Arthroscopic Meniscal Repair and Meniscectomy for Adult Discoid Lateral Meniscus Results in Progression to Valgus Alignment and Lateral Compartment Degeneration Compared With Nonoperative Treatment and Nondiscoid Lateral Meniscus

Joon Hee Cho, M.D., Hee Seung Nam, M.D., Seong Yun Park, M.D., Jade Pei Yuik Ho, M.D., and Yong Seuk Lee, M.D., Ph.D.

Purpose: To analyze the effect of the arthroscopic meniscal procedure in adult discoid lateral meniscus (DLM) according to the age and meniscal-preserving by making comparisons with the nondiscoid lateral meniscus (N-DLM). **Methods:** From March 2014 to October 2020, a comparative analysis was performed in adults with DLM who underwent arthroscopic meniscal procedures (operative DLM: 134 knees), nonoperative treatment (nonoperative DLM: 56 knees), and adult N-DLM who underwent arthroscopic meniscal procedures (operative N-DLM: 64 knees). These patients were between 20 and 65 years old and completed a minimum follow-up of 2 years. Patients with DLM who underwent arthroscopic procedure were divided into subgroups according to age and extent of the meniscal-preserving. The following parameters were assessed and compared between the groups: (1) coronal limb alignment, (2) osteoarthritis grade, and (3) clinical outcomes and the minimal clinically important difference. **Results:** The coronal limb alignment was significantly changed to valgus in the order of operative DLM, N-DLM, and nonoperative DLM (Δ mechanical hip−knee−ankle angle: 3.23 ± 1.85 vs $1.35 \pm 1.03°$ vs $-0.57 \pm 1.88°$; $P < .05$). Operative DLM showed most prominent osteoarthritic change in the lateral compartment, followed by the N-DLM and nonoperative DLM groups (40.3% vs 17.2% vs 5.3%; $P < .05$). These changes in operative DLM were more prominent in older adults who underwent meniscal-sacrificing procedures and resulted in less-satisfactory clinical outcomes (all $P < .05$). **Conclusions:** Arthroscopic surgery for adult DLM resulted in progression to valgus alignment and lateral compartment degeneration compared with nonoperative treatment and arthroscopic surgery of the adult N-DLM. Old ager and having a meniscal-sacrificing procedure showed more rapid radiographic changes and lower clinical outcomes. **Level of Evidence:** Level III, retrospective comparison study.

Discoid lateral meniscus (DLM) is a congenital anatomic variation of the meniscus, with a greater prevalence in the Asian population (10%-15%) than in the Western populations (3%-5%).[1-4] It is vulnerable to degeneration and tear because of its characteristics, such as collagen arrangement abnormalities, atypical shapes, and poor vascularization. Therefore, DLM commonly causes symptoms such as pain, clicking, or locking at relatively young ages.[5] However, some patients with DLM have no complaints or symptoms until middle age and osteoarthritic changes have been reported.[6,7]

The arthroscopic meniscal procedure often fails to maintain stability or congruency of the knee joint, and the functions of lubrication or load absorption can be impaired. In addition, abnormal changes in limb alignment are a manifestation of intrinsic mechanical imbalance, indicating ongoing or impending intra-articular injuries after meniscectomy.[8-14] In these cases, the patient is susceptible to osteoarthritic changes.[9,10,12,14] However, little information is available in the literature regarding the prognosis and

From the Department of Orthopedic Surgery, Seoul National University College of Medicine, Seoul National University Bundang Hospital, Gyeonggi-do, South Korea.

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Address correspondence to Yong Seuk Lee, M.D., Ph.D., Department of Orthopedic Surgery, Seoul National University College of Medicine, Bundang Hospital, 166 Gumi-ro, Bundang-gu, Seongnam-si, Gyeonggi-do 463-707, South Korea. E-mail: smcos1@hanmail.net or smcos1@snu.ac.kr

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efficacy of arthroscopic meniscal procedure in adult patients. Furthermore, the changes in limb alignment and progression of osteoarthritis (OA) according to age and treatment methods in adult patients have not been clearly established.

Therefore, the purpose of this study was to analyze the effect of the arthroscopic meniscal procedure in adult DLM according to the age and meniscal-preserving by making comparisons with the nondiscoid lateral meniscus (N-DLM). Our hypotheses were that (1) patients with DLM who underwent arthroscopic meniscal procedure would have a significant change in limb alignment and progression of OA in the lateral tibiofemoral (TF) joint; and (2) those changes would be more prominent in older patients and in patients who failed to preserve the meniscus.

Methods

Patients who presented with knee symptoms at the authors' institution from March 2014 to October 2020 were retrospectively reviewed. Those who were between 20 and 65 years old, whose magnetic resonance imaging revealed a DLM or torn N-DLM, and who completed a minimum follow-up of 2 years after initiation of treatment were included in this study. The exclusion criteria were as follows: (1) patients who had concomitant discoid medial meniscus, (2) concomitant surgery in the medial compartment, (3) history of major trauma such as fracture or ligament injury, and (4) history of previous surgery on the involved knee. Institutional review board approval was obtained before commencement of this study (B-2302-810-103).

To analyze the characteristics and evaluate the clinical and radiologic outcomes of adult DLM, a comparative study was conducted. The patients were allocated into 3 groups (an operative DLM group, who underwent arthroscopic meniscal procedures; nonoperative DLM group, who treated nonoperatively; and operative N-DLM group). In addition, subgroup analysis according to age and extent of the meniscal procedure in operatively treated patients with DLM was performed. The operative DLM group was further divided into 2 distinct subgroups according to age: older than 40 years group and younger than 40 years group.[11,15] According to the extent of the meniscal procedure, the meniscal-preserving group (peripheral rim of more than 6 mm from the peripheral capsular attachment) underwent meniscal repair and/or partial meniscectomy, and the meniscal-sacrificing group (peripheral rim of less than 6 mm) underwent subtotal meniscectomy with or without meniscal repair, or total meniscectomy (Figs 1 and 2). Radiologic and clinical assessment were performed before, 3 months, 6 months, and 1 year after the treatment and annually thereafter at subsequent follow-ups. The assessment at initial and last follow-up were used for the analyses.

Nonoperative Treatment and Arthroscopic Meniscal Procedure

Nonoperative treatment was indicated in patients with mild-to-tolerable symptoms who underwent physical therapy, topical ointment, medication, or intra-articular injections. If nonoperative treatment was ineffective or symptoms worsened within 3 to 6 months, arthroscopic meniscal procedure was considered. All arthroscopic surgeries were performed at a single institution by a single surgeon. Based on the tear, deformation, stability, and viability of the meniscus, partial, subtotal, or total meniscectomy and/or meniscal repair was performed in both operative DLM and N-DLM groups.[16] Partial meniscectomy was performed to remove the central portion and the torn unstable part of the meniscus and to leave a stable rim of more than 6 to 8 mm from the peripheral capsular attachment. If there was complex meniscal injury or little viable meniscus, subtotal or total meniscectomy was performed. For subtotal meniscectomy, unstable meniscal fragments were removed, and the stable portion was preserved as much as possible. If possible, 2 to 3 mm of the peripheral rim was designed to remain. Total meniscectomy was performed only in cases with a non-viable meniscus[17] (Fig 2). Repair was the first priority and was performed in patients with peripheral instability or tears. Postoperative rehabilitation did not differ between either group. An early weight-bearing protocol was employed for all patients; however, caution was emphasized when engaging in knee flexion of approximately 90° in the case of meniscal repair.

Radiologic Evaluation

Radiologic measurements were performed twice at 6-week intervals by 2 orthopaedic fellows with 9 years of experience (J.H.C. and H.S.N.). To assess radiologic outcomes, coronal limb alignment and OA of the TF joint were evaluated. All radiologic measurements were performed twice by 2 independent authors using a picture archiving and communication system (INFINITT, version 5.0.9.2, Seoul, South Korea), and the average of the 2 measurements was used for analysis. To assess coronal limb alignment, the mechanical hip–knee–ankle angle (mHKA), mechanical medial proximal tibial angle, mechanical lateral distal femoral angle, and joint line convergence angle (JLCA) were assessed using whole-leg anteroposterior weight-bearing radiographs. The mHKA was defined as the angle formed by the mechanical axes of the femur and tibia. Varus alignment was expressed as a negative number, and valgus alignment was expressed as a positive number. The JLCA was measured as the angle made by the 2 tangential lines at the distal femoral and proximal tibial articular surfaces, for which the lateral opening was designated as a positive value. The degree

of OA in the TF joint was evaluated using the Kellgren–Lawrence (KL) grading system.[18] KL grade was assessed separately in the lateral and medial compartments on plain knee radiographs (standing knee anteroposterior and posteroanterior 45° flexion view [Rosenberg view]). All enrolled knees were sorted into 2 groups: no to mild OA (KL grade 1 or 2) and moderate-to-advanced OA (KL grade 3 or 4). In addition, we defined the progression of OA based on the change from "no to mild OA" to "moderate-to-advanced OA."

Clinical Evaluation

Clinical outcomes were assessed by a single senior orthopaedic surgeon (Y.S.L.) and an orthopaedic physician's assistant with 8 years of experience. The evaluations by questionnaires related to patient-reported outcomes were performed face-to-face. Clinical outcomes were evaluated using the Lysholm and International Knee Documentation Committee (IKDC) scoring systems.[19,20] The minimal clinically important difference (MCID) was also calculated

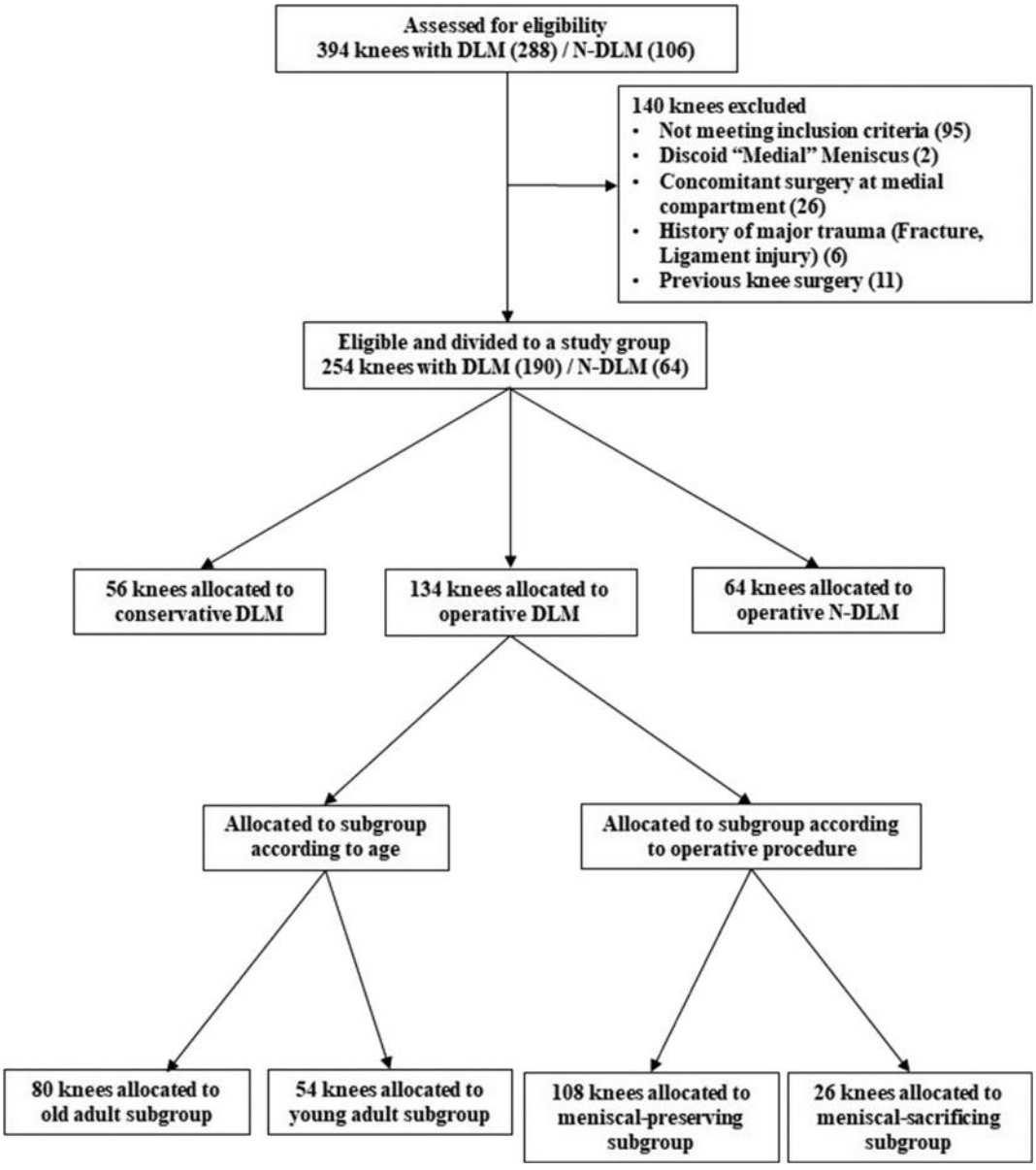

Fig 1. Flow chart of enrollment. (DLM, discoid lateral meniscus; N-DLM, nondiscoid lateral meniscus; old adult, older than 40 years old; young adult, younger than 40 years old; meniscal-preserving, meniscal repair and/or partial meniscectomy with remaining peripheral rim of more than 6 mm from the peripheral capsular attachment; meniscal-sacrificing, subtotal meniscectomy with or without meniscal repair, or total meniscectomy, with remaining peripheral rim of less than 6 mm from the peripheral capsular attachment).

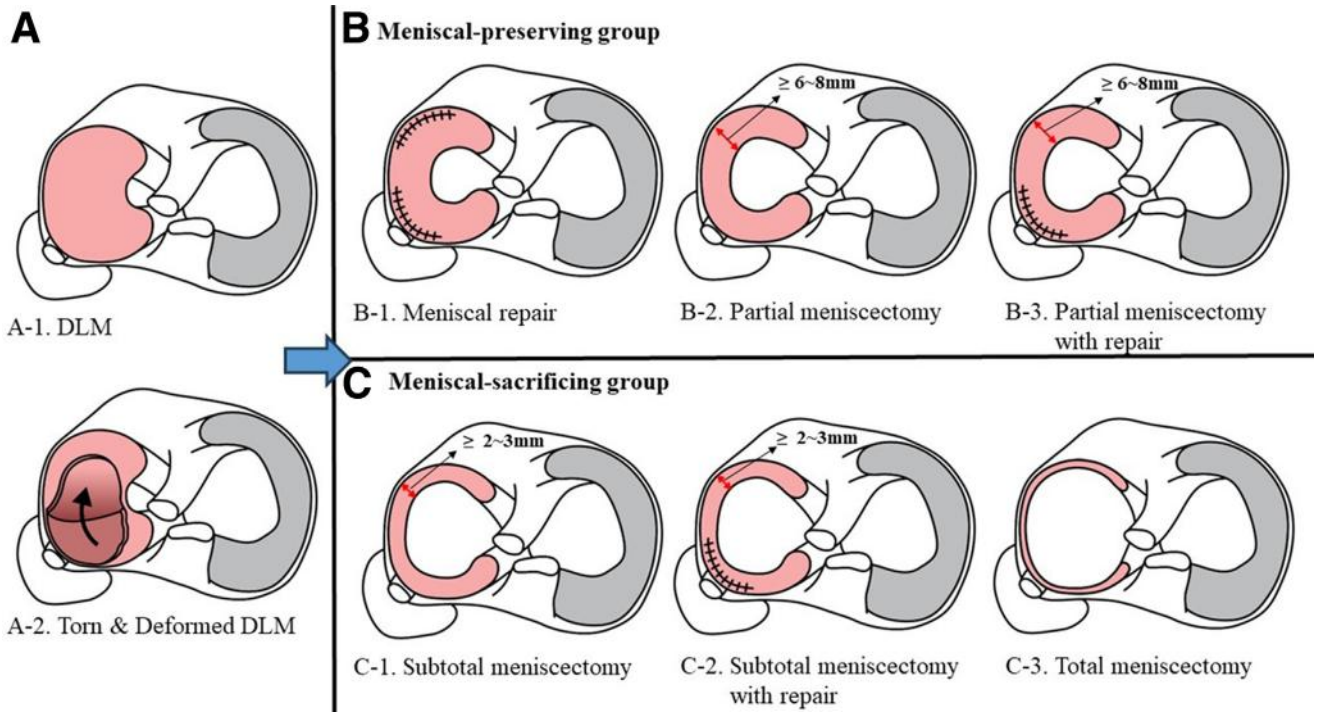

Fig 2. Schematic illustration of the left knee showing the subgrouping of operative discoid lateral meniscus (DLM) according to the extent of the meniscal procedures. (A1) DLM; and (A2) torn and deformed DLM. (B) Meniscal-preserving group with remaining peripheral rim of more than 6 mm from the peripheral capsular attachment. (B1) Meniscal repair, (B2) partial meniscectomy with remaining peripheral rim of more than 6∼8 mm, and (B3) partial meniscectomy with repair. (C) Meniscal-sacrificing group with remaining peripheral rim of less than 6 mm from the peripheral capsular attachment. (C1) Subtotal meniscectomy with remaining peripheral rim of more than 2∼3 mm, (C2) Subtotal meniscectomy with repair, (C3) total meniscectomy with remaining peripheral rim of less than 2 mm.

according to established guidelines.[21] The MCID for the Lysholm was 10.1 and 16.7 for the IKDC score.[22,23]

Statistical Analysis

All analyses were performed using SPSS, version 13.0, for Windows (SPSS, Chicago, IL). Inter- and intraobserver measurement reliabilities were assessed using intraclass correlation coefficients. G-power 3.1.9.7 (Dusseldorf, Germany) was used to calculate the sample size. An a priori power analysis was performed to determine the number of patients in each group. In the a priori power analysis, at least 53 patients were required in each group ($\alpha = 0.10$, $\beta = 0.90$). For continuous variables, the Student t test, Mann−Whitney U test, and one-way analysis of variance with statistically significant differences assessed using post-hoc Tukey tests were used to compare between groups. In each group, pre- and post-therapeutic measurements were evaluated using paired t-tests and Wilcoxon signed-rank tests. Differences in categorical variables were analyzed using the Pearson χ^2 test or Fisher exact test. The significance level was set at $P < .05$.

Results

Of the 394 knees (288 with DLM and 106 with N-DLM) that were eligible for inclusion, 140 were excluded based on the exclusion criteria (not meeting inclusion criteria [95 knees], concomitant discoid medial meniscus [2 knees], concomitant surgery at medial compartment [26 knees], history of major trauma [6 knees], history of previous knee surgery [11 knees]). Finally, 254 knees (190 with DLM and 64 with N-DLM) were included. The operative DLM group (134 knees), nonoperative DLM group (56 knees), and operative N-DLM group (64 knees) were enrolled. In subgroup analysis, the old adult group (80 knees) and young adult group (54 knees) were included according to the age. According to the extent of the meniscal procedure, the meniscal-preserving group (108 knees) and meniscal-sacrificing group (26 knees) were included (Fig 1). The inter- and intraobserver reliabilities for the measurement of radiographic parameters were excellent, and their mean values were 0.86 (range 0.80-0.91) and 0.89 (range 0.84-0.93), respectively. The average duration of follow-up was 47.61 ± 25.59 months (range 24-132 months), and the average age of the patients at the time of treatment was 41.66 ± 13.28 years.

Table 1. Baseline Characteristics of the Three Groups

	Operative DLM (N = 134)	Nonoperative DLM (N = 56)	Operative N-DLM (N = 64)	*P* Value
Age, y	41.17 ± 13.31	44.96 ± 13.04	39.80 ± 13.11	.085
Sex (male/female)	57/77	20/36	34/30	.193
Laterality (Right/Left)	70/64	28/28	29/35	.152
BMI	24.39 ± 3.82	24.99 ± 2.79	25.23 ± 4.09	.528
Trauma, n (%)	52 (38.8%)	20 (35.7%)	26 (40.3%)	.388
Symptom duration (months)	15.30 ± 14.45	13.68 ± 12.35	13.44 ± 12.74	.628
Follow-up period (months)	48.37 ± 20.02	49.29 ± 31.27	54.00 ± 29.00	.106
Operation type				
Repair	10 (7.5%)		28 (43.8%)	**.000**
Partial meniscectomy + repair	40 (29.9%)		8 (12.5%)	**.008**
Partial meniscectomy	58 (43.3%)		16 (25.0%)	**.013**
Subtotal meniscectomy + repair	6 (4.5%)		0 (0%)	.086
Subtotal meniscectomy	12 (9.0%)		12 (18.8%)	.052
Total meniscectomy	8 (6.0%)		0 (0%)	**.046**
Meniscal-preserving	108 (80.6%)		52 (81.3%)	.913
Meniscal-sacrificing	26 (19.4%)		12 (18.8%)	.913

NOTE. Statistical significance was set at $P < .05$. Statistically significant values are indicated in bold.

Meniscal-preserving: meniscal repair and/or partial meniscectomy group; meniscal-sacrificing: subtotal meniscectomy with or without meniscal repair or total meniscectomy group.

BMI, body mass index; DLM, discoid lateral meniscus; N-DLM, nondiscoid lateral meniscus.

The baseline characteristics of the patients are summarized in Table 1. There were no significant differences between the 3 groups in terms of demographics. In terms of operation type, operative DLM underwent partial meniscectomy ± repair ($P < .05$) and total meniscectomy (6.0 % vs 0 %; $P < .05$)

Table 2. Comparison of Radiologic Outcomes Between the Three Groups

	Operative DLM (N = 134)	Nonoperative DLM (N = 56)	Operative N-DLM (N = 64)	*P* Value (post-hoc)
mHKA, °				
Initial	−1.36 ± 3.04	−2.14 ± 2.91	−0.44 ± 2.13	**.004 (ON > OD, ND)**
Final	1.87 ± 2.91	−2.72 ± 3.57	0.91 ± 2.11	**.001 (OD > ON > ND)**
Δ Final − Initial	3.23 ± 1.85	−0.57 ± 1.88	1.35 ± 1.03	**.001 (OD > ON > ND)**
P value	**.000**	**.026**	**.000**	
mMPTA, °				
Initial	86.76 ± 2.54	86.55 ± 2.49	87.10 ± 2.04	.469
Final	87.90 ± 2.41	86.43 ± 2.24	87.60 ± 1.86	**.001 (OD, ON > ND)**
Δ Final − Initial	1.13 ± 1.5	−0.12 ± 1.18	0.51 ± 1.40	**.000 (OD > ON, ND)**
P value	**.000**	.492	**.005**	
mLDFA, °				
Initial	87.24 ± 2.20	87.29 ± 2.17	86.52 ± 3.00	.120
Final	86.21 ± 1.85	87.49 ± 3.02	86.05 ± 2.55	**.002 (ND > OD, ON)**
Δ Final − Initial	−1.03 ± 1.67	0.20 ± 1.89	−0.47 ± 1.16	**.000 (ND > OD)**
P value	**.000**	.596	**.002**	
JLCA,				
Initial	0.99 ± 1.45	1.14 ± 1.79	0.49 ± 0.94	**.029 (ND > OD)**
Final	−0.96 ± 1.42	1.31 ± 1.72	−0.28 ± 1.48	**.000 (ND > ON > OD)**
Δ Final − Initial	−1.94 ± 1.56	0.17 ± 1.56	−0.77 ± 1.11	**.000 (ND > ON > OD)**
P value	**.000**	.456	**.000**	
Initial moderate-to-advanced OA				
Medial compartment	4 (2.9%)	1 (1.7%)	0 (0%)	.163
Lateral compartment	4 (2.9%)	1 (1.7%)	1 (1.6%)	.551
Progression of OA				
Medial compartment	15 (11.2%)	2 (3.7%)	5 (7.8%)	.093
Lateral compartment	54 (40.3%)	4 (7.1%)	11 (17.2%)	**.001 (OD > ON, ND)**

NOTE. Statistical significance was set at $P < .05$. Moderate to advanced OA: Kellgren-Lawrence grade 3 or 4. Statistically significant values are indicated in bold.

DLM, discoid lateral meniscus; JLCA, joint line convergence angle; mHKA, mechanical hip−knee−ankle axis; mLDFA: mechanical lateral distal femoral angle; mMPTA: mechanical medial proximal tibial angle; ND, nonoperative DLM; N-DLM, nondiscoid lateral meniscus; OA: osteoarthritis; OD, operative DLM; ON, operative N-DLM.

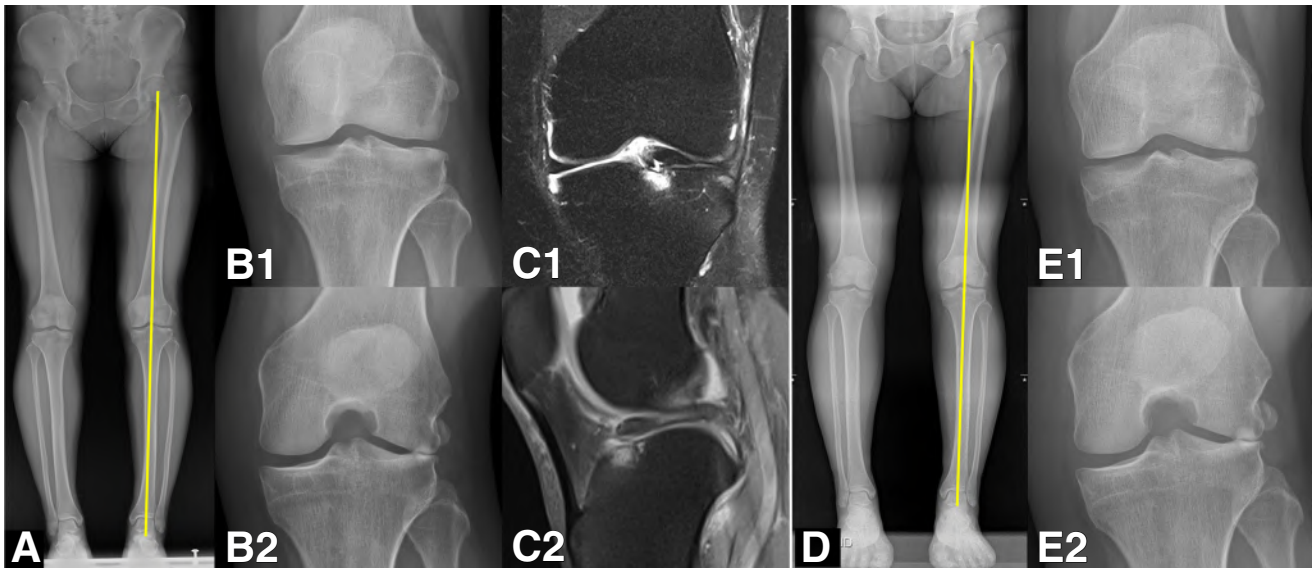

Fig 3. (A) A whole-leg anteroposterior weight-bearing radiograph in a 45-year-old woman shows neutral alignment in the left knee. (B-1) An anteroposterior view and (B-2) posteroanterior 45° view show osteoarthritic change (KL grade 4) in the lateral compartment. (C-1) Coronal magnetic resonance imaging and (C-2) Sagittal magnetic resonance imaging shows an anterocentral shift type deformation of discoid lateral meniscus. (D) A whole-leg anteroposterior weight-bearing radiograph shows no alignment change in the left knee, (E-1) An anteroposterior view and (E-2) posteroanterior 45° view show no osteoarthritic change in the lateral compartment at 4 years' follow-up. (KL, Kellgren-Lawrence.)

more frequently than operative N-DLM. In contrast, operative N-DLM underwent meniscal repair (43.8 % vs 7.5 %; $P < .05$) more often than operative DLM.

A comparison of the radiologic outcomes among the 3 groups is summarized in Table 2. In the assessment of coronal limb alignment, operative DLM and nonoperative DLM demonstrated more varus alignment initially than operative N-DLM (mHKA: -1.36 ± 3.04 and -2.14 ± 2.91 vs $-0.44 \pm 2.13°$; JLCA: 0.99 ± 1.45 vs $1.44 \pm 1.79°$ vs $0.49 \pm 0.94°$; all $P < .05$). However, in the final follow-up, coronal limb alignment was significantly changed to valgus in the order of operative DLM, N-DLM, and nonoperative DLM (Δ mHKA: 3.23 ± 1.85 vs $1.35 \pm 1.03°$ vs $-0.57 \pm 1.88°$; ΔJLCA: -1.94 ± 1.56 vs $-0.77 \pm 1.11°$ vs $0.17 \pm 1.56°$; all $P < .05$).

When considering OA of the knee joint, OA in the lateral compartment progressed in all 3 groups; however, operative DLM showed most prominent progression, followed by the operative N-DLM and nonoperative DLM groups (40.3 % vs 17.2 % vs 5.3 %; $P < .05$). In the medial compartment, although OA progression was observed in a small proportion of patients, there was no significant difference ($P = .093$). A representative case of nonoperative DLM is shown in Figure 3.

A subgroup analysis of operative DLM is summarized in Table 3. There were no significant differences in the baseline characteristics. According to the age, coronal limb alignment in old adult group was changed to valgus significantly more frequently than young adult group (Δ mHKA: 4.68 ± 1.85 vs $2.96 \pm 2.00°$; ΔJLCA: -2.31 ± 1.29 vs $-1.41 \pm 1.77°$; all $P < .05$). OA in each compartment was significantly more progressed in old adult group than young adult group at the final follow-up (lateral compartment: 56.3 % vs 16.7%, medial compartment: 18.8% vs 0.0%; all $P < .05$). According to the extent of the meniscal procedure, coronal limb alignment in meniscal-sacrificing group was changed to valgus significantly more frequently than in meniscal-preserving group (Δ mHKA: 4.79 ± 1.44 vs $2.86 \pm 1.74°$; ΔJLCA: -2.72 ± 1.44 vs $-1.76 \pm 1.53°$; all $P < .05$). OA in the lateral compartment was significantly more progressed in meniscal-sacrificing group than in meniscal-preserving group (69.2 % vs 33.3%; $P < .05$). Representative cases from the older adult and younger adult groups are shown in Figures 4 and 5.

The comparison of clinical outcomes is summarized in Table 4. All clinical outcomes among the 3 groups improved postoperatively compared with the preoperative values. In addition, the percentage of patients surpassing the established MCID thresholds for each patient-reported outcome was also compared. There was no significant difference among the 3 groups. In subgroup analysis according to the age, old adult group showed a lower final IKDC score than young adult group (81.49 ± 10.18 vs 85.33 ± 9.34; $P < .05$). However, there was no significant difference in the percentage of surpassing the MCID thresholds. In subgroup analysis according to the extent of the meniscal procedure, meniscal-sacrificing group showed a lower percentage of surpassing the MCID thresholds (IKDC: 84.6% vs 96.3%, Lysholm: 88.5% vs 98.1%; all $P < .05$).

Table 3. Subgroup Analysis in Operative DLM

	Old Adult (N = 80)	Young Adult (N = 54)	*P* Value	Meniscal-Preserving (N = 108)	Meniscal-Sacrificing (N = 26)	*P* Value
Age, y	50.27 ± 6.56	27.20 ± 6.87	**.000**	40.71 ± 13.88	43.08 ± 10.63	.344
F/U period, mo	42.45 ± 22.25	37.30 ± 15.86	.144	41.60 ± 19.63	47.77 ± 20.29	.054
Symptom duration, mo	20.20 ± 18.81	14.56 ± 14.19	.198	14.93 ± 14.36	23.23 ± 21.59	.121
Operation type						
Meniscal-preserving	62 (77.5%)	46 (85.2%)	.270			
Meniscal-sacrificing	18 (22.5%)	8 (14.8%)	.270			
mHKA, °						
Initial	−2.55 ± 2.84	−1.30 ± 2.55	**.010**	−1.27 ± 3.16	−1.74 ± 2.49	.482
Final	2.13 ± 2.81	1.66 ± 3.25	.378	1.58 ± 3.06	3.05 ± 1.81	**.002**
Δ Final − Initial	4.68 ± 1.98	2.96 ± 2.00	**.010**	2.86 ± 1.74	4.79 ± 1.44	**.000**
P value	**.000**	**.000**		**.000**	**.000**	
mMPTA, °						
Initial	86.56 ± 2.45	87.06 ± 2.33	.268	86.71 ± 2.50	86.97 ± 2.67	.637
Final	88.16 ± 2.33	87.51 ± 2.50	.127	87.68 ± 2.24	88.79 ± 2.91	.078
Δ Final − Initial	1.60 ± 1.56	0.45 ± 1.32	**.000**	0.97 ± 1.82	1.82 ± 1.53	**.015**
P value	**.000**	**.014**		**.000**	**.000**	
mLDFA, °						
Initial	87.51 ± 1.85	86.86 ± 2.60	.093	87.05 ± 2.17	88.05 ± 2.14	.039
Final	86.30 ± 1.79	86.08 ± 1.95	.503	85.98 ± 1.76	87.20 ± 1.93	**.005**
Δ Final − Initial	−1.20 ± 1.68	−0.77 ± 1.63	.144	−0.85 ± 2.10	−1.07 ± 1.55	.615
P value	**.000**	**.001**		**.000**	**.049**	
JLCA, °						
Initial	1.26 ± 1.43	0.58 ± 1.39	**.007**	0.94 ± 1.50	1.18 ± 1.20	.379
Final	−1.05 ± 1.56	−0.83 ± 1.19	.399	−0.82 ± 1.49	−1.54 ± 0.89	**.020**
Δ Final − Initial	−2.31 ± 1.29	−1.41 ± 1.77	**.001**	−1.76 ± 1.53	−2.72 ± 1.44	**.004**
P value	**.000**	**.000**		**.000**	**.000**	
Initial moderate-to-advanced OA						
Medial compartment	4 (5.0%)	0 (0%)	.095	2 (1.9%)	2 (7.7%)	.116
Lateral compartment	4 (5.0%)	0 (0%)	.095	2 (1.9%)	2 (7.7%)	.116
Progression of OA						
Medial compartment	15 (18.8%)	0 (0%)	**.001**	11 (10.2%)	4 (15.4%)	.450
Lateral compartment	45 (56.3%)	9 (16.7%)	**.000**	36 (33.3%)	18 (69.2%)	**.001**

NOTE. Old adult: older than 40 years; young adult: younger than 40 years; meniscal-preserving: meniscal repair and/or partial meniscectomy group; meniscal-sacrificing: subtotal meniscectomy with or without meniscal repair or total meniscectomy group. Moderate-to-advanced OA: Kellgren-Lawrence grade 3 or 4. Statistical significance was set at $P < .05$. Statistically significant values are indicated in bold.

DLM, discoid lateral meniscus; JLCA, joint line convergence angle; mHKA, mechanical hip−knee−ankle axis; mLDFA: mechanical lateral distal femoral angle; mMPTA: mechanical medial proximal tibial angle; ND, nonoperative DLM; N-DLM, nondiscoid lateral meniscus; OA: osteoarthritis; OD, operative DLM; ON, operative N-DLM.

Discussion

The principal finding of this study was that operative DLM showed significant change to valgus alignment and progression of OA of the lateral compartment at average 47.61 ± 25.59 months follow-up compared with other groups. These changes were more prominent compared with nonoperative DLM and operative N-DLM. Moreover, these changes in operative DLM were more prominent in older adults who underwent meniscal-sacrificing procedures and resulted less satisfactory clinical outcomes.

In DLM, the lateral meniscus covers all or most of the area of the lateral compartment in the knee joint, which has a greater wedge content than the medial compartment. Therefore, the knee with DLM is more prone to varus alignment than that with N-DLM.[7,8,24] Following arthroscopic meniscectomy, the volume effect in the lateral compartment is reduced more in DLM than in N-DLM.[8] Moreover, DLM has different characteristics from those of normal menisci.[5-7,25] Although the volume of the residual meniscus is sufficient, residual meniscal tissue is susceptible to degeneration, and its function may be inferior to that of the normal meniscus.[26,27] Consequently, these may lead to valgus alignment and OA progression in the lateral compartment after arthroscopic meniscal procedure.[8,13,28] In addition, these effects may be more pronounced depending on the age and extent of the meniscal procedure.

It is known that the healing potential of the remnant meniscus declines and progression of OA can be prominent in older age.[9,29] Allen et al.[10] and Habata et al.[11] found that the change in coronal limb alignment and the progression of OA in the lateral compartment are interrelated with age, and these changes are more

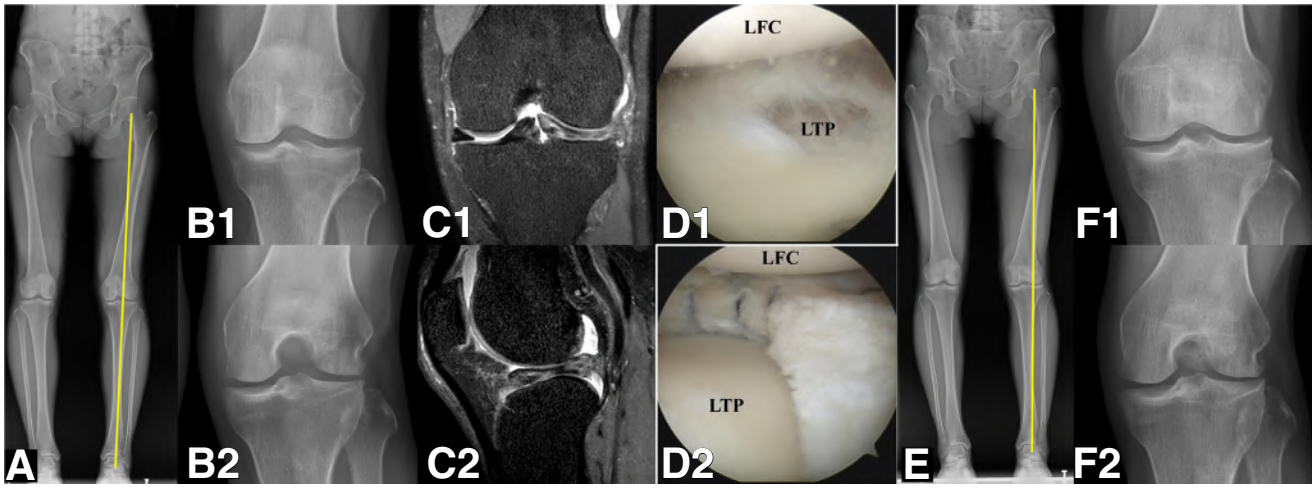

Fig 4. (A) A whole-leg anteroposterior weight-bearing radiograph in a 50-year-old woman shows slightly valgus alignment in the left knee. (B-1) An anteroposterior view and (B-2) posteroanterior 45° view show osteoarthritic change (KL grade 1-2) in the lateral compartment. (C-1) Coronal and (C-2) sagittal magnetic resonance imaging show central shift type deformation with degenerative tear of discoid lateral meniscus. (D-1) Arthroscopic findings show a degenerative tear with central hole of discoid lateral meniscus. (D-2) Arthroscopic partial meniscectomy and meniscal repair were performed. (E) A whole-leg anteroposterior weight-bearing radiograph shows valgus alignment change in the left knee, (F-1) An anteroposterior view and (F-2) posteroanterior 45° view show progression of osteoarthritic change (KL grade 3) in the lateral compartment at 4 years' follow up. (KL, Kellgren-Lawrence; LFC, lateral femoral condyle; LTP, lateral tibial plateau.)

prominent in old age. These results were consistent with the findings of the present study.

Kim et al.[12] and Zhang et al.[13] found that the change in coronal limb alignment and the progression of OA in the lateral compartment are more prominent in total meniscectomy than in partial meniscectomy. After the total meniscectomy, the contact area of the TF joint decreased by approximately 50%.[30] As a result, the contact stress increased by 235% to 335%.[31] However, after partial meniscectomy, the resection area would be smaller, the contact area would decrease by 10% only, and the contact stress would increase by 65%.[32] As the

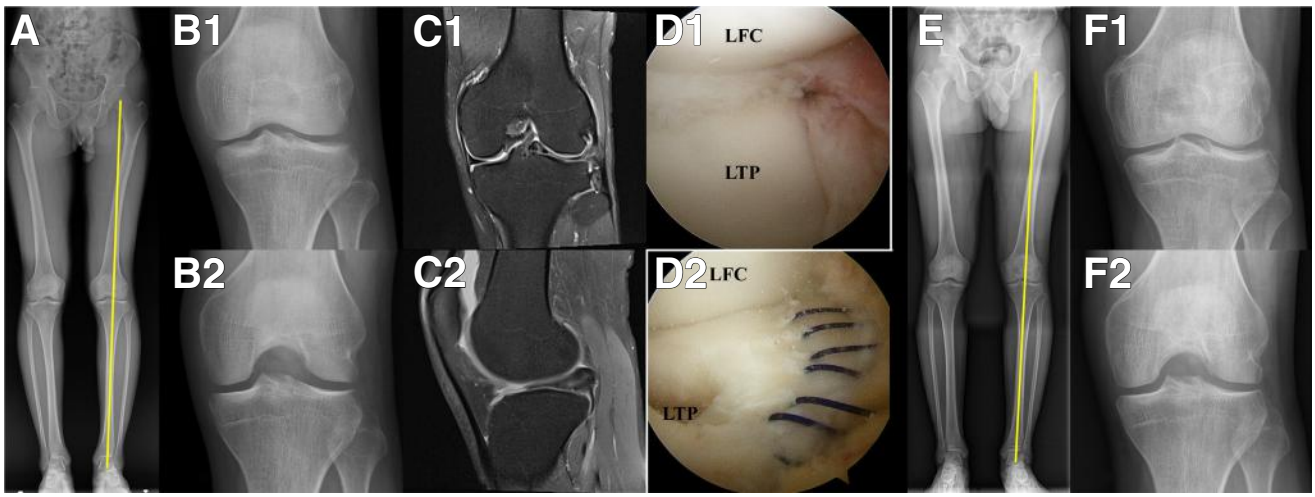

Fig 5. (A) A whole-leg anteroposterior weight-bearing radiograph in a 26-year-old man shows slightly valgus alignment in the left knee. (B-1) An anteroposterior view and (B-2) posteroanterior 45° view show no osteoarthritic change (KL grade 0) in the lateral compartment. (C-1) Coronal and (C-2) Sagittal magnetic resonance imaging show posterocentral shift type deformation of discoid lateral meniscus. (D-1) Arthroscopic findings show naked LTP due to posterocentrally shifted discoid lateral meniscus. (D-2) Arthroscopic partial meniscectomy and meniscal repair were performed. (E) A whole-leg anteroposterior weight-bearing radiograph shows no alignment change in the left knee, (F-1) An anteroposterior view and (F-2) posteroanterior 45° view show no progression of osteoarthritic change (KL grade 1-2) in the lateral compartment at 4 years' follow up. (KL, Kellgren-Lawrence; LFC, lateral femoral condyle; LTP, lateral tibial plateau.)

Table 4. Comparison of Clinical Outcomes

	Operative DLM (N = 134)	Nonoperative DLM (N = 56)	Operative N-DLM (N = 64)	*P* Value (Post-Hoc)
IKDC				
Initial	42.60 ± 10.74	53.56 ± 15.33	43.56 ± 15.63	**.031 (ND> OD, ON)**
Final	82.95 ± 10.01	87.36 ± 8.51	85.93 ± 13.12	.089
P value	**.000**	**.000**	**.000**	
Above MCID	126 (94.0%)	53 (94.6%)	60 (93.8%)	.638
Lysholm				
Initial	44.07 ± 11.92	56.56 ± 14.63	48.56 ± 17.52	**.026 (ND> OD, ON)**
Final	83.81 ± 9.03	88.56 ± 7.52	86.47 ± 12.62	.102
P value	**.000**	**.000**	**.000**	
Above MCID	129 (96.3%)	53 (94.6%)	58 (90.6%)	.105

	Old Adult (N = 80)	Young Adult (N = 54)	*P* Value	Meniscal-Preserving (N = 108)	Meniscal-Sacrificing (N = 26)	*P* Value
IKDC						
Initial	41.75 ± 10.10	43.85 ± 11.62	.268	46.77 ± 11.94	41.59 ± 10.24	**.027**
Final	81.49 ± 10.18	85.33 ± 9.34	**.036***	83.60 ± 10.06	80.46 ± 9.59	.149
P value	**.000**	**.000**		**.000**	**000**	
Above MCID	74 (92.5%)	52 (96.3%)	.363	104 (96.3%)	22 (84.6%)	**.024**
Lysholm						
Initial	43.10 ± 11.74	45.52 ± 14.50	.290	50.00 ± 12.72	42.65 ± 12.61	**.009**
Final	82.64 ± 85.71	85.71 ± 7.81	.064	84.04 ± 9.50	82.92 ± 7.05	.508
P value	**.000**	**.000**		**.000**	**.000**	
Above MCID	76 (95.0%)	53 (98.1%)	.346	106 (98.1%)	23 (88.5%)	**.019**

NOTE. Old adult: older than 40 years; young adult: younger than 40 years; meniscal-preserving: meniscal repair and/or partial meniscectomy group; Meniscal-sacrificing: subtotal meniscectomy with or without meniscal repair or total meniscectomy group. Statistical significance was set at $P < .05$. Statistically significant values are indicated in bold.

DLM, discoid lateral meniscus; IKDC, International Knee Documentation Committee subjective score; JLCA, joint line convergence angle; MCID, minimal clinically important difference; mHKA, mechanical hip–knee–ankle axis; mLDFA: mechanical lateral distal femoral angle; mMPTA: mechanical medial proximal tibial angle; ND, nonoperative DLM; N-DLM, nondiscoid lateral meniscus; OA: osteoarthritis; OD, operative DLM; ON, operative N-DLM.

volume of resected DLM increased, higher contact stress was applied to the lateral TF joint.[33,34] The decreased meniscal volume and increased contact stress may contribute to alternation of alignment and articular cartilage and subchondral bone injury. Thus, the meniscal-preserving procedure had less impact on the axial load of the knee joint, and the changes in coronal limb alignment and the progression of OA were smaller than those of the meniscal-sacrificing procedure.[9,12,17]

Our study showed that all patients had satisfactory clinical outcomes at average 47.61 ± 25.59 months follow-up, even though some patients showed the progression to valgus alignment and lateral compartment degeneration. This result is consistent with those of previous studies.[11,12,15] The reason for these satisfactory clinical outcomes is thought to be due to the elimination of pain-inducing DLM and the relatively short-term follow-up periods. When meniscus was sacrificed, nevertheless, the percentage of surpassing the MCID thresholds in clinical outcomes was rather low compared to when meniscus was preserved. Because DLM is less repairable and more severely deformed than N-DLM, patients with DLM more often underwent subtotal or total meniscectomy than N-DLM. In practice, because anteriorly deformed menisci frequently show posterolateral defects, anterocentral deformation of the meniscus frequently requires a meniscal-sacrificing procedure.[35] Therefore, caution is required in this case. We also found that changes in coronal limb alignment and progression of OA were observed less in patients with nonoperative DLM than in operative DLM. Although this study showed that patients with nonoperative DLM obtained satisfactory clinical and radiologic outcomes, it remains unclear whether, over the long term, nonoperative treatment in symptomatic adult with DLM can maintain the satisfactory clinical and radiologic outcomes.

The valgus mal-aligned lateral OA after arthroscopy might be candidates for additional treatment for joint preservation. Surgical treatments, including distal femoral osteotomy (DFO), unicompartmental knee arthroplasty, or possibly meniscal allograft transplantation, can be another options for the treatment of meniscus-deficient knees by replacing meniscal tissue or altering joint alignment.[36] Among them, considering age, DFO can be a good treatment option for the valgus

mal-aligned lateral OA after meniscectomy.[37,38] In total, 18 of 254 patients (17 in operative DLM and 1 in operative N-DLM) had 5° or more of valgus alignment in this study. Their coronal alignment profiles were mHKA ranged from 5 to 6.52°, mechanical medial proximal tibial angle: 86.35 to 91.6°; mechanical lateral distal femoral angle 83.19 to 88.02°, and JLCA: −1.18 to −2.13°. Although they had acceptable coronal alignment and obtained satisfactory clinical outcomes, DFO can be considered if symptoms get worse or radiologic changes progressed in long-term follow-up.

Limitations

This study also has several limitations. First, this study had a relatively short follow-up period and evaluated the progression in OA using only plain knee radiographs. Second, a selection bias may exist because the enrollment of groupings and the distribution according to meniscal procedures was heterogenic. There was a possibility that meniscal-sacrificing DLM group has more severe meniscal lesions than nonoperative DLM group. In addition, the non-DLM group has a greater percentage of repairs than DLM group. Third, unknown confounders are inherent in a nonrandomized, retrospective study.

Conclusions

Arthroscopic surgery for adult DLM resulted in progression to valgus alignment and lateral compartment degeneration compared with nonoperative treatment and arthroscopic surgery of the adult N-DLM. Older age and having a meniscal-sacrificing procedure showed more rapid radiographic changes and lower clinical outcomes.

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