Load to Shear Failure of Cemented Patellar Components in Well-functioning Postmortem Total Knee Arthroplasties

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INTRODUCTION: Anterior knee pain is a common cause of dissatisfaction after total knee arthroplasty (TKA). The patella is thought to contribute to anterior knee pain, with patella fixation inferior to tibial and femoral fixation. Shear forces on the patella can lead to component loosening and failure. Prior studies evaluating shear failure relied on patellar implants prepared in cadaveric specimens. The objectives of this study were to (1) evaluate the mechanical load to shear failure in a unique cohort of cemented patellar components from well-functioning postmortem TKAs, and (2) determine the influence of clinical and radiographic factors on load to shear failure.

METHODS: Twenty-two patellae were harvested from postmortem well-functioning knees (mean length of implantation 9.1 years (range, 1.7-19.6 years)). Three different all-polyethylene 3-peg onlay patellar designs were used: round dome, oval dome, and anatomic. The patellae were evaluated for implant-to-bone size ratios, bone mineral density and microarchitectural parameters according to high-resolution peripheral quantitative CT, implant-bone integration according to MRI, articular surface polyethylene surface damage scoring, and patellar button design. Patellar specimens were mounted onto a V-block and loaded with isolated shear stress using a servo-hydraulic test frame (Fig. 1) until failure occurred (Fig. 2). Load-displacement curves were recorded. Univariate and multivariable linear regression models were used to analyze the effects of clinical and radiographic factors on load to failure.

RESULTS: The mean load to failure was 1881 + 621 N. Nine patella failed at the bone-cement interface, 7 failed at the implant-cement interface, and 6 involved both interfaces. There were no failures related to shearing at the peg-implant junction. On univariate analysis (Table 1), increased load to shear failure was associated with shorter length of implantation ($p=0.002$), male sex ($p=0.002$), decreased implant-to-bone surface area ($p=0.03$), and increased bone volume fraction ($p=0.004$). On multivariable analysis ($R2=0.85$, Table 2), increased load to failure was associated with decreased BMI ($p=0.008$), decreased length of implantation ($p<0.001$), increased implant-bone integration ($p=0.009$), decreased implant-to-bone surface area ($p=0.008$), and increased bone volume fraction ($p<0.001$). Load to shear failure was not associated with surface damage ($p=0.99$) and did not differ across the three patellar implant designs ($p=0.35$).

DISCUSSION AND CONCLUSION: In this novel cohort of cemented patellar buttons from well-functioning postmortem TKAs, load to shear failure was higher than previously reported in cadaveric native patellae. This highlights the difficulty of modeling patella implant fixation using cadaveric native patellae. Maximizing the patellar implant size relative to the available bone was associated with decreased shear failure load after accounting for other pertinent factors. When choosing between two patellar button sizes, surgeons should consider opting for the smaller size, which may improve the maximum shear strength of the patella construct.

Figure 1. A) Side and B) front views of a patella mounted in a V-block shear testing fixture

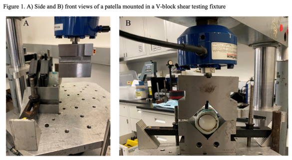

Figure 2. A) side and B) top views of an example patella with a patellar component after shear testing

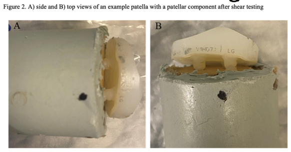

Table 1. Univariate analysis of clinical and radiographic factors associated with load to shear failure

Category	Variable	R^2	Beta	Standardized Beta	P-value
Demographic	Age (years)	0.003	5.1	0.06	0.797
	Body mass index (kg/m²)	0.07	53.2	0.26	0.240
	Length of implantation (years)	0.38	-75.9	-0.62	**0.002**
	Sex	0.39	783.0	0.62	**0.002**
MRI	Implant Integration (total score)	0.10	218.5	0.31	0.154
Damage	Surface damage (total score)	0.00	0.7	0.003	0.988
Failure interface	Failure interface (implant vs. cement)	0.12	422.1	0.35	0.115
Design Parameters	Implant Design	0.04	170.6	0.21	0.354
	Posterior stabilized vs. cruciate retaining	0.10	394.0	0.32	0.148
	Rotating platform vs. fixed bearing	0.08	-348.5	-0.29	0.195
Implant / Bone Ratios	Surface area implant / bone	0.22	-2925.5	-0.47	**0.028**
	Medial-lateral length implant / bone	0.20	-3489.7	-0.44	**0.039**
	Proximal-distal length implant / bone	0.34	-3192.2	-0.59	**0.004**
Bone microarchitecture	Bone volume fraction	0.35	2435.8	0.59	**0.004**
	Volumetric bone mineral density	0.03	3.6	0.18	0.421

Table 2. Multivariable analysis of clinical and radiographic factors associated with load to shear failure using a backward stepwise regression model ($R^2=0.848$)

Variable	Beta	Standard Error	Standardized Beta	P-value
(Constant)	2601.01	1036.89		**0.023**
BMI (kg/m^2)	-81.79	26.85	-0.40	**0.008**
Length of implantation (years)	-67.58	12.66	-0.55	**<0.001**
Implant integration (MRI)	206.75	69.28	0.30	**0.009**
Surface area implant / bone	-1885.06	622.74	-0.30	**0.008**
Bone volume fraction	2614.77	529.94	0.64	**<0.001**