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TRAUMA SURGERY

Lateral rim variable angle locked plating versus tension band wiring of simple and complex patella fractures: a biomechanical study

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Abstract

Introduction Treatment of both simple and complex patella fractures is a challenging clinical problem. Although tension band wiring has been the standard of care, it can be associated with high complication rates. The aim of this study was to investigate the biomechanical performance of recently developed lateral rim variable angle locking plates versus tension band wiring used for fixation of simple and complex patella fractures.

Materials and methods Sixteen pairs of human anatomical knees were used to simulate either two-part transverse simple AO/OTA 34-C1 or five-part complex AO/OTA 34-C3 patella fractures by means of osteotomies, with each fracture model created in eight pairs. The complex fracture pattern was characterized by a medial and a lateral proximal fragment, together with an inferomedial, an inferolateral, and an inferior (central distal) fragment mimicking comminution around the distal patellar pole. The specimens with simple fractures were pairwise assigned for fixation with either tension band wiring through two parallel cannulated screws or a lateral rim variable angle locking plate. The knees with complex fractures were pairwise treated with either tension band wiring through two parallel cannulated screws plus circumferential cerclage wiring or a lateral rim variable angle locking plate.

Each specimen was tested over 5000 cycles by pulling on the quadriceps tendon, simulating active knee extension and passive knee flexion within the range of 90° flexion to full extension. Interfragmentary movements were captured via motion tracking.

Results For both fracture types, the articular displacements measured between the proximal and distal fragments at the central patella aspect between 1000 and 5000 cycles, together with the relative rotations of these fragments around the mediolateral axis were all significantly smaller following the lateral rim variable angle locked plating compared with tension band wiring, $p \leq 0.01$.

Conclusions From a biomechanical perspective, lateral rim variable angle locked plating of both simple and complex patella fractures provides superior construct stability versus tension band wiring under dynamic loading.

Keywords Simple patella fracture · Complex patella fracture · Lateral rim variable angle locked plating · Tension band wiring · Biomechanics · Motion tracking

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Introduction

Fractures of the patella account for up to 1.5% of all human fractures [37], featuring an increase in their incidence by approximately 40% over the past 70 years [6]. Comminuted patella fractures AO/OTA 34-C3 are the most common fracture type, followed by simple transverse fractures [16]. A combination of a direct trauma on the anterior patella surface with a contracted quadriceps muscle represent the predominant injury mechanism [4]. Surgical treatment is commonly indicated if the extensor mechanism is disrupted, leading to displaced simple or comminuted patella fracture fragments [37]. High patella-femoral joint forces obligate an anatomic reduction and re-establishment of a congruent articular surface to prevent posttraumatic osteoarthritis [5, 25].

Tension band wiring (TBW) is the standard of care for transverse patella fractures, placing either two parallel Kirschner (K-) wires or two cannulated screws perpendicular to the fracture plane, and augmenting the fixation with anterior cerclage wiring around the implants in a figure-of-eight technique [8, 14, 23, 24, 36]. Similarly, surgical fixation of comminuted patella fractures can be achieved via TBW with additional circumferential cerclage wire often used to augment the fixation of the comminuted fragments [4, 15, 20]. Due to inferior outcomes seen with TBW of patella fractures, increased use of locking plates have emerged over the past decade as competing alternatives to the former, believed to provide enhanced maintenance of congruity and neutralization of tensile forces in all their different design modifications [29, 32, 38].

Being a part of the broader Variable Angle (VA) Locking Patella Plating System, recently, Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7 (DePuy Synthes, Zuchwil, Switzerland) was developed for treatment of both simple and comminuted patella fractures (Fig. 1).

The plate is offered in either medical grade stainless steel (316LVM) or commercially pure titanium (cp-Ti) materials and is available in a small 18-hole or a standard 24-hole size versions, with each hole accepting 2.4 mm or 2.7 mm VA locking or cortex screws. The VA locking holes enable a screw angulation up to 15° relative to the nominal axis. The plate development evolved from standard mesh plates used for treatment of forefoot and midfoot fractures, and adapted for specific multiplanar fixation of patella fractures, underlying the concept established by Lorich et al. [19, 34]. This multiplanar fixation is facilitated by various screw hole options to address different patella fracture patterns. One of the prominent characteristic plate features is its lateral rim, allowing for placement of bicortical screws from lateral to medial, superior to inferior, and inferior to superior. Hence, in contrast to most other patella plates for anterior application, this plate is applied on the lateral rim of the patella, necessitating a peripatellar retinacular release. The range of plates addresses different fracture patterns as per approved indication and different patient anatomy. The plates are precontoured to fit to patients' patellar surface, however, their design facilitates further shape optimization with dedicated instruments in terms of cutting, bending, and contouring to meet patient-specific needs. In addition, the windows can used to attach soft tissue with a suture.

The aim of the current study was to investigate the biomechanical performance of the Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7 versus TBW used for fixation of simple and complex patella fractures. It was hypothesized that plating would demonstrate less interfragmentary movements under dynamic loading.

Materials and methods

Specimens and preparation

Sixteen pairs of fresh-frozen (−20 °C) human anatomical knees from seven female and nine male donors (mean age 81 years, range 68–94 years) were used. All donors gave informed consent within the donation of anatomical gift statement during their lifetime. The knees were thawed at room temperature for 24 h prior to preparation and biomechanical testing. Each femur and tibia were transected at 15 cm and 25 cm from the knee joint, respectively.

The patellae of all knees were assessed for bone mineral density (BMD) within their trabecular region via computed tomography (CT) scanning (Revolution EVO, General Electric Healthcare, Buckinghamshire, UK) using a phantom (BDC-6, QRM GmbH, Möhrendorf, Germany) and subsequent image analysis (Amira, v.6.0, Thermo Fisher

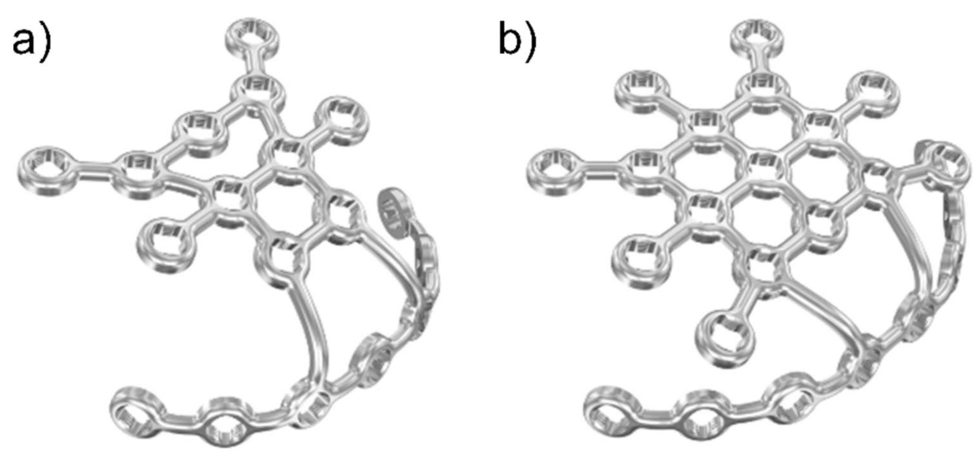

Fig. 1 Small (**a**) and standard (**b**) Variable Angle (VA) Locking Lateral Rim Patella Plate 2.4/2.7 designed for treatment of simple and complex patella fractures and available in medical grade stainless steel and commercially pure titanium

Scientific, Waltham, MA, USA) with segmentation between 150 and 450 mgHA/cm^3.

Based on BMD, the knees were randomized to two clusters consisting of eight pairs each. The specimens in one of the clusters were assigned for creation of a simple two-part transverse patella fracture type AO/OTA 34-C1, whereas the knees in the other cluster were assigned for simulation of a complex comminuted five-part patella fracture type AO/OTA 34-C3. Further, two groups with four right and four left specimens each (n = 8) were created within each cluster by splitting of its pairs. This sample size was calculated based on a priori power analysis for statistical power of 0.8 at a level of significance 0.05 under the assumption that after biomechanical testing the specimens in the simple TBW group would reach a mean fracture displacement of 1.0 mm [31]. Furthermore, it was assumed that a 30% lower displacement in the corresponding plating group would be a clinically meaningful difference, and that a standard deviation (SD) of 75% of this mean difference (effect size: 0.3, SD: 0.225) could be expected deviations. Based on these assumptions, a sample size of 8 specimens would be necessary to reach significant differences between the 2 groups.

Whereas a mid-axial longitudinal approach was applied to open the skin and expose the anterior patella surface for the specimens assigned for TBW, a lateral parapatellar longitudinal incision was performed in preparation of the specimens assigned for plating. In each case, a lateral parapatellar arthrotomy was conducted to allow a direct visualization of the articular surface. A horizontal cutting line was marked centrally after identification of the proximal and distal poles. The fracture creation was adopted from a previous study investigating the biomechanical performance of the complementary anterior patella plates [31], and was performed via osteotomies using custom cutting guides attached on the anterior patella surface (Fig. 2a–b). Each cutting guide was aligned with the corresponding horizontal mark. The simple fracture pattern was set by a single cut through the transverse slot. The complex fracture pattern was characterized with a smaller medial and a larger lateral proximal fragment, together with an inferomedial, an inferolateral and an inferior fragment mimicking comminution around the distal patella pole. The corresponding slots of the cutting guide were designed radially, crossing each other at one central point. All fragments were fully separated from each other during osteotomizing (Fig. 2c–d). The extensor retinaculum was divided in line with each transverse cut. The lateral arthrotomy allowed direct provisional fracture reduction using pointed forceps and temporary K-wires. A smooth articular surface was confirmed by palpatory inspection.

The two paired groups with simple patella fractures were assigned for fixation via either TBW through two parallel cannulated screws or using a standard VA Locking Lateral Rim Patella Plate 2.4/2.7. The TBW procedure started with retrograde insertion of two 1.6 mm K-wires across the fracture gap in parallel manner, followed by their over-drilling using a 3.2 mm cannulated bit. A short-threaded 4.5 mm cannulated screw was inserted over each K-wire in retrograde fashion. The length of each screw was measured individually for each specimen, ensuring that each screw tip remains completely intraosseous. Two sections of a 1.25 mm cerclage wire were inserted through each cannula of the screws, crossed, and positioned in a figure-of-eight fashion.

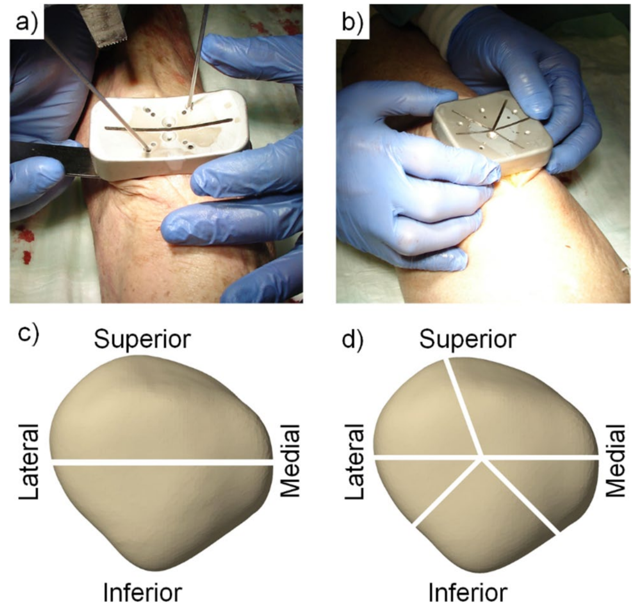

Fig. 2 Photographs of cutting guides positioned on specimens for creation of a simple (**a**) or a complex (**b**) fracture. Schematic views of the simple (**c**) and complex (**d**) fracture models [31]

The lateral rim plating of the simple fractures started with selection of the plate size individually for a best-possible match to the specimen's patella. The next step comprised plate positioning and rim contouring, such that the rim of the plate was beneath the patellar ligament and the quadriceps tendon in a way that the plate did not interfere with the articular surface. Provisional attachment was performed with compression K-wires. Definitive plate fixation by means of 2.7 mm VA locking screws was performed first on the rim section, occupying up to seven of its holes with screws directed across the fracture plane and fixed in bicortical manner. Subsequently, the anterior body of the plate was fixed with four monocortical screws in anterior–posterior direction, with each two screws fixing the proximal and distal fragment. Prior to screw insertion, pilot holes were pre-drilled with 2.0 mm drill bits using VA drill guides, allowing to set appropriate drill hole direction with a maximum deviation from the nominal axis of the plate hole up to 15°. The screws were then inserted and locked at 1.2 Nm.

The other two paired groups with complex fractures were assigned for fixation with either TBW through two parallel cannulated screws plus circumferential cerclage wiring or a standard VA Locking Lateral Rim Patella Plate 2.4/2.7—the same as used for the simple patella fracture.

The TBW of the complex fractures resembled the one applied for transverse fractures. Care was taken that all fragments were traversed by the screw trajectories. An additional 1.25 mm cerclage wire was circumferentially placed around the patellar rim.

The lateral rim plating of the complex fractures commenced with placement and orientation of the plate, conducted as needed to best stabilize the fragments based on specimen's anatomy. Care was taken for each fragment (1) to receive a screw through at least one of the rim holes, and (2) to be stabilized with at least two screws. Pilot hole drilling and screw placement was performed as with the rim plating of simple fractures.

All used implants were made of stainless steel (316LVM) and provided by the same manufacturer (DePuy Synthes, Zuchwil, Switzerland). Two experienced surgeons performed all instrumentations under fluoroscopic control (Fig. 3) by adhering to the corresponding technical prescriptions [1, 21], ensuring thereby consistency of the procedures. Skin and subcutaneous tissue were completely excised after instrumentation.

The fibula and all surrounding muscles were removed, with exception of the extensor mechanism, ligaments and knee joint capsule that were preserved. A closure of the lateral arthrotomy was performed with a heavy suture approximating the tensor fascia lata and the lateral retinaculum. The proximal 6 cm of the femur and the distal 6 cm of the tibia were embedded in a polymethylmethacrylate (PMMA, Suter Kunststoffe AG, Fraubrunnen, Switzerland) socket. A threaded steel rod was secured in the intramedullary canal of the tibia during embedding, allowing attachment of a 3.1 kg disc at a distance of 25 cm from the knee joint to mimic lower limb weight [5, 25, 27, 33]. Retro-reflective marker sets were attached to the tibia, as well as either to the proximal and distal patella fragments in case of a simple fracture, or to the medial proximal and central distal fragments in case of a complex fracture for motion tracking.

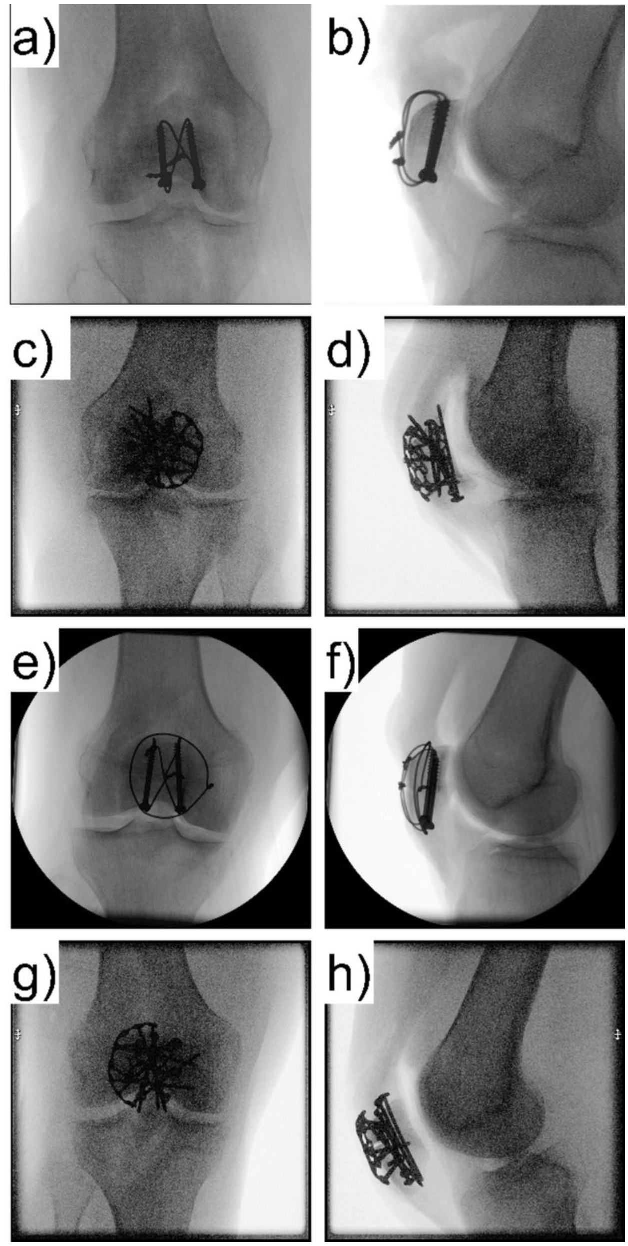

Fig. 3 Exemplified medio-lateral (**a**, **c**,**e**, **g**) and antero-posterior (**b**, **d**, **f**, **h**) radiographs of specimens with simple (**a–d**) and complex (**e–h**) fractures treated by TBW (**a**, **b**, **e**, **f**) or lateral rim VA locked plating (**c**, **d**, **g** **h**)

Biomechanical testing

Biomechanical testing was performed on a servo-hydraulic material testing machine (Bionix 858.20, MTS Systems Corp., Eden Prairie, MN, USA)—equipped with a 5 kN load cell (MCS10-005, HBM, Darmstadt, Germany)—adopting a test setup and a loading protocol from previous studies (Fig. 4) [15, 22, 31]. The proximal part of each femur was mounted horizontally on the machine base. Pulling force was transmitted to the quadriceps tendon via a steel cable directed via a pulley to the machine actuator.

Each specimen underwent cyclic loading at 1/6 Hz over 5000 cycles mimicking knee movements of a sitting patient between 90° flexion and full knee extension. Starting from a preload of 20 N with the knee flexed at 90°, the quadriceps tendon was pulled during each cycle until full knee extension and then returned to 90° flexion, applying a bell-shaped loading profile with 300 N peak tensile force.

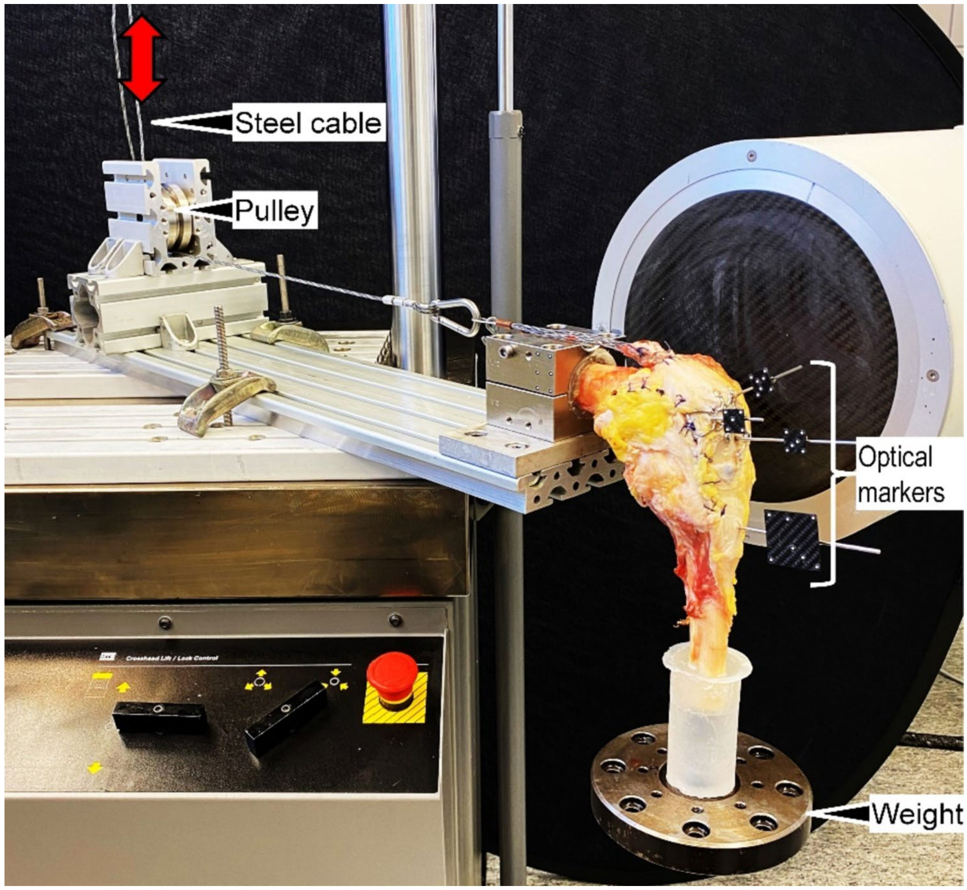

Fig. 4 Setup with a specimen implanted with a standard Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7, equipped with markers for motion tracking and mounted for biomechanical testing. Vertical double-arrow indicates movement direction of the machine transducer

Following cyclic loading, each specimen was tested to failure. Whereas the knee was constrained to 90° flexion, quasistatic tension was applied at 50 N/s.

Data acquisition and analysis

Machine data in terms of actuator displacement and pulling force were collected from the test system controllers at 128 Hz. In addition, two optical cameras (Aramis SRX, GOM GmbH, Braunschweig, Germany) continuously recorded the marker positions for motion tracking, operating at resolution of 12 megapixel and a maximum acceptance error of 0.004–0.02 mm [26]. Interfragmentary movements were evaluated at the initial stage after 50 loading cycles and then after 1000, 2000, 3000, 4000 and 5000 cycles with respect to the beginning of the test as follows. The magnitude of the fracture site displacement—defined as Displacement—was calculated at the most articular margin of the horizontal osteotomy plane located centrally in medio-lateral direction. For that purpose, the location of the articular margin was registered prior to test start by using a touch probe and assigned virtually in a rigid-body constellation (1) once to the proximal and once to the distal fragment in case of a simple fracture, or (2) once to the medial proximal and once to the central distal fragment in case of a complex fracture. Based on this, the magnitude of the relative displacement between these two virtually registered margins was calculated. Further, interfragmentary rotation around the mediolateral axis—defined as Rotation—was evaluated. Both metrics were derived at 90° knee flexion and calculated between the proximal and distal fragments for simple fractures, and between the medial proximal and central distal fragments for complex fractures.

Machine data acquired during the load to failure tests were considered for evaluation of construct stiffness within the load range 500 N – 1000 N, which was found to be linear in each specimen, and peak force. Failure modes were documented by means of photography and radiography.

Statistical analysis was performed using SPSS software package (IBM SPSS Statistics 27, IBM, Armonk, NY, USA). Normality of data distribution within each fracture model and fixation technique was screened and proved with Shapiro–Wilk test. One-Way Analysis of Variance (ANOVA) was applied to confirm appropriate randomization of the specimens based on BMD. Paired-Samples T-test and General Linear Model Repeated Measures test were applied for each separate cluster of specimens to identify significant differences between the corresponding fixation techniques. Level of significance was set to 0.05 for all statistical tests.

Results

BMD (mgHA/cm^3) was 282.4 ± 116.2 (mean ± standard deviation, SD) for lateral rim plating and 283.7 ± 119.6 for TBW in the cluster of specimens with a simple fracture, and 210.0 ± 71.9 for lateral rim plating and 219.4 ± 81.5 for TBW in the cluster of specimens with a complex fracture, demonstrating a homogeneous distribution within each cluster ($p \geq 0.771$).

The results for the two outcomes characterizing interfragmentary movements after 50 loading cycles and summarized in Table 1, featuring lateral rim plating as having significantly smaller Rotation versus TBW for both fracture types ($p \leq 0.028$), with no further significant differences between the paired groups ($p \geq 0.122$).

Table 1 Outcomes after 50 loading cycles for each separate fixation technique (lateral rim plating (Plate) or TBW) and fracture model (simple or complex fracture) presented in terms of mean value and standard deviation, together with the corresponding p-values from the statistical comparisons between the paired groups

Outcome	Plate	TBW	P-value
Simple fracture			
Displacement (mm)	0.012 (0.011)	0.153 (0.141)	0.381
Rotation (°)	0.072 (0.060)	0.524 (0.402)	0.003
Complex fracture			
Displacement (mm)	0.022 (0.016)	0.174 (0.161)	0.122
Rotation (°)	0.078 (0.052)	1.238 (0.793)	0.028

For each separate fracture type, the outcome measures for both investigated metrics evaluated after 1000, 2000, 3000, 4000, and 5000 loading cycles, were significantly smaller following lateral rim plating versus TBW ($p \leq 0.010$, Fig. 5, Table 2).

For both fracture types, plating was associated with a significant increase of both outcome measures over time ($p \leq 0.017$). In contrast, the outcome measures for TBW increased significantly only for Rotation within the simple fracture type, and for Displacement within the complex fracture type ($p \leq 0.024$), whereas they remained comparable for Displacement within the simple fracture and Rotation within the complex fracture type ($p \geq 0.094$).

All cyclic tests were completed without catastrophic implant failure in any of the specimens (Fig. 6).

The failure modes from the load to failure tests were proximal fragment cutout in 1 specimen treated with lateral rim plating within the simple fracture cluster, and in each 4 specimens treated with lateral rim plating and TBW within the complex fracture. Furthermore, distal fragment cutout was detected in 1 specimen treated with TBW within the simple fracture cluster, and in each 1 specimen treated with lateral rim plating and TBW within the complex fracture cluster (Fig. 7). In all other specimens the failure was characterized by pullout of the Chinese finger traps off the

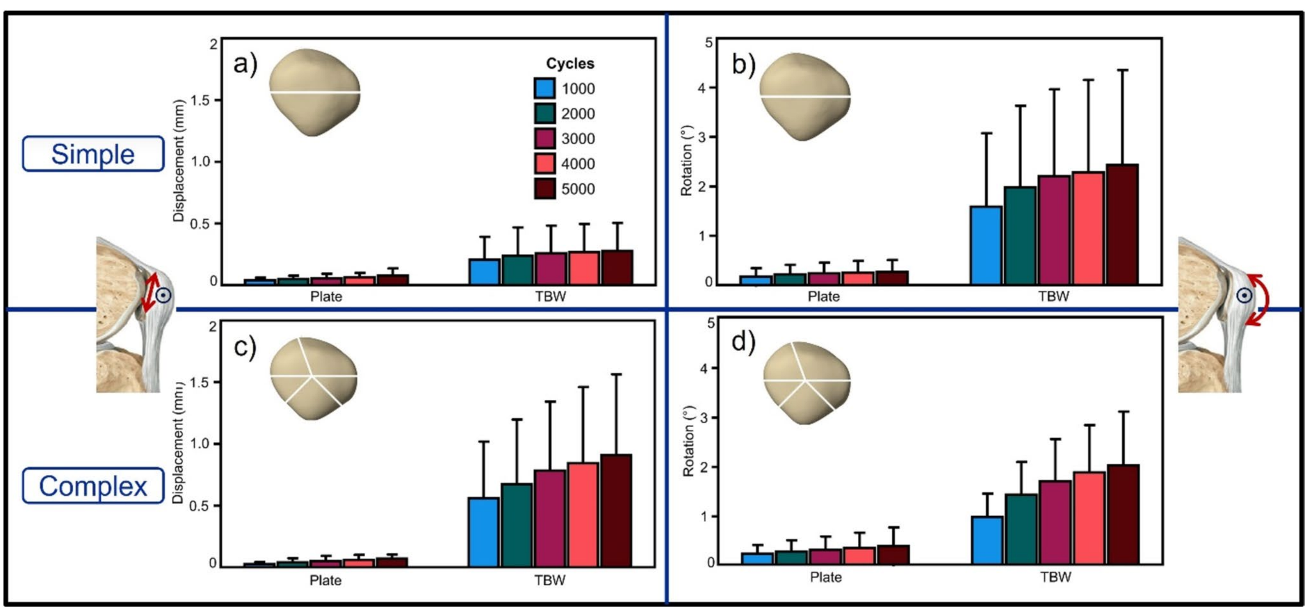

Fig. 5 Articular displacement at the central articular aspect of the patella (Displacement, **a**, **c**), and interfragmentary rotation around the mediolateral axis (Rotation, **b**, **d**) in terms of mean value and standard deviation, measured between the corresponding proximal and distal patella fragments after 1000, 2000, 3000, 4000 and 5000 test cycles and featuring simple (**a**, **b**) and complex (**c**, **d**) fractures fixed by either Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7 (Plate) or TBW

Table 2 P-values (1) for outcomes' progressions over time after 1000, 2000, 3000, 4000, and 5000 loading cycles (Increase over cycles) considering each separate fixation technique (Plate or TBW), (2) from outcomes' comparisons between fixation techniques (Plate versus TBW), and (3) for the effect of BMD on the outcome measures for each separate fixation technique (Plate or TBW)

Outcome	Increase over cycles		Plate versus TBW	Effect of BMD	
	Plate	TBW		Plate	TBW
Simple fracture					
Displacement	0.017	0.094	0.008	0.839	0.217
Rotation	0.015	0.019	0.010	0.095	0.244
Complex fracture					
Displacement	0.002	0.024	0.003	0.646	0.127
Rotation	0.003	0.107	0.009	0.665	0.420

All values are presented separately for simple and complex fractures

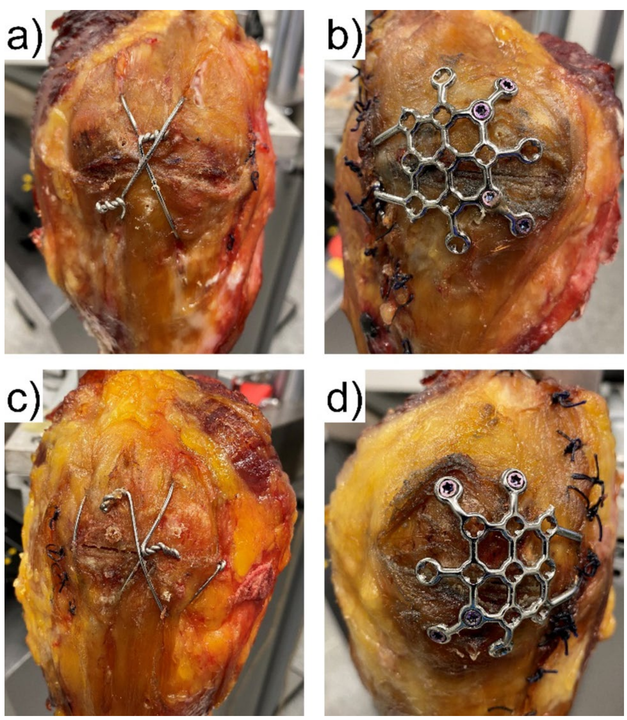

Fig. 6 Exemplified post-test photographs of specimens with simple (**a**, **b**) or complex (**c**, **d**) fractures treated by TBW (**a**, **c**) or Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7 (**b**, **d**)

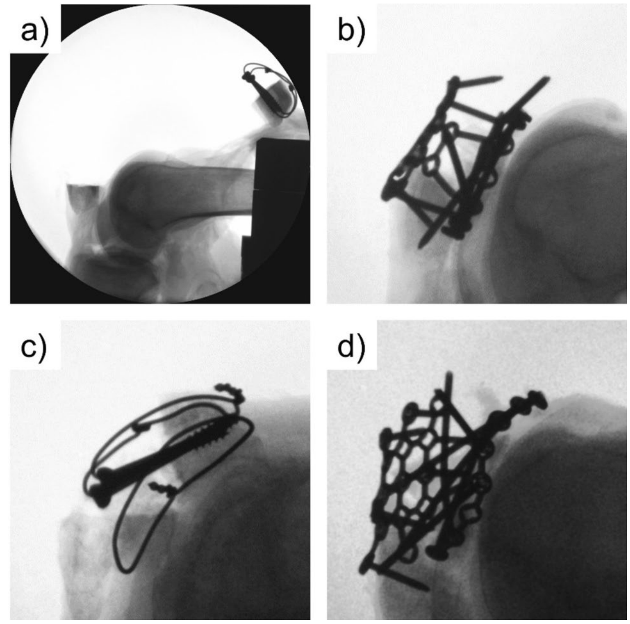

Fig. 7 Exemplified post load to failure test mediolateral radiographs of specimens with simple (**a**, **b**) or complex (**c**, **d**) fractures treated by TBW (**a**, **c**) or Variable Angle Locking Lateral Rim Patella Plate 2.4/2.7 (**b**, **d**)

quadriceps tendon fixation. Mean construct stiffness evaluated from the load to failure test was 83.8 ± 11.5 N/mm for lateral rim plating and 76.8 ± 10.0 N/mm for TBW in the cluster of specimens with a simple fracture, and 80.7 ± 12.8 N/mm for lateral rim plating and 62.9 ± 21.0 N/mm for TBW in the cluster of specimens with a complex fracture, demonstrating significantly higher values for lateral rim plating versus TBW in the latter cluster, p=0.045, and no significant differences between the groups in the former cluster, p=0.414. Mean peak force at catastrophic failure was 1803.7 ± 0 N (only 1 specimen reached catastrophic failure in the bone-implant construct) for lateral rim plating and 1816.5 ± 596.1 N for TBW in the cluster of specimens with a simple fracture, and 1562.0 ± 457.5 N for lateral rim plating and 1182.6 ± 138.2 N for TBW in the cluster of specimens with a complex fracture, with no significant differences between the two groups in each cluster, p ≥ 0.175.

Discussion

The current biomechanical study demonstrated significantly less motion in the transverse fracture gap following plating using a novel VA Locking Lateral Rim Patella Plate versus TBW in a human anatomical model with simple and complex patella fractures. These findings highlight the advantage of the static plate stabilizing system using locking screw technology over the dynamic fixation technique of TBW. The plate design with a rim and an anterior section provides the ability to capture the fragments with screws from different directions, achieving multiplanar stability. These biomechanical results are consistent with clinical findings demonstrating improved function outcomes using a lateral rim plate compared to TBW [18].

The higher construct rigidity following rim plating under dynamic loading is attributed to a higher resistance against pulling forces generated by the quadriceps tendon, i.e., shear and bending forces acting on the screws are minimized by the rigid plate via the VA locking screw technology. On the other hand, the TBW constructs have several inferior aspects, including only two screws acting against pulling and bending moments, the risk of unwinding of the cerclage wire, and a possible imperfect positioning of the wires by interposed soft tissue [7]. However, as reflected by the results, these disadvantages can be minimized by accurate application of the TBW technique, which requires appropriate experience and skills. In the present study, none of the TBW constructs exceeded the clinically important threshold of 2 mm fragment displacement at the articular fracture site, despite applying a relatively aggressive loading protocol. These results support the continued use of TBW in all its modifications, even for difficult patella fractures with comminution [2, 9, 10, 13, 41–43]. However, the increased fracture motion demonstrated in this study may explain the poor mid-term functional results seen clinically following TBW [12, 17, 30, 37, 39].

The advantages of patella plating over TBW have repeatedly been demonstrated both clinically and experimentally [15, 28, 31, 33, 35, 38, 40]. Although biomechanical studies investigating complex patella fractures are not common, more recent studies have begun to investigate this clinical entity. Two most recent studies addressed comminuted patella fractures, and each one compared a different anterior patella plate design against TBW through cannulated screws plus anterior cerclage wiring in a biomechanical model comparable to the current one [31, 35]. Whereas in the study performed by Stoffel et al. [31], the authors additionally applied circumferential cerclage wiring for the comminuted fracture types and loaded the knees over 5000 cycles, this additional cerclage was omitted in the other study, and each specimen was tested for primary stability over only 100 cycles [35]. However, both studies demonstrated significantly less interfragmentary movements after plating compared to TBW, which agrees with the results presented here.

In contrast to anterior plates, our study investigated lateral rim plates, which were developed with the introduction of multiplanar fixation by means of lateral mesh plating [19]. To the best of our knowledge, the lateral rim plate in its most recent design version has never been biomechanically investigated. Kfuri et al. [15] assessed the biomechanical competence of the lateral mesh plating technique in a comminuted patella fracture model featuring a coronal split in the distal patella region, in comparison to TBW using K-wires and anterior mesh plating, to report superior performance of the latter. In contrast, the findings from the current study indicate comparable stability achieved with the lateral rim plate versus anterior variable-angle locked plating biomechanically tested in previous work using the same simple and complex anatomical fracture models [31]. In both these investigations, the magnitudes of the displacements at the central articular patella aspect and the interfragmentary rotational movements around the medio-lateral axis remained below 0.2 mm and 1° for both fracture patterns, respectively. In addition, both plating techniques demonstrated superior performance versus TBW with cannulated screws.

One of the most challenging aspects in comminuted patella fractures is to address the often-present inferior pole comminution, which becomes more difficult with decreasing fragment size [45]. Worth noticing in this regard is the fact that the rim section, arch-shaped over a span of almost 180°, together with the VA technology and the plate malleability, allows reaching all aspects of the patella lying within the area being not only enclosed by the rim, but which are also located on the medial patella site.

One disadvantage of the lateral rim plating technique may be the extensive use of hardware and the associated increased costs in comparison to TBW, especially if the latter applies K-wires instead of cannulated screws. However, this may be overcompensated considering the less re-operation or hardware removal rates as well as improved performance biomechanically and clinically.

Interfragmentary compression is of utmost importance for primary bone healing, preventing shear and out-of-plane bending movements. In this regard, TBW was shown in a previous study to maintain initially applied compression over different knee flexion angles, implying to be a rather static, but still effective fixation technique [44]. Because of this, TBW does not necessarily always work as in theory, i.e., during extension there are pulling forces at the articular patella site, too. Besides this, if TBW is not performed perfectly, there is a chance of gapping at the fracture site after just several cycles of loading. On the other hand, constructs fixed with locking screws have demonstrated to lose interfragmentary compression following reduction clamp removal [3]. Indeed, stability of plated constructs could probably have been enhanced by previous fragment fixation with lag screws. However, the results of this study indicate that plate fixation even without previous lag screw fixation outperformed TBW. This can be attributed multiplanar fixation combined with bicortical screw fixation in coronal plane. Locked plating with use of bicortical locking screws enhances the fixation stability compared to monocortical screw fixation because of increased working length, which is especially helpful in poor bone quality [11].

This study has some limitations inherent to all human anatomical investigations using a limited number of specimens. Moreover, within the knee specimens with comminuted fractures not all fragments could be monitored via motion tracking due to setup-related technical reasons. In this regard, the quality of anatomical reduction not only plays a crucial role for prevention of posttraumatic arthritis, but also significantly contributes also to biomechanical stability by determining the contact area and contact pressure of the reduced fragments. However, such a pressure measurement was not assessed in this study because it would require insertion of an electronic foil between the fragments influencing the stability of fixation. Nevertheless, the most important anticipated relative movements were identified and accordingly tracked. Next, and inherent with the used comminuted fracture model, all distal fragments could be addressed with the plate screws, which may not be the case for other types of comminuted fractures. Therefore, an anatomical study applying different fracture models may assess the universality of the current plate design.

Methodological strengths of this study include the use of an accurate motion tracking system, allowing precise investigation of interfragmentary movements. Moreover, the statistical power deemed high enough as significant differences between the groups were demonstrated for the most relevant parameters. Finally, a matched paired design was used for each fracture model, ensuring comparable conditions between the tested fixation techniques.

Deeper analysis and follow-up studies are needed to determine how the study's findings will impact clinical applications. More specifically, future studies should focus on the biomechanical and clinical comparisons between the different plating systems available on the market to assess their various strengths and weaknesses. Such comparisons will be critical for further implant design optimizations.

In conclusion, from biomechanical perspective, plating of both simple and complex patella fractures with a VA Locking Lateral Rim Patella Plate provides superior construct stability versus tension band wiring under dynamic loading. This finding is consistent with the improved clinical outcome observed when using this plate design compared to TBW.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00402-024-05266-w.

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Declarations

Conflicts of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval All donors gave their informed consent inherent within the donation of the anatomical gift statement during their lifetime. Therefore, no local or national ethical approval was necessary. This study was performed in accordance with the Declaration of Helsinki.

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