Analysis of Validity of TTTG Distance using Dynamic 3D Printed Knee in Various Flexion Angles with CT and CAD as Controls

Deepak Goyal*,

Ankur Shah**

Bhanupratap Gaur, Rupesh Ghyar, Prof Ravi Bhallamudi***

- *Saumya Arthroscopy & Sports Knee Clinic, Ahmedabad, India. www.knee.in
- **Sadbhav Imaging Center, Ahmedabad, India.
- ***Biomedical Engineering and Technology Incubation Center- BETIC Lab, Mechanical Department, Indian Institute of Technology, Bombay, India.

Disclaimer

- **Funding for 3D printing**
  - Department of Science and Technology (DST), New Delhi, India.
  - Rajiv Gandhi Science and Technology Commission (RGSTC), Mumbai, India.

- **Acknowledgement**
  - Mr Balaji Vitthalrao Shinde for 3D modelling support.

- **Conflict of Interest**
  - None.

BETiC

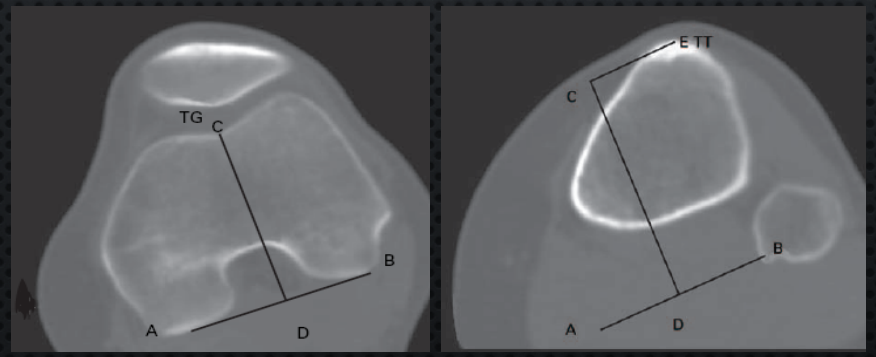
Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

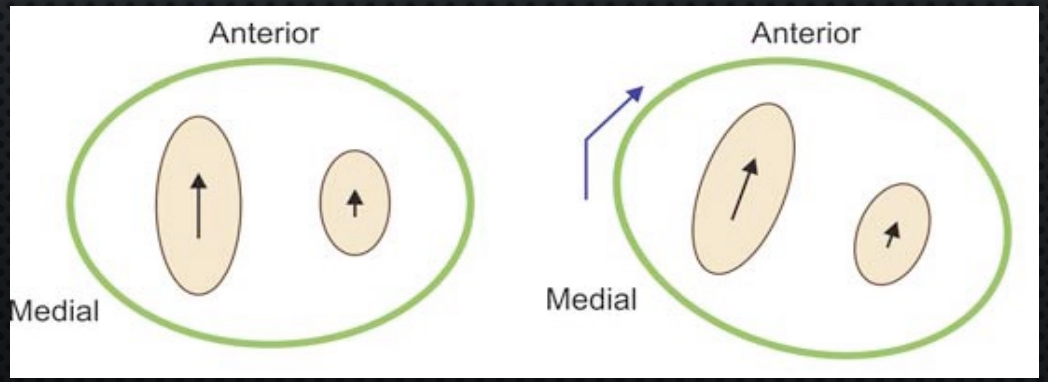
Introduction

- The TTTG distance is an important parameter to measure the position of tibial tuberosity (TT) in relation to the trochlear sulcus; which in turn allows to determine if medialization of the TT is needed or not.

- Due to the screw home mechanism, tibia rotates 5° externally in the last 15° of extension and rotates internally on early flexion. Hence, position of the TT cannot be static due to the external / internal rotation of tibia during terminal extension/ early flexion.

- If position of TT is not static than, TTTG cannot be a static measurement!



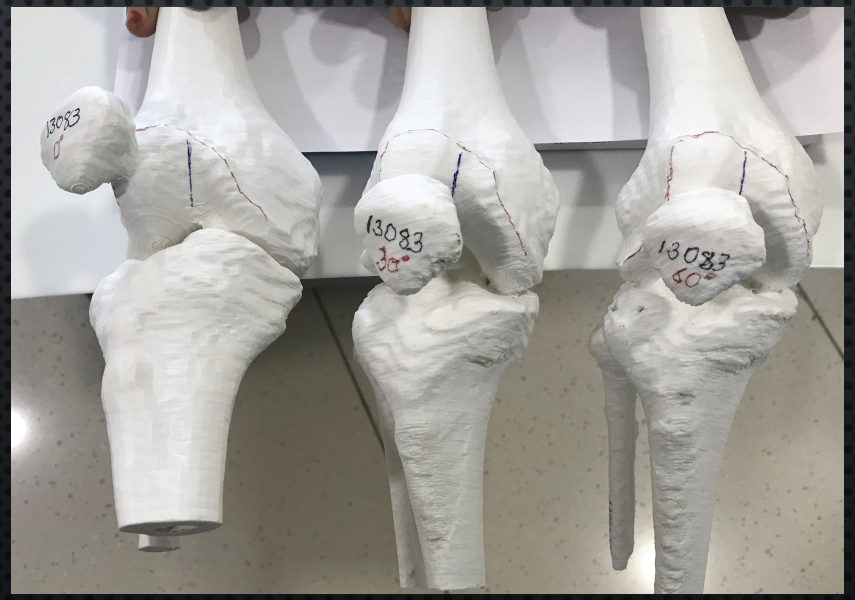


BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Purpose

- To determine the dynamic relationship between TT and TG on dynamic 3D printed knee models in various ROM.
- To revalidate data with CT control and CAD control.
- To analyze the validity of routinely performed TTTG and its clinical usefulness.



BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

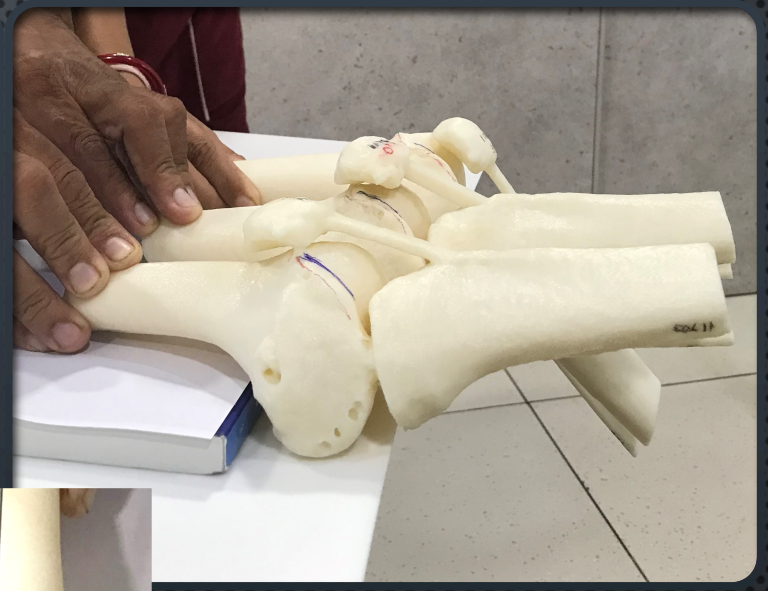
Methods

- In order to minimize the cost and the radiation hazard of CT scans in different degrees of flexion, only five patients were selected in stage 1.
- Only those patients who will otherwise need a dynamic 3D printed knee due to complex pathologies in their knees, were selected.
- Methodological steps
  - CT scan in different degrees of flexion
    - Hyperextension, neutral flexion, 0°, **30°** and **(60° in a few case.)**
  - Collect DICOM images
  - 3D image processing by mechanical/biomedical engineers
  - ABS printing using 3D printer
  - Dynamic 3D printed knee

BETiC

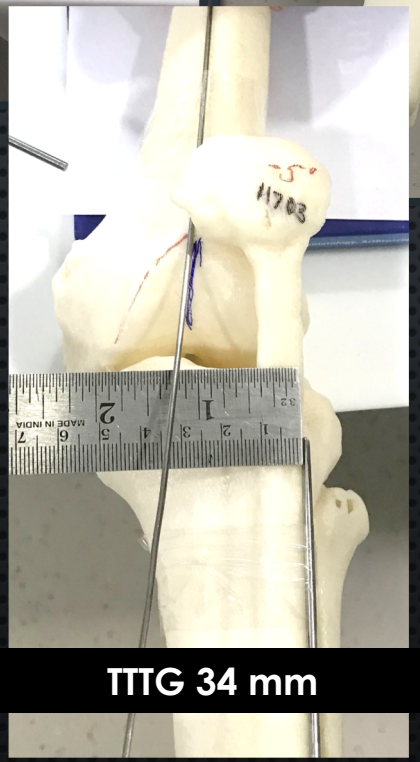
Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Results: # 11703 (Dynamic TTTG-3D Prints)

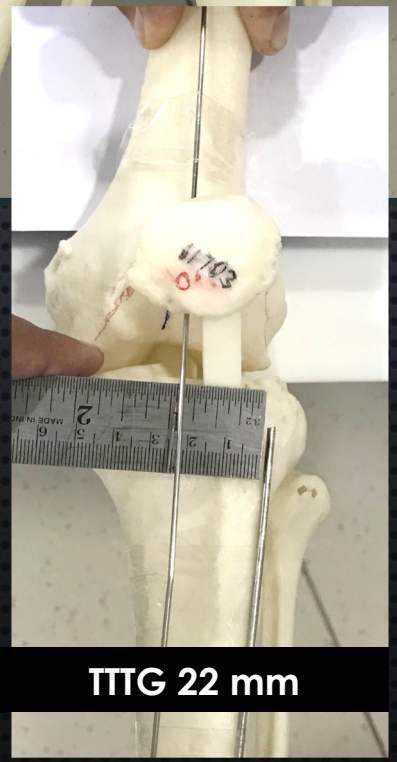


Dynamic Printed 3D Knee models -View from lateral side-

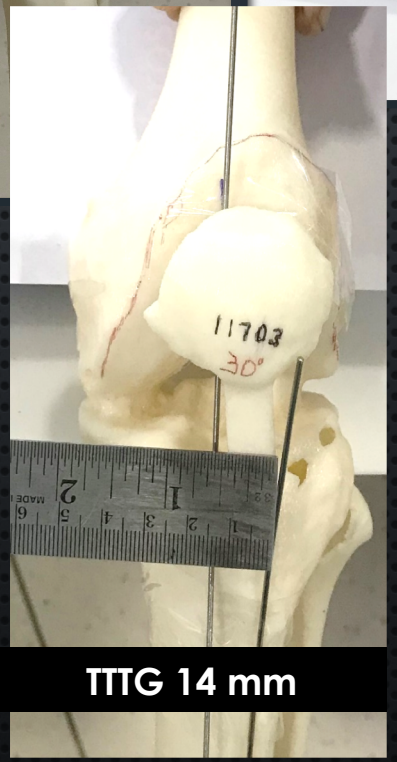
Dynamic Printed 3D Knee models -View from medial side-



TTTG 34 mm



TTTG 22 mm

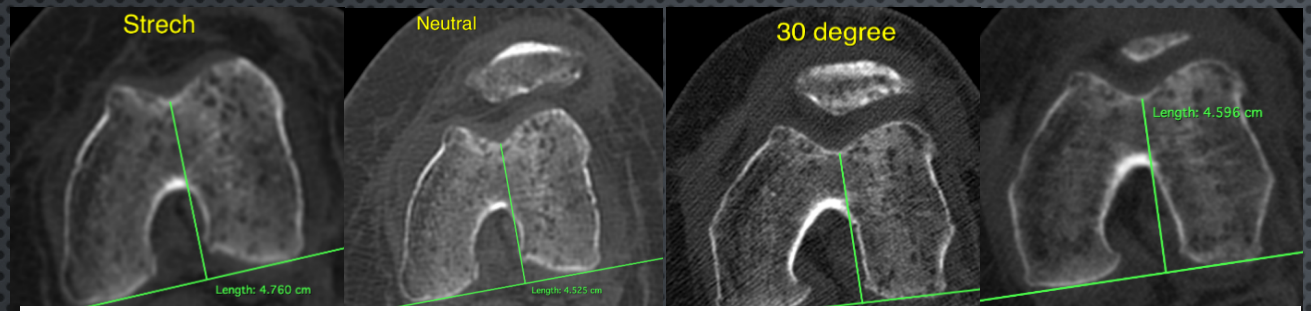


TTTG 14 mm

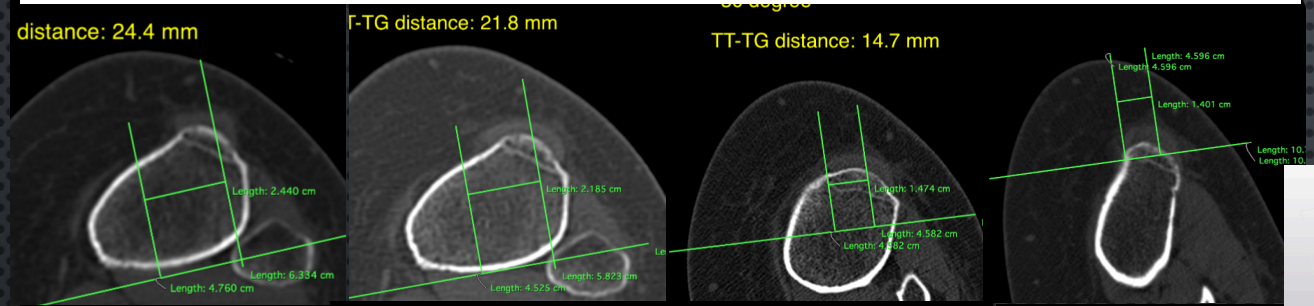
BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Results: # 11703 (Dynamic TTTG-CT and CAD Control)



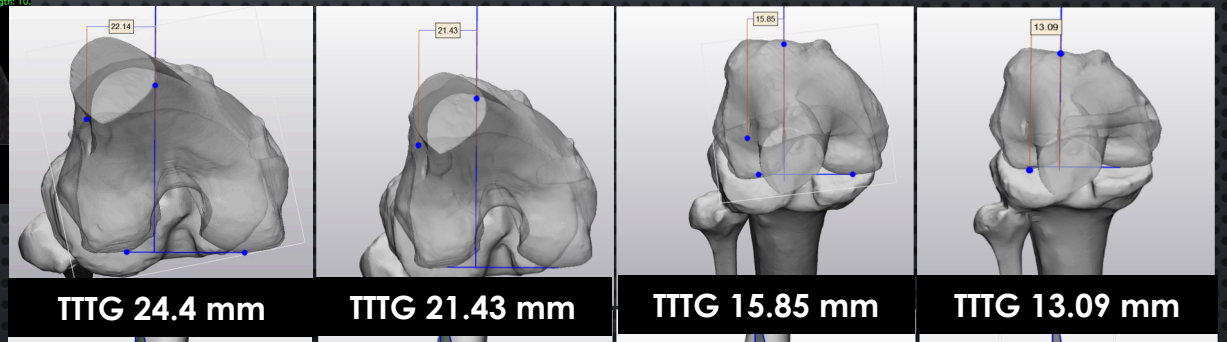
TTTG 24.4 mm | TTTG 21.8 mm | TTTG 14.7 mm | TTTG 14 mm



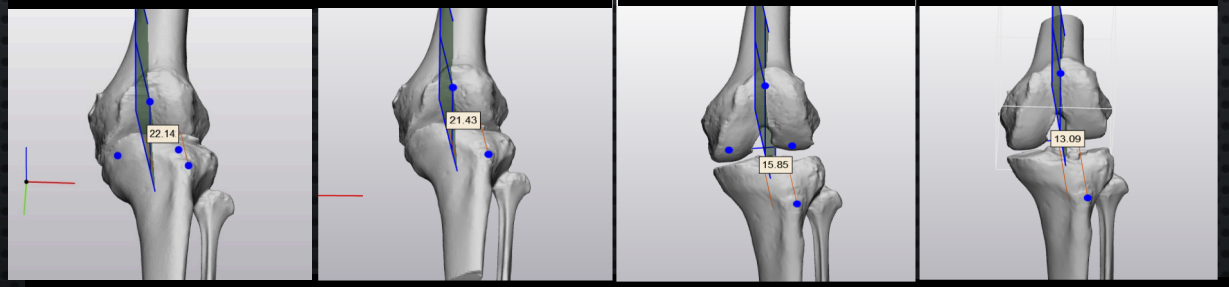
Hyperextension | Neutral Extension | 30° Flexion | 60° Flexion

CT Control
-Significant reduction in TTTG from 0-30° Flexion-

CAD Control
-Significant reduction in TTTG from 0-30° Flexion-



TTTG 24.4 mm | TTTG 21.43 mm | TTTG 15.85 mm | TTTG 13.09 mm

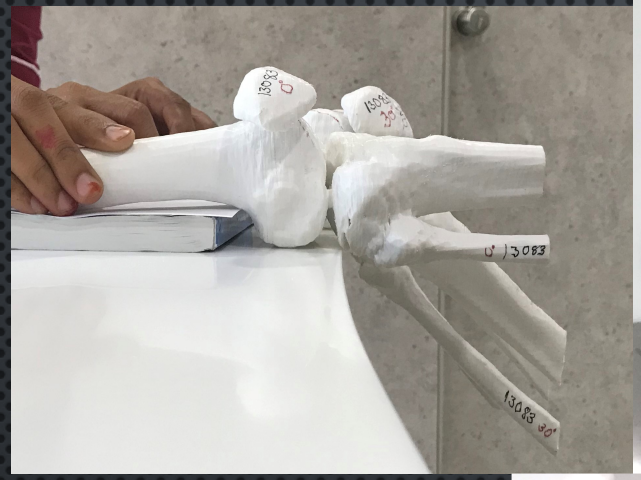


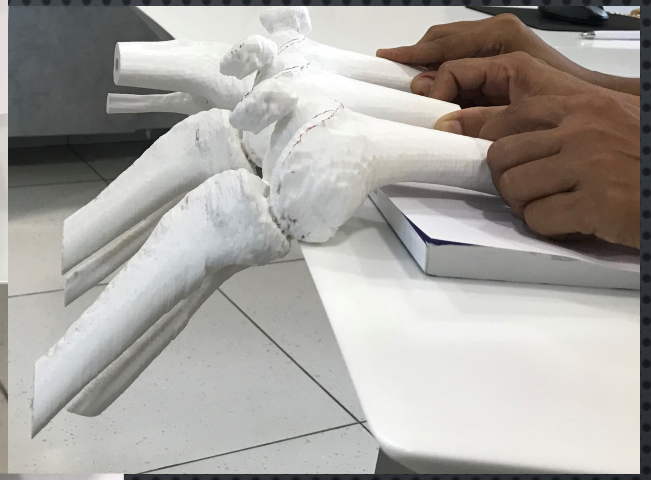
Hyperextension | Neutral Extension | 30° Flexion | 60° Flexion

BETiC

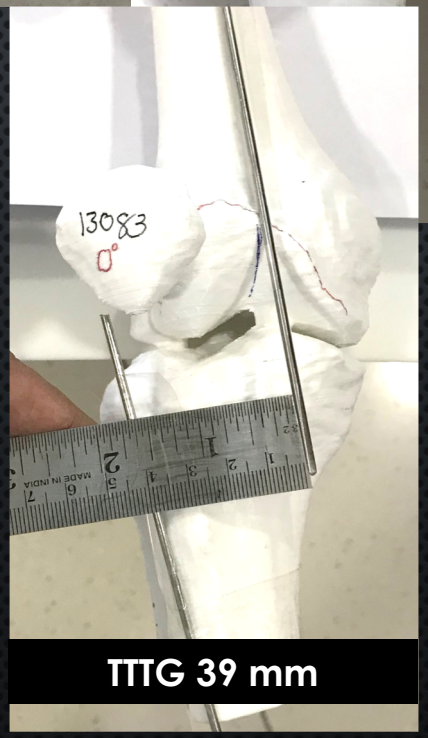
Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Results: # 13083 (Dynamic TTTG- 3D Print)

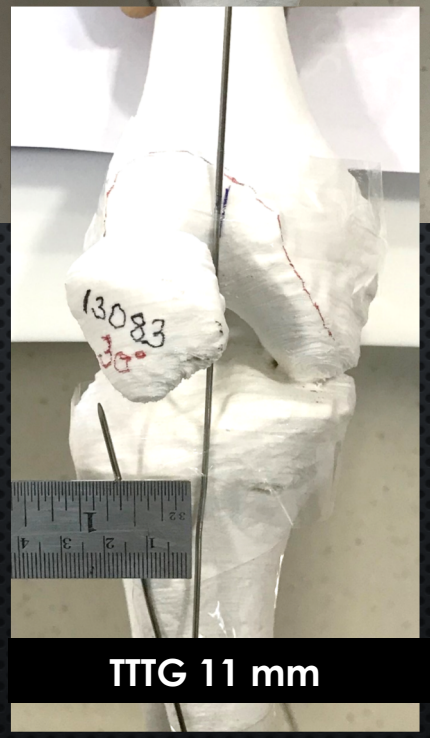




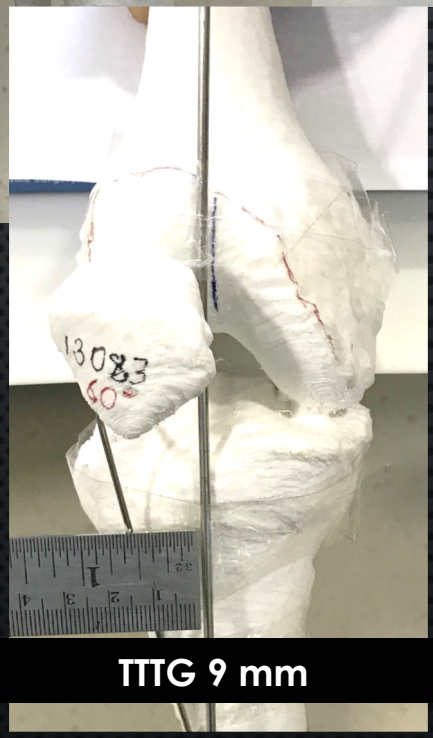
Dynamic Printed 3D Knee models -View from lateral side-



TTTG 39 mm



TTTG 11 mm



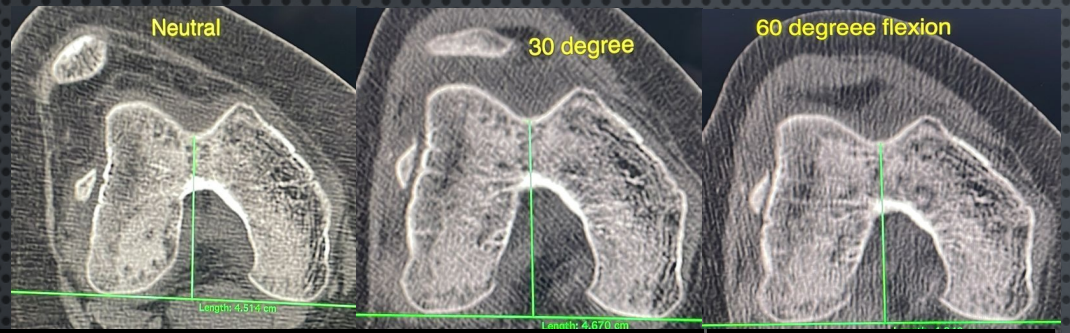
TTTG 9 mm

Dynamic Printed 3D Knee models -View from medial side-

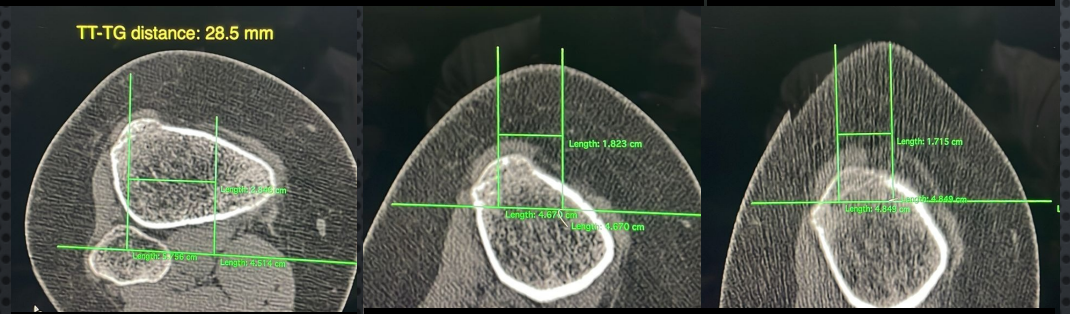
BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Results: # 13083 (Dynamic TTTG- CT and CAD Control)



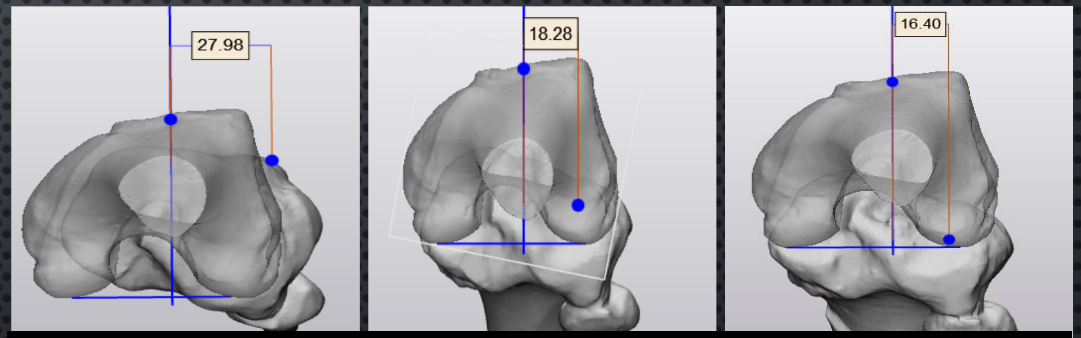
TTTG 28.5 mm | TTTG 18 mm | TTTG 17 mm



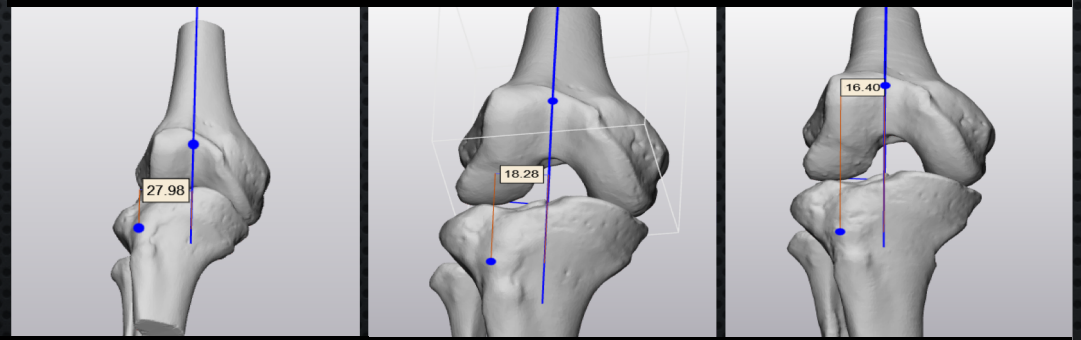
Hyperextension | Neutral Extension | 30° Flexion

CT Control
-Significant reduction in TTTG from 0-30° Flexion-

CAD Control
-Significant reduction in TTTG from 0-30° Flexion-



TTTG 28.5 mm | TTTG 18 mm | TTTG 17 mm



Hyperextension | Neutral Extension | 30° Flexion

BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

TTTG in different degrees of flexion on Dynamic 3D Knee Print Vs CT Vs CAD Mean Difference

Methodology	Hyperextension-0° Extension	0° Extension- 30° Flexion	30° Flexion- 60° Flexion
Dynamic 3D print	18.45%	**39.71%**	8.57%
CT scan	11.1%	**36.18%**	5.16%
CAD models	5.94%	**34.78%**	13.85%

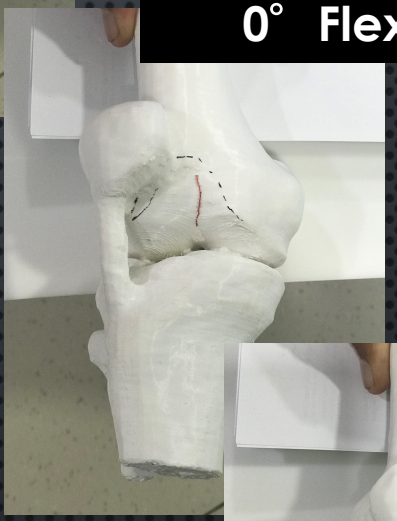
- Dynamic 3D Printed Knee model confirmed that Proximal tibia rotates internally from hyperextension to flexion, reducing TTTG.
- The most significant reduction in TTTG values (39.71%) occurred from 0° to 30° of flexion on dynamic 3D printed knee models, which also matched with CT and CAD controls.

BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Discussion

Dynamic 3D Printed Knee Models



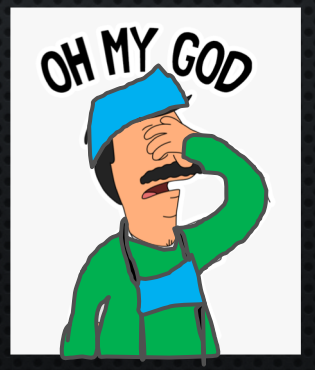
Fact 1

- There is a screw home mechanism.
- We confirmed that TTTG reduces > 35% from extension to 30° flexion.

Fact 2

- Patella engages in trochlea in approximately 30° of flexion.
- Means TT, thru patellar tendon drags patella into trochlea at 30° flexion.
- Thus, TTTG value is meaningful at the point of engagement of patella in trochlea and not in neutral extension position.

Then why are we measuring TTTG in extension?



BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

Conclusion

TTTG Measurement Validity

- Relation between TT and TG is not a static relation but a dynamic relation which changes with different degrees of flexion.

- TTTG measured in extension is meaningless as it reduces >35% from full extension to 30° flexion. TTTG measured at an angle when patella engages into trochlea is clinically important rather than TTTG measured at neutral extension.

- If at all, clinician wants to measure TTTG, it should be measured in 30° flexion.

BETiC

Arthroscopy & Sports Knee Clinic
Preserving Knees since 2004

THANKS A LOT

DEEPAK GOYAL***, ANKUR SHAH**, BHANUPRATAP GAUR*, RUPESH GHYAR*, PROF RAVI BHALLAMUDI*

- **References**

- Dejour H, Walch G, Nove-Josserand L, Guier Ch. Factors of patellar instability: An anatomic radiographic study. *Knee Surg, Sports traumatol, Arthroscopy*. 1994;2(1):19-26. doi:10.1007/BF01552649
- Dietrich TJ, Betz M, Pfirrmann CWA, Koch PP, Fucentese SF. End-stage extension of the knee and its influence on tibial tuberosity-trochlear groove distance (TTTG) in asymptomatic volunteers. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(1):214-218. doi:10.1007/s00167-012-2357-z
- Goutallier D, Bernageau J, Lecudonnec B. [The measurement of the tibial tuberosity. Patella groove distanced technique and results (author's transl)]. *Rev Chir Orthop Reparatrice Appar Mot*. 1978;64(5):423-428.
- Piazza SJ, Cavanagh PR. Measurement of the screw-home motion of the knee is sensitive to errors in axis alignment. *J Biomech*. 2000;33(8):1029-1034. doi:10.1016/s0021-9290(00)00056-7