Original Research Article

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Contralateral Knee Alignment Parameters Have Limited Influence on Coronal Alignment Progression Compared With Ipsilateral Parameters in Patients With Knee Osteoarthritis

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Abstract

Objective. To compare alignment parameters in bilateral lower extremities and evaluate the effect of contralateral limb on hip-knee-ankle angle (HKAA) longitudinally. *Methods*. Native bilateral lower extremities of 3,045 Korean patients with long-leg radiographs were followed for progression of knee osteoarthritis. Concordance rates of Functional Knee Phenotypes (FKPs) and Coronal Plane Alignment of the Knee (CPAK), the proportion of patients with identical bilateral subtypes, were assessed. Varus, neutral, and valgus alignments were defined as baseline HKAA ≤177°, 177°< HKAA <183°, and HKAA ≥183°, respectively. Multivariable linear regressions for follow-up HKAA were conducted. *Results*. Concordance rates for FKPs and CPAK were 41.6% (95% confidence interval: 39.9-43.4%) and 53.5% (51.7-55.2%), respectively, at baseline and 35.5% (33.8-37.2%) and 55.4% (53.7-57.2%) at a mean 4.0-year follow-up. Contralateral parameters, Kellgren-Lawrence grade ($P = 0.005$) in bilateral varus group, medial proximal tibial angle (MPTA) ($P = 0.046$) in ipsilateral varus-contralateral neutral group, MPTA, and mechanical lateral distal femoral angle in bilateral neutral ($P < 0.001$; $P = 0.012$, respectively) and valgus ($P = 0.003$; $P = 0.004$) groups, were associated with follow-up HKAA. However, their standardized β values were smaller than ipsilateral values. *Conclusion*. Concordance rates of FKPs and CPAK between bilateral limbs were 41.6% and 53.5% at baseline, respectively. Contralateral parameters have limited influence on coronal alignment progression compared with ipsilateral parameters.

Keywords
coronal alignment, hip-knee-ankle angle, knee osteoarthritis, contralateral, Functional Knee Phenotypes

Introduction

Theoretically, symmetry between the right (R) and left (L) lower extremities is expected, as they share the same genetic background and programmed development.[1] Contralateral lower extremity has been used as a rule-of-thumb reference for templating and surgical planning in operations, such as total knee arthroplasty (TKA).[2,3] To improve patient satisfaction after TKA, there are attempts to restore the pre-arthritic alignment.[4] Phenotypic approaches, such as Functional Knee Phenotypes (FKPs)[5,6] and Coronal Plane Alignment of the Knee (CPAK),[7] have been developed to achieve this goal. In this context, there is a renewed interest in the symmetry between R and L limbs. However, the reliability of using contralateral alignment parameters for surgical planning has been questioned in previous studies.[8-10]

Clinically, symmetric coronal alignment progression is frequently observed in patients with knee osteoarthritis (KOA). Parallel progression of coronal alignment has empirically been interpreted as reflecting contralateral influence, such as in studies examining the effect of contralateral total hip arthroplasty (THA).[11] However, whether progression in one knee truly drives alignment changes in the contralateral knee, rather than reflecting shared baseline characteristics and independent local pathology, has not been longitudinally examined in a large population.

This retrospective cohort study aimed to (1) compare alignment parameters, FKPs, and CPAK types in R and L

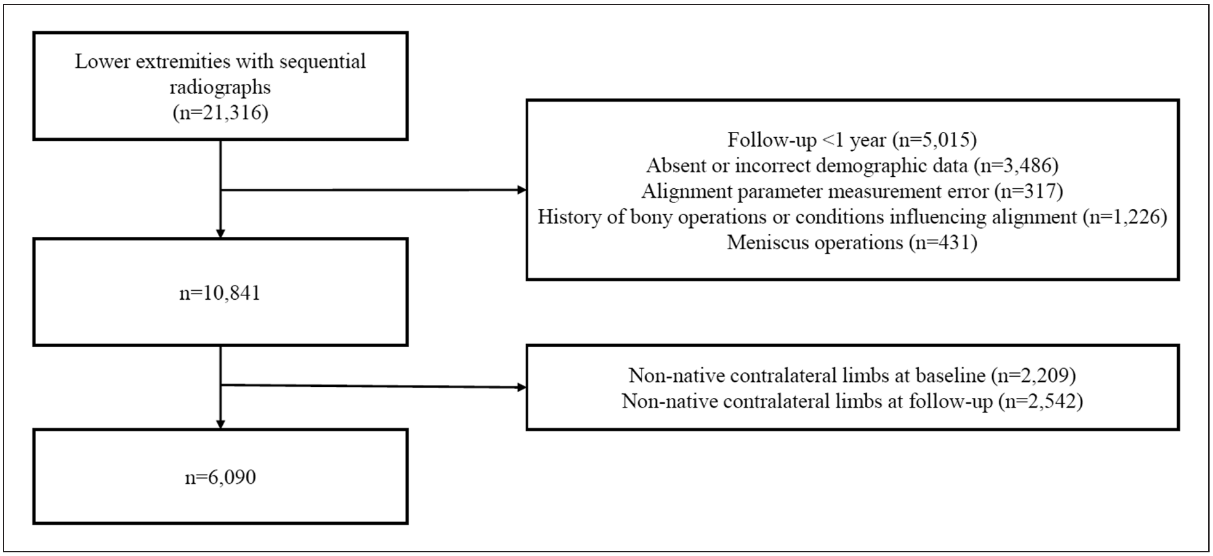

Figure 1. Flow chart of lower extremities included in the analysis.

limbs and (2) evaluate the effect of contralateral lower extremity on hip-knee-ankle angle (HKAA) in different combinations of varus, neutral, and valgus lower extremities over time. It was hypothesized that the alignments in R and L lower extremities are similar and their progression is primarily attributed to ipsilateral alignment parameters rather than contralateral parameters.

Methods

Data Collection

This study was conducted in the same population as the study on accelerated coronal alignment progression.[12] Standing anteroposterior (AP) weight-bearing long-leg radiographs (LLRs) of knee patients who visited the authors' hospital between January 2002 and June 2022 were analyzed. Demographic data, including age, sex, and body mass index (BMI) of the patients, were collected.

Inclusion and Exclusion Criteria

LLRs were available for 21,316 native lower extremities followed for KOA progression. The 2 radiographs with the longest interval for each limb were selected to maximize longitudinal effects. The earlier and later time points of these radiographs were termed as "baseline" and "follow-up," respectively. The same exclusion criteria were applied as the previous study.[12] To exclude "non-native" effects of operative procedures or acquired deformities on the contralateral lower extremity, cases in which the contralateral limb was non-native at baseline (n = 2,209) and follow-up (n = 2,542) were excluded, resulting in 6,090 R and L limbs from 3,045 individuals **(Fig. 1)**.

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Radiographic Measurements

Details of the radiographic assessments were explained in the previous study.[12] LLRs were taken in the position of full extension of the knee and patella facing forward. Radiographic measurements were performed in LLRs. HKAA was defined as the angle between the mechanical axes (MA) of the femur and tibia. HKAA <180° and >180° were assigned for varus and valgus alignments, respectively. Medial proximal tibial angle (MPTA) or tibial mechanical angle (TMA) was defined as the medial angle between the MA of the tibia and the tangential line to the tibial plateau. Mechanical lateral distal femoral angle (mLDFA) and femoral mechanical angle (FMA) were measured as the lateral and medial angles between the MA of the femur and the tangential line to both femoral condyles, respectively. Joint line convergence angle (JLCA) was defined as the angle between the tangents to the tibial plateau and the femoral condyles. Positive and negative values were given for JLCA with lateral and medial opening, respectively. Radiographic analyses were performed using CONNEVO KOA V1.0.0 and METRIC V1.0.0 (CONNECTEVE Co., Ltd., South Korea). The artificial intelligence (AI) software for measurement of alignment parameters has been utilized in previous studies[13-15] with high inter- and intra-observer intraclass correlation coefficients (ICCs), 0.98 or higher.[16] Kellgren-Lawrence (K-L) grade was used to assess the severity of KOA.[17] The AI software for K-L grading used Swin Transformer and EfficientNet architectures and was validated in a multicenter study.[18]

Outcomes

Concordance rates of FKPs[5,6] and CPAK types[7] between R and L limbs were calculated as the proportion of patients with identical FKPs and CPAK types. Varus, neutral, and valgus alignments were defined as baseline HKAA ≤177°, 177°< HKAA <183°, and HKAA ≥183°, respectively.[10,12,19] Bilateral limbs were categorized into following combinations: bilateral varus (varus [B]), bilateral neutral (neutral [B]), bilateral valgus (valgus [B]), varus and valgus (varus [R/L] & valgus [L/R]), varus and neutral (varus [R/L] & neutral [L/R]), and valgus and neutral (valgus [R/L] & neutral [L/R]). Alignment parameters were compared between R and L limbs within each group. Multivariable linear regression analyses, including contralateral alignment parameters and K-L grade, were conducted to predict the follow-up ipsilateral HKAA.

The study was approved by the Institutional Review Board (IRB) of the authors' hospital (IRB number H-2110-200-1269) and conducted in accordance with the international ethical guidelines for research involving human subjects. The requirement of informed consent was waived, because it was a retrospective study.

Table 1. Population Characteristics at Baseline and F/U.

Variable		Baseline Mean ± SD	F/U Mean ± SD	*P*-value
Age (years)		64.9 ± 8.1	69.4 ± 8.1	<0.001
HKAA (°)		176.2 ± 4.1	175.3 ± 5.0	<0.001
MPTA (°)		86.4 ± 2.4	86.2 ± 2.5	<0.001
mLDFA (°)		88.1 ± 2.4	88.1 ± 2.4	0.005
JLCA (°)		2.4 ± 2.4	3.0 ± 2.9	<0.001
		n (%)	n (%)	
K-L grade	0	881 (14.5)	554 (9.1)	<0.001
	1	1497 (24.6)	1047 (17.2)	
	2	1458 (23.9)	1399 (23.0)	
	3	1992 (32.7)	2460 (40.4)	
	4	262 (4.3)	630 (10.3)	

F/U = follow-up; SD = standard deviation; HKAA = hip-knee-ankle angle; MPTA = medial proximal tibial angle; mLDFA = mechanical distal femoral angle; JLCA = joint line convergence angle; K-L = Kellgren-Lawrence.

Statistical Analysis

Categorical variables are presented as frequencies and percentages, and continuous variables as means and standard deviations (SDs). Chi-square or Fisher's exact tests were used for categorical variables. Normality was assessed using the Kolmogorov-Smirnov test. Despite statistically significant results for most variables, visual inspection of histograms and Q-Q plots supported approximate normality, likely reflecting the influence of large sample sizes on the test results **(Suppl. Table S1 and Suppl. Fig. S1)**. Paired *t*-tests were performed to compare R and L limbs and baseline and follow-up values. Multivariable linear regression analyses were conducted to predict follow-up HKAA, including baseline ipsilateral and contralateral MPTA, mLDFA, JLCA, K-L grade, age, sex, BMI, and follow-up duration. Variance inflation factors (VIFs) were calculated to assess multicollinearity. All statistical analyses were performed using R software (version 4.4.3; R Foundation for Statistical Computing, Vienna, Austria), and a P value <0.05 was considered statistically significant.

Results

Population Characteristics

Mean baseline age and BMI were 64.9 ± 8.1 years (range: 38-87 years) and 25.4 ± 3.7 kg/m^2, respectively. There were 1,096 (18.0%) male and 4,994 (82.0%) female limbs. During 4.0 ± 2.8 years (range: 1-16 years) of follow-up, mean varus progression (ΔHKAA per year = −0.3 ± 0.9°/year) was observed. The combined proportion of K-L grades 3 and 4 increased from 37.0% (95% confidence interval [CI]: 35.8%-38.2%) to 50.7% (49.5%-52.0%) over the follow-up **(Table 1)**.

Table 2. Concordance Rates of FKP and CPAK Between Right and Left Lower Extremities.

	Baseline		F/U	
	Proportion	% (95% CI)	Proportion	% (95% CI)
HKA	1267/3045	41.6% (39.9%-43.4%)	1081/3045	35.5% (33.8%-37.2%)
TMA	1732/3045	56.9% (55.1%-58.6%)	1676/3045	55.0% (53.3%-56.8%)
FMA	1796/3045	59.0% (57.2%-60.7%)	1751/3045	57.5% (55.7%-59.3%)
TMA × FMA	1037/3045	34.1% (32.4%-35.8%)	997/3045	32.7% (31.1%-34.4%)
CPAK	1628/3045	53.5% (51.7%-55.2%)	1686/3045	55.4% (53.7%-57.2%)

FKP = Functional Knee Phenotype; CPAK = Coronal Plane Alignment of the Knee; F/U = follow-up; CI = confidence interval; HKAA = hip-knee-ankle angle; TMA = tibial mechanical angle; FMA = femoral mechanical angle.

Concordance Rates of FKPs and CPAK Types Between R and L Lower Extremities at Baseline and Follow-Up

Concordance rates between R and L lower extremities for HKA FKPs and CPAK were 41.6% (95% CI: 39.9%-43.4%) and 53.5% (51.7%-55.2%), respectively, at baseline and 35.5% (33.8%-37.2%) and 55.4% (53.7%-57.2%) at follow-up. Although concordance rates of TMA and FMA were higher than 50% at both baseline (TMA: 56.9% [55.1%-58.6%], FMA: 59.0% [57.2%-60.7%]) and follow-up (TMA: 55.0% [53.3%-56.8%], FMA: 57.5% [55.7%-59.3%]), those for the combination of TMA and FMA were 34.1% (32.4%-35.8%) at baseline and 32.7% (31.1%-34.4%) at follow-up **(Table 2; Figs. 2 and 3)**.

Comparison of Alignment Parameters at Baseline and Follow-Up According to Groups

Although statistically significant differences in HKAA, MPTA, and mLDFA at baseline and follow-up were observed between R and L limbs in the varus (B) group, and in mLDFA and JLCA at baseline and follow-up, and follow-up MPTA in the neutral (B) group, all differences did not exceed 0.3° (**Table 3**). There was no significant difference in R and L limbs in valgus (B) group. Comparisons in other groups are presented in **Suppl. Table S2. Figs. 4 and 5** describe ΔHKAA—duration, and baseline and follow-up HKAA in combinational groups. **Table 4** describes ΔHKAA per year according to alignment combinations, which showed no difference in R and L limbs of each group.

Multivariable Linear Regression Analyses for Follow-Up HKAA According to Groups

Contralateral parameters were significantly associated with ipsilateral follow-up HKAA only in (ipsilateral, contralateral) combinations of (1) (varus, varus), (2) (varus, neutral), (3) (neutral, neutral), and (4) (valgus, valgus). Ipsilateral follow-up HKAA of varus limb was associated with (1) K-L grade of contralateral varus limb ($P = 0.005$) and (2) MPTA of contralateral neutral limb ($P = 0.046$). Ipsilateral follow-up HKAA of neutral limb was associated with (3) MPTA ($P < 0.001$) and mLDFA ($P = 0.012$) of contralateral neutral limb. Ipsilateral follow-up HKAA of valgus limb was associated with (4) MPTA ($P = 0.003$) and mLDFA ($P = 0.004$) of contralateral valgus limb. However, their standardized β coefficients were small compared with those of ipsilateral JLCA, MPTA, and mLDFA (**Suppl. Tables S3-S5 and Fig. 6).** All VIFs were <5.

Discussion

The most important findings of this study are twofold. First, concordance rates between R and L lower extremities for FKPs and CPAK were 41.6% and 53.5%, respectively, at baseline and 35.5% and 55.4% at follow-up, although differences in mean HKAA, MPTA, mLDFA, and JLCA between R and L lower extremities were small in varus (B), valgus (B), and neutral (B) groups at baseline and follow-up. Second, even though few contralateral parameters showed statistically significant influence on alignment progression, their standardized β coefficients were small compared with those of ipsilateral.

The novelty of this study is grounded on the large longitudinal dataset of bilateral lower extremities with a mean follow-up duration of 4.0 ± 2.8 years. As a result, not only baseline but also follow-up concordance rates between R and L limbs were reported. Although this study demonstrated nearly negligible differences in mean values of R and L alignment parameters at both baseline and follow-up, the reliability of contralateral lower extremities as reference for ipsilateral surgical planning may not be adequate. Concordance rates were relatively low for FKPs and CPAK, reaching at most 55.4%. A wide range of concordance rates have been reported **(Table 5)**.[8-10] The concordance rate of FKPs for the combination of TMA and FMA (34.1% [95% CI: 32.4%-35.8%]) in this study was higher than those

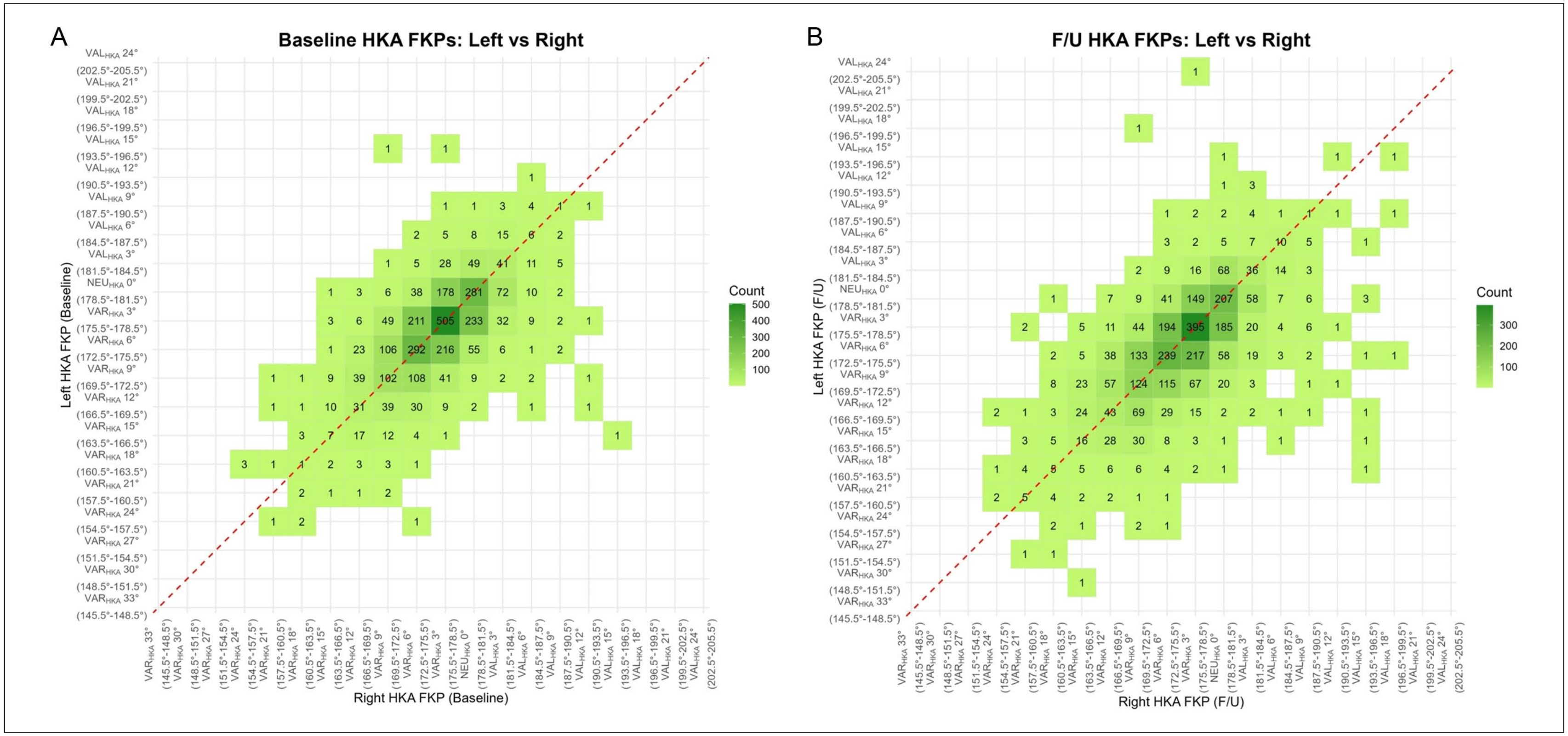

Figure 2. Frequency heatmap of baseline and F/U HKA FKPs of left and right lower extremities. **(A)** Baseline. **(B)** F/U. F/U= follow-up; HKAA/HKA = hip-knee-ankle angle; FKP = Functional Knee Phenotype. The dashed diagonal red line indicates concordance between the left and right subtypes.

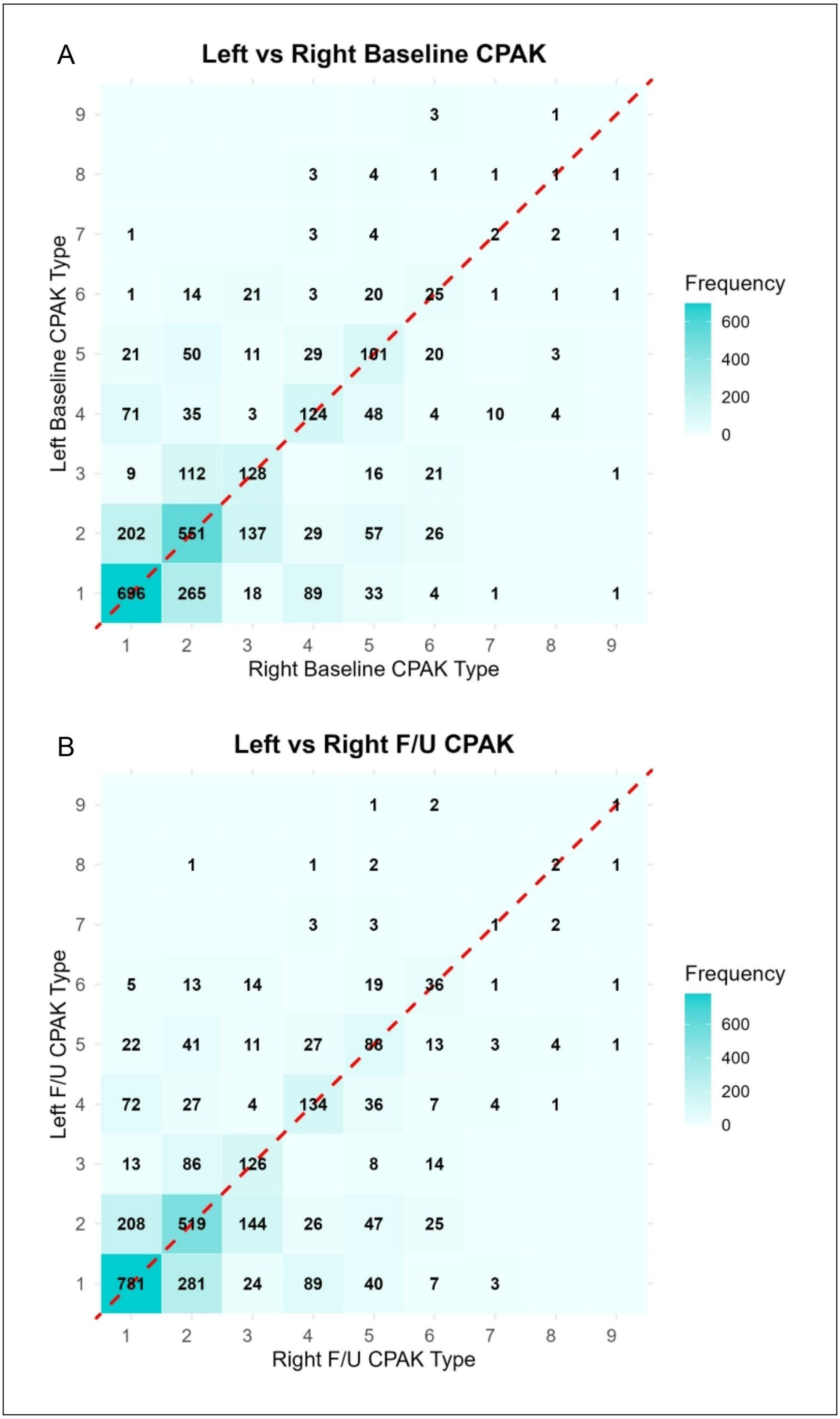

Figure 3. Frequency heatmap of baseline and F/U CPAK types of left and right lower extremities. **(A)** Baseline. **(B)** F/U. F/U = follow-up; CPAK = Coronal Plane Alignment of the Knee. The dashed diagonal red line indicates concordance between the left and right subtypes.

Table 3. Comparison of Baseline (0) and F/U (1) Alignment Parameters.

Group	Variable	Right mean ± SD (°)	Left mean ± SD (°)	*P*-value
Varus (B) (*n* = 2644)	HKAA0	173.1 ± 3.1	172.9 ± 3.3	0.032
	HKAA1	171.9 ± 4.0	171.7 ± 4.1	0.017
	P-value	<0.001	<0.001	
	MPTA0	85.3 ± 2.1	85.1 ± 2.1	<0.001
	MPTA1	85.0 ± 2.3	84.8 ± 2.3	0.006
	P-value	<0.001	<0.001	
	mLDFA0	89.1 ± 2.2	89.2 ± 2.2	0.023
	mLDFA1	89.1 ± 2.3	89.2 ± 2.2	0.043
	P-value	0.243	0.212	
	JLCA0	3.4 ± 2.5	3.3 ± 2.5	0.055
	JLCA1	4.2 ± 2.9	4.2 ± 3.0	0.980
	P-value	<0.001	<0.001	
Valgus (B) (*n* = 68)	HKAA0	185.8 ± 2.3	185.7 ± 2.1	0.880
	HKAA1	186.7 ± 4.4	185.6 ± 3.5	0.106
	P-value	0.098	0.759	
	MPTA0	89.3 ± 2.0	89.8 ± 2.2	0.079
	MPTA1	89.8 ± 2.7	89.5 ± 2.2	0.350
	P-value	0.060	0.225	
	mLDFA0	83.9 ± 2.3	84.3 ± 2.1	0.133
	mLDFA1	84.2 ± 2.6	84.6 ± 2.2	0.174
	P-value	0.331	0.206	
	JLCA0	-0.3 ± 2.5	-0.1 ± 2.6	0.656
	JLCA1	-0.9 ± 3.0	-0.5 ± 2.9	0.390
	P-value	0.043	0.133	
Neutral (B) (*n* = 1618)	HKAA0	179.3 ± 1.5	179.3 ± 1.4	0.251
	HKAA1	178.9 ± 2.3	178.7 ± 2.3	0.113
	P-value	<0.001	<0.001	
	MPTA0	87.7 ± 1.9	87.6 ± 1.9	0.081
	MPTA1	87.7 ± 2.0	87.4 ± 2.0	<0.001
	P-value	0.150	<0.001	
	mLDFA0	87.0 ± 1.9	87.2 ± 2.0	0.009
	mLDFA1	87.1 ± 2.1	87.3 ± 2.0	0.007
	P-value	0.115	0.127	
	JLCA0	1.5 ± 1.7	1.3 ± 1.9	0.002
	JLCA1	1.8 ± 2.1	1.6 ± 2.1	0.003
	P-value	<0.001	<0.001	

F/U = follow-up; SD = standard deviation; B = bilateral; R = right; L = left; HKAA = hip-knee-ankle angle; MPTA = medial proximal tibial angle; mLDFA = mechanical distal femoral angle; JLCA = joint line convergence angle.

reported by Sava *et al.*[8] and Pujol *et al*,[10] but it may still be insufficient to justify using contralateral lower extremities as an accurate reference for surgical planning.

In interpreting longitudinal alignment transitions, the CPAK system seems to have limited value. In contrast to the knees of healthy individuals,[20] variability in coronal alignment increases with the progression of KOA.[21] Accordingly, concordance rates of FKP and CPAK between R and L limbs at follow-up were expected to decrease compared with those at baseline. While concordance of FKP indeed decreased, the symmetry in CPAK classification paradoxically increased. Rather than being interpreted as R and L lower extremities becoming more symmetric, this phenomenon may reflect an inherent limitation of the CPAK classification in describing longitudinal alignment transitions due to restricted number of subtypes.[22] Specifically, CPAK type I may represent a terminal stage of varus-aligned lower extremities, encompassing a wide spectrum of varus deformities. Consistent with the tendency of CPAK to shift toward type I as KOA progresses,[13] the present

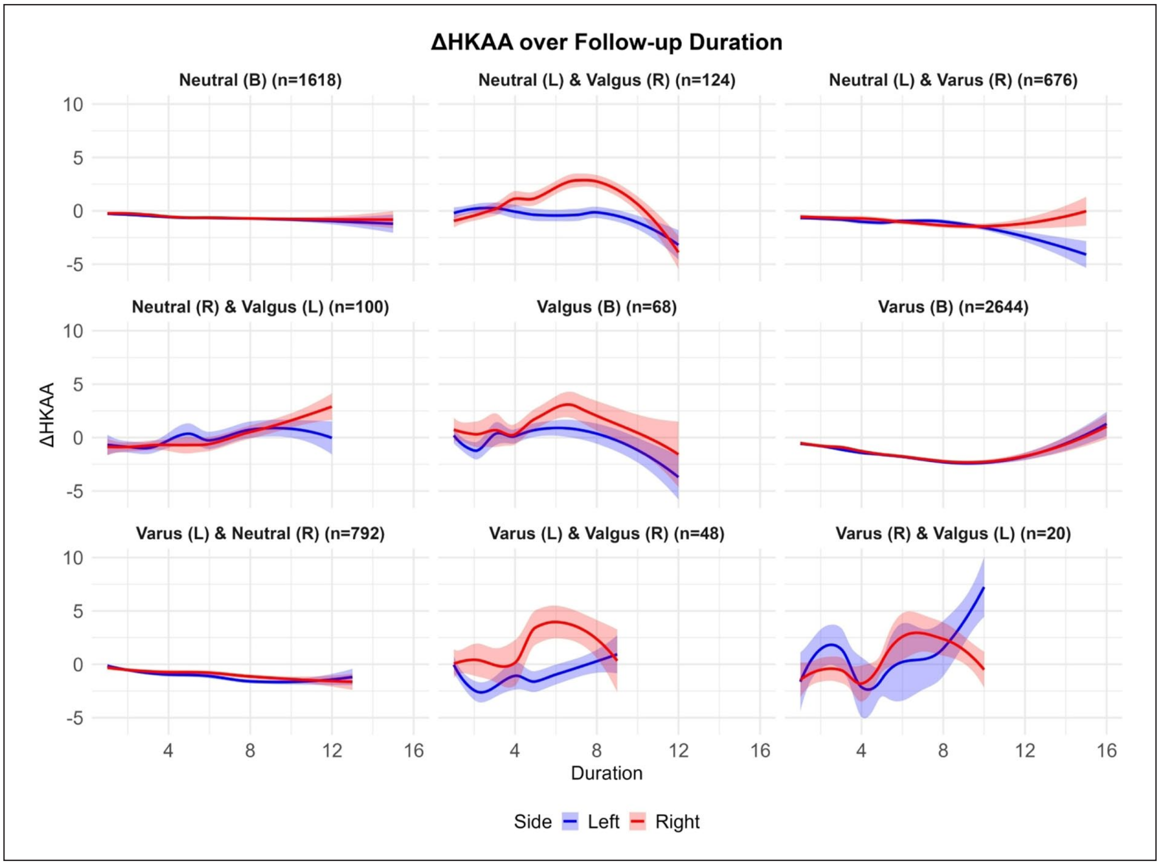

Figure 4. ΔHKAA over F/U duration according to alignment groups. HKAA = hip-knee-ankle angle; F/U = follow-up; SD = standard deviation; B = bilateral; L = left; R = right. Means and ±1 standard deviation are indicated by lines and shaded area, respectively.

study also demonstrated an increased proportion of CPAK type I at follow-up, increasing overall symmetry in CPAK types.

Considering that an individual has 2 lower limbs, independent interpretation of data from bilateral knees requires caution. Including bilateral lower extremities from the same individual in orthopedic research has raised concerns about potential bias related to random effects.[23] While several studies have reported either the presence[24,25] or absence[26] of effect of contralateral factors on ipsilateral KOA, effect of contralateral factors on ipsilateral coronal alignment has not been investigated. In the present study, standardized β values of contralateral alignment parameters and K-L grade were smaller compared with those of ipsilateral JLCA, MPTA, and mLDFA in multivariable linear regression analyses for follow-up HKAA. This finding may provide support for the independent interpretation of each limb in alignment studies that include bilateral limbs from individuals. Moreover, because the effect of contralateral parameters on alignment progression was negligible even among patients with a unilateral neutral limb (varus [R/L] & neutral [L/R] and valgus [R/L] & neutral [L/R]) or windswept deformities (varus [R/L] & valgus [L/R]), surgical procedures which correct coronal deformities such as high tibial osteotomy (HTO) or mechanical alignment TKA may also have limited impact on contralateral coronal alignment progression. Nevertheless, this inference warrants further investigation.

There are limitations in this study. First, this study suggested that biomechanical interaction between R and L limbs is small. However, this study presented associations rather than causal inference because the study was retrospective. Second, the generalizability of the results may not be applicable to other ethnic groups. Studies in diverse ethnic groups and geographic regions are warranted to establish a comprehensive understanding of the influence of contralateral parameters on alignment. Third, selection bias may be present, as the cohort had a high prevalence of varus lower extremities with KOA and a smaller number of valgus limbs. Accordingly, the applicability of our findings to valgus or non-osteoarthritic limbs is limited. Moreover, **Fig. 4** should be interpreted with caution, as the number of limbs with longer follow-up durations was relatively small. Fourth, medical conditions, including inflammatory diseases, were not applied as specific exclusion criteria, as this

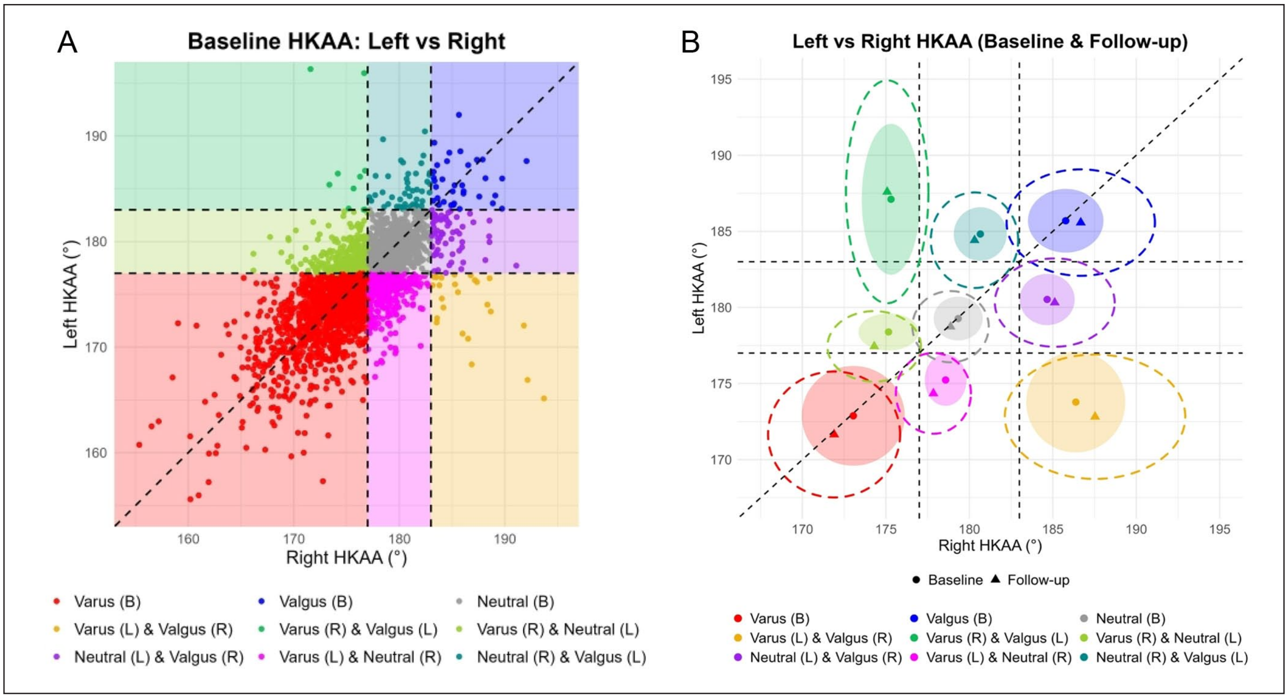

Figure 5. Scatter plot and mean ± 1 SD plot describing the combinational group of baseline left and right HKAA. **(A)** Scatter plot. **(B)** Mean ± 1 SD plot. In **Fig. 5A**, the corresponding regions of each HKAA classification group, defined by cutoff values of 177° and 183°, are shaded using different colors. The dashed diagonal black line denotes concordance between the left and right HKAA. In **Fig. 5B**, area encompassing 1 SD of each HKAA classification group, defined by cutoff values of 177° and 183°, is highlighted using different colors. Shaded area and dashed ellipses indicate 1 SD of baseline and follow-up, respectively. Mean points at baseline and follow-up are described with circles and triangles, respectively. The dashed diagonal black line indicates concordance between the left and right HKAA. SD = standard deviation; HKAA = hip-knee-ankle angle; L = left; R = right; B = bilateral.

Table 4. ΔHKAA Per Year in Right and Left Lower Extremities According to Groups.

Group	Right mean ± SD (°/year)	Left mean ± SD (°/year)	*P*-value
Varus (B) (*n* = 2644)	−0.4 ± 1.0	−0.4 ± 1.0	0.350
Neutral (B) (*n* = 1618)	−0.1 ± 0.6	−0.2 ± 0.7	0.411
Valgus (B) (*n* = 68)	0.3 ± 1.4	0.0 ± 1.1	0.152
Varus (R) & Neutral (L) (*n* = 676)	−0.3 ± 0.9	−0.3 ± 0.8	0.457
Varus (R) & Valgus (L) (*n* = 20)	−0.2 ± 0.5	0.0 ± 0.8	0.453
Varus (L) & Neutral (R) (*n* = 792)	−0.2 ± 0.8	−0.2 ± 0.8	0.892
Neutral (R) & Valgus (L) (*n* = 100)	−0.3 ± 0.7	−0.3 ± 0.9	0.948
Varus (L) & Valgus (R) (*n* = 48)	0.2 ± 1.4	−0.4 ± 1.2	0.130
Neutral (L) & Valgus (R) (*n* = 124)	−0.1 ± 1.1	0.0 ± 1.0	0.676

HKAA = hip-knee-ankle angle; SD = standard deviation; B = bilateral; R = right; L = left.

study was based on a review of LLRs with radiographic measurements rather than on medical record review. Fifth, slight positional difference, flexion contracture, and rotation of the limbs could have affected radiographic measurements despite the standardized protocol. Sixth, K-L grade was assessed only on LLRs, which may have resulted in an underestimation of KOA severity.[27]

Conclusion

Over a mean follow-up of 4.0 years in Korean patients, concordance rates of FKP and CPAK types between bilateral limbs were 41.6% and 53.5%, respectively, at baseline and 35.5% and 55.4% at follow-up, despite similar mean values of alignment parameters. The influence of contralateral

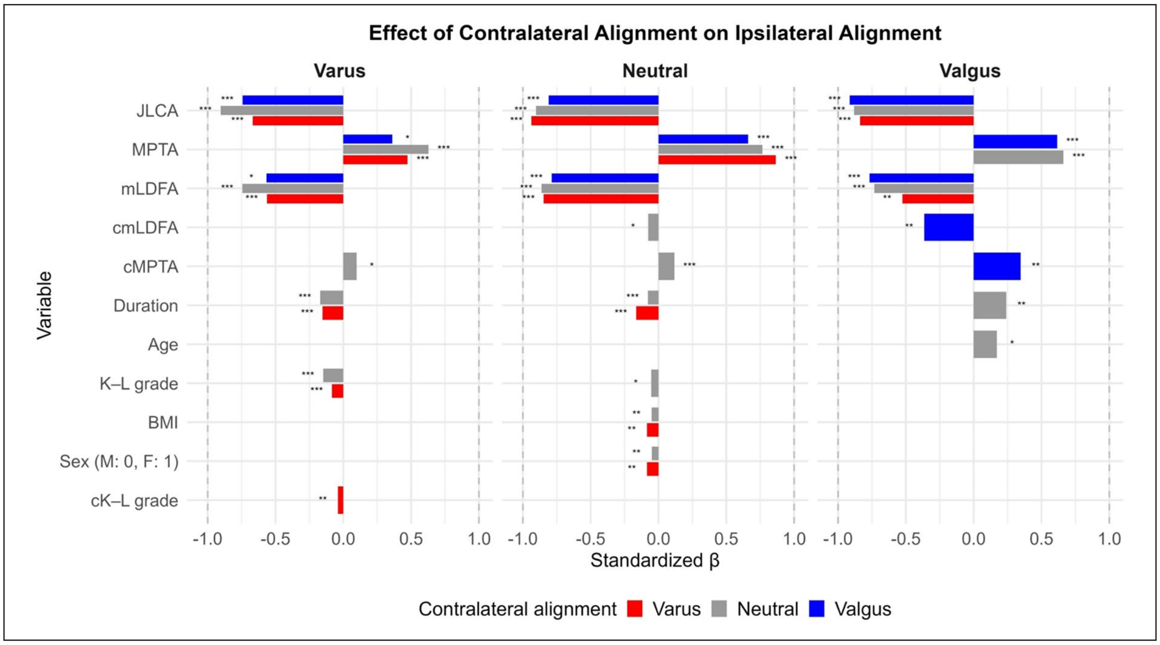

Figure 6. Standardized β for ipsilateral F/U HKAA in the varus, neutral, and valgus groups according to contralateral alignment. F/U = follow-up; HKAA = hip-knee-ankle angle; JLCA = joint line convergence angle; MPTA = medial proximal tibial angle; mLDFA = mechanical lateral distal femoral angle; cmLDFA = contralateral mLDFA; cMPTA = contralateral MPTA; K-L = Kellgren-Lawrence; BMI = body mass index; M = male; F = female; cK-L = contralateral K-L. *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$.

Table 5. Comparison of Different Studies Which Reported Concordance Rates of FKP and CPAK Between Right and Left Lower Extremities.

	Beckers *et al.*[9]	Sava *et al.*[8]	Pujol *et al.*[10]	This study
n	250	141	76	3,045
Subjects	Young and healthy adults	Non-osteoarthritic patients	Osteoarthritic patients scheduled for TKA	Mostly osteoarthritic patients
FKP (HKA)	59%	58.2%	30%	41.6%
CPAK			38%	53.5%
FKP (TMA x FMA)		26.2%	11%	34.1%

TKA = total knee arthroplasty; FKP = Functional Knee Phenotype; CPAK = Coronal Plane Alignment of the Knee; HKA = hip-knee-ankle angle; TMA = tibial mechanical angle; FMA = femoral mechanical angle.

parameters on coronal alignment progression was limited compared with that of ipsilateral parameters.

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Ethical Considerations

This retrospective cohort study was approved by the Institutional Review Board (IRB) of a tertiary referral hospital in Seoul, Korea (IRB number H-2110-200-1269) and conducted in conformity with the international ethical guidelines for research involving human subjects.

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Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The authors have nothing to declare. Du Hyun Ro is CEO of CONNECTEVE Co., Ltd., South Korea; however, he has no conflicts of interest to disclose regarding this study.

Data Availability Statement

The data of this study are not openly available because the subjects did not consent to public sharing of their data. The IRB of our institution also did not approve public sharing of the data. The data are available from the corresponding authors only upon reasonable request. Data are located in controlled access data storage at our institution.

Supplemental Material

Supplementary material for this article is available on the Cartilage website at http://cart.sagepub.com/supplemental.

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