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# Mechanical effects of sagittal plane angle on transverse cut in OWHTO and OWDTO : A finite element method

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# Faculty Disclosure Information

I have no financial relationships to disclosure.

# Background

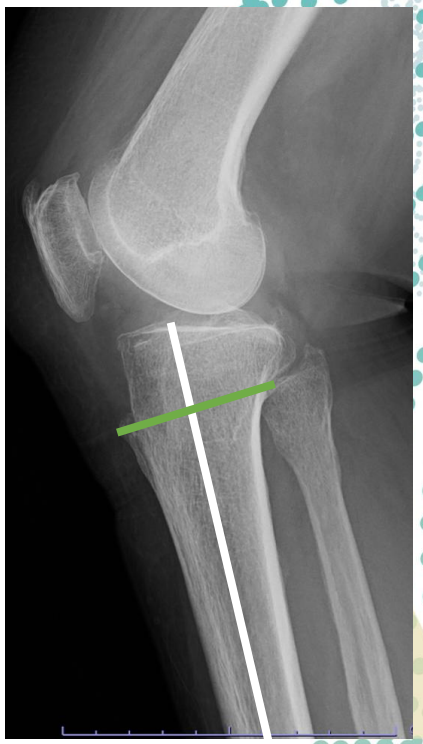
- Open wedge high tibial osteotomy (OWHTO) and open wedge distal tuberosity osteotomy (OWDTO) are relatively common surgical procedures for medial osteoarthritis of the knee (medial OA) in middle-aged active patients.
- Both OWHTO and OWDTO involve creating a transverse cut.
- However, there is **no consensus on the sagittal plane angle of the transverse cut.**

**Osteotomy parallel to the tibial articular surface?**

or

**Osteotomy perpendicular to the tibial axis?**

**Paralell**



**Perpendicular**

# Purpose

- In the transverse cut,

① In the case of osteotomy **parallel** to the tibial joint surface
② In the case of osteotomy **perpendicular** to the tibial bone axis

**Which is mechanically suitable for the tibia and the plate?**

The purpose of this study is to analyze which approach is mechanically more suitable for the tibia and plate using the finite element method.

# Methods

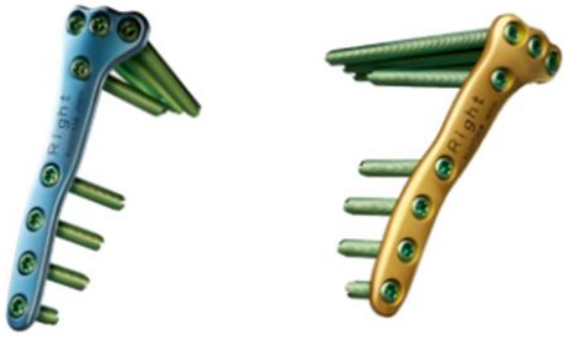
- CT data： 64-year-old Female
  Right knee
  Osteoarthritis of the knee
  （K-L grade 2）
  HKA 2° varus
  Posterior tibial slope angle 6-degree

- Plate and screw：
  CAD data provided by ASPICIOUS (Japan)

Aspic plate® is a T-sheped locking plate with four screw holes (A, B, C, and D) for proximal fixation and another four holes (1,2,3,and 4)

- Finite element analysis was performed MECHANICAL FINDER®

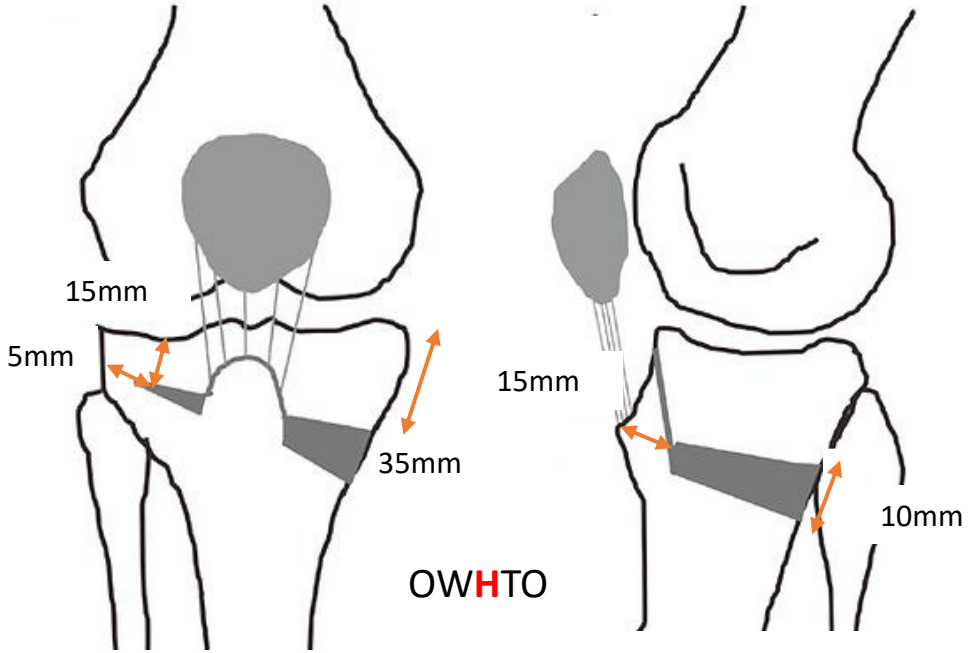
X-ray of lower limb

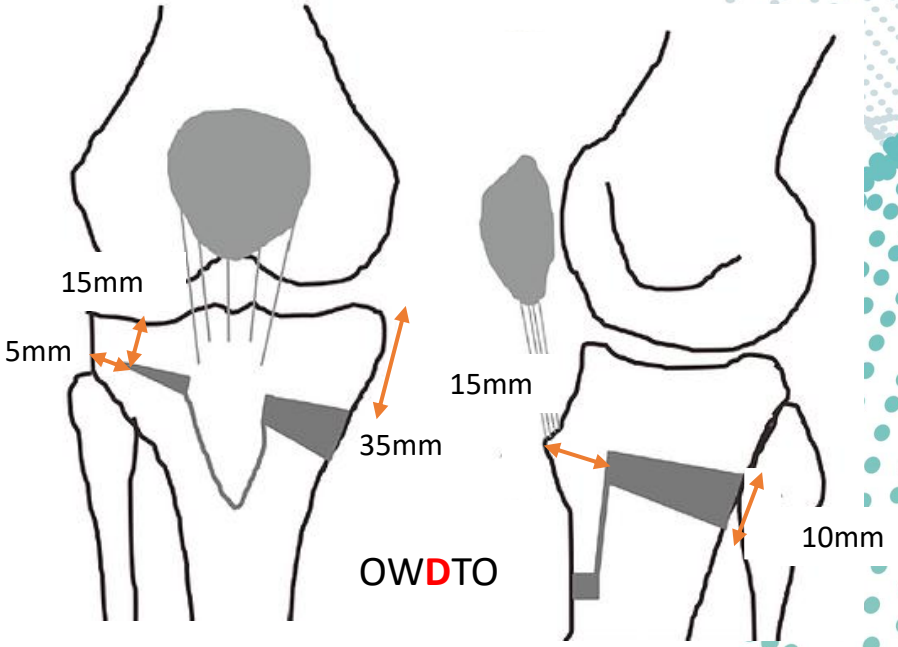


ASPIC plate® by ASPICIOUS

# Methods

## Osteotomy models




- The cutting start point was 35 mm from medial tibial plateau and 15 mm from lateral tibial plateau.
- An intact hinge of lateral tibial cortex was set at a width of 5 mm
- A width of tibial tuberosity was set at 15 mm.
- Artificial bone was placed into the osteotomy gap in both models.

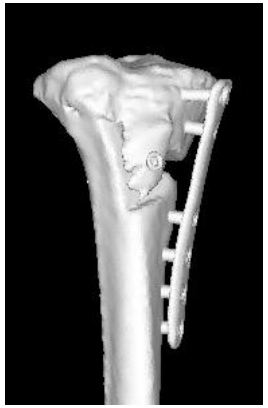
# Methods

## Osteotomy models

OWHTO

① **The model of parallel to the tibial articular surface**

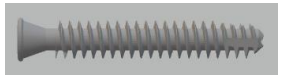
② **The model of perpendicular to the tibial axis**



OWDTO

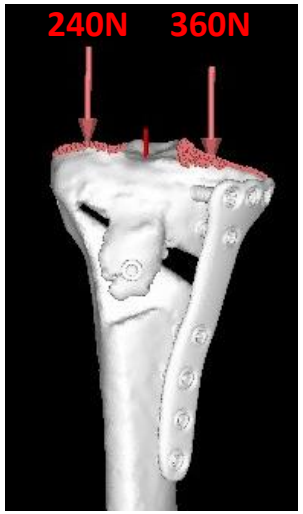
① **The model of parallel to the tibial articular surface**

② **The model of perpendicular to the tibial axis**



| | Plate and screws | Artificial bone |
|---|---|---|
| Young's modulus/GPa | 108.9 | 0.3 |
| Poisson's ratio | 0.3 | 0.4 |
| Tensile strain/MPa | 899.3 | 20 |
| Compressive stress/MPa | 824.7 | 20 |
| Stress relaxation coefficient | 0.1 | 0.1 |
| Density mg/cm3 | 4430 | 1300 |
| Fracture strength/μ | 100000 | 3000 |

- The plate and screws was fixed.
- The screws and bone was fixed.
- Young's modulus of the bone ：We use Keyak's formula. *Keyak JH et al. J. Biomech. 1998.*
- Mesh size：All materials were set at 2 mm.




- The ankle joint was fixed, and the load of 600 N was applied in the vertical direction of the tibial joint surface while assuming a bilateral stance.
- The load was distributed with a ratio of 3:2 between the medial and lateral sides.

*J.C. Yang et al. J. Orthop. Transl. 2020.*
*C. Jacquet, et al. Clin. Biomech. 2020.*

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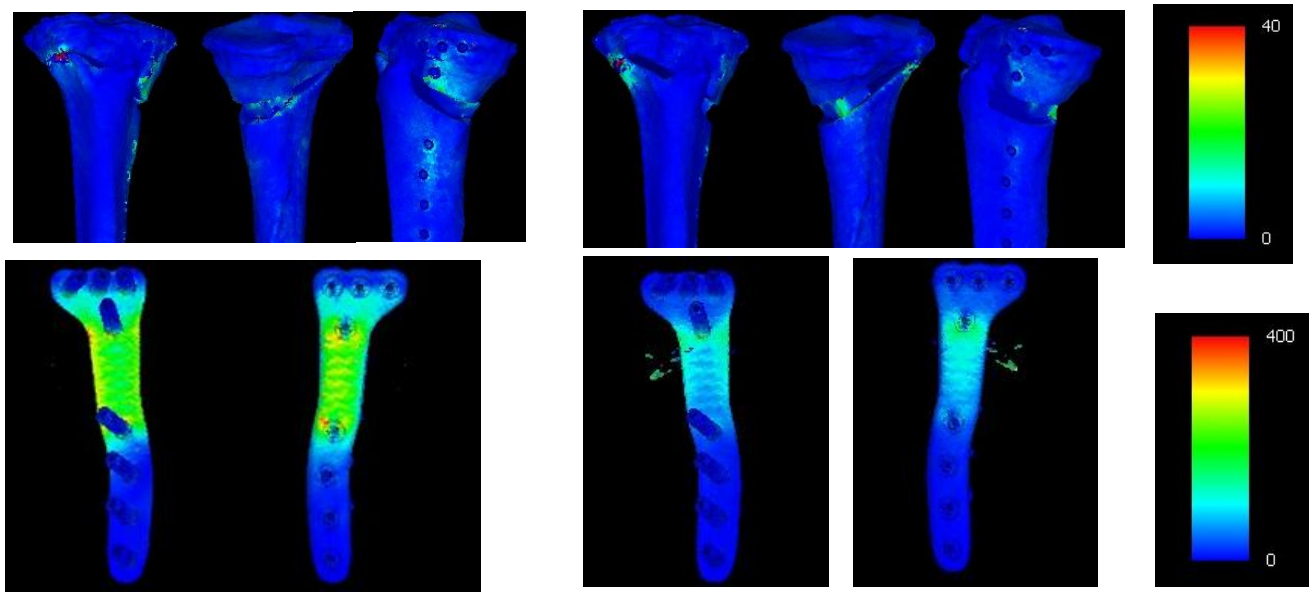
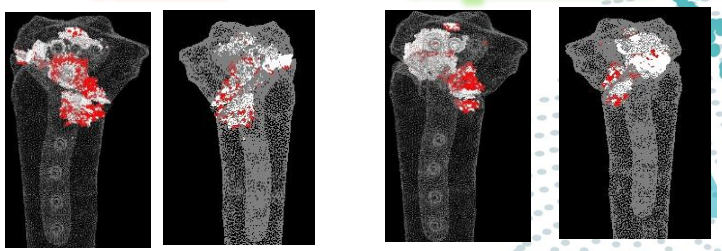
# Results (OWHTO)

**Paralell** **Perpendicular**

Unit: MPa

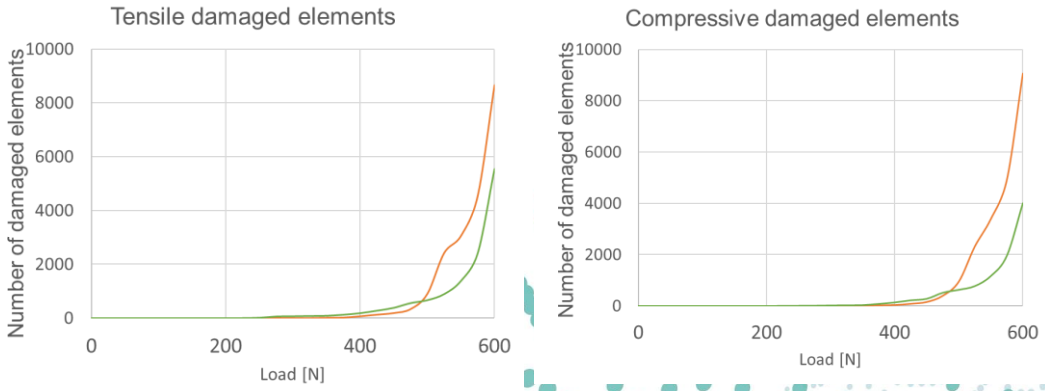



**Paralell** **Perpendicular**



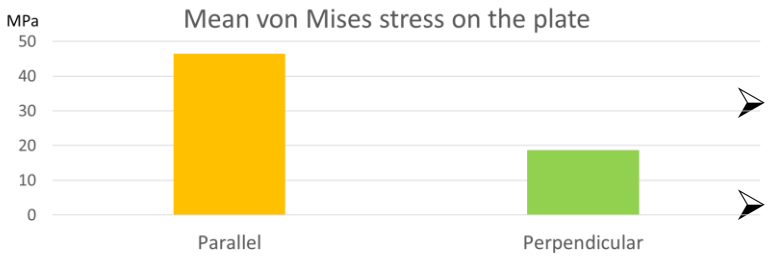
White：Tensile fracture
Red：Compression fracture

Change in the number of damaged elements of OWHTO




**Parallel**

**Perpendicular**




- In the OWHTO models, both parallel and perpendicular models have stress concentrated at the lateral hinge.
- The average von Mises stress generated on the plate was **smaller in the direction perpendicular** to the bone axis.
- The number of damage elements in OWHTO was **lower when perpendicular** to the bone axis for both tensile and compressive fractures.

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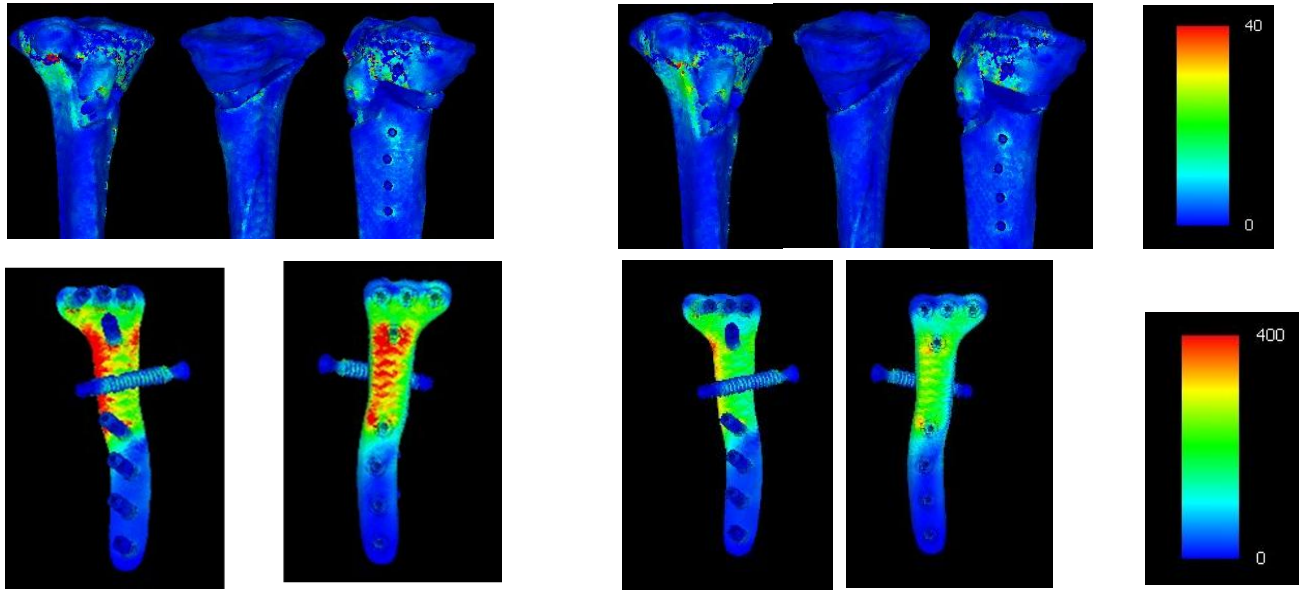
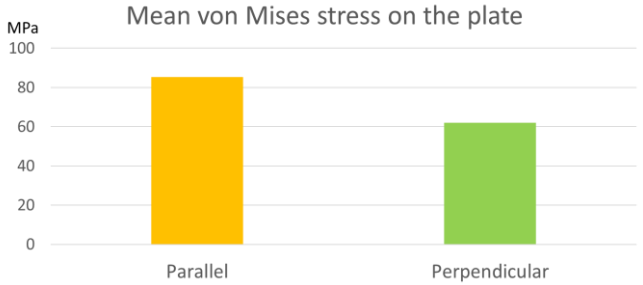
# Results (OWDTO)

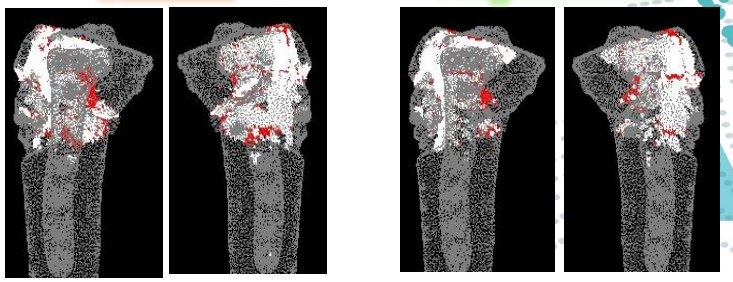
**Paralell** **Perpendicular**

Unit: MPa



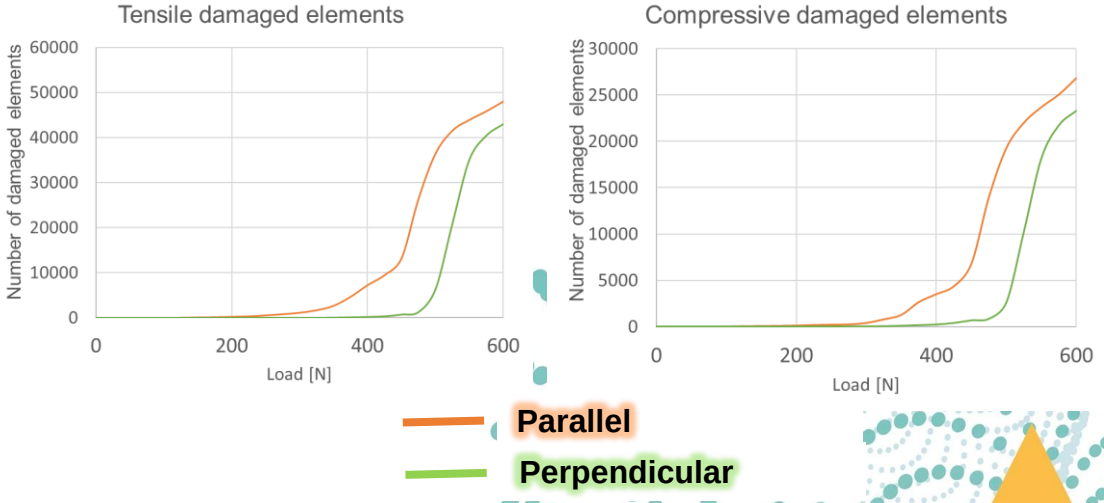




**Paralell** **Perpendicular**



White：Tensile fracture
Red：Compression fracture

Change in the number of damaged elements of OWDTO




- In the OWDTO models, both parallel and perpendicular models have stress concentrated at the lateral hinge.
- The model **perpendicular** to the bone axis exhibited less stress distribution compared to the model parallel to the joint surface.
- The number of damage elements in OWDTO was **lower when perpendicular** to the bone axis for both tensile and compressive fractures.

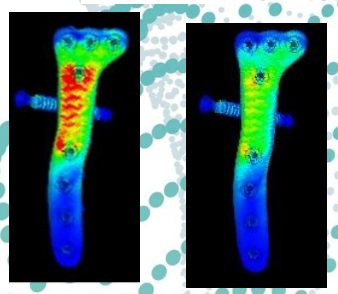
# Discussion

- Nha et al. analyzed plate failures in 12 cases of HTO, all of which occurred at the D hole. *Nha, et al. Medicine. 2019*
- It has been reported that finite element analysis of OWHTO shows increased stress concentration around the D hole to 1 hole of the plate. *Kang TK, et al. J Orthop Surg Res. 2020* *Itou J, et al. BMC Musculoskeletal Disorders 2021.*

In this study, stress concentration around the D hole to 1 hole was observed in both the OWHTO and OWDTO models.

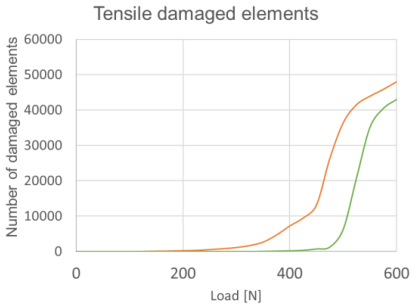
**The results indicated that a transverse cut perpendicular to the bone axis is suitable for reducing stress concentration on the plate.**

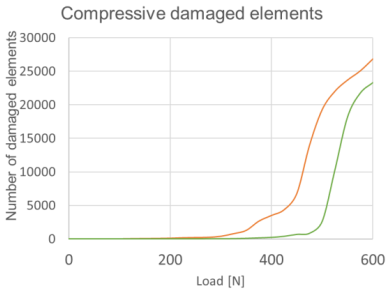
OWDTO



**Paralell** **Perpendicular**

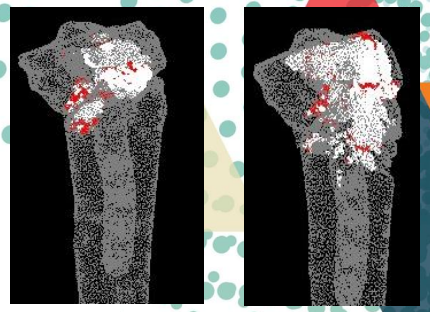
- The results also showed that, in terms of the number of tibial damage elements, a transverse cut perpendicular to the bone axis imposed less mechanical burden.
- Since the number of damaged elements was concentrated around the hinge area, it was suggested that a model **perpendicular to the bone axis may reduce the risk of hinge fractures.**




**Parallel**

**Perpendicular**



OWHTO OWDTO

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# Limitation

- The analysis was conducted on a single patient.
- The bone-screw interface was assumed to be fixed, and the effect of micro-motion was not considered.
- The influence of patellar tendon tension was not taken into account.
- The analysis was performed under static conditions.

# Conclusion

- A finite element analysis was conducted to evaluate the mechanical properties of the transverse cut sagittal plane angle in both OWHTO and OWDTO models.
- In both OWHTO and OWDTO, it was found that creating the transverse cut perpendicular to the bone axis was mechanically advantageous for the plate and tibia.

# References


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2. J.C. Yang, et al. Benefits of opposite screw insertion technique in medial open-wedge high tibial osteotomy: a virtual biomechanical study. J. Orthop. Transl. 2020.
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6. Itou J, et al. Monocortical fixation for locking plate distal screws does not impair mechanical properties in open-wedge high tibial osteotomy. BMC Musculoskeletal Disorders 2021.