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Surgically Modifiable Skeletal and Soft Tissue Variables and the Medial Pivot of the Knee

Dr Peter McEwen

MBBS FRACS FAOrthA DipModLang

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Correlation Between Knee Kinematics and Patellofemoral Contact Pressure in Total Knee Arthroplasty

Takuya Konno, MD [a], Tomohiro Onodera, MD, PhD [a], Yusuke Nishio, MD [a], Yasuhiko Kasahara, MD, PhD [a], Norimasa Iwasaki, MD, PhD [a], Tokifumi Majima, MD, PhD [b]

[a] Department of Orthopaedic Surgery, Hokkaido University Graduate School of Medicine, North 15 West 7, Kita-Ku, Sapporo Japan
[b] Department of Orthopedic Surgery, International Univ. of Health and Welfare Hospital, 537-3, Iguchi, Nasushiobara City, Japan

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ABSTRACT

The aim of this study is to evaluate the relationship between patellofemoral contact stress and intraoperative knee kinematic patterns after mobile bearing total knee arthroplasty (TKA). Medial osteoarthritic knees of forty-six posterior-stabilized total knee prostheses were evaluated using a computed tomography-guided navigation system. Subjects were divided into two groups based on intraoperative knee kinematic patterns: the medial pivot group (n = 18) and the non-medial pivot group (n = 27). Mean intraoperative patello-femoral contact stress was significantly lower in the medial pivot group than in the non-medial pivot group (1.7 MPa vs. 3.2 MPa, P < 0.05). An intraoperative medial pivot pattern results in reduced patello-femoral contact stress.

Total knee arthroplasty (TKA) has proven to be highly successful at alleviating pain and improving function in patients with advanced knee arthritis. As the indications of TKA have been widened, the demand for the procedure is increasing. Therefore, the number of revision TKAs is also rising, with a projected increase of 601% between 2005 and 2030 in The United States [1]. Patello-femoral problems are one of the common post-TKA complications and may result in revision surgery [2,3]. Several reports indicated that up to 12% of TKA revisions are due to patello-femoral dysfunction [2,4,5]. Various factors such as body mass index, patellar cartilage thickness, radiologically evident patello-femoral compartment osteoarthritis, and patellar tilt do not accurately predict patello-femoral dysfunction [6,7].

Five to 45% of post-TKA patients complain of residual anterior knee pain [8,9]. Patello-femoral complications have been attributed to errors in operative technique, inferior prosthetic design, components oversizing, and excessive patello-femoral loads. Several in vitro patellar resurfacing studies found a decrease in the retropatellar contact area, an increase in retropatellar pressure, and an increase in shear forces after resurfacing the patella [10,11]. However, the etiology of these complications with patellar resurfacing is yet to be clearly established [11,12]. Low patello-femoral pressure was considered to be advantageous because high pressures might account for anterior knee pain [12,13].

Large tibiofemoral kinematic variations, including the medial pivot [14,15] and the lateral pivot [16,17], are known to exist after conventional TKA. There is a wide variation in patellar kinematics associated with patello-femoral contact stress in the normal knee as well [18,19]. However, we have found no study of the relationship between tibiofemoral kinematic patterns after TKA and patello-femoral contact stress.

We hypothesized that tibiofemoral kinematic patterns after TKA will impact patello-femoral contact stress. The aim of this study was to evaluate the relationship between knee kinematics and patello-femoral contact stress in mobile bearing prosthesis with navigated TKA procedures.

Materials and Methods

One hundred and fifteen consecutive patients who had medial knee osteoarthritis were enrolled in this study. All knees had a Kellgren-Lawrence grade of 4 in the medial compartment and underwent a primary posterior stabilized mobile bearing total knee arthroplasty (PFC Sigma RP-F; Depuy, Warsaw, IN, USA) between May 2007 and October 2010. A computed tomography-guided navigation system (Vector Vision 1.6, Brain LAB, Heimstetten, Germany) was used for accurate implantation with a standardized navigated TKA technique for all cases. Surgeries were performed by a single surgeon using a subvastus approach to mitigate the influence of surgical approach to producing muscle balance. No patients received a lateral retinacular release. Approval for this experiment was obtained from our institutional investigational review board.

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2014.07.020.

Reprint requests: Tokifumi Majima, MD, PhD, Department of Orthopedic Surgery, International Univ. of Health and Welfare Hospital, 537-3, Iguchi, Nasushiobara City, 329-2763, Japan.

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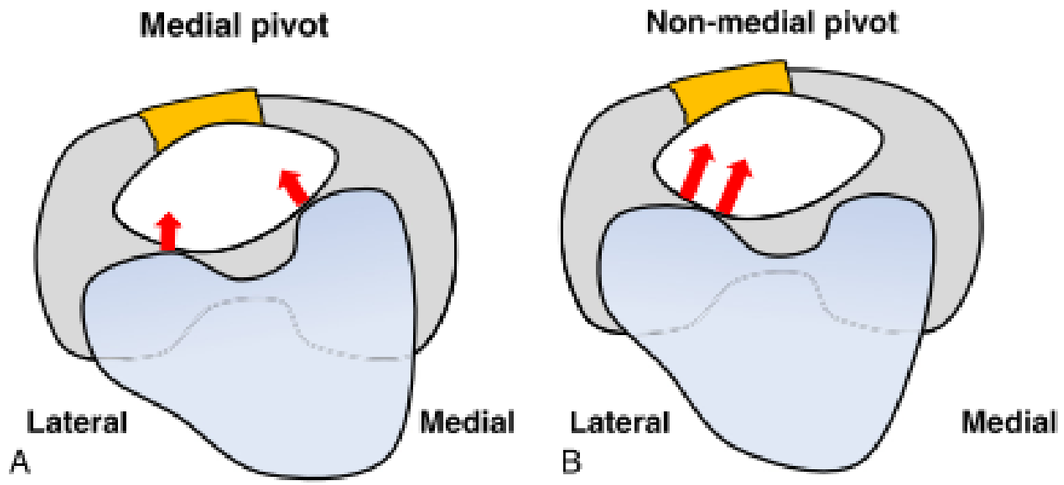
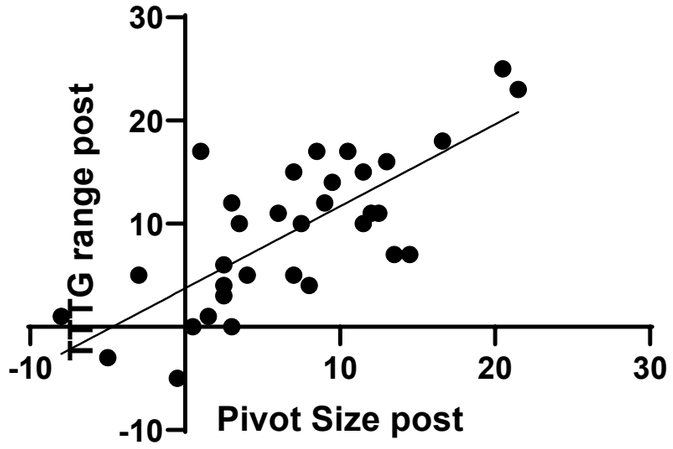


If the knee does not pivot medially, the lateral facet of the patella will remain heavily loaded, especially in deep flexion. This may be a cause of early patellar failure and ongoing anterior knee pain after total knee arthroplasty

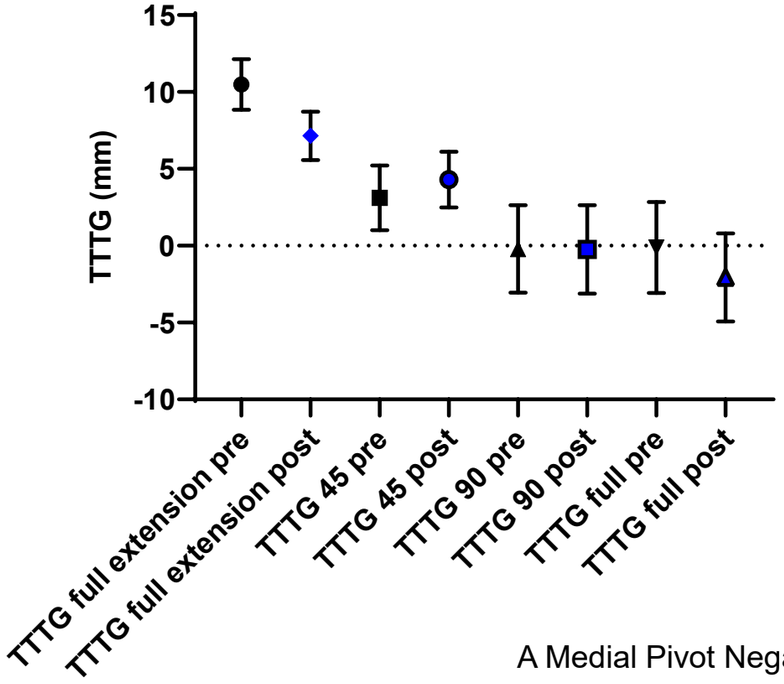
Correlation of TTTG range post and pivot post



Pearson r	
r	0.7475
95% confidence interval	0.5437 to 0.8680
R squared	0.5588
P value	
P (two-tailed)	<0.0001

A strong correlation exists between knee post-operative pivot range and post-operative TT–TG range

TTTG pre and post



In both native and post–implantation states the mean TT–TG offset is reduced to 0 mm

A Medial Pivot Negates Tuberosity Offset at Ninety Degrees of Knee Flexion. McEwen P, e-poster, ISAKOS Boston

Purpose

Having established that a medial pivot is necessary to neutralise the tibial tubercle–trochlear groove offset as the knee goes into flexion, the purpose of this study was to identify surgically modifiable skeletal and soft tissue variables associated with a medial pivot.

Understanding what skeletal and soft tissue variables that affect the pivot mechanics of the knee, especially those that are surgically modifiable, is important in optimising pivot mechanics and therefore the TT-TG offset and patellofemoral mechanics

Materials and Methods

- N=33
- Primary CR TKA with patellar resurfacing
- Enhanced optical navigation / Orthosensor
- Functional KA technique

Skeletal Parameters

- Hip–knee–ankle Angle
- Lateral Distal Femoral Angle
- Medial Proximal Tibial Angle
- Posterior Condylar Angle (relative to Sulcus Line)
- Mediolateral shift of distal trochlear point
- Proximodistal shift of distal trochlear point
- Tibial slope (implant)
- CPAK morphotype

Preop and postop measure

Postop measure only

Soft Tissue Parameters

- Medial extension gap laxity
- Lateral extension gap laxity
- Medial flexion gap laxity
- Lateral flexion gap laxity
- Medial compartment static compressive load at 10, 45, 90 and full flexion
- Lateral compartment static compressive load at 10, 45, 90 and full flexion
- Mediolateral static compressive load differential at 10, 45, 90 and full flexion
- PCL tension (measured digitally as change in tibiofemoral station at 90 degrees flexion

Assessment of Pivot

Tibia allowed to flex passively on the femur without any rotational constraint applied through the foot

Internal–external rotation recorded during movement (+ value equals internal rotation)

Pressure transducer track map in fluorescent green confirms differential rollback and true medial pivot rather than paradoxic rotation

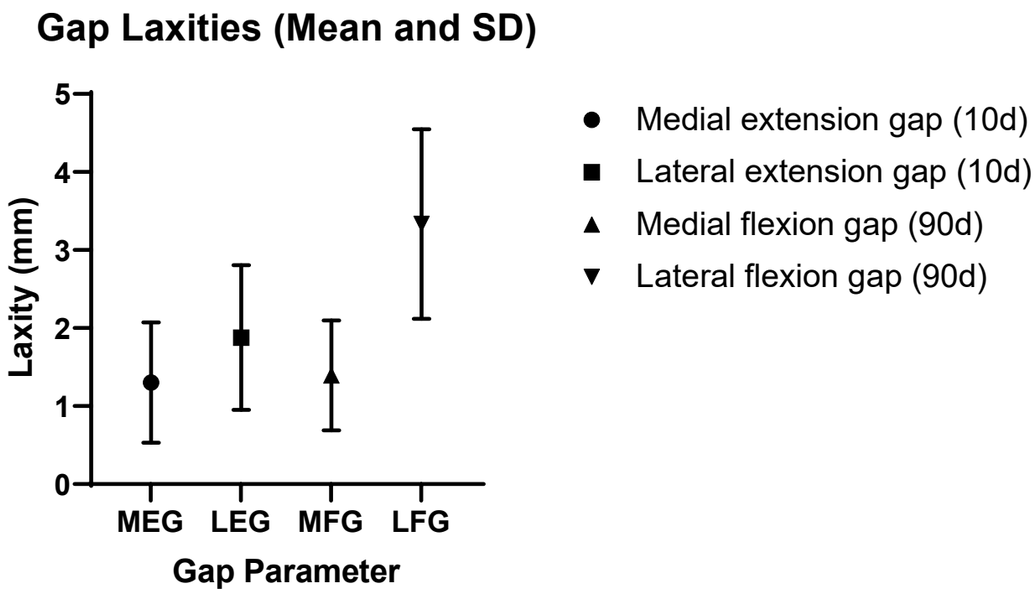
Analyze Initial Alignment

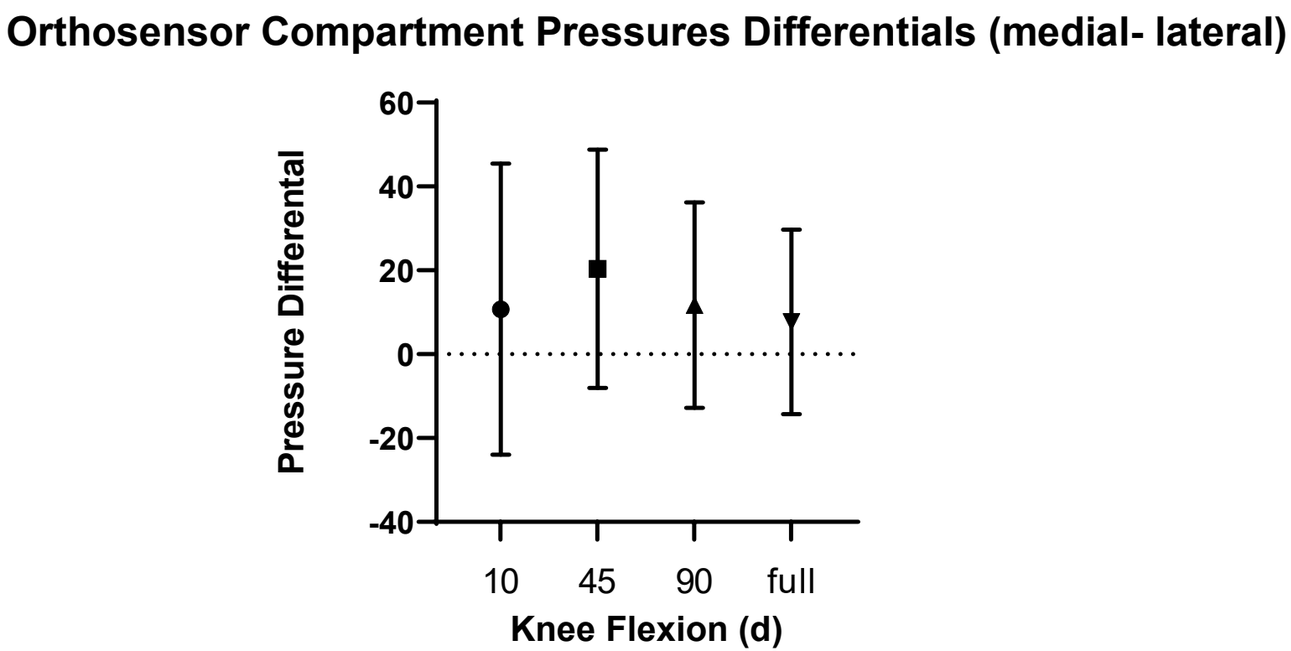
Record of Table

Table 1:

+	-	min						max
Flexion	Hyperextension	+9.5°	+0.0°	+30.0°	+45.0°	+60.0°	+90.0°	+126.0°
Valgus	Varus	-12.5°		-15.0°	-13.5°		-6.0°	-1.5°
Internal	External	-6.5°		-1.5°	+1.0°		+4.5°	+4.5°

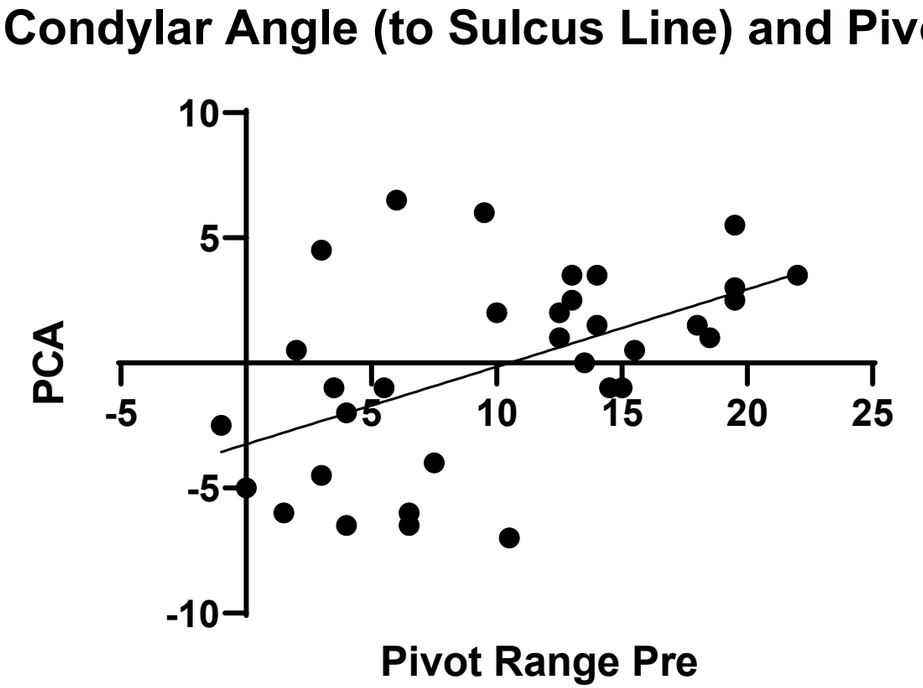
Results –Soft Tissue Balance





Results – Pre-operative Pivot

- Of the pre-operative measures, only the native posterior condylar angle (nPCA) correlated with pivot range (moderate correlation)

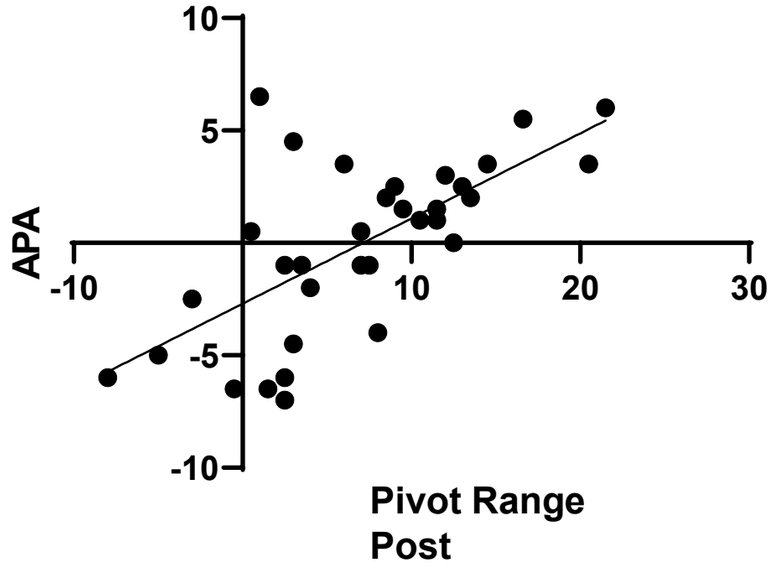


Pearson r	
r	0.5154
95% confidence interval	0.2091 to 0.7296
R squared	0.2657
P value	
P (two-tailed)	0.0021
P value summary	**
Significant? (alpha = 0.05)	Yes

Post-operative Pivot

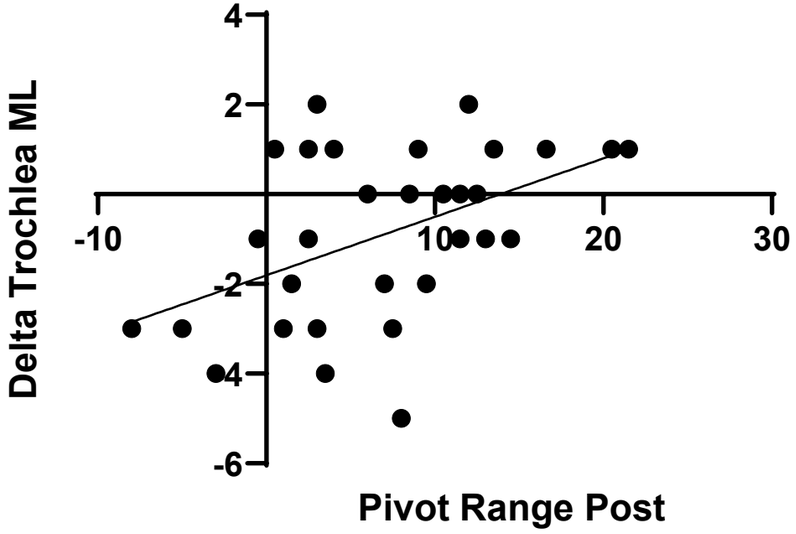
- No soft tissue parameter correlated with the post-operative pivot
- The prosthetic Posterior Condylar Angle (pPCA) had a strong correlation with the post-operative pivot
- Mediolateral shift of the distal trochlea point had a moderate correlation with post-operative pivot

Posterior Condylar Angle (to Sulcus Line) and Pivot Range Post



Pearson r	
r	0.6655
95% confidence interval	0.4175 to 0.8212
R squared	0.4428
P value	
P (two-tailed)	<0.0001
P value summary	****
Significant? (alpha = 0.05)	Yes

Change in Trochlear ML Position and Pivot Range Post



Pearson r	
r	0.4735
95% confidence interval	0.1555 to 0.7026
R squared	0.2242
P value	
P (two-tailed)	0.0054
P value summary	**
Significant? (alpha = 0.05)	Yes

Multiple linear regression was used to test if prosthetic PCA, prosthetic LDFA, mediolateral shift of distal trochlear point and proximodistal shift of distal trochlear point significantly predicted the post-operative pivot range

The overall regression was statistically significant (R^2 = 0.531, F(df regression, df residual) = 7.908, p = 0.0002)

It was found prosthetic PCA significantly predicted post-operative pivot range (β = 1.046, p = 0.0005) as did ML shift of distal trochlear point (β = 1.064, p = 0.046)

It was found that pLDFA and PD shift of distal trochlear point did not significantly predict post-operative pivot range

Conclusions

- In optimally balanced cruciate retaining total knee arthroplasty using a functional kinematic alignment technique Posterior Condylar Angle relative to the Sulcus Line is the primary predictor of post-operative pivot range.

- The more externally rotated the PCA is to the Sulcus Line the greater the medial pivot.

- Functional kinematic alignment largely restores the pre-– arthritic posterior condylar line. It remains unknown whether externally rotating the femoral component will improve medial pivot or reverse a lateral pivot and should be a focus a further study.

- The more lateral the distal end of the prosthetic sulcus sits relatively to the native sulcus the better the medial pivot. The practice of lateralising the femoral component assists with producing a medial pivot. Future prosthetic design should lateralise the trochlea relative to the centre of the prosthesis.