



Clinical Results after Design Modification of Lospa Total Knee Arthroplasty System: Comparison between Posterior-Stabilized (PS) and PS Plus Types

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Background: Lospa posterior-stabilized (PS) Plus type is a modified version of Lospa PS, in which the polyethylene insert shape is modified to reinforce stability and prevent patella-post impingement compared to Lospa PS. However, studies comparing the clinical and radiographic results of the two designs have not been reported yet. This study aimed to compare the clinical results of total knee arthroplasty (TKA) using the existing PS type and the modified Lospa PS Plus type.

Methods: A retrospective study was performed on 558 knees of 342 patients who underwent TKA using the Lospa PS or PS Plus types and were followed up for at least 2 years. Cases were divided into two groups according to the implant used: 212 cases in the PS group and 346 cases in the PS Plus group. For clinical outcome assessment, knee range of motion (ROM), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, and Knee Society Score (KSS) were recorded before surgery and at the 2-year follow-up. Radiographic outcomes were evaluated according to the American Knee Society method. The incidence of postoperative complications and survival rates were compared between the two groups.

Results: Both groups showed significant clinical improvement after surgery. The average KSS significantly improved from 53.4 points in the PS group and 52.3 points in the PS Plus group preoperatively to 91.3 points and 93.2 points after surgery, respectively ($p < 0.001$). The average WOMAC score improved from 50.4 points in the PS group and 52.3 points in the PS Plus group before surgery to 15.6 points and 14.8 points after surgery, respectively ($p < 0.001$). There was no significant difference between the two groups in ROM, the alignment of the lower limbs, and the implant position after surgery. The complication rates were also similar between the groups ($p = 0.167$).

Conclusions: The Lospa PS Plus model is a modified design that improves the post structure from the previous PS type. Compared to the PS type, the PS Plus type showed similar statistical results at 2-year follow-up and good clinical results. The short-term average survival rate was over 98%, showing promising results.

Keywords: *Knee, Total knee arthroplasty, Posterior-stabilized*

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The purpose of total knee arthroplasty (TKA) is to restore normal, functional knee joint dynamics by reducing pain and securing joint stability. Demands on maintaining range of motion (ROM) after TKA are especially high in Asian patients.¹⁾ The implant design is one of the important factors affecting ROM after TKA. Hence, the Lospa knee system (Corentec Inc., Cheonan, Korea) was developed and commercialized for the first time in South Korea

in 2011. In theory, the Lospa knee system facilitates deep flexion by using a single radial axis of the femoral component, more rounded femoral contour, and deepened patellar groove. Satisfactory clinical results, including the post-operative knee ROM comparable to high-flexion designs, have been reported.^{2,3)}

It is known that the posterior-stabilized (PS) prosthesis can be beneficial to achieve good range of rotation and ROM due to constant femoral rollback.^{4,5)} In contrast, there is an opposite opinion that the PS type implant may cause inconsistency between flexion and extension gaps and disadvantages such as joint mismatch, which lead to inferior long-term outcomes.^{6,7)} Also, impingement of the patellar component against the tibial post may occur during deep knee flexion after PS TKA.⁸⁾

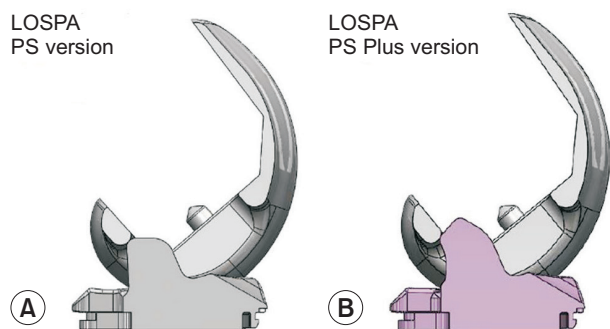


Fig. 1. Comparison of Lospa posterior-stabilized (PS; A) and PS Plus (B) types. The pictures are reproduced by courtesy of the manufacturer.

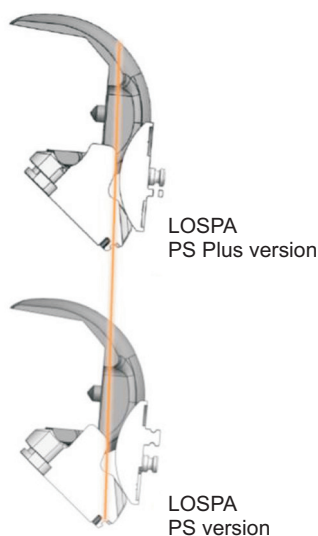


Fig. 2. Modified polyethylene design may help to avoid impingement of the patellar component with anterior post fillet during high-flexion of the knee joint. PS: posterior-stabilized. The pictures are reproduced by courtesy of the manufacturer.

A biomechanical study confirmed that recent modifications of the post-cam design used in the PS prosthesis increased the contact area and conformity, which may contribute to a lower contact stress during knee-high flexion. However, none of the prostheses showed consistently low contact stresses throughout the flexion range. Therefore, further modification of the post-cam mechanism is necessary to lower the risk of polyethylene failure in the knee with hyperflexion.⁶⁾

In 2015, the Lospa PS Plus type, in which the polyethylene component's post shape was modified, was developed. It enhanced stability while maintaining the advantages of existing PS types by modifying the polyethylene component design. There are some characteristic changes from Lospa PS. First, the post height was higher than that of the existing PS type, and the shape of the polyethylene post was changed from a trapezoid to shark pin post fillet, while the width of the post was the same (Fig. 1). Theoretically, it was modified to reduce patellar impact during high flexion. (Fig. 2). Second, insertion of the polyethylene insert was made easier even without anteriorly dislocating the tibia during the procedure by forming a chamfer structure at the connecting part of the polyethylene tibial prosthesis (Fig. 3).

Despite the design modification, it has not been reported yet whether there is any clinical difference between the existing Lospa PS type and the modified PS Plus type design. Therefore, this study aimed to compare and analyze the clinical results of TKA performed using the existing PS type and the PS Plus type with a modified polyethylene shape.

METHODS

The study was conducted with Institutional Review Board approval (IRB No. 2019-05-038-007). The requirement for informed consent was waived due to the retrospective na-

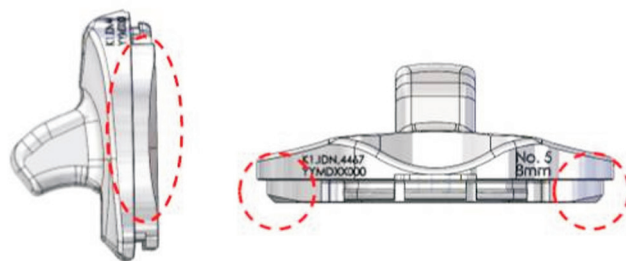


Fig. 3. The bottom chamfer cutting may allow easier insertion of the polyethylene insert so excessive anterior dislocation of the tibia is not required. The pictures are reproduced by courtesy of the manufacturer.

ture of this study.

Patients

Among 946 TKAs performed using the Lospa PS or PS Plus type during the period from April 2011 to February 2018, a total of 558 knees of 342 patients who were followed up for 2 years or more were included in this study. One senior surgeon (JML) operated all cases. There were 212 knees in 125 patients with the PS type, and 346 knees in 217 patients with the PS Plus type (Table 1). There was a difference in time for each type used in TKA: Lospa PS was used from 2011 to October 2015, while Lospa PS Plus was used after November 2015. All primary TKAs performed for primary osteoarthritis, rheumatoid arthritis, spontaneous osteonecrosis of the knee, and posttraumatic arthritis were included in the study. Primary TKAs required higher constraint than PS type to manage the extension mechanism insufficiency, global knee instability, and infection, and all revision TKAs were excluded.

Operation Technique

One senior surgeon (JML) performed all operations, and the same surgical method was used regardless of the type (PS or PS Plus) used. A tourniquet was inflated, and the knee joint was exposed using a mid-vastus approach. After exposing the medial and lateral condyles of the femur and tibial plateau, the proximal tibia was resected first using an extramedullary alignment guide device targeting the tibial

inclination perpendicular to the tibial mechanical axis in the coronal plane and the tibia posterior inclination angle of 3° in the sagittal plane. After distal femur resection, the rotational alignment was determined based on the femur's intercondylar axis, and femur resection was performed using the anterior reference system. Bone resection and maintenance of ligament balance were performed by applying the principle of the modified gap technique. Patella replacement was performed in all patients. Cement was applied to both the implant and the bone surface. After inserting the polyethylene trial implant, the knee joint was fully extended and maintained for about 10 minutes to fix the joint until the cement was completely hardened. Then, the tourniquet was released, and hemostasis was performed. The tourniquet was inflated again, and the real polyethylene was inserted. A drainage tube was placed in the joint, and the operation was completed. Immediately after surgery, an intermittent pneumatic compression device was used to prevent deep vein thrombosis, and straight leg elevation and continuous passive motion were started from the first day after surgery. Walking was started using a walker, and the drainage tube was removed 2–3 days after surgery.

Clinical and Radiographic Evaluation

Clinical and radiographic results, complications, and survival rates were compared between the PS and PS Plus groups. For patients who underwent bilateral TKAs, clini-

Table 1. Patient Demographics of PS and PS Plus Groups

Variable	PS (n = 212)	PS Plus (n = 346)	p-value
Sex (male : female)	51 : 161	83 : 263	0.164*
Operation side (right : left)	108 : 104	158 : 188	0.268*
Age (yr)	70.5 (58–83)	72.8 (54–92)	0.009 [†]
Body mass index (kg/m ²)	26.1 ± 3.7 (17.1–39.1)	26.3 ± 3.4 (17.1–39.1)	0.748 [†]
Follow-up period (mo)	27.6 (24–67)	25.2 (24–48)	0.015 [†]
Bone marrow density (T-score)	-1.0 ± 1.5 (-4.5 to 3.5)	-1.1 ± 1.7 (-4.4 to 3.9)	0.474 [†]
Diagnosis			0.318*
Osteoarthritis (case)	219	340	
Rheumatoid arthritis	2	4	
Spontaneous osteonecrosis of the knee	1	1	
Posttraumatic osteoarthritis	0	1	

Values are presented as mean (range) or mean ± standard deviation (range).

PS: posterior-stabilized.

*Chi-square test. [†]t-test.

cal and radiographic evaluations were performed separately for each knee to reduce bias. For clinical evaluation, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores and Knee Society Score (KSS) were recorded before surgery and at the 2-year follow-up. The ROM of the knee joint was measured, including knee flexion contracture and maximum flexion angle. Passive ROM was measured with the patient in a supine position using a goniometer. For radiographic examination, anterior-posterior view, lateral view, and patellar skyline images were taken before surgery and at 6 weeks, 3 months, 6 months, and annually after surgery. The radiographs were evaluated by a single observer (CH) twice with an interval of 3 weeks or more using the radiographic evaluation method of the American Knee Society.⁹⁾ The hip-knee-ankle angle, femorotibial angle, and tibial slope angle were measured. The valgus angle (α) of the femoral component and the varus angle (β) of the tibial component were measured on an anterior-posterior radiograph, and the flexion angle (γ) of the femoral component and the posterior tilt angle (δ) of the tibial component were measured on the lateral radiograph (Fig. 4). The presence of any obvious (> 2 mm) radiolucent line around the prosthesis or any sign of insert wear was recorded. Insert wear was defined as a decrease in the distance between the ends of the femur when a horizontal line was drawn on the upper, central surface of the base plate. We assessed intraobserver reliability using intraclass correlation coefficients ranging from 0.83 to 0.97 for the variables.

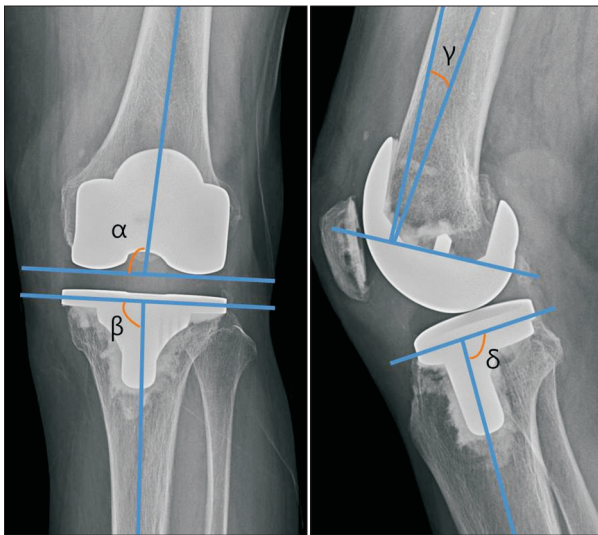


Fig. 4. Radiographs showing the measurement of prosthesis alignment angles according to the Knee Society total knee arthroplasty roentgenographic evaluation system. α : femoral valgus angle, β : tibial valgus angle, γ : femoral flexion angle, δ : tibial flexion angle.

Postoperative complications including superficial or deep infection, loosening, wear, instability, and periprosthetic fracture were investigated by referring to the definition published by the TKA Complications Workgroup of the Knee Society.¹⁰⁾ Survival rates of the implants were calculated. Failure was defined as reoperation for any reason after TKA.

Statistical Analysis

Clinical and radiographic results of each PS type and PS Plus type TKA before and after surgery were compared using a paired *t*-test. Differences between the two groups were compared using a *t*-test for continuous variables and chi-square test for noncontinuous variables. The survival rate of the implant was calculated using Kaplan-Meier analysis. A commercially available program (IBM SPSS ver. 25.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis, and the significance level was set at $p < 0.05$ in all tests.

RESULTS

Demographics

The mean age of the patients at the time of surgery was 70.5 years (range, 53–83 years) in the PS group and 72.8 years (range, 54–92 years) in the PS Plus group, and there was a statistically significant difference ($p = 0.009$). There was no statistically significant difference between the two groups in the ratio of men to women ($p = 0.164$): 51 men to 161 women in the PS group and 83 men to 263 women in the PS Plus group. The mean follow-up period was 27.6 months (range, 24–67 months) in the PS group and 25.2 months (range, 24–48 months) in the PS Plus group. There were no significant differences between the two groups in variables such as the affected side, bone mineral density before surgery, body mass index, and diagnosis before surgery (Table 1).

Clinical Results

The average KSS improved in both groups: preoperative 53.4 points (range, 10.0–59.0) to postoperative 91.3 points (range, 63.0–96.0) in the PS group and preoperative 52.3 points (range, 10.0–57.0) to postoperative 93.2 points (range, 64.0–98.0) in the PS Plus group ($p < 0.001$). The mean WOMAC score also significantly improved in both groups: preoperative 50.4 points (range, 35.0–78.0) to postoperative 15.6 points (range, 12.0–35.0) in the PS group and preoperative 52.3 points (range, 37.0–80.0) to postoperative 14.8 points (range, 11.0–36.0) in the PS Plus group ($p < 0.001$). However, the results of comparing the

KSS ($p = 0.340$) and WOMAC score ($p = 0.267$) between the PS group and the PS Plus group after surgery did not show any significant difference. The mean ROM was improved in both groups: from preoperative 112° (range, 7.0°–129.0°) to postoperative 124° (range, 2.0°–130.0°) in the PS group and from preoperative 107° (range, 7.0°–126.0°) to postoperative 128° (range, 1.0°–140.0°) in the PS Plus group. There was no significant difference in the postoperative ROM between the two groups ($p = 0.102$) (Table 2).

Radiographic Results

The HKA angles were significantly corrected after surgery ($p < 0.001$), and there was no significant difference in alignment between the two groups ($p = 0.142$): a mean of 8.1° varus before surgery (range, valgus 17.4°–valgus 34.7°) to a mean of 2.1° valgus (range, valgus 0°–7.2°) after surgery in the PS group and from a mean of 9.4° varus (range, valgus 6.9°–varus 34.6°) before surgery to a mean of 2.5° valgus (range, valgus 0°–8.5°) after surgery in the PS Plus group. At the 2-year follow-up, the mean α angle of the femoral component was 98.2° (range, 75°–109°) in the PS group and 96.1° (range, 78°–108°) in the PS Plus group ($p = 0.933$); the mean β angle of the tibial compo-

nent was 89.6° (range, 82°–100°) in the PS group and 90.4° (range, 82°–100°) in the PS Plus group ($p = 0.713$). Lateral images showed the average angle of flexion of the femoral component (γ) was 1.2° (range, 0°–2.5°) in the PS group and 1.7° (range, 0°–3.1°) in the PS Plus group ($p = 0.566$), and the average posterior inclination of the tibia (δ) was 87.6° (range, 80°–98°) in the PS group and 87.4° (range, 77°–98°) in the PS Plus group ($p = 0.458$). Radiolucent lines around the implant were observed in 2 cases (0.9%) in the PS group and in 1 case in the PS Plus group (0.2%) ($p = 0.480$). But there was no progression at follow-up and they were not related to clinical symptoms (Table 3).

Complication and Survival Rate

A total of 5 cases (4.0%) of complications occurred in the PS group: 2 superficial infections, 1 deep infection, 1 joint stiffness, and 1 intraoperative periprosthetic fracture. Complications in the PS Plus group were 4 cases (1.8%) in total: 2 cases of superficial infection and 2 cases of deep infection. As a result of comparing the incidence of complications between the two groups, there was no significant difference ($p = 0.167$) (Table 4). The minimum 2-year follow-up survival rate was 98.6% in the PS group and 98.8% in the PS Plus group. There was no significant

Table 2. Comparison of Clinical Results between PS and PS Plus Groups

Variable	PS	PS Plus	<i>p</i> -value
KSS (point)			
Preoperative	53.4 (10–59)	52.3 (10–57)	0.269
Postoperative	91.3 (63–96)	93.2 (64–98)	0.340
WOMAC score (point)			
Preoperative	50.4 (35–78)	52.3 (37–80)	0.333
Postoperative	15.6 (12–35)	14.8 (11–36)	0.267
Knee ROM (°)			
Preoperative	112 (7–129)	107 (7–126)	0.353
Postoperative	124 (2–130)	128 (1–140)	0.102
Knee flexion contracture (°)			
Preoperative	7.1 (0–30)	7.8 (0–30)	0.358
Postoperative	2.4 (0–20)	1.4 (0–15)	0.120
Maximal knee further flexion (°)			
Preoperative	124 (90–130)	129 (100–130)	0.375
Postoperative	128 (120–140)	131 (120–140)	0.346

PS: posterior-stabilized, KSS: Knee Society Score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index, ROM: range of motion.

Table 3. Comparison of Radiographic Results between PS and PS Plus Groups

Variable	PS	PS Plus	<i>p</i> -value
Preoperative HKA axis (°)	Varus 8.1 (valgus 17–varus 35)	Varus 9.4 (valgus 7–varus 35)	0.540
Postoperative HKA axis (°)	Valgus 2.1 (0–7)	Valgus 2.5 (0–9)	0.142
α -angle (°)	98.2 (75–109)	96.1 (78–108)	0.933
β -angle (°)	89.6 (82–100)	90.4 (82–100)	0.713
γ -angle (°)	1.2 (0–3)	1.7 (0–3)	0.566
δ -angle (°)	87.6 (80–98)	87.4 (77–98)	0.458
Radiolucent line	2	1	0.480
Femoral side	0	0	
Tibia side	2	1	

Values are presented as mean (range).

PS: posterior-stabilized, HKA: hip-knee-ankle.

Table 4. Comparison of Complications between PS and PS Plus Groups

Variable	PS	PS Plus	<i>p</i> -value
Superficial infection	2 (1.6)	2 (0.9)	
Deep infection	1 (0.8)	2 (0.9)	
Joint stiffness	1 (0.8)	0	
Periprosthetic fracture	1 (0.8)	0	
Total	5 (4.0)	4 (1.8)	0.167

Values are presented as number (%).

PS: posterior-stabilized.

difference between the two groups ($p = 0.154$) (Fig. 5).

DISCUSSION

In this study, we found that both the existing PS type and the modified PS Plus type of the Lospa showed satisfactory short-term follow-up results after TKA. In addition, there was no significant radiographic or clinical difference between Lospa PS and PS Plus types, and the complication and survivor rates were similar. These results are consistent with those of other studies using the existing Lospa PS type TKA.^{3,11–13} Previous studies using the Lospa implant reported an average of 123°, 126.7°, and 128.8° of postoperative ROM, which showed similar results to our study, in which the average ROM was 124° for the PS type and 128° for the PS Plus type.^{2,3,12} As in previous studies, there were no early revision surgery cases due to loosening, os-

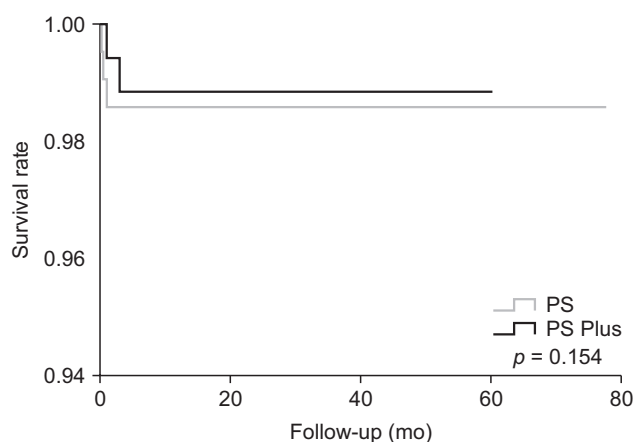


Fig. 5. Kaplan-Meier curves illustrating prosthetic survival, with reoperation for any reason as the end point, after Lospa posterior-stabilized (PS) and PS Plus total knee arthroplasty.

teolysis, or wear other than an infection. In our study, the presence of a radiolucent line of 2 mm or more around the prosthesis was observed only in 3 cases (2 cases for the PS type and 1 case for the PS Plus type) on the simple radiographic examination. Other previous studies using the Lospa implant reported a higher incidence of radiolucent lines (range, 7.9%–13.8%) although there was no clinical significance in terms of early loosening. Therefore, the incidence of component loosening should be assessed in future studies that involve a long-term follow-up and a larger study population.^{2,3,14–17}

Lospa is the first TKA implant developed in South Korea in 2011. The Lospa PS type has a spherical condyle and a constrained liner design. It is advantageous for fem-

oral rollback. It minimizes knee instability in the middle of the flexion while maintaining the isometry of the ligament up to middle flexion by maintaining the single radial axis of the femoral prosthesis from 0° to 90°. ¹⁸⁾ The spherical femoral contour and deep patellar groove prevent patella dislocation during knee flexion and provide enhanced stability. ¹²⁾ Also, the polyethylene insert design is advantageous for high flexion by resection of the posterior angular part, and it has a rotating articular surface, allowing for some knee joint rotation even with a fixed insert artificial joint. There are features designed to help movements that require rotation of the knee joint, such as sedentary positions. It has been reported that stability and clinical and radiographic follow-up results of Lospa PS showed similar statistical results compared to the existing pre-implantation instruments, and good clinical results were also shown at 2–4 year follow-up. ^{2,3)}

The Lospa Plus model, which changed the post shape on the insert, had several modifications. First, the post height was increased compared to the existing PS type, and the trapezoidal shape was changed to a shark fin shape. It was attempted to lower the risk of dislocation of TKA as the jump distance increased from 16 mm to 19.7 mm. The modified post was designed to prevent collision between the anterior part of the post and the patella during high knee flexion. In our study, there was no particular discomfort in both the PS and PS Plus groups when the patellar clunk syndrome was present or the patient required high flexion such as squatting. There was no statistically significant difference in ROM or the maximum flexion angle. Our results showed the same results as those of Seo et al. ¹⁹⁾ in that there was no clinical and radiographic difference in the comparison of two implants with different designs and cam-post structures. Second, by forming a chamfer structure at the binding portion of the polyethylene and tibial prosthesis, insertion of the polyethylene insert was made easier even though anterior dislocation was not increased during surgery. It is thought that the risk of ligament damage and fracture, such as avulsion fracture of the medial collateral ligament attachment part, can be reduced by reducing excessive displacement of the knee joint when inserting polyethylene.

Lospa PS Plus type has slightly increased the amount of bone resection in box cutting from 39.2 cm³ to 39.8 cm³ due to the change in the post structure, but there is concern that the constraint force may increase as the size of the post increases. It can be considered consistent with the results of this study, and there were no complications of early implant loosening in the short-term follow-up. On previous high-flexion type implants, it has been reported

that early loosening may be caused by additional bone resection in the posterior femoral condyle region. However, considering the difference from other implants in that the increased bone resection is box resection without further bone resection of the posterior femoral condyle, the increase in box bone resection is thought to be less related to early loosening of TKA. However, other studies using the high-flexion implant reported that progressive radiolucent lines appeared after an average of 32 months. Therefore, long-term follow-up is necessary. ^{14,15,20,21)}

Our study is meaningful as the first comparison of the short-term follow-up results of the modified polyethylene design Lospa PS Plus. However, there are some limitations of this study. First, the retrospective nature of this study is an obvious limitation. There were significant differences in the mean age and follow-up period between the two groups, so the possibility that these characteristics could have affected the outcome cannot be excluded. Second, the major concern related with the more constrained type of insert is implant loosening; however, a 2-year follow-up period may not be sufficient to compare the loosening incidence between two groups. Third, it is difficult in a patient who has undergone bilateral TKA to separate the function of each knee, but efforts were made to evaluate each knee joint individually to minimize bias. Fourth, all the radiographic parameters were measured twice by a single observer only, so interobserver reliability for the measurements could not be evaluated. Finally, the scores that specifically address patellofemoral joint symptoms after TKA were unavailable in this study. It would have been helpful to evaluate clinical scores related to patellofemoral symptoms since one of the theoretical advantages of tibial post modification is to prevent patella-post impingement during high flexion. However, the knee scores used in this study were validated for evaluating TKA outcomes and are comprised of indirect measures for examining the patellofemoral joint status.

The Lospa PS Plus model is a modified design that improves the post structure from the previous PS type. Compared to the PS type, the PS Plus type showed similar statistical results and good clinical results at a 2-year follow-up. The short-term average survival rate was also over 98%, showing promising results. Long-term follow-up research will be required in the future to evaluate the stability of the implant through post structural improvement.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was

reported.

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REFERENCES

- Dennis DA, Komistek RD, Colwell CE Jr, et al. In vivo anteroposterior femorotibial translation of total knee arthroplasty: a multicenter analysis. *Clin Orthop Relat Res.* 1998;(356):47-57.
- Kim MS, Koh IJ, Jang SW, Jeon NH, In Y. Two- to four-year follow-up results of total knee arthroplasty using a new high-flexion prosthesis. *Knee Surg Relat Res.* 2016;28(1):39-45.
- Chon JG, Song IS, Sun DH, Jang SW, Lee JG. Comparison of two year follow-up results in high flexion total knee arthroplasty with Lospa and Scorpio NRG. *J Korean Orthop Assoc.* 2013;48(6):449-56.
- Victor J, Mueller JK, Komistek RD, Sharma A, Nadaud MC, Bellemans J. In vivo kinematics after a cruciate-substituting TKA. *Clin Orthop Relat Res.* 2010;468(3):807-14.
- Incavo SJ, Beynon BD, Johnson CC, Churchill DL. Knee kinematics in genesis total knee arthroplasty: a comparison of different tibial designs with and without posterior cruciate substitution in cadaveric specimens. *Am J Knee Surg.* 1997;10(4):209-15.
- Akasaki Y, Matsuda S, Shimoto T, Miura H, Higaki H, Iwamoto Y. Contact stress analysis of the conforming post-cam mechanism in posterior-stabilized total knee arthroplasty. *J Arthroplasty.* 2008;23(5):736-43.
- Abdel MP, Gesell MW, Hoedt CW, Meyers KN, Wright TM, Haas SB. Polished trays reduce backside wear independent of post location in posterior-stabilized TKAs. *Clin Orthop Relat Res.* 2014;472(8):2477-82.
- Minoda Y, Sugama R, Ohta Y, Ikebuchi M, Nakamura H. Impingement of the patellar component against the tibial post depends on the design of the post-cam mechanism: Comparison between 12 posterior stabilized total knee prostheses. *Knee.* 2018;25(4):676-81.
- Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. *Clin Orthop Relat Res.* 1989;(248):9-12.
- Healy WL, Della Valle CJ, Iorio R, et al. Complications of total knee arthroplasty: standardized list and definitions of the Knee Society. *Clin Orthop Relat Res.* 2013;471(1):215-20.
- Moon KH, Lee DJ, Lee JS, Kim YT. Total knee replacement arthroplasty with NexGen-LPS: minimum 5 year follow-up results. *J Korean Orthop Assoc.* 2011;46(5):405-11.
- Kim MS, Kim JH, Koh IJ, Jang SW, Jeong DH, In Y. Is high-flexion total knee arthroplasty a valid concept? Bilateral comparison with standard total knee arthroplasty. *J Arthroplasty.* 2016;31(4):802-8.
- Kim HJ, Kim TS, Mun JU, Kyung HS. Results of high-flex total knee arthroplasty: minimum 3-year follow-up result. *J Korean Orthop Assoc.* 2016;51(2):145-50.
- Cho SD, Youm YS, Park KB. Three- to six-year follow-up results after high-flexion total knee arthroplasty: can we allow passive deep knee bending? *Knee Surg Sports Traumatol Arthrosc.* 2011;19(6):899-903.
- Han HS, Kang SB, Yoon KS. High incidence of loosening of the femoral component in legacy posterior stabilised-flex total knee replacement. *J Bone Joint Surg Br.* 2007;89(11):1457-61.
- Tanavalee A, Ngarmukos S, Tantavisut S, Limtrakul A. High-flexion TKA in patients with a minimum of 120 degrees of pre-operative knee flexion: outcomes at six years of follow-up. *Int Orthop.* 2011;35(9):1321-6.
- Bauman RD, Johnson DR, Menge TJ, Kim RH, Dennis DA. Can a high-flexion total knee arthroplasty relieve pain and restore function without premature failure? *Clin Orthop Relat Res.* 2012;470(1):150-8.
- Shimizu N, Tomita T, Yamazaki T, Yoshikawa H, Sugamoto K. In vivo movement of femoral flexion axis of a single-radius total knee arthroplasty. *J Arthroplasty.* 2014;29(12):2407-11.
- Seo JG, Moon YW, Chang MJ, et al. Design modifications of high-flexion TKA do not improve short term clinical and radiographic outcomes. *BMC Musculoskelet Disord.* 2014;15:433.
- Cho SD, Ko SH, Park MS, et al. Early loosening of femoral component after primary total knee arthroplasty: report of 4 cases. *Knee Surg Relat Res.* 2006;18(1):107-11.
- Zelle J, Janssen D, Van Eijden J, De Waal Malefijt M, Verdonchot N. Does high-flexion total knee arthroplasty promote early loosening of the femoral component? *J Orthop Res.* 2011;29(7):976-83.