Biomechanical Analysis of Patellar Resurfacing with Onlay and Inset Patellar Implant Fixation in TKR
A Comparison of Conventional and Highly Cross-linked Polyethylene

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# Conflict of interest

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High forces generating at patella

- Patella shift and tilt during knee flexion generate great **compressive and shear forces**
- Getting worse if patellar mal-tracking occurs

(Ishimaru M et al., 2014)  (Ali A et al., 2015)
Clinical and biomechanical studies

- **Conventional UHMWPE** peg fractures was found in our clinical reports
  - Heavy body weight
  - Osteonecrosis
  - Weakness of the pegs

- Computer simulation only for *conventional material*

- How about the new HXLPE materials with decreased mechanical strength?

(Huang CH et al., J Arthroplasty, 1999)
(Huang CH et al., Knee Surg Sports Traumatol Arthrosc, 2017)
**HXLPE peg fracture**

- **HXLPE** peg fractures in both knees was reported for one patient (Nature Knee, Zimmer.)
  - Return to normal activities with very well function /even play tennis!
  - However, both patella fractured after 20 and 31 months
  - Revised to UHMWPE and have normal functions

![Images of HXLPE peg fractures in both knees at 20 and 31 months]

Left knee: 20 months

Right knee: 31 months

(Stulberg et al., 2014)
Do new materials guarantee safety?

- In addition to choice of new materials,
  - Patellar fixation could play an important role on the mechanical strength but not well discussed
    - Onlay (rely on three pegs on the resected bone merely)
    - Inset (the whole patella is embedded into patellar bone)
Objective

- To evaluate the mechanical characteristics for different types of patellar fixation techniques
- If newly material is selected
  - **Experimental study**: maximum force and displacement at breakage
  - **Finite element analysis**: stress, strain and plastic deformation
Biomechanical evaluations

Experimental study

Finite element analysis

Input material property to FE software

Mesh convergence test on pegs

Lu YC et al., Clin Biomech, 2018

Stress-Strain Curve

Mesh convergence test

Mesh convergence test
Experimental results

- Inset fixation increased approximately 35% of shear strength compared with onlay patella
  - Material selection had less effect on bonding force: consistent cement fixation
- Typical failure sample of onlay fixation
  - Shear fracture starts at single-peg side
  - Following pull-out and breakage of the remained pegs

![Graph showing Patella Shear Force comparison between onlay and inset fixation.](image1)

![Image of a typical failure sample showing Shear Fracture and Pull Fracture.](image2)

*Shear Fracture (weak point) and Pull Fracture*
Finite element results

- Compared to conventional UHMWPE, a higher stress was calculated in HXLPE design, but lower in VEPE.
- Plastic permanent deformation was obviously decreased for VEPE patella.
  - Might provide an advantage of avoiding the risk from peg fracture.

Onlay

Onlay-UHMWPE
Onlay-HXLPE
Onlay-VEPE

Highest value in HXLPE
Lowest value in VEPE
Inset fixation technique offers an advantage in reducing stress and decreasing plastic deformation on backside peg.
Conclusion

- Fixation techniques mainly affects its bonding strength
  - Bonding strength of inset fixation was much higher than onlay
- Recommendation for surgical selection,
  - VEPE help lower the risk of permanent deformation
  - If HXLPE is selected, inset fixation technique is recommended for decreasing the risk of patella loosening or peg fracture
References

