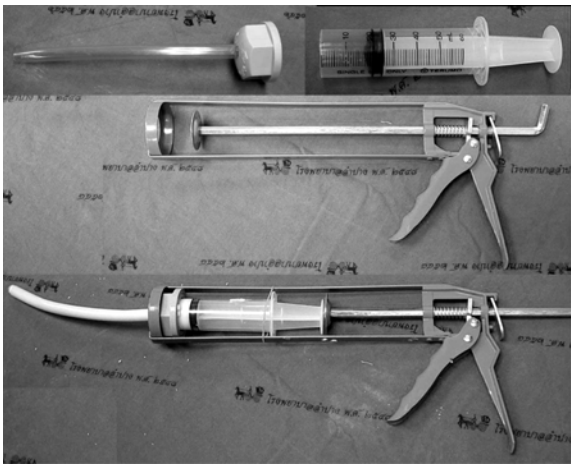

Fig. 2 The authors' cement injection kit invented from a household caulking gun, a 50-ml disposable syringe, a 1" PVC internal threaded cap and a piece of 3/8" polyethylene tube

Material and Method

The present experimental study was carried out in the operating room and X-ray room of Lampang Hospital. Ten matched-pairs of fresh adult bovine femora, from a slaughterhouse, were used in the present study. The cementing procedure was performed by the senior surgeon (AP) in all pairs of specimens. The femoral neck was cut and the femoral head was excised. The lateral aspect of the residual neck was removed by using a box osteotome. A smooth, tapered awl was introduced to locate the medullary canal. The femoral broach (Zimmer, USA) was inserted in approximately 15 degrees of anteversion, beginning with the smallest size (No.0). It was alternatively impacted and extracted to facilitate its passage. Next, the larger broach (No.1) was used to crush and remove the cancellous bone in the proximal femur. It was impacted to be fully seated at the level of femoral neck cut and then removed. The femoral canal was snuggly occluded with a rubber cap of saline bottle at the level distal to the anticipated tip of the stem. The loose debris and bone marrow were removed. The femoral canal was thoroughly cleaned, brushed and irrigated with normal saline solution. Thereafter, it was packed with a long, ribbon gauze to dry the femoral canal.

At this point, the specimen was ready to be cemented and inserted with the prosthesis. Each pair of bovine femora was randomly selected to be cemented with a standard injection gun (Miller bone cement injector and front loading cartridge kit, Zimmer, USA) in one side (Fig. 1). The other side was injected with a caulking gun and the authors' invented kit (Fig. 2). Two 40-g packages of PMMA bone cement (Zimmer, USA) were mixed and filled into the cement cartridge, then engaged to the gun. The cement was retrogradely injected via the nozzle into the femoral canal in early dough stage. Thereafter, the nozzle was disconnected

from the cartridge and introduced with an obturator to push out residual cement. The cement was pressurized manually for 10 seconds; then the femoral prosthesis (CPT stem size No. 1, Zimmer, USA) was inserted and held motionless. After the cement had fully hardened, the specimens had radiographs taken in the antero-posterior and lateral view (Fig. 3). The radiographs were assessed by two independent raters and repeated again one week later.

The quality of femoral cementation was evaluated by radiographic findings of cement inter-digitation using the score modified from Barrack cement grading system[7] (Table 1). Cement distribution was categorized into 14 zones of Gruen[12,13] (Fig. 4). The data was statistically analyzed by mean score and range and compared between standard gun vs. caulking gun Wilcoxon matched pairs signed-rank test. The inter-observer and intra-observer agreement was analyzed by Kappa statistic. A p-value of less than 0.05 was considered a statistically significance different.

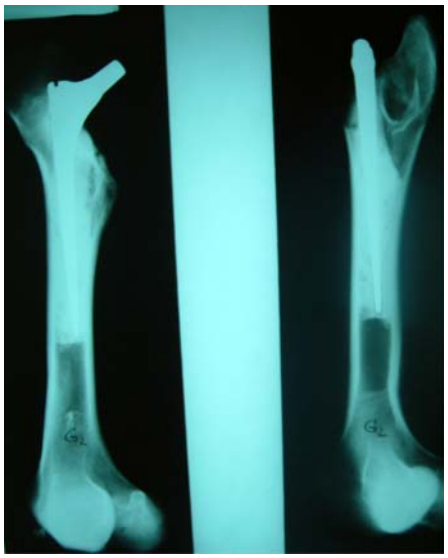

Fig. 3 Lateral and antero-posterior radiographs of bovine femora in which the femoral prosthesis was cemented

Results

Radiographic quality score of femoral cementation in the group using the caulking gun was not statistically different from the group using the standard gun in all 14 Gruen zones ($p > 0.05$, Table 2). The mean score of the standard gun group ranged from 3.00 to 4.92 and the caulking gun group ranged from 2.77 to 4.97. The standard gun group had a higher score in 6 zones (zone 4, 6, 8, 9, 11, 13), whereas the caulking gun group had a higher score in 8 zones (zone 1, 2, 3, 5, 7, 10, 12, 14).

In the antero-posterior radiographs, the highest and lowest mean score of both guns was in zone 7 and 4 respectively. In lateral radiographs, the highest mean score of both guns was in zone 14 whereas, the lowest mean score of the standard gun was in zone 12 and the caulking gun was in zone 11. The cement zones around the stem tip in antero-posterior view (zone 3-5) and lateral view (zone 10-12) all had a mean

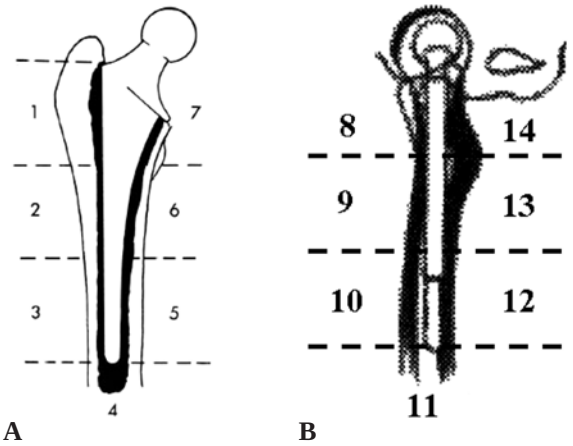

Fig. 4 Zones of cement distribution in proximal femur, as described by Gruen in antero-posterior (a) and lateral (b) radiographs

Table 1. Radiographic scoring system for evaluating the quality of femoral cementation, modified from Barrack's cement grading system

Cement appearance	Score
White-out, adequate (2 mm thick or more) of cement mantle, no void	5
Thin area (< 1 mm thick) of cement mantle, no void	4
Void, incomplete radiolucent line of cement-bone interface	3
Complete radiolucent line of cement-bone interface	2
Radiolucent line of cement-stem interface, rare cement	1

Table 2. Radiographic quality score of bovine femoral cementation in 14 Gruen zones (zone 1-7 in antero-posterior view and zone 8-14 in lateral view), comparing between injected with standard gun and caulking gun

Gruen zone	Standard gun (n = 10)		Caulking gun (n = 10)		p-value*
	Mean (min-max)	SD	Mean (min-max)	SD	
1	4.72 (3.0-5.0)	0.59	4.77 (3.0-5.0)	0.48	0.623
2	4.47 (3.0-5.0)	0.82	4.50 (3.0-5.0)	0.78	0.829
3	3.27 (1.0-5.0)	0.93	3.45 (1.0-5.0)	0.93	0.259
4	3.20 (1.0-5.0)	1.39	2.77 (1.0-5.0)	1.37	0.061
5	3.67 (2.0-5.0)	1.09	3.97 (3.0-5.0)	0.89	0.081
6	4.82 (3.0-5.0)	0.97	4.67 (3.0-5.0)	0.73	0.180
7	4.92 (4.0-5.0)	0.27	4.97 (4.0-5.0)	0.16	0.317
8	4.90 (4.0-5.0)	0.30	4.77 (3.0-5.0)	0.48	0.132
9	4.20 (4.0-5.0)	0.88	4.05 (3.0-5.0)	0.96	0.210
10	3.30 (1.0-5.0)	0.99	3.42 (1.0-5.0)	1.15	0.160
11	3.05 (1.0-5.0)	1.25	3.00 (1.0-5.0)	1.41	0.572
12	3.00 (1.0-5.0)	0.59	3.30 (1.0-5.0)	0.94	0.106
13	4.67 (3.0-5.0)	0.73	4.35 (3.0-5.0)	0.89	0.131
14	4.92 (3.0-5.0)	0.35	4.95 (3.0-5.0)	0.32	0.785

* Analyzed by Wilcoxon matched pairs signed-rank test

score of less than 4. The higher mean score (more than 4) was found in the zones close to the femoral neck (zone 1, 7, 8, 14) and middle area (zone 2, 6, 9, 13). Agreement of measurement was moderate. The Kappa value was 0.71 for intra-observer and 0.59 for inter-observer agreement.

Discussion

Implication of the household caulking gun for clinical use had been demonstrated in several manners such as inflation of tissue-expander prostheses in plastic reconstruction surgery, administration of high viscosity barium during small-bowel enteroclysis or injection of contrast material[14-17]. To the authors' knowledge, the present study is the first study regarding the use of a household caulking gun for orthopedic purpose. The volume of extrusion cement from the nozzle of a caulking gun and Zimmer gun is 8 ml and 7.7 ml per trigger respectively. As the nozzle diameter is 3/8 inch (9 mm) equally in both injection guns, so the size and flow rate of squeezed cement at the nozzle tip are not different between two groups. The pressure produced by the Zimmer gun was more than the manual caulking gun. Maltry et al[18] found that peak pressure developed during cement injection using the Zimmer cement gun was 73.6 +/- 27.1 psi and able to sustain a minimum pressure of at least 6.5 psi through cementation when used in conjunction with a flexible pressurizing seal. Likewise, Benjamin et al[19] demonstrated the benefit of sustained pressure at least 1.5 psi to counteract the efforts of bleeding from the bone. The manual caulking gun was mostly used for delivery of silicone sealant with the recommended pressure less than 45 psi[20], enough to sustain the pressure during the cementing process. It could not inject the high viscosity cement in the late dough stage, or the plunger of Terumo syringe might be broken before complete cement delivery. Nevertheless, during the present study the authors had not found any injection difficulty with low viscosity cement in the early dough stage.

The distribution of cement around femoral prosthesis and quality of cementation were not significantly different between the standard gun and caulking gun in all 14 Gruen zones ($p > 0.05$).

Number of higher score zones belonged to the caulking gun group, slightly more than the standard gun group. Anyway, the average quality score in zone 4 and 11 was less than the others because there was residual greasy marrow in the distal end of the femoral canal. It could not be clearly removed and caused the voids around stem tip in some specimens, even when using copious irrigation and canal brushing,. This finding was found similar in both groups of injection guns. Interestingly, the posteromedial portion of the femoral neck and calcar femorale (zone 7 and 14) yielded the highest quality score of both groups because its area was the widest bone opening and easier to clean. Its shape also curved horizontally to counteract the

vertical force during cement pressurization, leading to better cement-bone interdigitation.

The agreement assessed by Kappa analysis is considered to represent high, moderate and low if it shows $K > 0.75$, $0.4 < K < 0.75$ and $K < 0.4$ respectively. The Kappa value for intra-observer (0.71) and inter-observer agreement (0.59) of the present study were in the moderate range. Harvey et al also used Barrack's femoral grading system to assess the quality of cementing technique in total hip arthroplasty and reported the observer agreement in only 69% to 77% of the x-rays[21]. Nevertheless, Barrack's grading system is still widely used to evaluate the surgical technique and compare the arthroplasty result nowadays.

The limitation of the present study was the small sample size that may not have been enough to detect any differences between two groups. The matched-pairs study design and cementing procedure performed by a single surgeon were aimed to minimize the confounding factors. The other limitation was the fact that in the *vivo* human situation, there was fat and blood in the femoral canal which can produce back pressure absent in the study. Moreover, the experiment used bovine femoral bones instead of cadaver bones. Bovine femora have a plate-like structure as opposed to the rod-like structure found in the human trabeculae. The bovine bone is slightly more dense than human trabecular bone, i.e. 2.06 and 1.8-2.0 g/cm^3 respectively[22]. However, linear relationship between human and bovine cancellous bone was demonstrated for various porosities and cement intrusion depth[23]. It was valid for comparative purpose relative to human use.

In conclusion, the radiographic quality of femoral cementation using a caulking gun for cement delivery was not significantly different from using the standard cement gun. Caulking gun and the authors' invented kit could be applied in clinical use and save the cost of hip replacement surgery.

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คุณภาพของการบรรจุซีเมนต์ลงในโพรงกระดูกต้นขา เปรียบเทียบระหว่าง ปืนฉีดซิลิโคนกับปืนฉีดซีเมนต์มาตรฐาน: การศึกษาจากภาพรังสีของกระดูกต้นขาวัว

อนุวัตร พงษ์คุณากร, ณัฐวุฒิ เพ็งคง, วัชระ มณีรัตนโรจน์

***ภูมิหลัง**: วิธีการใช้ซีเมนต์ยึดกับกระดูกต้นขาในการผ่าตัดเปลี่ยนข้อสะโพกเทียมที่เป็นมาตรฐานในปัจจุบันจำเป็นต้องใช้ชุดปืนฉีดซีเมนต์ช่วยในการบรรจุซีเมนต์ลงไปในโพรงกระดูก ซึ่งมีราคาแพงและนำเข้าจากต่างประเทศ ยังไม่เคยมีการศึกษาถึงการนำปืนฉีดซิลิโคนมาประยุกต์ใช้เป็นอุปกรณ์ฉีดซีเมนต์ยึดกระดูก*

***วัตถุประสงค์**: เพื่อศึกษาคุณภาพของการบรรจุซีเมนต์ลงในโพรงกระดูกต้นขา เปรียบเทียบระหว่างการบรรจุด้วยปืนฉีดซีเมนต์มาตรฐาน กับอุปกรณ์ฉีดซีเมนต์ที่ประดิษฐ์จากปืนฉีดซิลิโคน*

***วัสดุและวิธีการ**: เป็นการศึกษาแบบทดลองในกระดูกต้นขาหลังของวัวที่ผ่านการชำแหละแล้วจำนวน 10 คู่ หลังจากที่เจาะปลายกระดูกส่วนต้นให้เป็นโพรงแล้ว กระดูกแต่ละคู่จะถูกบรรจุซีเมนต์ลงไป โดยสุ่มให้ข้างหนึ่งใช้ชุดปืนฉีดซีเมนต์มาตรฐาน อีกข้างหนึ่งใช้อุปกรณ์ฉีดซีเมนต์ที่ประดิษฐ์จากปืนฉีดซิลิโคน ใส่ก้านข้อสะโพกเทียมและนำกระดูกไปถ่ายภาพรังสี ประเมินคุณภาพการแทรกตัวของซีเมนต์เข้าไปในเนื้อกระดูก และปริมาณการกระจายตัวของซีเมนต์โดยอ่านจากภาพรังสี แล้วให้คะแนนตามเกณฑ์ที่ดัดแปลงจากวิธีของ Barrack โดยแบ่งเป็น 14 zone ตามวิธีของ Gruen เปรียบเทียบกันทั้ง 2 ข้าง โดยใช้สถิติ Wilcoxon matched pairs signed-rank test วิเคราะห์ความสอดคล้องของการวัด โดยการวัดซ้ำด้วยผู้วัดคนเดิมและผู้วัดต่างคนกันด้วยการวิเคราะห์ Kappa*

***ผลการศึกษา**: คุณภาพของการแทรกตัวของซีเมนต์เข้าไปในเนื้อกระดูก และปริมาณการกระจายตัวของซีเมนต์ที่อ่านจากภาพรังสี ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ระหว่างกลุ่มที่บรรจุซีเมนต์ด้วยชุดปืนฉีดซิลิโคนกับกลุ่มที่บรรจุด้วยชุดปืนฉีดซีเมนต์มาตรฐาน ทั้ง 14 Gruen zone ($p > 0.05$) ความสอดคล้องของการวัดโดยผู้วัดคนเดิม และผู้วัดต่างคนกัน อยู่ในระดับปานกลาง (Kappa = 0.71 และ 0.59 ตามลำดับ)*

***สรุป**: คุณภาพของการบรรจุซีเมนต์ลงในโพรงกระดูกต้นขาของอุปกรณ์ฉีดซีเมนต์ที่ประดิษฐ์จากปืนฉีดซิลิโคนกับปืนฉีดซีเมนต์มาตรฐาน ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติเมื่อประเมินจากภาพถ่ายรังสี อุปกรณ์ที่ประดิษฐ์ขึ้นนี้สามารถนำไปประยุกต์ใช้ในทางคลินิก เพื่อประหยัดค่าใช้จ่ายในการผ่าตัด*