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In vivo stability of total knee arthroplasty using a navigation system

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Abstract The aim of this study was to evaluate in vivo stability for mediolateral laxity in extension and anteroposterior laxity in 90° of flexion and to correlate these and the range of motion (ROM) in 42 total knee arthroplasties (TKA) performed using a navigation system, with a minimum 1-year follow-up. The following parameters were measured at the final follow-up: mediolateral laxity in extension and anteroposterior laxity in 90° of flexion as determined by stress radiographs and a Telos arthrometer, modified HSS scores (excluding laxity and range of motion) and the range of motion (ROM). The mean modified HSS score was 82% of 82 maximum allowable points, and the mean postoperative ROM was $128.1 \pm 10.4^\circ$. Mean medial laxity was $3.5 \pm 1.4^\circ$, mean lateral laxity was $4.4 \pm 2.2^\circ$ and mean anteroposterior laxity was 7.1 ± 4.1 mm. We found no significant correlation between mediolateral laxity and postoperative ROM. However, a significant correlation was found between postoperative ROM and anteroposterior laxity. In conclusion, the use of a navigation system in TKA assists the surgeon to achieve good in vivo stability. Short-term clinical results are promising.

Résumé Le but de cette étude est d'évaluer la stabilité latérale en extension et la stabilité antéropostérieure en flexion à 90° des PTG en corrélation avec le degré de mobilité sur 42 genoux mis en place en utilisant un système de navigation, avec un minimum de suivi d'un an. La laxité médio-latérale en extension, la laxité antéropostérieure en flexion à 90° ont été évaluées en utilisant des radiographies en stress (arthromètre Télès), a également été utilisé le score HSS et l'évaluation du degré de flexion du genou au dernier recul. Le score HSS était dans plus de 82% des cas

supérieur à 82 points avec une flexion moyenne du genou de $128,1 \pm 10,4^\circ$. La laxité interne de la mesure a été de $3,5 \pm 1,4^\circ$, la laxité externe de $4,4 \pm 2,2^\circ$ et la laxité antéropostérieure de $7,1 \pm 4,1$ mm. Nous n'avons pas trouvé de corrélation significative entre la laxité latérale et le degré de flexion du genou. Cependant nous avons retrouvé une corrélation significative entre le degré de flexion du genou et la laxité antéropostérieure alors qu'il n'y avait pas de corrélation entre laxité médio-latérale et la mobilité. En conclusion, l'utilisation d'un système de navigation dans la mise en place d'une prothèse totale du genou est une aide certaine pour obtenir une meilleure stabilité et des résultats à court terme prometteurs.

Introduction

Accurate alignment and soft tissue balance are essential for successful total knee arthroplasty (TKA). Malalignment and soft tissue imbalance in TKA produce unequal loads on the medial and lateral tibial plateaus and thereby substantially increase component wear. In order to obtain well-balanced knees, good varus and valgus alignment and equal flexion and extension gaps must be achieved [4].

Computer-assisted navigation systems are a recent development that have enabled surgeons to improve alignment accuracy during TKA. These reductions in alignment error as a direct result of these systems have also been independently confirmed [13–16]. However, despite improved alignment accuracy, soft tissue balance continues to present a challenge. To the best of our knowledge no report has been published to date on the in vivo stability of TKA performed using a navigation system.

Our hypothesis was that navigation can help provide a well-balanced knee through the real-time feedback of alignment accuracy and gap sizes in flexion and extension. The purpose of this study, therefore, was to evaluate in vivo stability for mediolateral laxity in full extension and anteroposterior laxity in 90° of flexion in navigation-assisted TKA and to determine the correlation between these and the range of motion (ROM).

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Table 1 Patient preoperative demographic data

Patients	42
Sex(M/F)	2/40
Flexion contracture	10.7±6.5°
Maximum flexion	127.6±17.9°
HSS score	67.5±7.3
Mechanical axis ^a	-12.1±7.1°

^a-, Varus

Materials and methods

Forty-six consecutive patients scheduled for navigation-assisted primary TKA were enrolled in this trial. Two knees were excluded due to a switch to conventional TKAs (resulting from navigation system registration failure), and two knees were lost to follow-up, leaving 42 patients with a minimum 1-year follow-up available for the study. Institutional review board approval was obtained, and all patients provided written informed consent. All TKAs were performed using a standard medial parapatellar approach and the Orthopilot (ver. 4.08, Aesculap; Tuttlingen, Germany) navigation system under the control of the senior author (E.K.S), who had performed over 20 TKAs with this navigation system before this study was initiated.

Patient demographic data are presented in Table 1. The posterior cruciate ligament was retained, and e-motion (Aesculap; Tuttlingen, Germany) was implanted with cement in all cases.

TKA was performed using a medial parapatellar incision with patellar eversion and a navigation system. The Orthopilot navigation system is an image-free system which uses kinematic analysis of the hip, ankle and knee joints and anatomical mapping of the knee joint to construct a working model of a patient's knee.

After proximal tibial cutting at 0° in the coronal and sagittal planes, a distractor with two flat independent plates

was applied to measure the gap difference between the medial and lateral compartments of knees in extension and flexion. Extension and flexion gaps were measured, and femoral distal and posterior ends were resected to achieve equal gaps in extension and flexion. Extension and flexion stabilities were confirmed after a trial insertion to determine the size of the meniscal component, and then the actual component was inserted.

A modified HSS score (excluding laxity and range of motion), ROM and a full leg length weight-bearing radiograph were obtained to exclude bias for each patient at the final follow-up before initial stress radiographs.

To evaluate stability, we measured mediolateral laxity in extension and anteroposterior laxity in 90° of flexion of the knees in stress (150 N force) radiographs using a Telos arthrometer (Telos stress device; Austin & Associate, Fallston, Md.). Medial and lateral laxity were defined as opening angles on varus and valgus stress radiographs, and total (medial plus lateral) laxity was also calculated (Fig. 1). Anteroposterior laxities of knees at 90° of flexion were measured on stress radiographs. Measurements of anteroposterior laxity were taken by tracing a line along the posterior border of the tibial component and then measuring the perpendicular distance to a point marked at the most posterior part of the femoral component posterior condyle (Fig. 2). Total anteroposterior laxity was calculated because the resting position of the femoral component in relation to the tibial component varied. One observer who was blinded to the patient's surgical technique and clinical outcome performed the entire test and measurements at the last follow-up. We also measured the mechanical axis of the leg in full length weight-bearing radiographs.

Data were analysed to determine the relationship between laxity and postoperative ROM and modified HSS score. Pearson's correlation coefficients were used for the statistical analysis with an alpha level of 0.05, and analysis was performed using SPSS for Windows Release 11.0 (SPSS, Chicago, Ill.).

Fig. 1 Measurements of medial and lateral opening angle on valgus (a) and varus (b) stress radiographs in full knee joint extension

Fig. 2 Measurement of total anteroposterior laxity (differences of anterior and posterior displacement) on anterior (a) and posterior (b) stress radiographs. Displacement was defined as the perpendicular distance between a line along the posterior border of the tibial component (a) and a line at the most posterior part of the femoral component posterior condyle (b)

Results

The mean modified HSS score was 82% of 82 maximum allowable points, and mean postoperative ROM was $128.1 \pm 10.4^\circ$ (Table 2). Mean medial and lateral laxity were $3.5 \pm 1.4^\circ$ and $4.4 \pm 2.2^\circ$, respectively, and mean total mediolateral and anteroposterior laxity were $8.0 \pm 2.7^\circ$ and 7.1 ± 4.1 mm, respectively (Table 3).

No correlation was found between mediolateral laxity and postoperative ROM ($p=0.082$) or between modified HSS score and postoperative ROM ($p=0.752$). However, a significant correlation was found between postoperative ROM and total anteroposterior laxity ($p=0.012$). Modified HSS scores showed no significant correlations with mediolateral or anteroposterior laxity ($p>0.05$).

Discussion

Total knee arthroplasty (TKA) is performed routinely nowadays and has a satisfactory success rate. However, postoperative complications, such as instability, component loosening and premature wear, limit prosthetic implant lifetimes. Correct ligament tension and balance, particularly during flexion, are the keys to reducing the risks of complications, which can be almost eliminated if flexion and extension gaps are balanced and equal, and the ligaments are properly tensioned.

Recent advances in computer-assisted navigation systems enable surgeons to reduce some alignment errors in TKA [13–16], but soft tissue balancing remains the most subjective surgical issue during TKA; in addition, flexion and extension gaps must be accurately balanced to optimise spaces fitted by components, and collateral ligaments must be equally tensioned [1, 3, 18]. However, to date, information is lacking on the in vivo stability of navigation-assisted TKA.

In this study, we evaluated, for up to 12 months postoperatively, the in vivo stability of TKA with a posterior cruciate ligament (PCL) retaining, mobile-bearing prostheses performed using an OrthoPilot navigation system, which allows accurate soft tissue balancing via real time gap size feedback at all ranges of motion. Our results showed 8.0° of mediolateral laxity (3.5° medial and 4.4° lateral laxity) and 7.1 mm of anteroposterior laxity. Matsuda and Ishii [10] reported 4.0° of medial, 3.5° of lateral and 9.3 mm of anteroposterior laxity for TKA using a low-contact-stress (LCS) PCL, mobile-bearing prostheses. Their results are similar to ours in mediolateral laxity, but not in anteroposterior laxity. Our superior anteroposterior laxity result could be attributed to an equalisation of flexion and extension gaps through real time feedback and to the precise femoral component rotation made possible by the navigation system. However, these results may also be due to implant design geometry because stability is

Table 2 Clinical outcomes at final follow-up

	Mean $\pm$ SD	Ranges
Range of motion ($^\circ$)	128.1 ± 10.4	90~145
Modified HSS score (%)	82.0 ± 5.2	68.8~91.5
Mechanical axis ($^\circ$) ^a	$+1.0 \pm 1.9$	-4.7~3.0

^a+, Valgus; -, varus

Table 3 Mediolateral and anteroposterior laxity at final follow-up

	Mean $\pm$ SD	Ranges
Mediolateral laxity ($^\circ$)		
Medial laxity	3.5 ± 1.4	1.1~6.8
Lateral laxity	4.4 ± 2.2	0.8~9.3
Total laxity	8.0 ± 2.7	2.7~13.1
Anteroposterior laxity (mm)	7.1 ± 4.1	0.2~19.6

influenced by complex interactions between the implant and the soft tissue structures that surround the knee joint.

Various authors have examined the relationship between laxity and ROM or laxity and clinical outcome [2, 5, 8–12, 17, 19]. Some have reported a better postoperative ROM with less pain in lax knee prostheses [2, 8, 17], whereas others found no differences in functional outcome between lax and tight knee prosthesis [6]. In our study, we found no correlation between mediolateral laxity and postoperative ROM or between postoperative laxity and modified HSS score. However, a significant correlation was observed between anteroposterior laxity and postoperative ROM. In terms of anteroposterior laxity, our findings concur with those of Warren et al. [17] in showing a better ROM in slightly lax knees than in tight knees. In addition, our study shows comparable short-term clinical results to data published on conventional TKA with respect to HSS scores and ROMs [6, 7].

The study has two limitations, namely: the small number of participants and the short-term follow-up.

In conclusion, the results of the study demonstrate that the use of a navigation system in TKA does not compromise in vivo stability and produces promising stability results. The postoperative range of motion was found to be affected by anteroposterior laxity but not by mediolateral laxity. The short-term clinical results achieved using navigation-assisted TKA are promising. We also wish to add that in our opinion too much laxity is a potential cause of catastrophic long-term results, and suggest that further long-term study is needed.

References

- Asano H, Hoshino, Wilton TJ (2002) Soft-tissue tension total knee arthroplasty. *J Arthroplasty* 19:558–561
- Edwards E, Miller J, Chan KH (1998) The effect of postoperative collateral ligament laxity in total knee arthroplasty. *Clin Orthop* 236:44–51
- Griffin FM, Insall JN, Scuderi GR (2000) Accuracy of soft tissue balancing in total knee arthroplasty. *J Arthroplasty* 15:970–973
- Insall JN (1988) Presidential address to the knee society. Choices and compromises in total knee arthroplasty. *Clin Orthop* 226:43–48
- Ishii Y, Mastuda Y, Ishii R, Sakata S, Omori G (2003) Coronal laxity in extension in vivo after total knee arthroplasty. *J Orthop Sci* 8:538–542
- Kim YH, Kim JS (2004) Comparison of anterior-posterior-glide and rotating-platform low contact stress mobile-bearing total knee arthroplasty. *J Bone Joint Surg Am* 86:1239–1247
- Kim YH, Sohn KS, Kim JS (2005) Range of motion of standard and high-flexion posterior stabilized total knee prosthesis. *J Bone Joint Surg Am* 87A:1470–1475
- Kuster MS, Bitschnau B, Votruba T (2004) Influence of collateral ligament laxity on patient satisfaction after total knee arthroplasty: a comparative bilateral study. *Arch Orthop Trauma Surg* 124:415–417
- Matsuda S, Miura H, Nagamine R, Urabe K, Matsunobu T, Iwamoto Y (1999) Knee stability in posterior cruciate ligament retaining total knee arthroplasty. *Clin Orthop* 366:169–173
- Matsuda Y, Ishii Y (2004) In vivo laxity of LCS mobile bearing prostheses. *Clin Orthop* 419:138–143
- Matsuda Y, Ishii Y, Noguchi H, Ishii R (2005) Varus-valgus balance and range of movement after total knee arthroplasty. *J Bone Joint Surg Br* 87:804–808
- Pagnano M, Hanssen A, Lewallen D, Stuart M (1998) Flexion instability after primary posterior cruciate retaining total knee arthroplasty. *Clin Orthop* 356:39–46
- Seon JK, Song EK (2004) The accuracy of lower extremity alignment in a total knee arthroplasty using computer-assisted navigation system. *J Korean Orthop Assoc* 39:566–571
- Sparmann M, Wolke B, Czupalla H, et al. (2003) Positioning of total knee arthroplasty with and without navigation support. *J Bone Joint Surg Br* 85:830–835
- Stulberg SD, Loan P, Sarin V (2002) Computer-assisted navigation in total knee replacement: Results of an initial experience in thirty-five patients. *J Bone Joint Surg Am* 84:90–98
- Victor J, Hoste D (2005) Image-based computer-assisted total knee arthroplasty leads to lower variability in coronal alignment. *Clin Orthop* 428:131–139
- Warren P, Olanlokun T, Cobb A, Walker P, Iverson B (1994) Laxity and function in knee replacements. A comparative study of three prosthetic designs. *Clin Orthop* 305:200–208
- Winemaker MJ (2002) Perfect balance in total knee arthroplasty. *J Arthroplasty* 17:2–10
- Yamakado K, Kitaoka K, Yamada H, Hashiba K, Nakamura R, Tomita K (2003) Influence of stability on range of motion after cruciate-retaining TKA. *Arch Orthop Trauma Surg* 123:1–4