Results of Cement with Screw Augmentation for Large Tibial Defects in Primary TKA

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Objectives: *To compare the outcome of TKAs using screw augmentation and cement in cases involving a large tibial defect with conventional TKA procedures in cases with no tibial defect using clinical and radiographic data.*
Materials and Methods: *A retrospectively reviewed of 217 TKAs that operated at Nakhon Pathom Hospital from January 2010 - March 2021.TKAs have divided into 54 knees with a large tibial defect treated using screws with cement augmentation (the screws group), and 163 knees with a small or no tibial defect treated with conventional TKA procedures (the no screws group). Patient information collected included age, gender, limb alignment, length of follow-up period, defect depth, presence of radiolucency lines, Knee Society scores and incidence of prosthesis loosening.*
Results: *There was no statistically significant differences between the groups in mean ages (64 yrs.), follow-up period (6 yrs.), BMI, gender (female 88%) and post-operative overall alignment (4.35°). While pre-operative varus angle of screw group (-15.96°), incidence of radiolucency lines of screw group (59%) and improvement of Knee Society Scores after surgery were significantly differences (P-value < 0.001). The average defect depth was 11.99 mm and most of the depths was in range of 10-20 mm. There were 6 cases of loosening prosthesis in the no screws group and 3 cases in the screws group. The survival rate of implants was 96% in the no screws group and 94% in the screws group with no difference in statistic.*
Conclusions: *At mean follow-up of 6 years, the cement with screw augmentation for large tibial defects had a survival rate equal to conventional TKA in cases without bone defect and had a lower cost than metal augmentation. This technique is recommended for defect depths of between 6-20 mm.*

Keywords: *Total Knee Arthroplasty, Tibial defect, Positioning Screw, Cement and screw, cost*

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Introduction

Total knee arthroplasty (TKA) is the treatment of choice of most orthopedic surgeons for late stage osteoarthritic knees. In most cases, primary TKA surgery is used for patients without bone defects; however, a number of patients are found during the surgical process to have a large bone defect (bone depressed more than 5 mm) which requires additional special techniques to treat the bone defect.

Bone defects are a critical issue which mostly arises during revision TKA when they are discovered in a femur or tibia. Most large tibial defects are uncontained bone defects (AORI classification) [4]. A large defect in a tibial bone creates a problem for placing an implant on the tibial bone and can affect both the stability of the knee as well as the survival of the implant. In patients with severe varus-valgus deformity which is often found in tibia, on the other hand, primary TKA is commonly used [1-3].

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There are several alternative methods for solving tibial bone defects. Deeper tibial bone resection through the defect base level provides a flat surface, but has a negative impact on mechanical stability due to the smaller size, poorer bone quality and compromised soft tissue envelope attachments. In common practice in cases of small bone defects (bone depressed less than 5 mm), only polymethylmethacrylate (PMMA), a bone cement, is used for augmentation, although some studies have mentioned its use with large defects [5]. Autografts have been recommended for small, contained bone defects, while allografts are suggested for large, uncontained bone defects. One problem with the allograft technique is fragmentation and resorption of the graft [6-10]. Metal augmentation is the most popular method to correct a large tibial defect, but the high cost of metal augmentation limits the use of this method. The cement with screws technique was chosen for this study because of its low price, its convenience and because it preserves bone and soft tissue. Many studies have reported mid to long term failure rates using cement with screws which are as low as with conventional TKA [18-21]. The aim of this study was to compare the clinical and radiological results of the cement and screws technique with conventional TKA.

Materials and Methods

The records of 304 primary TKA operations for late stage osteoarthritis of the knee during the period January 2010 through December 2015 were reviewed. Of those, 87 knees were excluded due to incomplete data and 217 knees were included in the study. All TKAs had been performed by same surgeon using a prosthesis model (Scorpio single radius model). Retrospective data was collected through March 2021. The TKAs were divided into two groups: conventional TKAs with no defect or less than a 5 mm tibial defect (the no screws group) and TKAs with more than a 5 mm tibial defect (the screws group).

This study controlled for TKA type. It also presents a positioning screw fixation technique.

Surgical Techniques

The procedure used in all cases was a conventional medial parapatellar approach with subperiosteal release of the superficial medial collateral ligament. An extramedullary tibial guide was used for the tibial cut. The ligament-balancing technique was used to balance the flexion and extension gaps.

In the no screws group, the tibial cut level was 2 mm below the anterior surface on the defect side or 8 mm below on the intact side. After the tibial cut, there were no or less than 5 mm defect of tibial cut surface. A conventional TKA was performed and the small defect was filled with cement.

In the screws group, a large bone depression was clearly visible during surgery so the reference for the tibial cut was on the intact side of plateau. The level of resection was less than with the standard technique due to the laxity of the ligament which results in a larger tension gap space. The greater the bone depression, the less bone cut was required. After the tibial cut, the balance gaps should be sufficient for inserting a tibial prosthesis 8-10 mm thick. In this group the defect depth was more than 5 mm from tibial cut surface and was filled with cement and screws augmentation. This positioning screw fixation technique was first used by the Nakhon Pathom orthopedics team. Soft tissue and cartilage were removed from the sclerotic bone, and a 3.5 mm cortical screw was inserted vertically from the thick sclerotic bone to the metaphyseal cortex. The number of screws depended on the area of the bone defect and ranged from 1 to 3 screws. The area of the defect was visually estimated to range from 15 to 40% of the total surface area of the tibial plateau. The screw heads were placed 1 mm beneath the tibial cut surface to prevent direct contact with the prosthesis. Different cementing techniques were used for the tibial and the femur prostheses. Preoperative and postoperative radiographic images of the surgical technique are shown in Figure 1.

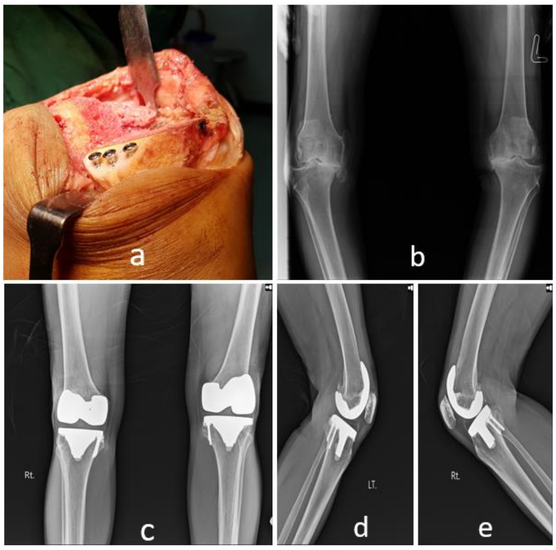

Fig. 1 (a) Typical posterior medial bone defect after tibial bone resection at the appropriate level. Vertical screws are fixed. **(b)** Preoperative view. **(c)** Postoperative AP view. **(d, e)** Postoperative lateral view.

Measurement data

Demographic data, including age, sex, body mass index (BMI) as well as follow-up period, clinical and a radiographic information (limb alignment, defect depth, radiolucency) were obtained from hospital records. The standard follow-up schedule was every 6 months to 1 year. Preoperative and postoperative clinical data is expressed in the form of Knee Score and Functional Score using the Knee Society scoring system [21]. Scores were collected preoperatively and the latest follow up. Knees were checked radiographically at each follow-up. The depth of the bone defect was measured in radiographic AP view from the maximum depth of the defect to the lower end of the implant using a digital x-ray program. The depth of each defect was repeatedly measured by the author at distance of after a period of 4 weeks. Defects were dived into 4 classes based on the depth of the defect: 6-10 mm (Class 1), 10-20 mm (Class 2), 20-30 mm (Class 3) and more than 30 mm (Class 4). The Tibiofemeral angle was measured using x-rays of both knees in standing view and included both varus and valgus angles. The angles were measured in the same way as the defect. Radiolucent lines at the bone-cement-prosthesis interface were identified using a modified radiographic evaluation system [22]. Routine Follow-up was halted when signs of loosening of the prosthesis were detected.

Statistical Methods

The sample size was determined using the G*Power program (version 3.1). The successful outcome ratio of the no screws group was 0.7 and for the screws group was 0.5. The statistical significance level (α) was 0.05 and the power of the test was 0.8. There was data on three times as many patients in the no screws group than in the screws group, so the size of the no screws group was 160 cases and the size of the screws group was 48 cases.

All data are presented as frequencies and percentages or means and standard deviations as appropriate. Chi-square analysis was used to test relationships between categorical variables and to examine proportional differences. The two-sample t-test was used to determine mean differences between groups. A Kaplan-Meier survival analysis was used to determine if there was a statistically significant difference in the survival rate between the two groups. All statistical analyses were conducted using SPSS software for Windows version 23.0 (SPSS, Inc., Chicago, IL). A P-value of less than 0.05 was considered statistically significant.

Ethics approval was obtained from the Institutional Review Board, Nakhon Pathom Hospital Ethic Committee (NPH – RECNo. 014/2021).

Results

There were 163 knees in no screws group and 54 knees in screws group. TKA patient demographic data is shown in Table 1. There were no statistically significant differences in age, gender, and BMI or follow-up period between the two groups. The average age of the patients was 64 years (range, 48-87 years), BMI was 26.54, follow up was for 75 months (6.3 years; range, 30-128 months) and 88% of the patients were female. The intra-rater reliability of defect depth and Tibiofemeral angle measurements was analyzed by Kappa statistic and showed a very good agreement.

The screws group had a larger preoperative varus angle (-15°) than the no screws group (-7°) (*P*-value < 0.001). The combined average post-operative limb alignment was 4.35° (range, -9.8° to 9°) with no significant difference between the groups. All defects were of the uncontained metaphyseal type and the average depth was 11.99 mm (range 6.74-33). Most of the defects were Class 2 (35 knees) followed by Class 1 (18 knees); there was only 1 knee in Class 4. In both groups the post-operative knee scores and function scores were significantly better than the pre-operation scores (*P*-value < 0.001) (Table 2).

Table 1 Demographics of TKAs.

	No Screw		**Screw**		***P*-value**	**Overall**	
	Avg. (S.D.)	**Range**	**Avg. (S.D.)**	**Range**		**Avg. (S.D.)**	**Range**
Age (yrs.)	63.79 (6.51)	[48-87]	65.48 (7.45)	[51-78]	0.111	64.21 (6.78)	[48-87]
Female	145 knees	89%	46 knees	85%	0.459	191	88%
Male	18 knees	11%	8 knees	14%	-	26	12%
BMI (kg/m^2)	26.8	[24.9-29.8]	26.3	[23.5- 31.5]	0.233	26.54	[23.5- 31.5]
Overall pre-op (deg.)	-5.39 (6.59)	[-21 to 28]	-15.28 (7.50)	[-30 to 21]	< 0.001	-7.85 (8.05)	[-30 to 28]
Pre-op varus (deg.)	-7.04 (3.30)	[-2 to -21]	-15.96 (5.62)	[-7 to -30]	< 0.001	-9.43 (5.66)	[-2 to -30]
Pre-op valgus (deg.)	10.69 (7.20)	[2-28]	21.0	-	-	11.29 (7.41)	[2-28]
Overall post-op (deg.)	4.57 (1.91)	[1-9]	3.71 (3.32	[-9.8 to 8]	0.075	4.35 (2.36)	[-9.8 to 9]
Follow-up (months)	77.04 (19.61)	[33-128]	72.56 (14.35)	[30-123]	0.101	75.69 (19.22)	[30-128]
Defect Depth (mm)	-	-			-	11.99 (4.03)	[6.74-33]
Class 1 (18 knees)			8.66 (0.87)	[6.74-9.8]			
Class 2 (35 knees)			13.10 (2.21)	[10-20]			
Class 3			-	-			
Class 4 (1 knees)			33	-			

Table 2 Comparison of average Knee score and Function Score between pre-op and post-op in the no screws and the screws groups.

Group		Pre-op		Post-op		t	*P*-value
		$\bar{X}$	S.D.	$\bar{X}$	S.D.		
No screws	Knee Score (Points.)	46.39	9.39	81.88	5.90	-40.65	<0.01
	Function Score (Points.)	56.33	9.18	87.40	5.15	-40.98	<0.01
Screws	Knee Score (Points.)	35.28	16.08	85.00	5.07	-21.60	<0.01
	Function Score (Points.)	49.17	13.19	88.59	3.01	-21.87	<0.01

In each group, 32 knees were found to have radiolucent lines present at the bone-cement interface but only in tibial component. Radiolucency was more frequent in the screws group (59%) than the no screws group (20%), a statistically significant difference (Fisher's Exact Test, P-value <0.001). In the screws group, the greatest number of cases with radiolucent lines were found in Class 2 (20 knees) followed by Class 1 (11 knees) and Class 4 (1 knee). Most of the radiolucent lines had a narrow width (less than 4 mm) and limited in 2 zone from 7 zone of category at the end of follow up, except for 9 cases, the radiolucent lines have progressed and end up with loosening of the tibial component. Of the cases with prosthesis loosening, 6 were in the no screws group and 3 were in the screws group. In the no screws group, the average age of patients with prosthesis loosening was 57 years (range 51-62) and the average post-operative period to failure was 76 months (range 42-120). Analysis of the correlation between severity of defects with radiolucency and a loosening prosthesis was conducted. No correlation between defect depth and radiolucency (Table 3) or between defect depth and loosening prosthesis was found (Table 4).

At an average of 6.3 years post-operation, the survival rate of the implants was 96% in the no screws group and 94% in the screws group. A Kaplan-Meier survival curve analysis found no difference in the survival curves of the two groups (Wilcoxon P-value=0.514, log-rank P-value=0.058) (Figure 2).

Table 3 Comparison of defect depth and incidence of radiolucency.

Defect Depth	No		Yes		Chi-square	*P*-value
	knees	percent	knees	percent		
Class 1	7	38.9	11	61.1		
Class 2	15	42.9	20	57.1	0.77	1.00*
Class 1	7	38.9	11	61.1		
Class 4	0	0	1	100	0.616	1.00*
Class 2	15	42.9	20	57.1		
Class 4	0	0	1	100	0.735	1.00*

Yes: with radiolucency, No: without radiolucency; * Fisher's Exact Test

Table 4 Comparison of class of defects and loosening prostheses.

Defect Depth	Failed		Success		Chi-square	*P*-value
	knee	percent	knees	percent		
Class 1	1	5.6	17	94.4		
Class 2	1	2.9	34	97.1	0.238	1.00*
Class 1	1	5.6	17	94.1		
Class 4	1	100	0	0	8.972	0.105*
Class 2	1	2.9	34	97.1		
Class 4	1	100	0	0	17.486	0.056*

Failed: loosening prosthesis case, Success: No-loosening prosthesis case, * Fisher's Exact Test

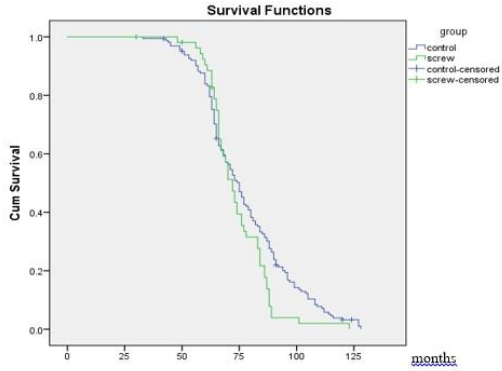

Fig. 2 Kaplan-Meier survival curves of the screws and no screws groups.

Discussion

At present, there has not been an in vivo study comparing the methods for treating large tibial bone defects in a single report. All methods are considered acceptable options. Surgeons can select a method based on various factors, e.g., the evidence of past studies, experience of the surgeon, availability of tools, bone quality, and cost of each technique. Cement augmentation alone is a simple technique. Lotke et al., based on 7 years of experience, reported successful results filling defects smaller than 20 mm in depth [5], but, based on biomechanical testing, Brook et al. reported more bone deflection than either the combined screw technique or metal augmentation [16]. Grafting with bone from the femoral and tibial cut has the advantage of adding bone stock. Many studies have reported good results with autograft augmentation in both contained and uncontained defects, i.e., there was graft union formation and no loosening of the prosthesis at 3 to 7 years [6-9]. On the other hand, Raskin et al. reported an overall five-year success rate of only 67 percent [10]. In this study, due to the surgical technique used, the amount of autograft left over from the cut was insufficient for reinforcement of a large defect. Allografts are commonly used with an uncontained defect, but our institute has problems of availability and quality of the graft material. Metal augmentation, the most popular method in both in vivo and in vitro studies, has shown better results than other techniques, with most studies reporting survival rates similar to TKAs cases with no tibial defect at the 3-6-year follow up [11-14]. Disadvantages of metal augment include that it is not always available, is expensive, requires an intramedullary tibial stem, and may cause further bone loss due to the shelf design, reducing the available bone stock should a revision procedure be required in the future. The cement with screws technique was chosen for this study because it is economical, convenient and does not damage bone or soft tissue. According to 1986 and 1993 studies by Ritter et al. as well as a long-term study published in 2014[16-18], this method is as effective as conventional TKA in patients without bone defects. Although the above mentioned studies include numerous examples and long term data records, they collected information without controlling for the type of TKA. Those cases also involve the use of additional tools such as an intramedullary tibial stem. The present study differs from those studies because it provides a comparison of the results of this augmentation technique with conventional TKA in cases without defects where surgeons use the same type of TKA but without special instrumentation.

The concept of the positioning screw fixation technique comes from a construction principle. Cement is like the concrete used in construction, while cement augmented with screws is like concrete with a reinforced anchor pile. The pile must be perpendicular to support the load and must extend deep into solid soil or rock layers. In previous studies, a cancellous screw which had been inserted parallel to metaphyseal cortex into cancellous bone and sclerotic bone had later been removed [15-18]. The key difference in the techniques is that this study used a cortical screw vertically inserted from sclerotic bone into the metaphyseal cortex. A vertically oriented screw can support the axial load better than one in an oblique direction. Additionally, bi-cortical fixation allows the screws to be firmly attached to the bone which also improves adhesion of the cement to the bone and the prosthesis. Freeman et al. found that radiolucency appeared more frequently in screws with cement, results similar to the present study [15]; however, no correlation was found between the progression of radiolucency and the failure rate of implants in either the screws or the no screws group, also in subgroup of screws group. However, among the Class 4 patients in the screws group, there was one case of early loosening of the implant at the 30-month follow up, suggesting metal augmentation and an intramedullary tibial stem might be more appropriate in cases of very great defect depths.

In this study, in the screws group there were more cases of severe varus angle of deformity than in the no screws group; however, after surgery the overall alignment between the groups was not different. There were clinical improvements in both groups. The implant survival rates in both groups at the 6.3-year follow-up were similar, the same as in a previous study of Scorpio TKAs [23]. In Thailand, the price of metal augmentation with intramedullary tibial stem starts at twenty thousand baht, 50 times greater than the 300 baht per screw with the cement and screws method, i.e., the augmentation technique is a safe and less expensive method for resolving the problem. This study had some limitations: the study covered a relatively short period and the pool of patients was not large. The study did, however, have control over important variables including the surgeon performing the operations, the surgical technique used and the type of implant.

Conclusions

Cement with screws augmentation is a safe and cost-effective method for repairing large tibial defects in primary TKAs and does not require the use of special instruments. This technique has the same implant survival rate at the 6.3 years and at up to 10 year-follow-ups as conventional TKA in patients without a bone defect. This technique is recommended for cases with a defect depth of 6-20 mm.

Potential conflict of interest

None.

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การศึกษาการใช้ซีเมนต์และสกรูเพื่อเสริมภาวะบกพร่องขนาดใหญ่ของกระดูกทิเบียในการผ่าตัดเปลี่ยนข้อเข่าแบบปฐมภูมิ

วสุ เตชะไพฑูรย์, พบ

วัตถุประสงค์: *เพื่อศึกษาผลการใช้เทคนิคซีเมนและสกรูเพื่อเสริมในกลุ่มที่มีภาวะบกพร่องขนาดใหญ่ของกระดูกทิเบียเปรียบเทียบกับกลุ่มที่ไม่มีภาวะบกพร่องในการผ่าตัดเปลี่ยนข้อเข่าแบบปฐมภูมิ*

วัสดุและวิธีการ: *การศึกษาย้อนหลังของผู้ป่วยข้อเข่าเสื่อมที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าแบบปฐมภูมิ ตั้งแต่ มกราคม ค.ศ. 2010 ถึง ธันวาคม ค.ศ.2015 จำนวน 217 เข่า และติดตามจนถึง มีนาคม ค.ศ.2021 แบ่งเป็นกลุ่มที่มีภาวะบกพร่องขนาดใหญ่ของกระดูกทิเบียจำนวน 54 เข่า ได้รับการผ่าตัดข้อเข่าเทียมร่วมใช้เทคนิคซีเมนต์เสริมสกรู และกลุ่มที่ไม่มีภาวะบกพร่องจำนวน 163 เข่าได้รับการผ่าตัดข้อเข่าเทียมแบบมาตรฐาน ข้อมูลที่ใช้การศึกษา และสถิติที่ใช้ ได้แก่ อายุ, ระยะเวลาติดตาม, ดัชนีมวลกาย, ตำแหน่งแกนขา, เพศ, ความลึกของส่วนบกพร่องกระดูก, คะแนนฟังก์ชั่นเข่าก่อนและหลังผ่า, อุบัติการณ์การเกิดช่องว่างกระดุกในเอ็กเรย์, จำนวนเข่าที่ล้มเหลว, อัตราการอยู่รอดของข้อเข่า*

ผลการศึกษา: *ค่าเฉลี่ยโดยรวม อายุ 64 ปี, ค่าดัชนีมวลกาย 26.54, ระยะเวลาติดตามเฉลี่ย 6 ปี และติดตามนานสุด 10 ปี, อัตราส่วนหญิง 88 เปอร์เซ็นต์, ไม่มีความแตกต่างทางสถิติของทั้งสองกลุ่มการศึกษา ในกลุ่มที่ผ่าตัดใช้สกรูมีมุมเข่าโก่งนอกก่อนผ่าตัดมากกว่ากลุ่มที่ไม่ใช้สกรูแต่ภายหลังผ่าตัดมีมุมเข่าที่ปกติใกล้เคียงกัน คะแนนฟังก์ชั่นเข่ามีคะแนนที่ดีขึ้นเมื่อเทียบก่อนและหลังผ่าตัดของทั้งสองกลุ่ม ความลึกโดยเฉลี่ยของภาวะบกพร่องของกระดูกทิเบียเท่ากับ 11.9 มิลลิเมตร ช่วงความลึกของส่วนบกพร่องกระดูกที่พบมากที่สุดอยู่ระหว่าง 10 ถึง 20 มิลลิเมตร กลุ่มผ่าตัดใช้สกรูพบอัตราการเกิดช่องว่างของกระดูกในเอ็กเรย์ฟิล์มเท่ากับ 59 เปอร์เซ็นต์ ซึ่งมากกว่ากลุ่มไม่ใช้สกรูที่มีอัตราเท่ากับ 20 เปอร์เซ็นต์ พบมีข้อเทียมหลุดหลวม 6 รายในกลุ่มไม่ใช้สกรูและ 3 รายในกลุ่มใช้สกรู อัตราการอยู่รอดของข้อเข่าที่ระยะติดตามเฉลี่ย 6 ปีในกลุ่มใช้สกรูเท่ากับ 94 เปอร์เซ็นต์ กลุ่มไม่ใช้สกรูเท่ากับ 96 เปอร์เซ็นต์ จากการใช้สถิติการวิเคราะห์การอยู่รอดของ Kaplan-Meier พบว่าไม่มีความแตกต่างทางสถิติ*

สรุป: *ที่ระยะเวลาติดตามเฉลี่ย 6 ปี การใช้เทคนิคซีเมนต์และสกรูเพื่อแก้ไขภาวะบกพร่องขนาดใหญ่ของกระดูกทิเบียในการผ่าตัดเปลี่ยนข้อเทียมแบบปฐมภูมิได้ผลดีเทียบเท่ากับการผ่าตัดเปลี่ยนข้อเทียมภาวะปกติที่ไม่มีภาวะบกพร่องของกระดูกทิเบียและได้เปรียบในด้านราคาวัสดุที่ประหยัดกว่าเมื่อเทียบการใช้เหล็กพิเศษเสริมกระดูก ระดับความลึกของส่วนบกพร่องกระดูกระหว่าง 6 ถึง 20 มิลลิเมตรเหมาะสมสำหรับเทคนิคนี้*