

The Importance of Posterior Tibial Slope in TKR: Pre and Post-Operative Measurements in United States Osteoarthritic Patients

Frederick F. Buechel Sr¹, Frederick F. Buechel Jr²

¹Rutgers New Jersey Medical School, Department of Orthopaedic Surgery, Newark, USA

²Lenox Hill Hospital, Department of Orthopaedic Surgery, New York, USA

Email: buechelaakffb@yahoo.com, fbuecheljr@northwell.edu

How to cite this paper: Buechel Sr, F.F. and Buechel Jr, F.F. (2024) The Importance of Posterior Tibial Slope in TKR: Pre and Post-Operative Measurements in United States Osteoarthritic Patients. *Open Journal of Orthopedics*, 14, 374-379.
<https://doi.org/10.4236/ojo.2024.148032>

Received: June 28, 2024

Accepted: August 19, 2024

Published: August 22, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Background: Sagittal plane placement of the tibial component in total knee replacement (TKR) has important implications for maximizing the range of flexion motion, allowing collateral ligaments to function more normally, as well as providing ideal compressive loading on the tibial bone-prosthesis interface. This study attempts to quantify the normal posterior tibial slope (PTS) angle pre-operatively and post-operatively in osteoarthritic patients after using a conventional extramedullary tibial resection guide to assess its effectiveness. **Methods:** Forty-nine primary cementless total knee replacements in 34 osteoarthritic patients were measured radiographically pre-operatively and one year post-operatively to determine the PTS and its effect on range of motion. Lateral X-rays, using the anterior cortical line of the tibia, were employed for all measurements. **Results:** Pre-operative PTS measured 11.83° (range 5° - 18°), while post-operative PTS of implanted tibial components measured 11.30° (range 4° - 18°). The pre-operative range of motion of 112° (range 30° to 135°) was improved to 119° (range 90° to 135°) post-operatively after 1 year. **Conclusions:** Anterior tibial shaft referencing using a conventional extramedullary tibial resection guide provides an easy and convenient method for reproducing the anatomical PTS during TKR. This methodology provided improvement in average range of motion from 112° pre-operatively to 119° post-operatively at one year.

Keywords

Posterior Tibial Slope, Posterior Tibial Inclination, Extramedullary Tibial Resection Guide, Total Knee Alignment

1. Introduction

Sagittal plane placement of the tibial component has important implications for maximizing the range of flexion motion [1]-[3] as well as providing ideal compressive loading on the tibial bone-prosthesis interface [4] [5]. The normal posterior tibial slope angle varies from Western to Eastern populations [1] [6] [7]. Similarly, the average post-operative TKR range of motion is considered good at 110° in the West, while this is inadequate in the Asian world, which requires 135° or greater flexion to allow normal squatting activities of daily living.

Anatomically, posterior slope of the tibial cut in the lateral plane improves available flexion for TKR and should be considered a routine part of the surgical procedure [1] [2]. This study quantifies the sagittal plane posterior slope angle in a Western osteoarthritic patient cohort both pre and post-operatively to re-introduce this important concept for current and future surgical applications.

2. Methods

Forty-nine primary cementless Buechel-Pappas (B-P) semi-constrained rotating-platform total knee replacements [5] (Endotec, Orlando FL) in 38 osteoarthritic patients (14 males and 24 females) from southwest Florida (Naples), were measured radiographically pre-operatively (pre-op) and 1 year post-operatively (post-op). Patient demographics included: age ranging from 40 to 91 years (mean 66 years), height ranging from 59 inches (150 cm) to 74 inches (188 cm) (mean 66 inches (168 cm)) and weight ranging from 130 lbs (58.5 kg) to 300 lb (135 kg) (mean 195 lbs (88 kg)). Each patient's knee was examined radiographically in the lateral plane to determine the pre-op PTS angle using the anterior cortical line of the tibia as described by Yoo *et al.* [8] An extramedullary, adjustable tibial resection guide with a 7.5° posteriorly inclined cutting surface held with pins and an ankle clamp (B-P TKR Instrument System) (Endotec, Orlando, Florida) was used to make a perpendicular cut in the A-P plane and an anatomical, posteriorly inclined resection in the sagittal plane, see **Figure 1**. Pre-op range of motion (ROM) and 1 year post-op ROM were evaluated with a goniometer and available radiographs to determine maintenance or improvement in knee motion.

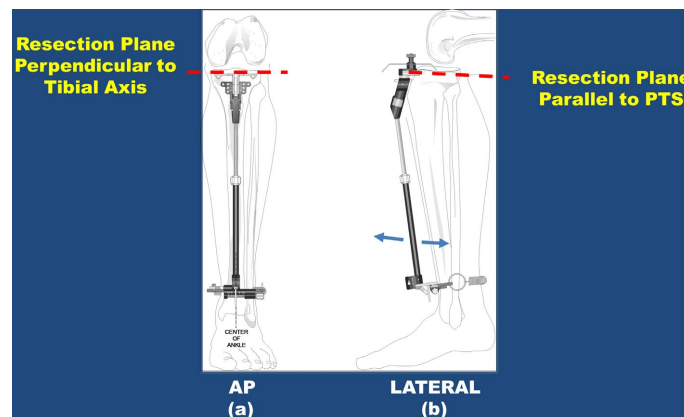


Figure 1. Alignment of tibial resection guide in the (a) A-P plane and (b) Lateral plane.

3. Results

The pre-op PTS was measured to be 11.83° (range $5^\circ - 18^\circ$) and the post-op PTS was 11.30° (range $4^\circ - 18^\circ$). Pre-op ROM in this study was measured to be 112° (range 30° to 135°), which improved to 119° (range 90° to 135°) post-op after 1 year. No loosening or component migration was seen in this study. Typical pre and post-op radiographs are shown in **Figure 2**.

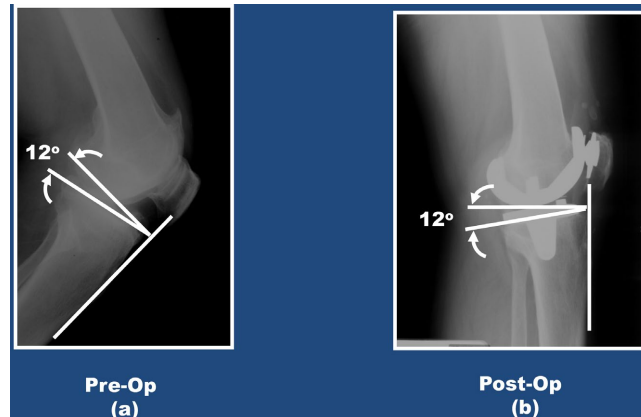


Figure 2. (a) Pre-operative and (b) post-operative lateral left knee X-Rays of a 60 year-old osteoarthritic male patient showing typical PTS of approximately 12° .

4. Discussion

Active flexion following TKR is a critical outcome measure, especially for Asian patients that require 135° or greater flexion for their normal squatting and cross-legged sitting activities. Aside from using a prosthesis that has an inherent range of motion of 160° or more, it is important to consider the surgical technical aspects of TKR that can influence improved range of motion.

Surgeons have a direct ability to remove overhanging posterior femoral condylar bone and osteophytes that can impinge on prosthetic bearings and block flexion beyond 110° . Surgeons can also influence flexion by using an anatomical posterior slope resection of the proximal tibia, which allows collateral ligaments to function more normally, than if a perpendicular resection is used [3] [7]. This is important since the tibial condylar surface is not perpendicular to the tibial axis. It is inclined posteriorly by approximately 11.4° as noted in a European population study by Brazier *et al* [9] and approximately 12.3° in a Nigerian population study by Didia *et al*. [10] Additionally, an anterior shear force on the bone-prosthesis junction, seen in perpendicular resections, is replaced by a compressive force with anatomical posterior slope [7].

For these reasons, it seems important to quantify the normal posterior slope angle of the proximal tibia so it can be reproduced during tibial component implantation. Measurements of posterior tibial inclination (slope) vary depending upon the reference system used [6] [8] [11]. Computer navigation equipment may be able to give the intramedullary tibial-ankle loading axis in the lateral plane, but this is difficult for conventional extramedullary surgical techniques.

The recent introduction of Robotic Arm Assisted Computer navigated partial knee replacement [12] has provided the surgeon with real-time intra-operative assessment of PTS. Using this tool, surgeons can preoperatively assess the true PTS angle and then reproduce it with a robotically controlled cutting burr. Using this technique, surgeons have also found that reproduction of the patients anatomic posterior slope allows for the best ligament balancing throughout the entire range of motion [13].

The intramedullary technique can give the approximate tibial-ankle axis [14] [15], but canal invasion can produce unwanted fat emboli to challenge cardio-pulmonary function [16]-[18].

Using anterior tibial shaft referencing, however, is easy and convenient, even in obese patients. A tibial resection guide with a 7° - 10° posteriorly inclined resection surface can be easily adjusted for greater or less inclination by moving the anterior alignment rod anteriorly or posteriorly, then locking the guide in position once the anatomical posterior slope has been achieved, see **Figure 1**. This anterior tibial shaft referencing correlates with the lateral plane radiographs of this study, see **Figure 2**. By aligning the tibial resection guide in line with the anatomical posterior slope, surgical resection has been simplified and quite accurate. The post-operative PTS of 11.30° seen in this study correlates well with the anatomical studies of Chiu *et al* [6] and Ishinishi *et al* [14] who determined the anatomic PTS to be 11.5° and 11.4°, respectively.

The pre-operative range of motion of 112° (range 30° to 135°) seen in this study was improved post-operatively to 119° (range 90° to 135°) after 1 year. Similar improvement in range of motion using this technique has been reported in medium [19] and long term studies [20]-[23], even though no difference in final range of motion was seen using a 0° or 5° posterior cutting block in the study of Kensara and Markel [24].

5. Conclusion

Providing anatomical PTS of the proximal tibial cut in the sagittal plane is important for maintaining or improving range of post-operative motion and allowing collateral ligaments to function more normally as well as providing compressive loading rather than shear at the bone-prosthesis interface. The degree of posterior slope in this study pre-operatively measured 11.83° (range 5° - 18°) and was surgically reproduced in the post-operative radiographs, which demonstrated a posterior inclination angle of 11.30° (range 4° - 18°) using a conventional extramedullary tibial resection guide, routine lateral radiographs and a goniometer. Reasonable surgical approximation of PTS is achievable using anterior tibial shaft referencing and an adjustable extramedullary tibial resection guide.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Marmor, L. (1985) Unicompartmental and Total Knee Arthroplasty. *Clinical Orthopaedics and Related Research*, **192**, 75-81. <https://doi.org/10.1097/00003086-198501000-00010>
- [2] Kim, J.-M. and Moon, M.-S. (1995) Squatting Following Total Knee Arthroplasty. *Clinical Orthopaedics and Related Research*, **313**, 177-186.
- [3] Lee, H., Kim, S., Kang, K., Kim, S. and Park, K. (2012) The Effect of Tibial Posterior Slope on Contact Force and Ligaments Stresses in Posterior-Stabilized Total Knee Arthroplasty-Explicit Finite Element Analysis. *Knee Surgery & Related Research*, **24**, 91-98. <https://doi.org/10.5792/ksrr.2012.24.2.91>
- [4] Pappas, M.J., Makris, G. and Buechel, F.F. (1987) Evaluation of Contact Stress in Metal-Plastic Knee Replacements. *Biomaterials and Clinical Applications*. Elsevier, Amsterdam, 259-264.
- [5] Senior, F.F.B., Junior, F.F.B. and Helbig, T.E. (2023) Cementless Semi-Constrained Rotating Platform Total Knee Replacement: A Concise Follow-Up of a Previous Report at a Minimum of Twenty Years. *Open Journal of Orthopedics*, **13**, 71-77. <https://doi.org/10.4236/ojo.2023.133008>
- [6] Chiu, K.Y., Zhang, S.D. and Zhang, G.H. (2000) Posterior Slope of Tibial Plateau in Chinese. *The Journal of Arthroplasty*, **15**, 224-227. [https://doi.org/10.1016/s0883-5403\(00\)90330-9](https://doi.org/10.1016/s0883-5403(00)90330-9)
- [7] Buechel, F.F. and Pappas, M.J. (2015) Principles of Human Joint Replacement: Design and Clinical Application. 2nd Edition, Springer Publishing Co.
- [8] Yoo, J.H., Chang, C.B., Shin, K.S., Seong, S.C. and Kim, T.K. (2008) Anatomical References to Assess the Posterior Tibial Slope in Total Knee Arthroplasty: A Comparison of 5 Anatomical Axes. *The Journal of Arthroplasty*, **23**, 586-592. <https://doi.org/10.1016/j.arth.2007.05.006>
- [9] Brazier, J., Migaud, H., Gougeon, F., Cotton, A., *et al.* (1996) Evaluation of Methods for Radiographic Measurement of the Tibial Slope: A Study of 83 Healthy Knees. *Revue de Chirurgie Orthopedique et Reparatrice de l'Appareil Moteur*, **82**, 195-200.
- [10] Didia, B.C. and Jaja, B.N.R. (2009) Posterior Slope of Tibial Plateau in Adult Nigerian Subjects. *International Journal of Morphology*, **27**, 201-204. <https://doi.org/10.4067/s0717-95022009000100034>
- [11] McLean, S.G., Oh, Y.K., Palmer, M.L., Lucey, S.M., Lucarelli, D.G., Ashton-Miller, J.A., *et al.* (2011) The Relationship between Anterior Tibial Acceleration, Tibial Slope, and ACL Strain during a Simulated Jump Landing Task. *Journal of Bone and Joint Surgery*, **93**, 1310-1317. <https://doi.org/10.2106/jbjs.j.00259>
- [12] Lonner, J.H., John, T.K. and Conditt, M.A. (2010) Robotic Arm-Assisted UKA Improves Tibial Component Alignment: A Pilot Study. *Clinical Orthopaedics & Related Research*, **468**, 141-146. <https://doi.org/10.1007/s11999-009-0977-5>
- [13] Buechel Jr., FF. (2013) Five Hundred Consecutive Robotic Arm Assisted Medial Uni-Compartmental Arthroplasties: An Outpatient Procedure that Consistently Increases Range of Motion. *JBJS*, **95B**, 250.
- [14] Ishinishi, T., Ogata, K., Nishino, I., *et al.* (1990) Comparison of Asian and Caucasian Normal and Osteoarthritic Knees. *Transactions of the ORS*: 562-563.
- [15] Simmons, E.D., Sullivan, J.A., Rackemann, S. and Scott, R.D. (1991) The Accuracy of Tibial Intramedullary Alignment Devices in Total Knee Arthroplasty. *The Journal of Arthroplasty*, **6**, 45-50. [https://doi.org/10.1016/s0883-5403\(06\)80156-7](https://doi.org/10.1016/s0883-5403(06)80156-7)
- [16] Hofmann, S., Hopf, R., Mayr, G., Schlag, G. and Salzer, M. (1999) *In Vivo* Femoral

- Intramedullary Pressure during Uncemented Hip Arthroplasty. *Clinical Orthopaedics and Related Research*, **360**, 136-146.
<https://doi.org/10.1097/00003086-199903000-00017>
- [17] Kim, Y., Kim, J., Hong, K., Kim, Y. and Kim, J. (2008) Prevalence of Fat Embolism after Total Knee Arthroplasty Performed with or without Computer Navigation. *The Journal of Bone and Joint Surgery-American*, **90**, 123-128.
<https://doi.org/10.2106/jbjs.g.00176>
- [18] Hofmann, S., Hopf, R., Frank, E., et al. (1996) Femoral Intramedullary Pressure and Pulmonary Fat Embolism During Uncemented Total Knee Replacement. *Journal of Orthopaedic Translation*, **20**, 145.
- [19] Kim, Y. and Kim, J. (2004) Comparison of Anterior-Posterior-Glide and Rotating-Platform Low Contact Stress Mobile-Bearing Total Knee Arthroplasties. *The Journal of Bone and Joint Surgery-American*, **86**, 1239-1247.
<https://doi.org/10.2106/00004623-200406000-00017>
- [20] Ali, M.S. and Mangaleshkar, S.R. (2006) Uncemented Rotating-Platform Total Knee Arthroplasty. *The Journal of Arthroplasty*, **21**, 80-84.
<https://doi.org/10.1016/j.arth.2005.04.018>
- [21] Buechel Sr., F.F., Buechel Jr., F.F., Pappas, M.J. and D'Alessio, J. (2002) Twenty-Year Evaluation of the New Jersey LCS Rotating Platform Knee Replacement. *Journal of Knee Surgery*, **15**, 84-89.
- [22] Buechel, F.F., Buechel, F.F., Helbig, T.E. and Pappas, M.J. (2012) 31 Year Evolution of the Rotating-Platform Total Knee Replacment: Coping with "Spinout" and Wear. *Journal of ASTM International*, **9**, 1-14. <https://doi.org/10.1520/jai103329>
- [23] Senior, F.F.B., Junior, F.F.B. and Helbig, T.E. (2023) Cementless Semi-Constrained Rotating Platform Total Knee Replacement: A Concise Follow-Up of a Previous Report at a Minimum of Twenty Years. *Open Journal of Orthopedics*, **13**, 71-77.
<https://doi.org/10.4236/ojo.2023.133008>
- [24] Kansara, D. and Markel, D.C. (2006) The Effect of Posterior Tibial Slope on Range of Motion after Total Knee Arthroplasty. *The Journal of Arthroplasty*, **21**, 809-813.
<https://doi.org/10.1016/j.arth.2005.08.023>