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Efficacy and Safety of a Novel Three-Step Medial Release Technique in Varus Total Knee Arthroplasty

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ABSTRACT

We investigated the efficacy and safety of our novel three-step medial release technique in varus total knee arthroplasty (TKA) over time. Two hundred sixty seven consecutive varus TKAs were performed by applying the algorithmic release technique which consisted of sequential release of the deep medial collateral ligament (step 1), the semimembranosus (step 2), and multiple needle puncturing of the superficial medial collateral ligament (step 3). One hundred seventeen, 114, and 36 knees were balanced after step 1, 2, and 3 releases, respectively. There were no significant differences in changes of medial and lateral laxities between groups in over a year. Our novel stepwise medial release technique was efficacious and safe in balancing varus knees during TKA.

Varus deformity is a common problem in total knee arthroplasty (TKA), and an uncorrected deformity has a bad influence on the longevity of the implants [1–6]. During the TKA procedure, we commonly have difficulty with remnant unbalanced gap after bone cutting, especially with a tight medial gap in varus knees [4,7,8]. There is a consensus among authors that a medial release should be performed sequentially depending on the degree of varus deformity [5,9–11]. The anatomical structures released in a tight medial gap include the deep medial collateral ligament (dMCL), superficial medial collateral ligament (sMCL), posterior oblique ligament, posterior medial capsule, semimembranosus, pes anserinus, and so on [12–14].

Verdonk et al [14] suggested dMCL release from the proximal tibial attachment as their first step of medial soft tissue release in varus knees, and the next step, depending on the amount of residual medial tightness, is pie-crusting of the sMCL at the joint line level using a #11 blade or distal release with an elevator. Mullaji et al [13] described more complicated balancing techniques, including sequential releases of dMCL, semimembranosus, posteromedial capsule, and pes anserinus, tibia reduction osteotomy, and extra-articular correction. In addition to the above mentioned studies, various and complex protocols of medial release have been reported [15–19]. Somewhat extensive release techniques can lead to complications such as instability and neurovascular injury [12]. Instability which leads to pain, walking difficulty, abnormal polyethylene wear, patellofemoral maltracking, and early loosening is still one of the major causes of TKA failure [6,20–22]. Even though medial soft tissue release has been accepted as an essential step for gap balancing, there exists a controversy in methods and the order of soft tissue release to achieve balanced gap during TKA of varus deformed osteoarthritic knee [8,15–19,23–25]. There is still a lack of evidence supporting the current numerous medial release techniques for varus TKA [12]. At any rate, minimal and efficacious algorithmic release is the prerequisite of the ideal soft tissue balancing technique in TKA. However, its efficacy and safety after the release have not been well established. To the best of our knowledge, there has been no study reporting on the safety of the medial release technique by comparing the mediolateral stability over time.

Until 2010, we had applied a concise three-step algorithmic release technique which consisted of (1) dMCL release, (2) semimembranosus release, and (3) pie-crusting of sMCL with use of a #11 blade in varus TKA. However, by experiencing overrelease in some knees, which underwent step 3, we had to reconsider our releasing technique. Since 2011, we adopted multiple needle puncturing of the sMCL as the third step of our algorithm, which is a safer alternative to pie-crusting of the sMCL [16]. In this study, we sought to determine (1) whether our novel algorithmic three-step method ensured appropriate release without the need for further surgical procedures; (2) whether our sequential release technique provided sufficient medial soft tissue tension over time after the procedure without the risk of instability or delayed rupture of the medial structures. We hypothesized that our new algorithmic three-step medial release technique would provide the appropriate gap balance and knee stability after TKA over time.

Materials and Methods

From January 2012 to May 2013, 322 primary TKAs were performed in 275 patients at a University Medical Center. Preoperatively, standing

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anteroposterior (AP), 45° flexion posteroanterior (PA), lateral, and merchant radiographs of the knee and weight-bearing full length radiograph of the lower extremity were checked to evaluate the arthritis grade and alignment of the knee. A total of 267 knees in 225 patients showed varus alignment of more than 0° of the femorotibial angle on preoperative standing AP radiograph and were enrolled in the study. All knees underwent medial release during TKA procedure. There were 210 women (250 knees) and 15 men (17 knees). The mean preoperative varus deformity was 4.7° (range, varus 0.1°–varus 21.8°). Mean age was 69 years (range, 52–85 years) and the mean BMI was 26.7 kg/m^2 (range, 18.2–48.5 kg/m^2). All patients gave written informed consent and the data were reviewed retrospectively. This study was approved by the Institutional Review Board of our hospital.

All TKAs were performed by a senior surgeon through the subvastus approach using posterior-stabilized (PS) TKA implants. Before bone cutting, both cruciate ligaments were resected and a meniscectomy was done. Without exception, dMCL was released at the menisco-capsular junction using a periosteal elevator. A periosteal elevator was inserted at the mid-medial portion of the medial capsule and the release was performed from the dMCL to antero-medial capsule with a knife (step 1 of the release, Fig. 1). The bone procedure started with cutting the distal femur in 6° of valgus to the anatomical axis. The femoral external rotation was decided using the posterior condylar axis, transepicondylar axis, and AP axis. Anterior and posterior condylar and chamfer cuts were performed after femoral component sizing. Next, a tibial cut was made perpendicularly to the mechanical axis of tibia, approximately 10 mm in thickness from the lateral tibial cortex by extra-medullary guided manner. Osteophytes which tether medial soft tissue structures were meticulously removed from the medial femoral and tibial condyles to obtain a symmetric rectangular gap. Flexion and extension gaps were measured using a spreader device (Aesculap, Tuttlingen, Germany). The flexion and extension gaps were considered balanced when the mediolateral gap difference was within 2 mm. In 117 knees (43.8%) of the 267 knees, gap balancing was obtained after dMCL release and bone cutting (group 1). Others still had trapezoidal unbalanced extension or flexion gap after the first step of the release procedure. For theses knees, semimembranosus release was performed. The expansions of the semimembranosus were cut

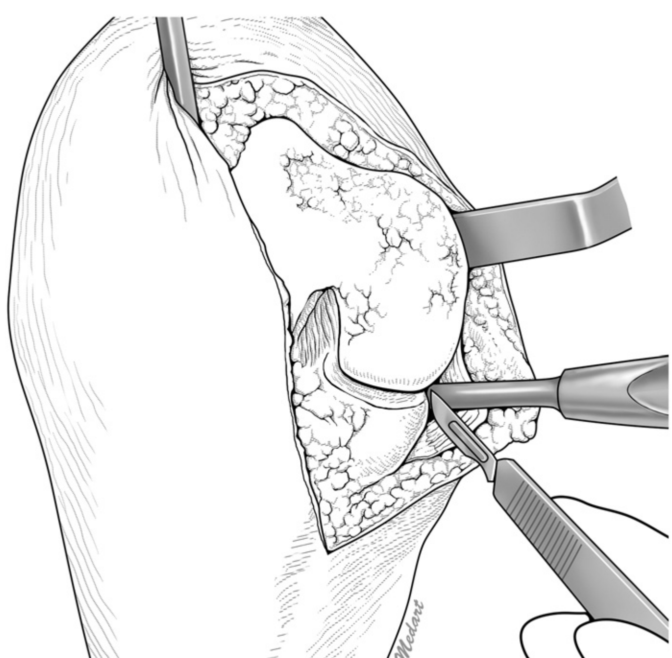

Fig. 1. Step 1: The deep medial collateral ligament (dMCL) was released with a periosteal elevator and knife.

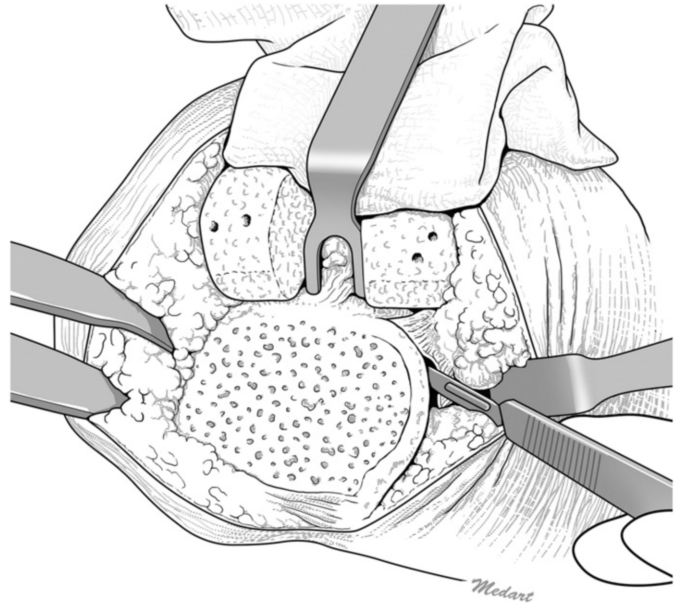

Fig. 2. Step 2: The semimembranosus was completely released from its tibial insertion.

using a knife and the tibial insertion of the semimembranosus was completely released, including the posteromedial capsule using a periosteal elevator (step 2 of the release, Fig. 2). One hundred fourteen knees (42.6%) were balanced after the two release steps (group 2). Thirty-six knees (13.5%) remained in a tight medial gap until step 2 of the release was performed. In these knees, sMCL release was done to achieve gap balance. Multiple needle puncturing of the sMCL was performed using an 18 G spinal needle until the trial components were inserted. All 36 patients showed medial gap tightness in both extension and 90° flexion positions. First, tensest portion around the femoral attachment of the sMCL was identified by finger palpation. Then needle puncturing was done by piercing the tensest fibers. Five needle punctures were performed as one unit. After every 5 needle punctures, the spreader device was inserted and slowly distracted. Flexion and extension mediolateral gap balance was reassessed after gap distraction. If the flexion gap balance was obtained, the trial components could be inserted in the flexion position. Next, the knee was gently extended as far as possible. When the extension medial gap was tight, the tensest portion of the sMCL was identified again and punctures were repeated until the gap balance was obtained in the extension position (step 3 of the release, Fig. 3). All 36 knees obtained mediolateral gap balance (group 3).

Patients were grouped according to medial release steps. In other words, group 1 consisted of patients whose knees were balanced after the first release step (117 knees). Group 2 consisted of patients whose knees needed semimembranosus release after the dMCL release to get a balanced gap (114 knees). Finally, group 3 consisted of patients whose knees underwent multiple needle puncturing of the sMCL using an 18 G spinal needle after the dMCL and semimembranosus release to obtain a gap balance (36 knees). Among 267 knees, 257 (96.3%) were diagnosed with osteoarthritis. Five knees had rheumatoid arthritis and the other 5 had osteonecrosis combined with osteoarthritis. There was no significant difference in diagnosis between the groups ($P = 0.135$).

Clinical and radiographic evaluations were done at 3, 6, and 12 months postoperatively. Each knee was rated using the clinical scores, Knee Society score and WOMAC score [26,27]. Active range of motion of the knee was measured using a standard 60-cm-long goniometer at the time of each follow-up visit. Postoperative knee alignment and four component alignment angles, specifically the femoral valgus angle (α), tibial valgus angle (β), femoral flexion angle (γ), and tibial flexion angle (δ) were measured using the postoperative AP and lateral radiographs of the knee [28]. Mediolateral laxity of the knee

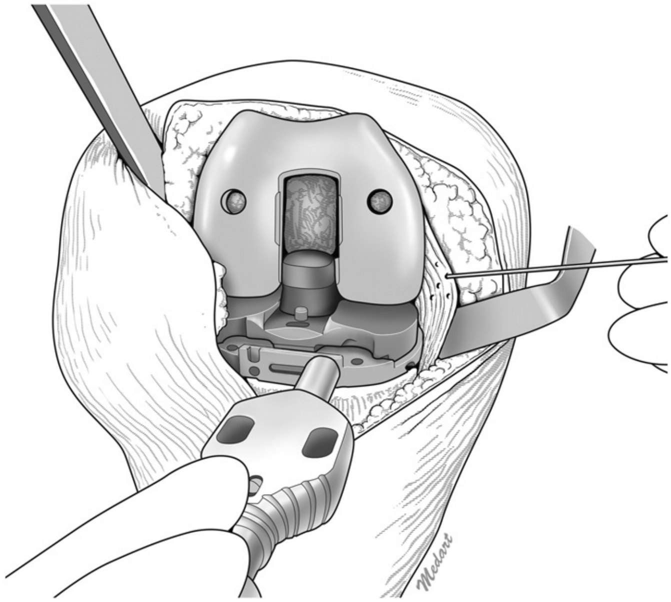

Fig. 3. Step 3: The superficial medial collateral ligament (sMCL) was released by multiple puncturing with an 18G-spinal needle.

was measured on the valgus and varus stress radiographs which were taken in extension position using a Telos Stress Device (Telos, Marburg, Germany). From the valgus stress radiograph, the medial opening angle formed by the line in contact with the bottom of the femoral component and the line in contact with the upper surface of the tibial plate was measured. The medial laxity (medial opening angle, °) was defined as the value of opening angle from the valgus stress radiograph. From the varus stress radiograph, the lateral opening angle was also measured as described above. The lateral laxity (lateral opening angle, °) was defined as the value of opening angle from the varus stress radiograph [29].

The Shapiro–Wilk test was used to determine the normality of the data. Results are presented as mean and standard deviation. One-way ANOVA test was used to determine if differences existed between the three groups. Repeated measures ANOVA test was used to ascertain differences in joint laxity among various postoperative follow-up visits between groups. When there was a significant difference with the ANOVA test ($P < 0.05$), Tukey's B post hoc test was employed to determine which means differed between groups. Statistical significance was defined at $P < 0.05$. The data were analyzed with SPSS version 20.0 statistical software (SPSS Inc., Chicago, Ill).

Results

Patient's demographics and preoperative clinical scores were presented in Table 1. There were no significant differences in gender ratio, age, BMI, range of motion of the knee, and knee scores among the 3 groups. There were significant differences in the preoperative knee alignment and mechanical axis between the 3 groups. Every group was significantly different in the preoperative knee alignment on post hoc test. More steps were required to obtain a balanced gap in cases of severer preoperative varus deformity. Additionally, the mean polyethylene thickness was 10.9 ± 1.5, 10.8 ± 1.8 and 11.9 ± 1.7 mm in groups 1, 2, and 3, respectively. Group 3 needed significantly thicker polyethylene than the other two groups on the post hoc test ($P = 0.005$).

One hundred three of 117 knees (88.0%) in group 1, 104 of 114 knees (91.2%) in group 2 and 31 of 36 knees (86.1 %) in group 3 completed 12 months of follow-up without missing clinical or radiographic data. There were no differences in postoperative knee alignment, Knee Society score and WOMAC score at the 12 month follow-up between the 3 groups ($P = 0.166$, 0.324 and 0.680, respectively), which is shown in Table 2. No difference was noted when comparing the outliers of knees achieving the ideal postoperative knee alignment (valgus 6 ± 3°) in the 3 groups ($P = 0.597$). With regard to component alignment angles, there were no differences between the 3 groups except femoral flexion angle ($P < 0.001$) (Table 2).

Stability of the knee on the coronal plane was measured postoperatively at 3, 6, and 12 months by using stress radiographs. Medial laxity (medial opening angle) was measured and found to be 3.1 ± 1.4°, 3.0 ± 1.2° and 2.8 ± 1.3° in group 1; 3.2 ± 1.7°, 3.1 ± 1.6° and 3.0 ± 1.2° in group 2; and 3.1 ± 1.5°, 2.9 ± 1.4° and 2.6 ± 1.4° in group 3 at 3, 6 and 12 months, respectively. No significant difference was observed in the postoperative medial laxity at the 3, 6 and 12 months follow-up between the 3 groups ($P = 0.774$, 0.762 and 0.312, respectively) which is shown in Fig. 4. There were no significant differences in changes in the medial laxity over time among groups ($P = 0.565$). Lateral laxity (lateral opening angle) was measured, and found to be 3.1 ± 1.9°, 3.9 ± 2.0° and 3.7 ± 1.9° in group 1; 3.2 ± 1.7°, 3.7 ± 1.7° and 3.8 ± 1.9° in group 2; and 4.1 ± 1.8°, 5.1 ± 1.9° and 4.0 ± 2.1° in group 3 at 3, 6 and 12 months, respectively. Group 3 showed a lateral gap that was significantly more lax than the groups 1 and 2 at 3 and 6 months follow-up ($P = 0.016$ and 0.006, respectively). However, the difference was disappeared at 12 months follow-up ($P = 0.730$), as in seen in

Table 1
Comparisons of Preoperative Demographics and Clinical Scores.

	Group 1 ($n = 117$)	Group 2 ($n = 114$)	Group 3 ($n = 36$)	P value
Gender[a] (F:M)	109 : 8	106 : 8	35 : 1	.637
Age[b]	68.7 ± 7.1 (52–85)	68.9 ± 6.6 (54–83)	69.1 ± 6.4 (55–82)	.928
Diagnosis (OA)[c]	111	112	34	.135
BMI (kg/m²)	27.2 ± 4.7 (19.2–48.5)	26.3 ± 3.2 (20.3–34.6)	26.5 ± 3.4 (18.2–32.0)	.265
Range of motion (°)	126 ± 10.4 (80–135)	124 ± 12.5 (80–135)	123 ± 15.5 (65–135)	.291
Preoperative KSS	121.0 ± 26.5 (40–160)	124.7 ± 25.9 (42–190)	124.0 ± 24.9 (37–165)	.254
Preoperative WOMAC	55.1 ± 17.0 (3–87)	54.5 ± 18.3 (4–92)	51.2 ± 14.0 (22–77)	.502
Preoperative knee alignment (°)[d]	varus 3.4 ± 3.0 (0.1–13.6)	varus 5.2 ± 4.1 (0.1–20.1)	varus 7.6 ± 5.7 (0.1–21.8)	<.001
T[e]	a	b	c	
Preoperative mechanical axis (°)[f]	171.0 ± 3.8 (160–179)	167.6 ± 4.7 (152–176)	166.1 ± 6.3 (151–177)	<.001
T[e]	a	b	b	

[a] Data are presented as number of knees.
[b] Data are presented as mean ± standard deviation (range).
[c] Data are presented as number of osteoarthritis (OA).
[d] Data are presented as femoro-tibial angle.
[e] The same letters indicate non-significant difference between groups based on Tukey's multiple comparison test.
[f] Data are presented as hip–knee–ankle axis.

Table 2
Comparisons of Postoperative Knee Alignment, Components Alignments, and Clinical Scores at 12 Months Follow-Up.

	Group 1 (n = 103)	Group 2 (n = 104)	Group 3 (n = 31)	P value
Postoperative knee alignment (°)[a]	Valgus 5.6 ± 2.0 (1.0 to 12.7)	Valgus 5.1 ± 2.0 (0.2 to 10.4)	Valgus 5.6 ± 2.0 (1.0 to 10.3)	.166
Outliers of knee alignment (%)	11.6 (12/103)	16.3 (17/104)	16.1 (5/31)	.597
Components alignments				
Femoral valgus angle (°)	96.4 ± 1.5 (92 to 103)	96.0 ± 1.7 (92 to 100)	96.1 ± 1.4 (92 to 103)	.216
Femoral flexion angle (°)	2.7 ± 1.8 (0 to 7)	1.9 ± 2.0 (−2 to 9)	3.4 ± 2.5 (−1 to 8)	<.001
T[b]	ab	a	b	
Tibial valgus angle (°)	89.5 ± 1.1 (87 to 92)	89.3 ± 1.0 (86 to 92)	89.3 ± 1.6 (86 to 94)	.203
Tibial flexion angle (°)	87.3 ± 1.8 (83 to 91)	87.4 ± 1.8 (83 to 93)	87.2 ± 1.9 (83 to 93)	.832
Postoperative KSS	180.4 ± 12.8 (145 to 200)	181.6 ± 16.4 (135 to 200)	175.8 ± 24.7 (113 to 200)	.324
Postoperative WOMAC	12.5 ± 9.8 (0 to 63)	11.1 ± 9.5 (0 to 42)	11.3 ± 10.7 (0 to 47)	.680

[a] Data are presented as mean ± standard deviation (range). Data are presented as femoro-tibial angle.
[b] The same letters indicate non-significant difference between groups based on Tukey's multiple comparison test.

Fig. 5. There was no significant difference in changes in lateral laxity over time among groups ($P = 0.094$).

No deep infection, stiffness, clinical signs of instability, or radiographic evidence of osteolysis or loosening was observed in any of the patients during the follow-up period.

Discussion

The major finding of this study was that our new algorithmic three-step medial release technique which consisted of sequential release of dMCL (step 1), semimembranosus (step 2), and multiple needle puncturing of the sMCL (step 3) addressed the medial tightness of all 267 consecutive varus knees during TKA without the need for additional procedures. For more than a year, those knees were stable without significant changes in mediolateral joint laxity.

Employment of a stepwise release technique is considered a reasonable solution to the medial contractures in varus knees to avoid unnecessary overrelease [7,18,19,30,31]. However, the releasing structures and sequence have varied according to the authors [8,9,23,31,32]. In our study, each group was classified according to the degree of the soft tissue release, and showed significantly different preoperative varus deformities. The cases of severer varus deformities required more steps for medial release to obtain a balanced knee. It denotes that our new algorithm is an appropriate step flow for the sequence for the medial gap balancing in terms of maintaining the joint stability.

Although some surgeons released the sMCL first for medial tightness [4,10], most authors recommended the dMCL release as the first step of the sequence [8,13,14,25]. We believe that dMCL release is the appropriate first step of medial release in terms of efficacy and safety. One hundred seventeen of 267 knees (43.8%) were balanced only with dMCL release in the present study. The second step of our algorithm, semimembranosus release, can raise questions about whether it is effective for gap balancing. Recently, Koh and In [8] reported that semimembranosus release has its desired effect on gap balancing in varus TKA. They evaluated gap changes after the semimembranosus release at knee positions of 0, 45 and 90°, which increased by 1.45, 2.00 and 2.25 mm, respectively. In our study, 231 of 267 knees (86.5%) were balanced after the step 1 and 2 releases.

Because the sMCL is the primary restraint to the valgus force of the medial side of the knee [33], conservation of sMCL is considered to be critical to maintain the joint stability when possible. However, in cases with profound varus deformity, the sMCL is the critical structure of medial tightness and release of the structure is necessary for proper gap balancing. Traditionally, many surgeons have released sMCL from the tibial attachment [34–36]. Meneghini et al [37] performed a cadaver study comparing the sMCL pie-crusting technique using a #15 blade and the traditional technique which elevates anterior fibers of the sMCL subperiosteally. They found that the pie-crusting group caused a characteristic stair-step failure mode at the joint line whereas the traditional technique group failed elastically at the tibial insertion. Verdonk et al [14] reported the pie-crusting of the sMCL in varus knees was safe and effective. However, in our practice, it was difficult to control the depth and size of the each puncture of the pie-crusting with a knife blade. We experienced some cases of overrelease with the pie-crusting. So, we introduced a novel stepwise medial release technique in varus knees including the multiple needle puncturing of the sMCL as the third step of the algorithm, which is a safer alternative to the pie-crusting technique [16]. Recently, Kwak et al [38] conducted a cadaver study showing that pie-crusting technique led to unpredictable gap increments and frequent early overrelease. Whereas Koh et al [39] reported that the multiple needle puncturing gradually safely increased the extension and flexion gap by 4 to 6 mm. When the third step, the

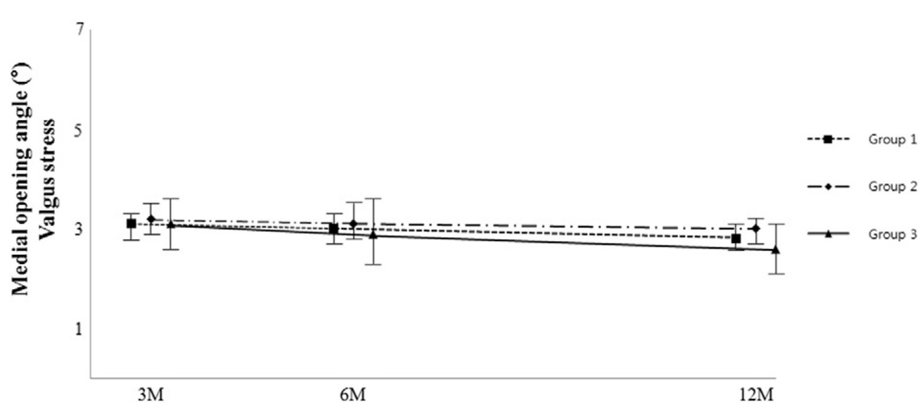

Fig. 4. Line graph shows the trends of mean medial joint laxity of each group at 3, 6, 12 months of follow-up. There was no significant difference in changes of medial laxity over time among groups. The error bars indicate the 95% confidence intervals (CIs).

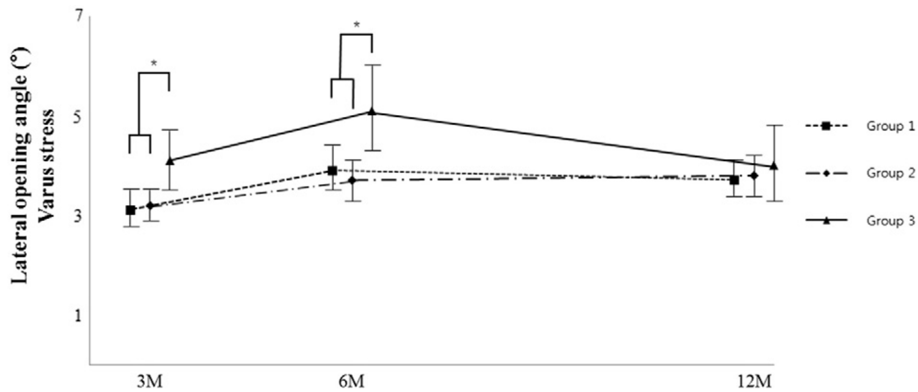

Fig. 5. Line graph shows the trends of mean lateral joint laxity of each group at 3, 6, 12 months of follow-up. Although group 3 showed significantly more lax lateral joint gap than those of groups 1 and 2 at 3 and 6 months, the difference was disappeared at 12 months follow-up. There was no significant difference in changes of lateral laxity over time among groups.

multiple needle puncturing with an 18 G spinal needle, was performed, all the knees in the patients we followed up on were stable on the medial side without any differences between the groups in over a year.

By applying the novel stepwise release technique to our patients with severe varus deformity, there was a concern as to whether other procedures beyond the three-step release technique would balance the deformity. Some surgeons recommended proximal tibial osteotomy as the final step of the procedure in patients with severe varus deformity [13,15]. We agree that an additional osteotomy can be performed for the knees with a combined severe varus angulation and bony deformity. However, in our series, a knee with a varus angulation of 21.8° could be balanced by applying our three-step release technique. As a technical detail, the flexion gap balance was easier to get than that of the extension gap in severely deformed knees in varus. We tried to get the flexion gap balance first using the spinal needle. Then the extension gap was obtained by gentle gradual extension and repeated multiple needle puncturing with the trial components in.

Group 3 needed significantly thicker polyethylene inserts than the other two groups. In order to match the tight ligamentous tension of the medial side to that of the lax lateral side, more release steps and thicker polyethylene inserts were needed in group 3. Berend et al [40] reported that thicker polyethylene inserts are associated with high failure rates in primary TKA. In their study, the failure rate in knees with bearings 14 mm or less was 0.7%, whereas the failure rate of knees with bearings 16 mm or greater was 2.3% ($P < 0.001$). In the present study, we have used only 2 polyethylene inserts with a thickness ≥16 mm during the procedure.Nevertheless, we observed a significantly more lax lateral gap in patients in group 3 compared to groups 1 and 2 patients at 3 and 6 months follow-up. However, there was no difference in the lateral joint opening angle between the 3 groups at 12 months follow-up. Our results coincide with those of Sekiya et al's [41]. They found that the residual lateral ligamentous laxity during TKA diminishes within 3 months. In our study, although the timeframe was different, the same phenomenon was observed in knees with severe varus deformity that needed multiple needle puncturing. The mild residual lateral laxity at the time of surgery can be left in knees with severe varus angulation, if the medial joint stability is guaranteed.

This study has several limitations. First, preoperative joint laxity of the knee was not evaluated. We compared only postoperative stress radiographs according to the release steps. Although the degree of preoperative varus deformity of the knee was significantly different between the 3 groups, the preoperative joint laxity could have been a confounding variable affecting the postoperative joint laxity. However, when comparing the postoperative stress radiographs, there were no significant differences in the changes of the medial and lateral laxities over time among the groups. Second, we compared only the extension stability on the coronal plane. While performing TKA, balancing the flexion and extension gaps is the priority. However, objective evaluation of the flexion gap laxity was difficult. Clinically, no patient has shown medial or lateral flexion instability. Third, there were some cases of missing data such as clinical scores or radiographs, which we excluded. Fourth, this study lacks long-term follow-up results. Although there were no differences in the clinical scores and mediolateral laxity of the knee joint at 12 months follow-up, a longer term follow-up would be needed to support this conclusion.

In conclusion, our study demonstrated that a novel three-step medial release technique which consisted of dMCL release (step 1), semimembranosus release (step 2) and multiple needle puncturing of the sMCL (step 3) was effective and safe in correcting varus deformities during TKA.

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