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Original Research

Preclinical Cyclic Testing of Adjunctive Fixation of the Humeral Epicondyle in a Lateral Condylar Fracture Model: Ex Vivo Comparison of a Locking Plate versus a Light-curable Composite

Robert Quinn[1], Odd V. Höglund[2], Daniel J. Hutchinson[3], Lorenzo Papini[4], Amene Tesfaye Ayane[3,4], Lola Opande[4], Erica Molenberg[4], Peter Schwarzenberg[5], Crhystian Torres Rodriguez[2], Michael Malkoch[3,4]

Affiliation addresses are listed at the end of the article.

ABSTRACT

Objective To compare the mechanical performance under cyclic loading of a biocompatible light-curable composite formed from two traizine-trione resin monomers and hydroxyapatite construct (AdhFix) against a standard locking plate used as adjunctive epicondylar stabilization in a simulated lateral condylar humeral fracture model.

Study Design Cadaveric biomechanical assessment.

Materials and Methods Paired canine cadaver humeri were used to simulate lateral condylar humeral fractures. All constructs were stabilized with a transcondylar 4.5 mm cortical screw placed in lag fashion. Adjunctive fixation was then applied in a within-cadaver comparison: One humerus received a light-curable composite construct incorporating 2.7 mm cortical screws, while the contralateral humerus received a 2.7 mm locking plate. Specimens were subjected to 95,000 cycles of axial compressive loading between 20 and 130 N. Groups were compared for displacement and construct dynamic stiffness ($p < 0.05$). Terminal monotonic testing was then performed until failure.

Results There was no mechanical failure in either group during cyclic testing. There were no statistically significant differences between groups in construct dynamic stiffness, displacement, or yield point in terminal monotonic testing.

Conclusion Cyclic testing support the use of AdhFix as adjunctive fixation in humeral condylar fractures.

Keywords condylar fracture, adjunctive fixation, composite fixators, mechanical testing

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Correspondence Michael Malkoch, PhD, Department of Fibre and Polymer Technology, KTH Royal Institute of Technology School of Engineering Sciences in Chemistry Biotechnology and Health, Teknikringen 56-58, 114 28, Stockholm, Sweden, Email: malkoch@kth.se

Introduction

Humeral condylar fractures are frequently encountered in veterinary surgery, with cocker spaniels and French bulldogs being most often affected.[1] Within this group of fractures, condylar fractures affecting the lateral part of the humeral condyle are the most common.[2]

Numerous methods for stabilizing these fractures have been described.[3–7] Contouring to the lateral aspect of the humeral condyle can be challenging due to the topography of the region and the need to avoid violation of the articular surface as well as the supratrochlear foramen. To address this, multiple manufacturers have released anatomical plates designed to fit the region.[8–10] To the authors' knowledge, none of these anatomical plates have been biomechanically compared with the standard implants used for adjunctive fixation, which have previously been reported. A recent publication comparing similarly designed straight locking plate constructs from different manufacturers in a fracture gap model showed a significant difference in the biomechanical properties of the seemingly identical plate–screw constructs.[11] The accompanying editorial highlighted the lack of regulatory process in veterinary implants with regards to all aspects of surgical implants, from material used to design and biomechanical properties.[12] In the absence of a regulatory process, the conscientious surgeon must rely on data published on implant mechanics; however, this is often absent at the time of products going to market.

Light-curable composite materials present a new opportunity for stabilizing fractures in both the human and veterinary clinical setting. The AdhFix concept uses high-energy visible light to cure the material and create a customized composite fixation that can fit any anatomical site or fracture configuration.[13] The use of composite material for adjunctive fixation of lateral condylar humeral fracture models has been previously compared with Kirschner wire (K-wire) fixation and reconstruction plate fixation in single load to failure test.[14] These implants were selected for comparison as they had already been tested against each other biomechanically as methods of adjunctive fixation, providing a baseline to compare with AdhFix.[15] The initial monotonic loading AdhFix study revealed the composite fixation to be mechanically superior to K-wire fixation and comparable to that of plate fixation.[14] While single load to failure testing is useful in assessing one aspect of biomechanical performance, cyclic testing is more relevant to the in vivo conditions of fractures in clinical patients.

This ex vivo study aimed to assess and compare performance at cyclic loading of adjunct epicondylar fixation with a light-curable composite material (AdhFix) secured around bone screws with that provided by a locking bone plate and screws in a lateral humeral condylar fracture model.

Materials and Methods

Bone Model

Paired canine cadaver humeri, from subjects weighing 7.9 to 22.0 kg, were used in this study; the complete list of cadaver weights is found in **Supplementary Table S1** (available in the online version only) in the Supporting Information. Ethical approval for use of cadavers was obtained from the Uppsala Animal Ethics Committee (Protocol number 04682–2020 and 12184–2023). Cadavers, donated to the Swedish University of Agricultural Sciences for teaching and research purposes, were obtained with the owners' written consent.

Specimen Preparation

Specimen preparation was analogous to that previously reported.[14] In brief, paired humeri were harvested from skeletally mature dogs euthanized for reasons unrelated to the study, and the distal 120 mm of each humerus was cleaned of soft tissues by dissection. The humeri were transected through the diaphysis in the transverse plane with a sagittal saw, 120 mm from the distal end. In cases where the humeral head remained partially intact, it was trimmed to match the width of the humeral diaphysis. To ensure rotational stability within the embedding resin, a 3.2 mm (diameter) central hole was drilled at 1 cm from the cut end, with a second perpendicular hole at 2 cm. The accessible marrow in the proximal end was removed with a curette to maximize stability via resin infill. The humeri were each positioned inside 85 mm diameter polypropylene circular molds, ensuring that the bone was upright in the sagittal and frontal planes, perpendicular to the medial-to-lateral epicondylar axis. A polyester resin (Fiber Fix, Färg-in AB, Kristinehamn, Sweden) with low initial viscosity was then poured into the mold to fill it, creating a base with a depth of approximately 40 mm. Specimens were labeled, wrapped in saline-soaked gauze, double sealed in bags, and placed in a refrigerated room (4 °C) overnight prior to fracture model construction. All specimens were prepared on the same day, and wrapped in saline-soaked gauzes to keep them moist between the individual steps of the construct preparation.

Construct Assembly

All construct preparation steps mimicked closely those previously described[14]; an overview is hereby provided. Detailed assembly procedures are provided in the **Supplementary Material** (available in the online version only).

Left and right humeri of each pair were randomly assigned to a fixation group (AdhFix or Plate). In all specimens, a transcondylar 1.1 mm K-wire was placed, followed by drilling with a 2.5 mm cannulated drill bit, passing from lateral to medial, slightly cranial and distal to the lateral and medial epicondyles. The lateral half of the transcondylar tunnel was overdrilled with a 4.5 mm bit using a drill stop. An insert sleeve was placed and the medial portion drilled with a 3.2 mm bit. After sleeve removal, the medial tunnel was prepared with a 4.5 mm cortical tap.

Fractures were created using an oscillating saw under laser line guidance. To align the humeral condyle and lateral epicondylar crest, a 4.5 × 32 mm overlong transcondylar cortical screw (N2, Portsmouth, UK) was then inserted and tightened to 1.5 Nm with a calibrated torque screwdriver (Felo, Neustadt, Germany). Adjunctive fixation was then applied.

For the plate group specimens, a 6-hole 2.7 mm locking plate (Evolox, N2, Portsmouth, UK) was contoured to the lateral to caudo-lateral aspect of the distal humerus. Plates were positioned with three screws proximal, one empty plate hole directly over, and two screws distal to the lateral epicondylar fracture site. Then 2.7 mm stainless steel locking screws (N2, Portsmouth, UK) were inserted after drilling with a 2.0 mm bit.

For the AdhFix group, a template was used to ensure the same screw was used consistently for spacing of the plate group. Holes were drilled with a 2.0 mm bit, and 2.7 mm stainless steel cortical non-locking screws (N2, Portsmouth, UK) were inserted to approximately 80% of their shaft length.

AdhFix was supplied by Biomedical Bonding AB (Sweden) as kits consisting of two triazine-trione resin components, and a powder containing hydroxyapatite and a photo-initiator. The resin components were mixed using connected luer-lock syringes; then the powder was blended in with a spatula. The final mixture was loaded into an applicator syringe for use.

The AdhFix mixture was applied around the shafts of the screws, which were then tightened to the bone. The mixture was cured with high-energy visible light from a handheld dental lamp (Bluephase 20, Ivoclar Vivadent AG, Liechtenstein) with two 5-second pulses per area. The gap between proximal and distal screws was bridged with the mixture and cured to form a single AdhFix composite patch. Two additional layers, each approximately 1 mm thick, were applied and cured sequentially, covering the screw heads with the final layer. The main steps of the AdhFix fixation procedure are illustrated in **Fig. 1**.

Immediately after assembly, all specimens were wrapped in isotonic saline-soaked gauze and double-sealed in labeled bags. All specimens were then radiographed to assess any bone abnormalities, defects, or pre-existing conditions that could influence their mechanical behavior. All samples were stored at 4 °C until testing. **Fig. 2** shows sample 10R (AdhFix) immediately after assembly (**Fig. 2**A) and its radiograph (**Fig. 2**B), alongside a radiograph of its contralateral humerus; sample 10L (plate) is shown in **Fig. 2**C, and the setup for mechanical testing for sample 10R in **Fig. 2**D.

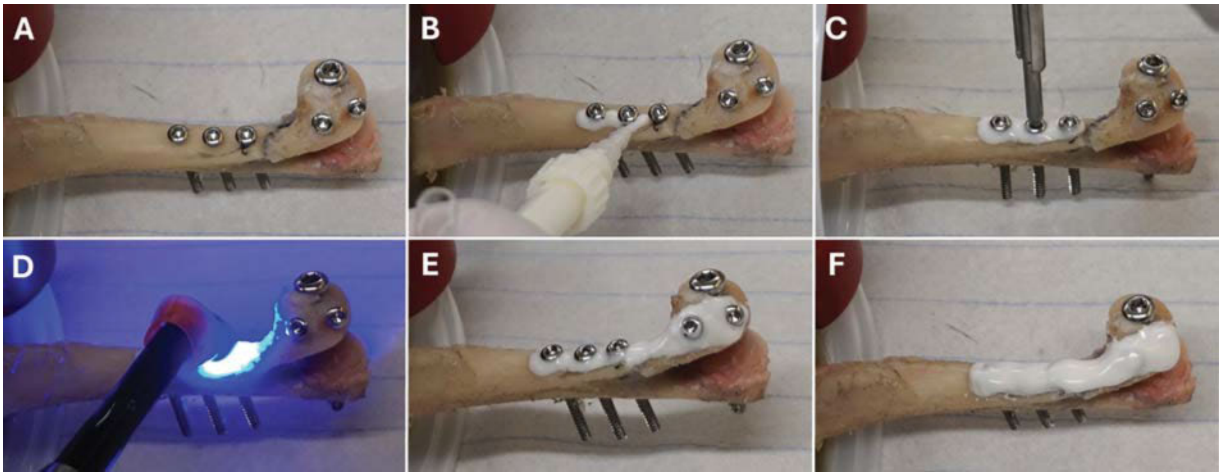

Fig. 1 Images of the steps involved in the AdhFix procedure, sample 8R. (**A**) Screws were inserted till the screw head and one to two screw threads remained exposed. (**B**) Mixture placed around distal screws. (**C**) Screws tightened. (**D**) Mixture cured. (**E**) Steps **B** to **D** repeated on distal side of osteotomy and bridging section. (**F**) Additional layers of composite added and cured.

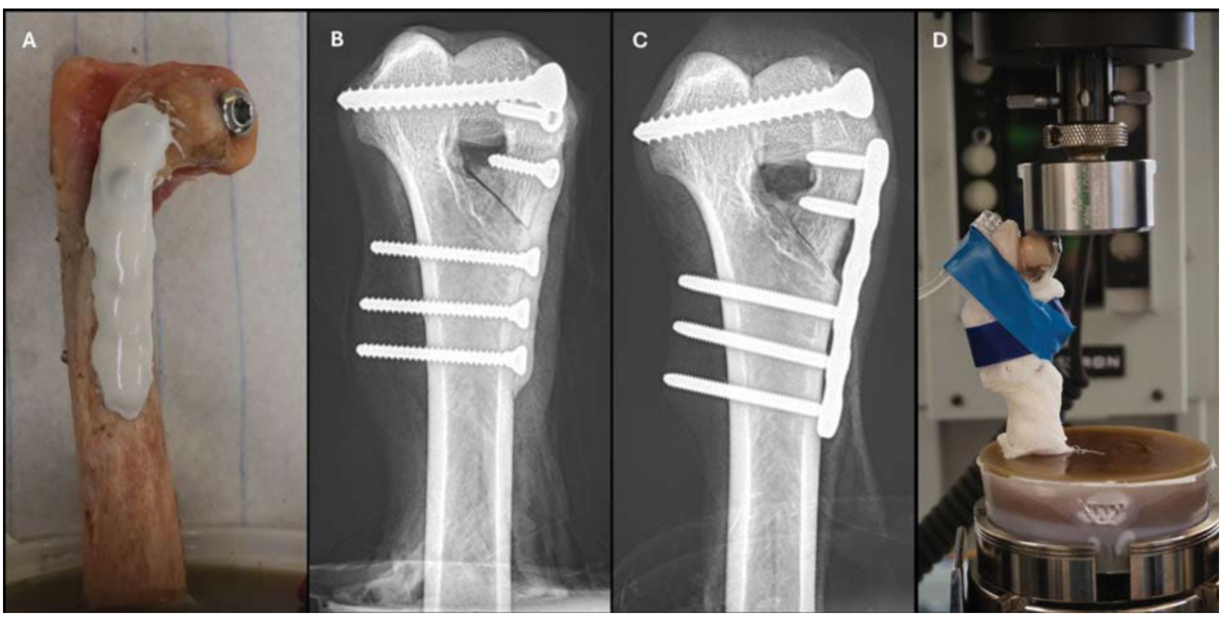

Fig. 2 (**A**) Image of sample 10R (AdhFix). (**B**) Radiograph of sample 10R. (**C**) Radiograph of the contralateral humerus 10L (plate). (**D**) Setup of 10R wrapped in gauze with saline during mechanical testing.

Mechanical Testing

The mechanical performance of the constructs was evaluated using an electromechanical universal testing machine (Instron 5566, Instron LLC, Korea) with a 10 kN load cell in compression mode. The samples were secured to the base plate using a standard chuck and positioned so that the head of the compression plate (50 mm Instron 2501 compression plate) applied a distal to proximal load to the capitulum of the humeral condyle.

A compressive preload was applied at 2.5 mm/min until a load of 1 N was reached. Cyclic compression testing was then automatically initiated at a crosshead speed of 5 mm/min corresponding to an approximate loading frequency of 2 Hz. All samples underwent 95,000 loading cycles between 20 and 130 N. We defined 130 N as the peak force representing 65% of the body weight of a 20 kg dog.[16–18] All samples were subjected to the same loading cycles regardless of the source dog's weight. Monotonic compression testing was performed with a compression rate of 60 mm/min, a preload of 1 N and preload speed of 2.5 mm/min. To prevent desiccation, the specimens were wrapped in saline-soaked gauze and kept moist with an isotonic saline drip system (approximately 2 drops/min). The setup is shown in **Fig. 2D**. Tests were conducted at 20°C and 50% relative humidity.

Data Acquisition and Processing

The performance of each construct was evaluated by its compressive dynamic stiffness and the crosshead's extension and movement throughout the testing cycles. Compressive load and crosshead extension were set to be recorded every 80 milliseconds and 50 N difference, resulting in 10 to 12 data points recorded per loading cycle.

Mechanical testing data were acquired via Bluehill 3 software (version 3.63, Illinois Tool Works Inc.) and processed using Python (v3.11.3). For the cyclic loading data, peaks and valleys were initially identified using SciPy's *find_peaks* function with default settings. An additional step was applied to segment peaks and valleys with a tolerance of ± 7.5 N from the maximum nominal value of 130 N and ± 5 N from the minimum nominal value of 20 N. Valid cycles were further segmented by ensuring a strictly increasing pattern from a valley to a peak, followed by a strictly decreasing pattern from the peak to the subsequent valley. The displacement for each cycle was calculated as the difference between the peak extension and the first valley of the corresponding cycle. Dynamic stiffness was calculated as the slope of the load–displacement curve for each valid cycle, using data points between the first valley and the peak of the cycle. All data (peak extension, displacement, and dynamic stiffness) were smoothed using a moving average over 100 cycles. For each measure, the first quartile, median, third quartile, and maximum values across the valid cycles were extracted to represent different time points through the test. Construct failure was pre-defined as an 80% drop in sustained load, prompting automatic test interruption. Additionally, failure was defined post-test as any visible deformation or damage to the construct, or as visually determined discontinuities in the load–displacement curves.

For the monotonic loading data, construct stiffness was calculated as the slope of the initial linear portion of the load–compression curve. The yield point was calculated using the 0.2% offset method from the load–compression curve.

Statistical Analysis

All statistical tests were performed using R (v4.4.2). All average values are presented as mean ± SD. Pairwise comparisons between the AdhFix and metal plate groups were performed at each quartile time point for each measure using the Wilcoxon signed-rank test, as not all groups passed the Shapiro-Wilk normality test. Repeated measures ANOVA were employed to assess changes within each group over time, with Greenhouse-Geisser correction applied to account for deviations from sphericity. Monotonic testing results were compared using two-tailed paired *t*-test. Statistical significance was assessed applying an α level of 0.05.

Results

Sample Inclusion

A total of 17 paired humeral specimens were harvested; however, only 12 pairs were included in the analysis. Four pairs were excluded due to fracture of the condyle during insertion of the transcondylar screw, and one pair was dismissed after screw stripping prevented completion of the fixation procedure.

All 24 samples survived 95,000 cycles without mechanical failure. No macroscopic damage or deformation was observed in any of the constructs after the last cycle, which was corroborated by the absence of abrupt changes in construct dynamic stiffness or crosshead movement during test sequences.

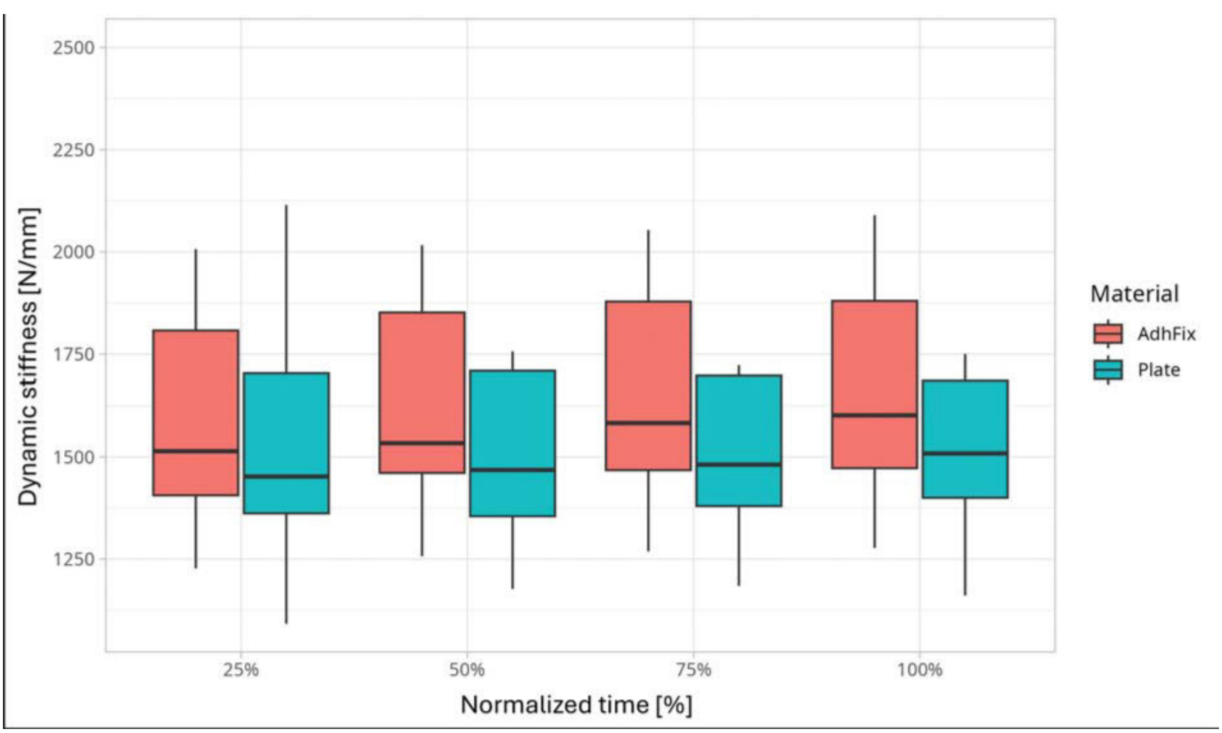

Fig. 3 Box plot of construct dynamic stiffness for AdhFix and plate groups at different time points.

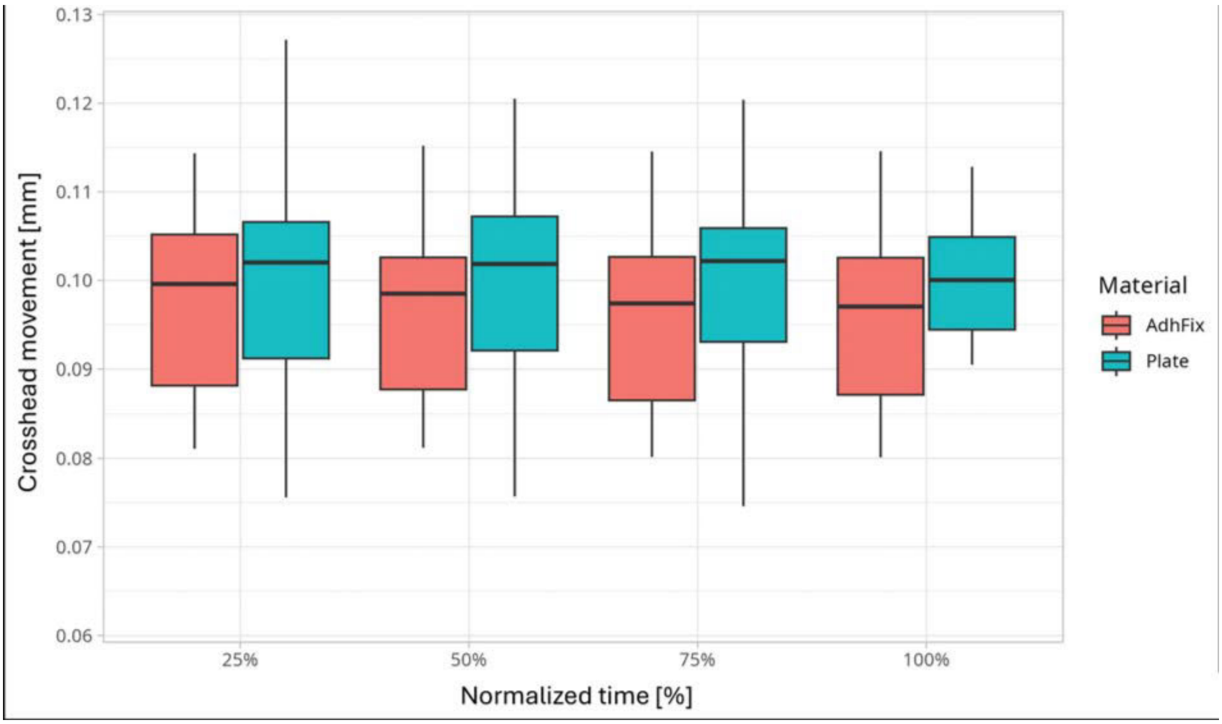

Fig. 4 Box plot of crosshead movement for AdhFix and plate groups at different time points.

Construct Dynamic Stiffness

Construct dynamic stiffness was quantified at four predefined cycle milestones corresponding to 25% (Q1), 50% (Q2), 75% (Q3), and 100% (Q4) of the test duration (**Fig. 3**). Both AdhFix and plate groups demonstrated modest increase in average dynamic stiffness over time: from 1,585 ± 265 N/mm to 1,647 ± 255 N/mm for AdhFix, and from 1,565 ± 369 N/mm to 1,636 ± 422 N/mm for plates. Pairwise Wilcoxon signed-rank tests showed no significant statistical difference between the groups at any point at Q1–Q4 ($p_{Q1} = 0.91$; $p_{Q2} = 0.73$; $p_{Q3} = 0.91$; $p_{Q4} = 0.97$) (**Fig. 3**).

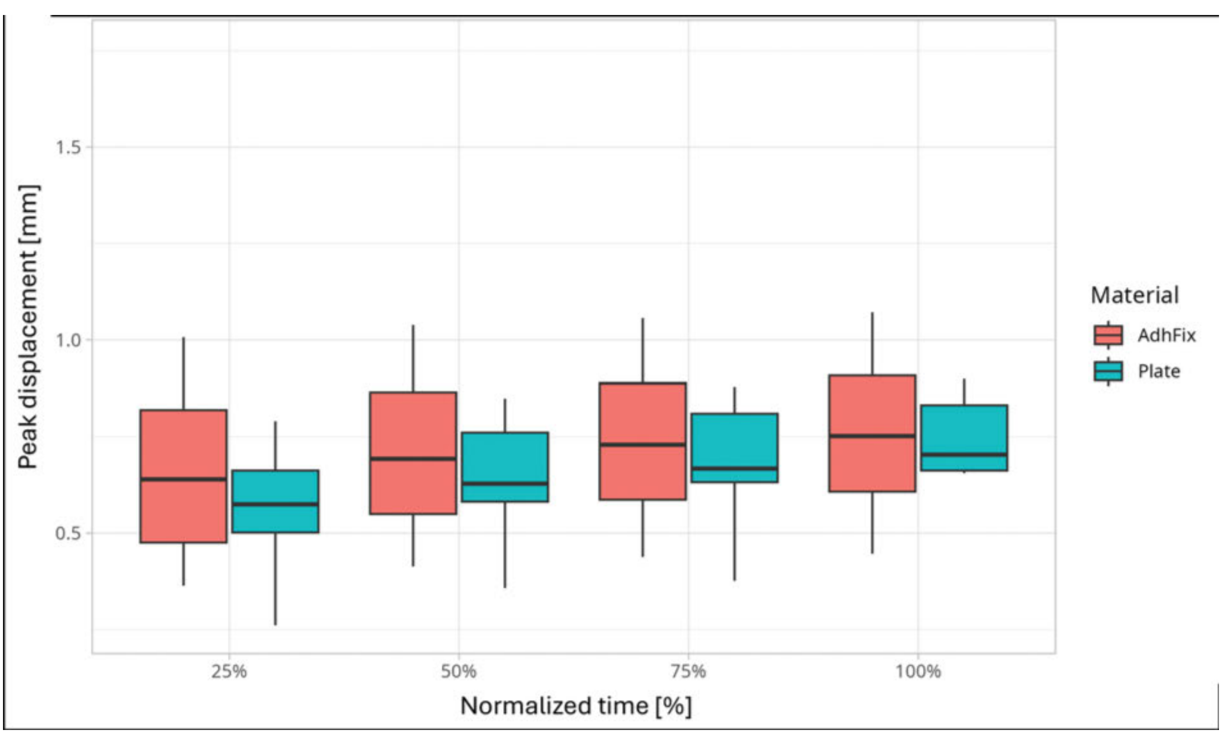

Fig. 5 Box plot of peak displacement for AdhFix and plate groups at different time points.

Crosshead Peak Displacement and Movement

The crosshead movement remained stable across all time points for both construct types (AdhFix: 0.10 ± 0.01 mm; plates: 0.10 ± 0.02 mm). Wilcoxon comparisons found no significant differences between groups at Q1–Q4 ($p_{Q1} = 0.85$; $p_{Q2} = 0.85$; $p_{Q3} = 0.68$; $p_{Q4} = 0.73$) (**Fig. 4**).

Peak crosshead displacement showed slight fluctuations throughout testing. In the AdhFix group, peak displacement varied from 0.71 ± 0.33 at Q1 to 0.81 ± 0.35 mm at Q4. In the plate group, peak displacement ranged from 0.67 ± 36 mm at Q1 to 0.83 ± 0.44 mm across the same periods. Statistical comparisons again indicated no significant intergroup differences at any quartile ($p_{Q1} = 0.79$; $p_{Q2} = 0.68$; $p_{Q3} = 0.57$; $p_{Q4} = 0.52$) (**Fig. 5**).

Monotonic Evaluation

No significant differences were observed between yield load ($p = 0.54$) in the AdhFix group (640 ± 142 N) and the plate group (692 ± 239 N). Similarly, no significant differences were observed for construct stiffness ($p = 0.62$) between the AdhFix group (1,394 ± 299 N/mm) and the plate group (1,444 ± 315 N/mm). A significant difference was found in the maximum load sustained by the constructs ($p = 0.00002$), with the AdhFix group sustaining 1,489 ± 304 N and the plate group 2,431 ± 530 N. Additional data on monotonic testing data can be found in **Supplementary Table S2** (available in the online version only) in the Supporting Information.

Discussion

In general, the majority of new implants brought to the veterinary orthopaedic market undergo little or no published biomechanical studies prior to launch. A common scenario is that new devices are used in clinical cases and then these cases become retrospectively reported, as proof that the implant works as intended.[9] In alignment with the editorial,[12] the authors considered it essential to first generate and publish biomechanical data prior to clinical application of the device. This approach reflects the importance of addressing potential challenges proactively and contributing constructively to the broader discussion within the field. The initial veterinary AdhFix study, published in 2023,[14] compared AdhFix adjunctive fixation to K-wire and plate fixation, using the study design by Coggeshall et al[15] as a baseline. This was a single load to failure study, which showed that AdhFix was superior to K-wire fixation and not significantly different to plate fixation.[14] Single load to failure studies provide useful information on part of the biomechanical data; however, they do not aim to replicate the forces experienced by a fracture during the recovery period. These early encouraging results warranted further investigation of AdhFix.

There are several variables when designing a cyclic testing study that need to be considered. The authors chose to perform 95,000 cycles at approximately 2 Hz based on the study by Castaldo et al,[17] where 63,000 cycles were performed at 2 Hz to mimic 30 minutes of walking exercise a day for 1 month. The typical interval from fracture repair to follow-up radiographs, at the lead author's clinical practice, is 6 weeks and as a result, the number of cycles performed was increased by 50%.

All constructs were tested under the same loading protocol, regardless of cadaver size. This approach was implemented to reduce variation between tested specimens, thereby improving the comparability of AdhFix's mechanical performance to that of locking plate fixation. Humeral condylar fractures most commonly affect Springer Spaniels.[2] The average weight of a Springer Spaniel is 40 to 50 lbs (18–22 kg).[19] Hence, a 20 kg dog was selected as the test model. We chose 130 N as the peak force representing 65% of the body weight of a 20 kg dog to reflect the approximate force applied to a thoracic limb at walking pace, similar to other published studies.[16–18] Specific evidence-based guidelines on the size of plate to use for adjunctive fixation of fractures of the lateral humeral condyle do not currently exist. However, a 2.7 mm locking plate is the implant the lead author would typically use in clinical cases of this size, supported by the retrospective data published by Eayrs et al.[4]

In clinical cases, fracture location on the epicondylar ridge varies and both the articular surface and the supratrochlear foramen need to be avoided when fixating the distal bone stock. The light-curable composite would allow screws to be placed in any position within the bone, allowing fixation of individual fractures to be adjusted based on, and maximizing use of, the available bone stock, while avoiding the articular surface and the supratrochlear foramen. Screw spacing in both groups was standardized by using a template. This measure was taken to prevent any potential unfair advantage in favour of the AdhFix group, as the system allows screws to be placed in any position. An alternative polymeric adjunct fixation such as polymethylmethacrylate was not selected as a comparator group due to the lack of its use clinically, outside of spinal fractures in canine patients. As a result, the authors felt it was more appropriate to compare the composite system to locking plates that are frequently used for the repair of humeral condylar fractures in dogs.

An additional advantage of the composite fixation is that it is not as radiopaque as metal plates, potentially allowing for easier monitoring of radiographic fracture healing, particularly when assessing the lateral view of the humeral condyle, where current laterally applied plates obscure the majority of the epicondylar fracture line.

While there is no published data on the frequency with which specific plates are used for adjunct epicondylar fixation, most of the recent publications on this area have reported the use of a variety of locking plates.[4,9] In addition, anecdotally, most surgeons are using locking plates in this scenario; hence, locking plates were chosen as the comparator for the study. There is evidence of a benefit of adjunctive fixation with an epicondylar plate over a K-wire in both ex vivo and in vivo settings albeit not specifying locking over non-locking plates.[5,15] To the authors' knowledge, the only available mechanical testing data available on fractures in this region involve single load to failure testing of adjunctive non-locking plates.[14,15] There is a single publication on anatomical plate design for the humeral condylar region; however, no mechanical testing of the implant has been published to date.[8] In contrast, there are multiple publications on cyclic testing of locking humeral plating systems designed for humans.[20,21]

No constructs in either group failed cyclic testing in this study. This is consistent with clinical reports where mechanical failure of adjunctive plate fixation is uncommon.[4,5] The absolute value of construct dynamic stiffness showed a significant spread, most likely caused by the inherently variable nature of the constructs' mechanics. The compressive load applied by the crosshead was distributed amongst three components: via the transcondylar screw to the intact lateral epicondyle, via the fixating constructs (AdhFix or plate and screws) to the humeral shaft, and through the fractured surface (if load-sharing reduction is achieved). Any variation of these components, for example, due to a difference in bone size, geometry, calcification, reduction of the fracture, or adaptation of the fixating element, can influence the final constructs' dynamic stiffness. Using paired humeri allowed this variability to be reduced relative to the bone's properties, and create stronger pairwise statistical inferences, which showed no significant difference between the two groups.

Monotonic testing to failure after the cyclic testing was performed to assess whether a significant difference could be detected between the groups as an occasional high peak force may occur during the recovery period as a result of a lapse from the owner or in pet compliance. There was a difference in maximum load; however, there was no difference in yield load. The most important value when assessing an articular fracture model, in a monotonic test, is the yield load as any movement at the articular surface would be deemed a failure. In addition, the forces at failure widely exceeded physiologically relevant loading conditions (AdhFix failing at approximately 1,400 N or 140 kg of force, compared with the plate failure at approximately 2,400 N or 240 kg, which would need to be applied to a single limb).

Limitations of the study also include the in vitro nature of the study. As such, bone healing could not be assessed; however, this was not the purpose of the study. A non-gap fracture model was selected as true gaps in clinically experienced lateral condylar fractures are rare in the lead authors' experience and the investigators wished to test a model as close to a clinical fracture as possible while maintaining as much standardization as possible.

Our results show similar performance under cyclic and subsequent monotonic testing of adjunctive fixation with AdhFix in comparison to a locking plate. AdhFix has undergone extensive biocompatibility studies, satisfying ISO 10993–3 (genotoxicity), 10993–5 (cytotoxicity), 10993–10 (sensitization), 10993–17 (toxicological risk assessment), 10993–18 (chemical characterization), and 10993–23 (skin irritation) compliant assessments in preparation for human clinical trials, including a 12-month in-rat implantation study, reporting no adverse effects nor material degradation.[13] An additional good laboratory practice (GLP) study as per ISO 10993–6 states that AdhFix can be considered a safe and biocompatible composite with good tissue integration. These data, in combination with the previous canine mechanical study and the research performed in rabbit and rat models,[13,22,23] support AdhFix as a viable option for adjunctive fracture fixation in small animals.

Author Affiliations

1 Vita Referrals, Wetherby, Thorp Arch Estate, United Kingdom of Great Britain and Northern Ireland

2 Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Uppsala, Sweden

3 Department of Fibre and Polymer Technology, KTH Royal Institute of Technology School of Engineering Sciences in Chemistry Biotechnology and Health, Stockholm, Sweden

4 Biomedical Bonding AB, Stockholm, Sweden

5 AO Research Institute Davos, Davos, GR, Switzerland

Statements and Additional Information

Conflict of Interest A.T.A. received stipend from Knut och Alice Wallenberg Stiftelse and salary from Biomedical Bonding AB (BMB). D.J.H. received grants from European Union, H2020 grant nr 952150 (BoneFix). E.M., L.O. and L.P. received salary from Biomedical Bonding AB. M.M. received funding from Knut och Alice Wallenberg Stiftelse, European Union (grant nr 952150) and Vinnova (grant nr 2021-04893, 2022-00804) for the academic R&D of the fixation technology, AdhFix. He is also affiliated with Biomedical Bonding AB (BMB). R.Q. declares that Biomedical Bonding AB covered the cost of my travel to, and accommodation in Sweden for the duration of the research project (3 days). No fees or renumeration has been given to R.Q., P.S., O.H. and C.T.R.

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Contributors' Statement R.Q. contributed to conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, w0riting—original draft; O.H. contributed to conceptualization, data curation, formal analysis, resources, writing—review and editing; D.J.H. contributed to data curation, formal analysis, investigation, visualization, writing—review and editing; L.P. contributed to data curation, formal analysis, investigation, methodology, validation, writing—original draft, writing—review and editing; A.T.A. contributed to data curation, formal analysis, investigation, visualization, writing—review and editing; L.O. contributed to data curation, formal analysis; E.M. contributed to data curation, formal analysis, visualization; P.S. contributed to data curation, formal analysis; C.T.R. contributed to data curation, formal analysis, investigation; M.M. contributed to conceptualization, funding acquisition, project administration, resources, supervision, writing—review and editing.

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Supplementary Material is available at https://doi.org/10.1055/a-2926-9519

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Title

Preclinical Cyclic Testing of Adjunctive Fixation of the Humeral Epicondyle in a Lateral Condylar Fracture Model: Ex Vivo Comparison of a Locking Plate Versus a Light-Curable Composite.

Supporting information:

Detailed construct assembly procedure

Left and right humeri of each pair were randomly assigned to a fixation group (AdhFix or Plate). In all humeri, a transcondylar 1.1 mm K-wire was placed, and a 2.5 mm cannulated drill bit was used once appropriate K-wire positioning was achieved, passing from lateral to medial, slightly cranial and distal to the epicondyles. The lateral half of the transcondylar tunnel was then overdrilled with a 4.5 mm drill bit using a drill stop. An insert sleeve was placed into the tunnel, and the medial part of the tunnel was drilled with a 3.2 mm drill bit. The insert sleeve was removed then a thread was tapped, using a 4.5 mm cortical tap, in the medial part of the tunnel.

Fractures were simulated by making a sagittal cut using an oscillating saw at the isthmus extending to the level of the supratrochlear foramen whilst secured in a vice. The bone was then repositioned in the transverse plane, to allow a 140-degree cut from the proximal aspect of the lateral epicondylar ridge to the proximal aspect of the supratrochlear foramen using a protractor and laser line. The laser line was set in the desired position and the sagittal saw blade aligned so that the laser line could be viewed up the length of the edge of the blade to ensure accurate cut position and direction. The 4.5 mm transcondylar cortical screw without a washer (N2, Portsmouth, UK) was then placed and tightened to 1.5 Nm with a calibrated torque limiting screwdriver (Felo, Neustadt, Germany) to align the articular surface of the humeral condyle and cortical bone of the lateral epicondylar crest. Overlong (32 mm) screws were used to ensure that there was full purchase in the trans-cortex. Adjunctive fixation was then applied.

For the specimens in the plate group, a 6-hole, 2.7 mm locking plate (Evolox, N2, Portsmouth, UK) was contoured to the lateral to caudo-lateral aspect of the distal humerus. Plates were positioned so that 3 screws were placed above the epicondylar fracture site, 1 screw hole directly over the fracture site and 2 screws were placed distal to the fracture site. Screw holes were drilled with a 2.0 mm drill bit and measured prior to placement of 2.7 mm stainless steel locking screws.

For the AdhFix group, specimens were prepared as follows. The same screw spacing was used as for the plate specimens, with a template used to ensure the same distance between the screw holes, as well as the same gap over the fracture site, was achieved. Holes were drilled with a 2.0 mm drill bit, measured, and tapped with 2.7 mm stainless steel cortical non-locking screws. The screws were inserted to approximately 80% of their shaft length.

AdhFix was supplied by Biomedical Bonding AB (Sweden) as kits constituted of two resin components, based on 1,3,5-triallyl-1,3,5-triazine-2,4,6(1H,3H,5H)-trione and 1,3,5-tris(3-mercaptopropyl)-1,3,5-triazinane-2,4,6-trione respectively, as well as a powder filler component of hydroxyapatite and a photo-initiator system. First, the resin components were mixed together using luer-lock syringes connected with a straight connector. Then the filler and initiator components were added and blended into the resin using a spatula. The final mixture was placed in an applicator syringe, ready to be used.

The AdhFix mixture was then applied around the shafts of the screws, then tightened onto the bone. The mixture was cured with high energy visible light from a handheld dental lamp (Bluephase 20, Ivoclar Vivadent AG, Liechtenstein), with wavelengths of 385-515 nm (dominant wavelengths of 400 and 470 nm) and an intensity of 2000 $mWcm^{-2}$. Each surface area was cured with two pulses of five second duration. The gap between the proximal and distal screws was then bridged with AdhFix and cured to create a single patch of cured composite around the screws. Two further layers of composite, approximately 1 mm in thickness, were applied and cured sequentially, resulting in the screw heads being covered by the final layer of composite.

Table S1: Specimen cadaver weight

Specimen #	Full body weight (kg)
2	12
3	13
4	16
7	7.9
8	16
10	22
11	17
12	15
13	16
14	15
15	11
17	22

Table S2: Descriptive statistics for monotonic mechanical tests results

Specimen group	Measure	Median	Mean	Range	p-value
AdhFix	Yield load (N)	604	640	505-933	0.54
Plate	Yield load (N)	650	692	396-1284	
AdhFix	Stiffness (N/mm)	1405	1394	850-1809	0.62
Plate	Stiffness (N/mm)	1437	1444	988-2219	
AdhFix	Max load (N)	1546	1489	1046-1906	0.00002
Plate	Max load (N)	2507	2431	1579-3632	