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Kelserra: an algae-inspired bioadhesive for use in minimally invasive surgeries

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Research Article

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Abstract

Current wound closure methods have drawbacks when used in minimally invasive surgery. Traditional sutures are complicated and time-consuming to apply in this context, and synthetic adhesives can be toxic when used internally. The class of bioadhesives address these challenges, however their independent use in practice is limited due to their low tensile strength. In this work, we develop Kelserra, a novel bioadhesive derived from brown algae with maximized tensile strength and biocompatibility to address a current unmet need in the surgical field. Kelserra's uniaxial yield stress peaked at 7.19 ± 0.47 kPa when the formulation contained 50 mg/mL alginate, 5 mg/mL phloroglucinol, 10 mg/mL xanthan gum and 2.09 mg/mL Ca-EDTA and was pre-cured using saturated aqueous gluconic acid for 45 minutes. Kelserra's uniaxial strength was higher than its lap shear strength when pre-cured. Additionally, the type of curing medium (air or PBS) did not significantly influence adhesive strength. This study is intended as a preliminary work inquiring into the possibility of the exploration of internal bioadhesives such as Kelserra, and further validation is required for translational applications. Internal bioadhesives like Kelserra could decrease surgery times, aid in the prevention of postoperative complications and reduce the burden on the healthcare system.

Introduction

Traditional wound closure methods such as sutures, staples and wires remain standard in surgical practice, but have several limitations. Suturing is technically demanding and prolongs operation time while staples and wires may induce tissue trauma, leading to scarring and inflammatory responses (Bal-Ozturk *et al.* 2021). These issues are amplified in minimally invasive surgeries, where intracorporeal suturing can increase surgery time up to 20% and contribute to postoperative complications (Annabi *et al.* 2014; Bal-Ozturk *et al.* 2021; Lim *et al.* 2017; Sanders and Nagatomi 2014). Consequently, there is growing interest in tissue adhesives as a viable alternative. Typically formulated as biocompatible gels, they are easier to apply, reduce operative time and decrease scarring and postoperative complications by rapidly forming a hemostatic barrier at the wound interface (Annabi *et al.* 2014). To validate and contextualize these assumptions, our team informally consulted medical professionals and researchers: the end-users of surgical technologies. These experts corroborated the idea that an adhesive may be faster and easier to apply than sutures, especially in difficult-to-reach areas of the body which decreases surgery time and benefits patient outcomes.

Tissue adhesives are broadly categorized as synthetic or natural, each with distinct trade-offs in adhesive strength, biocompatibility and clinical applicability. Synthetic adhesives – such as cyanoacrylate and polyethylene glycol (PEG) – exhibit strong adhesion and rapid curing (Bhagat and Becker 2017; Toriumi *et al.* 1990). Their adjustable chemical composition enables precise control over desired material properties, but biocompatibility remains a concern. While cyanoacrylate polymerizes rapidly and demonstrates high mechanical strength, the degradation process can be toxic and inflammatory in the case that longer alkyl chains such as *n*-butyl cyanocrylate (NBCA) or cyanide compounds are formed, which in rare cases leads to embolism (Toriumi *et al.* 1990). PEG-based adhesives demonstrate improved biocompatibility but have reduced strength, limiting application in high-load areas (Bhagat and Becker 2017).

Natural tissue adhesives, derived from biological sources, provide superior biocompatibility and biodegradability but have limited tunability, reduced mechanical strength, higher production costs and bear risks of immunogenicity or pathogen transmission as compared to

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synthetic adhesives. For example, fibrin-based sealants sourced from human plasma promote wound healing and reduce immunogenicity but may harbor bloodborne pathogens (Horowitz and Busch 2008). Gelatin-based adhesives exhibit strong tissue integration yet their high cost and inconsistent degradation behavior in aqueous environments limit their surgical applicability (Toriumi *et al.* 1990; Bao *et al.* 2022; Nejati *et al.* 2025). Biomimetic adhesives, a subclass of natural adhesives, mimic adhesion mechanisms observed in natural organisms.

Brown algae-inspired adhesives are an emerging frontier in biomimetic materials, offering a promising new solution for internal wound and incision closure. Alginate, an anionic polysaccharide derived from the cell walls of brown algae, is unique for its biocompatibility, biodegradability and ability to undergo gelation in the presence of divalent cations such as calcium ions, all valuable features in a surgical adhesive (Deng *et al.* 2021). Xanthan gum is another polysaccharide used alongside alginate to improve the glue's mechanical properties such as viscosity to ensure practical surgical use (Petri 2015). In cross-linked structures, calcium ions act as a key agent to facilitate the formation of a 3D cross-linked network which improves adhesion in aqueous environments and enables long-term binding (Modaresifar *et al.* 2016). There are various calcium sources available with their respective advantages and benefits for the adhesive's properties. $CaCl_2$ with ethylenediaminetetraacetic acid (EDTA) was chosen over other sources such as $CaCO_3$ for Kelserra due to its high solubility. In contrast, $CaCO_3$, the most popular calcium source, has low solubility and can hinder emulsification (Paiboon et al. 2023). The dissolution of $CaCO_3$ as a calcium source caused a heterogeneous distribution of Ca^{2+} inside particles, resulting in the broad size distribution of resulting particles.

Despite the advantages over suturing, current synthetic and natural tissue adhesives have trade-offs leading to critical limitations, highlighting the need for next-generation adhesives that are non-toxic, biodegradable, biocompatible, mechanically robust and fast-curing. During our informal consultations with field experts, they highlighted the importance of tensile strength to ensure the wound stays closed. Internal wounds are particularly critical, as the patient will not notice a rupture until a significant blood pressure drop. Advancements in bioadhesive technology could improve surgical outcomes by reducing procedural complexity, minimizing infection risk and accelerating post-operative healing. To develop a new product and successfully commercialize it, our team must consider its shelf life, affordability, regulatory approval timeline and user training.

In this study, our undergraduate student team developed Kelserra, a novel brown algae-derived adhesive designed for wound closure in minimally invasive surgery. The targeted use case is one where biodegradable sutures are impractical such as in anatomically constrained regions, minimally invasive procedures and laparoscopic surgeries. This body of work is intended as a preliminary investigation of bioadhesive properties and possible application through the development of the novel formula Kelserra. Thus, our characterization of Kelserra evaluated the adhesive through a global, user-oriented lens with multiple mechanical strength tests, shelf life and degradation analyses, as well as preliminary biocompatibility assays.

Methodology

Software-assisted formula optimization

A fractional factorial design (JMP v17.2) was used to optimize alginate and xanthan gum concentrations, generating 12 formulations (Table S1) whose strength was tested. The JMP Prediction Profiler identified Ca-EDTA as the optimal calcium source. Additional experiments varying xanthan gum and phloroglucinol concentrations were performed, with parameters listed in Table S2.

Adhesive Formulas and Preparation

Alginate, $CaCl_2$ and EDTA were obtained from Millipore Sigma; phloroglucinol, NaOH and $CaCO_3$ from the McGill Chemical Store; and fresh porcine skin from a local commercial butcher shop[1]. Kelserra formulations (Tables S1, S2) were prepared using a saturated aqueous solution of D-(+)-gluconic acid δ-lactone as a curing agent. For Ca-EDTA, equimolar $CaCl_2$ and EDTA were mixed and adjusted to pH 7 with 1 M NaOH; for other calcium sources, 5.5 mM $CaCl_2$ or $CaCO_3$ was used. Egg albumin adhesive (EAA) served as the benchmark due to its low cost and accessibility, prepared by mixing 0.875 g dried egg white powder with 1 mL water (Xu *et al.* 2017). Further comparisons with gum mastic (Mastisol®) were also attempted but ultimately excluded, as it is formulated for the securement of dressings and medical devices rather than for wound closure. Consequently, its adhesion mechanism is not directly comparable and falls outside the scope of the present validation protocols.

Lap shear and uniaxial tensile strength testing

Porcine skin was chosen as the substrate due to its structural and biomechanical similarity to human tissue, including comparable collagen density and viscoelastic properties (Nakanishi *et al.* 2019). The experimental setups for lap shear and uniaxial strength testing are shown by the diagram in Figure 1. The lap shear test was selected for its ability to closely replicate physiological shear forces experienced at tissue interfaces during internal surgical procedures, such as those caused by peristalsis, respiration and tissue manipulation, while tensile testing is used to evaluate cohesive strength (Song *et al.* 2024). Due to resource constraints, the validation was restricted to these protocols, as they were deemed most appropriate for providing an initial assessment of the feasibility of the adhesive for suturing applications. Tissue specimens were prepared and mounted onto cardboard backings using commercial cyanoacrylate (Krazy Glue) to ensure stability during testing. Preceding Kelserra application, 1 mL of the curing agent was mixed with the Kelserra adhesive solution and allowed to cure for varying pre-curing times (0–60 minutes) before application to the porcine skin substrate. 1 mL of pre-cured Kelserra was applied uniformly across a porcine skin surface area of 5 cm × 2.5 cm for lap shear testing and 2 mL were applied to 10 cm × 2.5 cm for uniaxial testing. Petroleum jelly was applied around the edges of the backing to prevent non-tissue adhesion. The adhered surfaces were weighted together for 45 minutes to ensure proper bonding, and curing was confirmed when residual adhesive became gelatinous. After compression, tensile strength testing was performed using a universal machine testing kit (UMTK) (Liu 2021) following ASTM International's Standard Test Method for Strength Properties of Tissue Adhesives in Tension (F2258-05) ('Standard Test Method for Strength Properties of Tissue Adhesives in Tension' n.d.). The UMTK applied controlled displacement to measure the maximum load-to-failure, with adhesive yield stress calculated by dividing this load (N) by the bonded area (cm^2) and expressing results in kilopascals (kPa) as standardized in ISO 4587:2003 ('ISO-4587-2003.pdf' n.d.).

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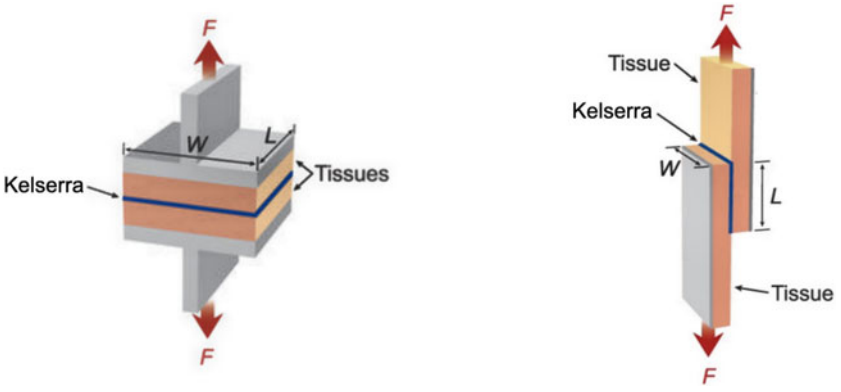


Figure 1. Strength testing protocol diagram showing the application of uniaxial stress (left) and lap shear stress (right) to tissues with Kelserra applied between them. Adapted from (Yuk *et al.* 2019).

Tensile strength testing in physiological conditions

We evaluated the performance of the bioadhesive under conditions that mimic physiological environments, providing valuable data on the bioadhesive's longevity (Gambino *et al.* 2013). To simulate physiological conditions, the porcine tissue samples were first covered in phosphate-buffered saline (PBS) at 4°C at the adhesive bonding site before Kelserra was applied. PBS was purchased from ThermoFisher. Sample dimensions and bonding areas were consistent with those described in Lap Shear and Uniaxial Tensile Strength Testing methodology. After the adhesive was applied, samples were placed in a sealed water bath at 37°C for 45 minutes to maintain a humid environment while the adhesive set. Subsequently, lab shear and uniaxial tensile strength testing was performed in air at 25°C as stated in the previous methodology.

Material and chemical longevity

As suggested by our informal expert consultancy, we assessed physical changes such as phase separations and polymer degradation after varying storage periods to evaluate the shelf life of Kelserra. We stored 3 mL Kelserra samples in sealed and sterile polypropylene vials at room temperature in a dark environment. The samples were analyzed by microscopy and ultraviolet-visible (UV-Vis) spectrophotometry after 0, 1, 7, 14 and 28 days. Kelserra samples were then imaged using bright-field, dark-field and polarized optical microscopy and changes in polymer structural changes, crosslinking and birefringence were recorded in comparison to a freshly prepared Kelserra sample. Kelserra was diluted 10× for UV-Vis spectrophotometry, which was chosen due to its accessibility and cost-effectiveness. Using an Infinite ® M Nano+ microplate reader, the absorbance spectra were measured on wavelengths ranging from 230 nm to 980 nm. This wavelength range was chosen to include UV and visible regions, enabling the detection of the following changes: aromatic ring degradation of phloroglucinol at 330 nm (Dawson *et al.* 1984), aggregation from 480 nm–730 nm (Bhagat and Becker 2017) and light scattering or turbidity from larger particles at 980 nm (Srivastava *et al.* 2022). Each time point was compared with the control using a one-way ANOVA and Tukey Tests to evaluate whether storage time had a statistically significant effect on absorbance values at each measured wavelength. The maximum storage time was limited by the semester's duration since our team is composed of undergraduate students on a part-time basis.

Biocompatibility and cytotoxicity assays

We assessed the preliminary biocompatibility of Kelserra with human cells to support its use on internal tissues. Human bronchial epithelial (HBE) cells were generously donated by Dr. Luc Mongeau. Pelleted viable HBE cells were resuspended in a 5% (m/v) sucrose solution following standard protocols as described by Helgason and Miller (2004). A Kelserra formulation consisting of 50 mg/mL alginate, 5 mg/mL phloroglucinol, 10 mg/mL xanthan gum and 2.09 mg/mL Ca-EDTA was used for biocompatibility testing and compared to results with EAA, water as a positive control and sodium hypochlorite (bleach) as a negative control. Each sample was incubated for 15 minutes and treated with 2 mL of trypan blue dye purchased from Millipore Sigma to stain the lysed cells. Samples were loaded onto a hemocytometer where viable cells were counted as a fraction of total cells. Single measurements were performed due to limited cell supply, financial constraints and our team's lack of expertise in live cell cultures. A single cell line was used since this was the only one our team had access to.

Results

Preliminary strength and cytotoxicity testing

During the first year of development, preliminary testing was conducted to evaluate the lap shear strength of 20 different formulations of the Kelserra adhesive (enumerated in Table S1 and S2) and EAA. Since this was intended as a broad initial screening, the experiment was only performed once. The resulting adhesive strength values are summarized in Figure 2 ($n = 1$). Formulation 14A (composed of 5 mg/mL phloroglucinol, 50 mg/mL alginate and 10 mg/mL xanthan gum in a total volume of 10 mL) exhibited the highest mechanical strength at 1.648 kPa. Subsequent mechanical evaluations and formulation refinements were conducted using formulation 14A as the base.

Preliminary cytotoxicity assay results indicated that HBE cells exposed to Kelserra exhibited a viability of 75.0% compared to 85.7% when exposed to a water vehicle. Viability for EAA was slightly lower at 72.7%, as shown in Figure S1. Given access restrictions of human natured cells and limited resource availability it was only performed once.

Lap shear and uniaxial strength

Following the initial formulation screening, further testing was conducted on formulation 14A to evaluate Kelserra's mechanical

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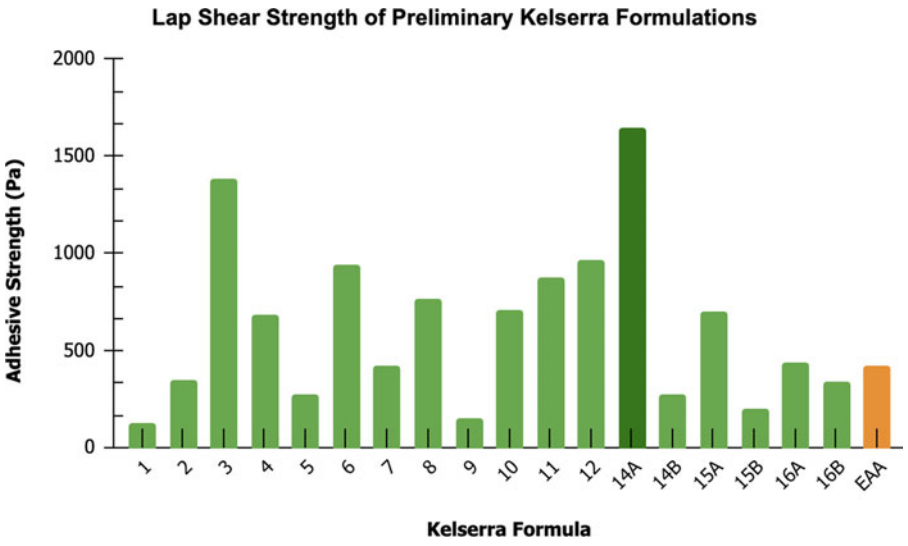


Figure 2. Preliminary lap shear adhesive strength of Kelserra formulations and EAA based bioadhesive formulations ($n = 1$). Formula ingredients are listed in Table S1 and S2.

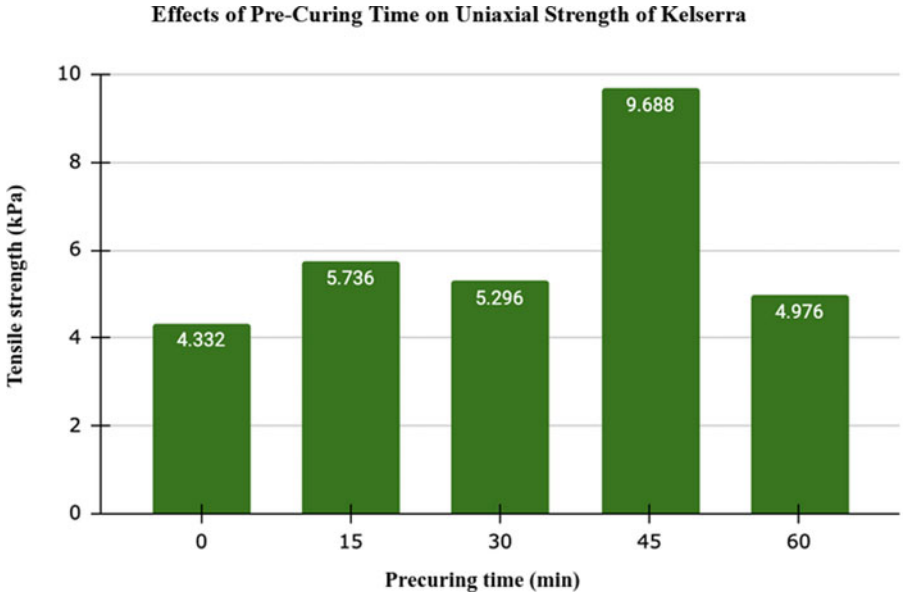


Figure 3. Effect of pre-curing on Kelserra's uniaxial tensile strength ($n = 1$). 45 minutes of pre-curing achieved a maximal strength of 9.688 kPa.

properties and shelf life. To optimize application protocols, the effect of pre-curing on Kelserra's adhesive strength was evaluated. Kelserra's uniaxial tensile strength improved when pre-cured, with peak adhesion of 9.688 kPa observed at 45 minutes of pre-curing time before declining at longer durations (Figure 3). Since this experiment aimed to optimize future protocols, only one replicate was performed.

It has been previously reported that a higher guluronic acid residue content (G-content) within alginate resulted in significant improvements to network strength within alginate hydrogels due to the stronger diaxial links that gluconic acid residues form (Bitton *et al.* 2009; Cao *et al.* 2023). We investigated the effect of higher G-content on mechanical strength by replacing our previous 39% G-content alginate source with sodium alginate at a G-content of 60–70%. However, we observed no significant difference in strength between adhesives formulated with each alginate variant (unpublished data).

Kelserra's shear and uniaxial strengths were evaluated with and without pre-curing compared to EAA (Figure 4). Comparisons between adhesives did not reach statistical significance. However, pre-cured Kelserra had a significantly higher uniaxial strength compared to its lap shear strength ($p = 0.0019$, Student's t-test).

We evaluated the impact of the curing medium on adhesive strength to replicate physiological conditions (Figure 5). No significant strength differences between air-cured and PBS-cured Kelserra were observed.

Material and chemical longevity

Microscopy revealed progressive physical changes over four weeks, as seen in Figure 6. At Day 0, all samples appeared homogeneous with minimal birefringence under polarized light. By Day 1, signs of early instability included slight unevenness, faint yellowing and microaggregate formation. At Day 7, phase separation and

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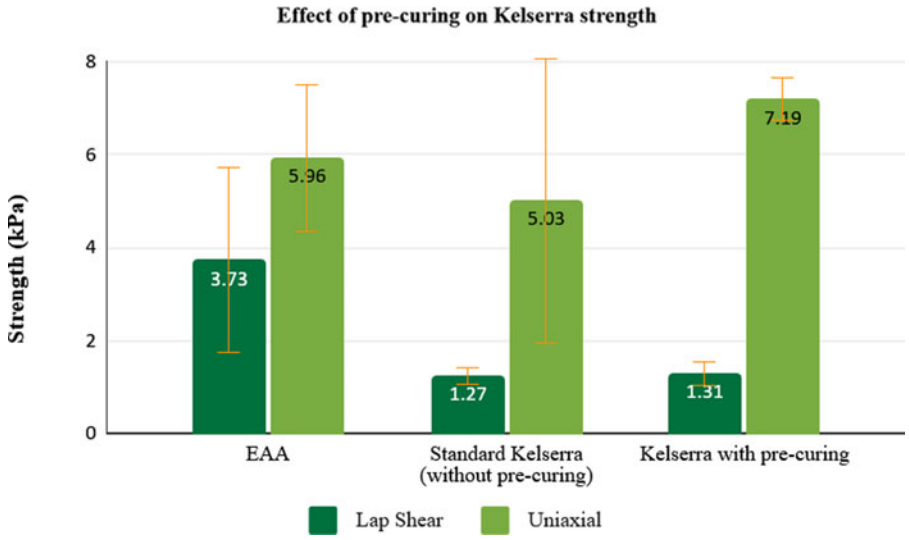


Figure 4. Shear and uniaxial strengths of EAA, standard Kelserra and pre-cured Kelserra. Pre-cured Kelserra was cured for 45 minutes before strength testing while EAA and standard Kelserra were not pre-cured. Error bars represent standard deviation ($n = 3$).

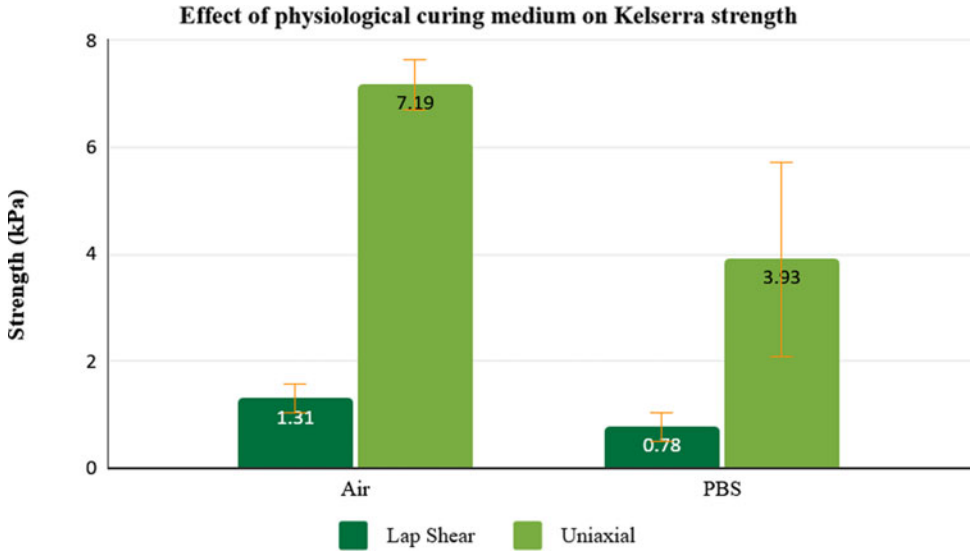


Figure 5. Lap shear and uniaxial strengths of Kelserra cured in air and in simulated physiological conditions (moist porcine skin in a sealed PBS bath). Error bars represent standard deviation ($n = 3$).

birefringence became evident indicating polymer chain ordering and crystallization and this continued throughout to Day 14. At Day 28, signs of advanced degradation included severe phase separation, large aggregates, strong birefringence and significant orange discoloration.

Kelserra's degradation as observed by microscopy was confirmed quantitatively by spectrophotometric analysis across multiple wavelengths, as shown in Figure 7. At all storage durations, absorbance was higher at lower wavelengths. Specifically, the absorbance data recorded at 355 nm was distinct from other wavelengths at a statistically significant level ($p < 0.001$, one-way ANOVA). All wavelengths show a similar pattern of absorbance over storage time, where absorbance initially decreased until Day 7. After Day 7, absorbance increased until the longest storage duration tested (28 days). This indicates that Kelserra became more transparent until Day 7, after which it gained opacity and darkened. Indeed, Kelserra appears translucent white when initially prepared before darkening from yellow to brown after multiple days of storage. This is consistent with the previous microscopy observations indicating degradation.

Discussion

Formula optimization

Our preliminary testing on various calcium sources suggested that EDTA resulted in the highest mechanical strength (Figure 2). This result is corroborated by literature, which has previously found that specific calcium chelators such as EGTA and EDTA result in adhesives with higher mechanical strength than $CaCO_3$ which has lower solubility and creates heterogeneous calcium distributions upon dissolution (Bitton *et al.* 2009; Paiboon *et al.* 2023). This may be due to the higher solubility of EDTA in water, which allows for more homogeneous mixing with alginate (Paiboon *et al.* 2023). Furthermore, our preliminary work suggested a trend of increasing mechanical strength with increasing alginate concentration (Figure 2), as is the case with previous studies on alginate hydrogel network strength (Fu *et al.* 2010; Lee and Mooney 2012). Incorporation of xanthan gum also improved tensile strength (Figure 2), which we theorize is a result of the thickening effect caused by its gelation after interaction with calcium ions (Petri 2015).

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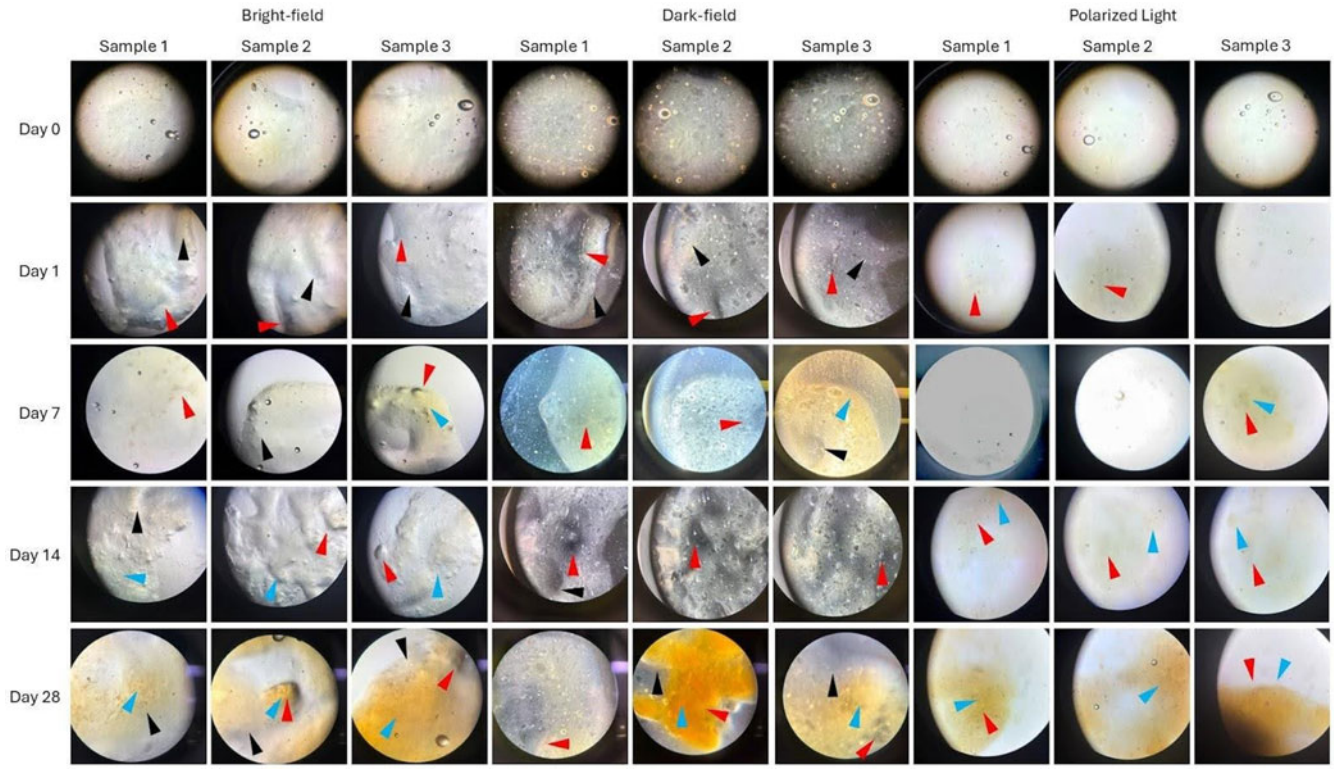


Figure 6. Microscopic images (20X magnification) of three Kelserra samples from the same preparation under bright-field, dark-field and polarized light over 28 days of ambient, dark storage. Key features include aggregation (red), phase separation (black) and color/texture change (blue).

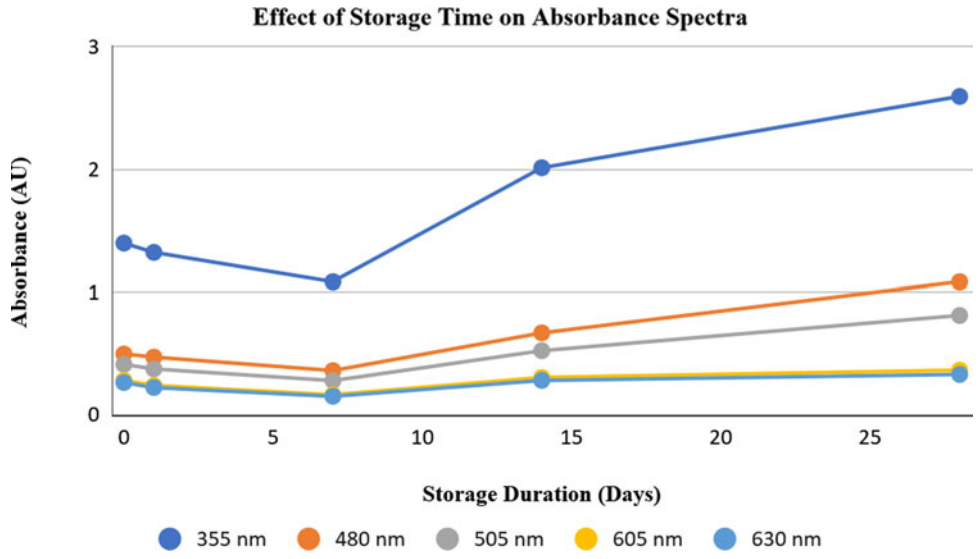


Figure 7. Time-dependent UV–Vis absorbance of Kelserra at selected wavelengths demonstrate color changes associated with degradation throughout storage duration.

Lap shear and uniaxial strength

Echoing our informal expert consultations, Ge and Chen state that shear strength is an important quality for surgical adhesives to resist muscle contractions and prevent wound reopening (2020). As shear strength had not been previously investigated, we performed lap shear tests which indicated that the shear strength of Kelserra was 1.31 ± 0.26 kPa. This is much lower than Kelserra's uniaxial strength of 7.19 ± 0.47 kPa ($p = 0.0019$) as well as the uniaxial strength of Bitton and colleagues' brown algae adhesive, reported as approximately 15 kPa (2009). Table 1 compares Kelserra's strength to other medical hydrogels reported in literature. We suspect this weakness is due to the temporary nature of crosslinks formed through calcium addition, as previous work on alginate gels suggests that these crosslinks shift or break upon shear force application (Mancini *et al.* 1999). Additionally, shear loading induces localized stress concentration and enables interfacial slippage, which may lead to premature breakage and a reduced load capacity (Newby *et al.* 1995). Other studies varying hydrogel concentration or composition have shown that increasing crosslinking density enhances network toughness and cohesion, but reduces chain

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Table 1. Adhesive strength of Kelserra and other natural adhesives reported in literature

Adhesive	Reported strength (kPa)	Source
Kelserra (uniaxial)	7.19 ± 0.47	This work
Kelserra (shear)	1.31 ± 0.26	This work
Brown algae adhesive	15	Bitton *et al.*, 2009
Gelatin-based adhesive	12–20	Bitton *et al.*, 2009; Wang and Kornfield, 2012
Chitosan-based adhesive	3	Bitton *et al.*, 2009; Wang and Kornfield, 2012
Collagen-based adhesive	23	Wang and Kornfield, 2012
Fibrin-based adhesive	27	Wang and Kornfield, 2012

mobility and interfacial interaction, thereby hindering adhesion (Pinkas *et al.* 2017; Song *et al.* 2024). This is attributed to the importance of polymer flow to fill in the micropores of the substrate, also called mechanical interlocking. As a result, lap shear strength typically increases more modestly with crosslinking density than tensile strength and declines well before tensile strength plateaus. Nevertheless, this point of failure severely undercuts the viability of using only alginate-based adhesives for wound closing.

Cytotoxicity

Kelserra showed 75% viability versus 85.7% in the control ($n = 1$, Figure S1). The expected range is 80–95%, but our replicates were insufficient to make statistically significant comparisons (Segeritz and Vallier, 2017). These preliminary results assess only initial cytotoxicity and are limited by restricted access to human-derived cultures and lack of independent replicates.

Physiological conditions

We initially theorized that densification due to dehydration of air-cured Kelserra may enhance its mechanical performance, possibly due to the partial solubility of the ionic network. When immersed in PBS, alginate-based hydrogels swell as they absorb water, which expands the network and increases the spacing between polymer chains, reducing the crosslinking density and weakening the overall structure of the hydrogel (Lee and Mooney 2012). PBS also contains salts that can disrupt electrostatic interactions and reduce the effectiveness of any ionic crosslinking present in the gel (Freeman and Kelly 2017). However, these moist and ion-rich conditions more closely replicate physiological conditions in the human body than air, so it is essential to test our surgical material under these conditions. Unexpectedly, Kelserra showed no statistically significant strength differences in air compared to PBS medium (Figure 5). If there is no loss of strength in physiological conditions compared to air, this means that results from strength testing in air should translate to physiological conditions. However, results for uniaxial strength trended toward a decreased strength in PBS medium (Figure 5). Specifically, the average strength differed by 3.26 kPa between air and PBS as curing media. Future work should also focus on characterizing Kelserra in dynamic physiological conditions that incorporate realistic substrate movements and torsion expected in a surgical environment.

Material and chemical longevity

Microscopic analysis reveals early microaggregate formation by Day 1, indicating that instability begins soon after preparation with birefringence emerging by Day 7 as evidence of crystalline or ordered polymer domains, possibly from drying or ionic interactions. Phase separation, color changes and increased particulate scattering at later stages point to oxidative or hydrolytic degradation and breakdown of the polymer matrix into separate domains (Mndlovu *et al.* 2024).

UV-Vis spectrophotometric data suggests degradation pathways are linked to oxidative processes at 330 nm and aggregation at 480–730 nm may be temperature or pH dependent. Early molecular reorganization was further supported at 355 nm, where one-way ANOVA testing confirmed a statistically significant change ($p < 0.001$). Progressive aggregation was detected at 480 nm and 505 nm, both showing significant increases in absorbance over time ($p < 0.001$ and $p < 0.001$) with additional confirmation at 405 nm (Bhagat and Becker 2017). At 580 nm, absorbance also increased significantly ($p < 0.001$), suggesting oxidative or chromophore-related degradation at later stages (Stepanenko *et al.* 2011). By contrast, 605 and 630 nm exhibited only minor, non-significant changes, while 730 nm and 980 nm showed trend-level effects ($p = 0.101$, ns), likely limited by small sample size and variability. Together, these findings indicate that Kelserra begins degrading chemically after Day 7. In future work, refrigeration at 4° C, airtight or nitrogen-sealed packaging and protection from light and humidity are expected to mitigate degradation and prolong shelf life (Jiang *et al.* 2025).

Resources and limitations

This project was realized by a self-directed team of undergraduate students working with very limited resources as opposed to an established research group. This work was an extracurricular research initiative done on a part-time basis by the students on the team. As such, the scope of this work was influenced by limited laboratory access, time, academic and financial constraints and lack of specialized equipment and technical skills for liquid cell culture handling. These constraints reinforce the preliminary nature of this work, notably due to the low number of replicates which limits the depth of experimental validation and statistical significance. Additionally, these conditions dictated our choice of which experiments to perform, and more sophisticated experiments are required to fully characterize Kelserra's properties. For example, EAA was chosen as a comparator bioadhesive due to its availability, but further testing should compare Kelserra to commercially available surgical bioadhesives. Despite these constraints, we believe our global and consumer-based design approach is a valuable and novel contribution to the current bioadhesive research field. By using alginate extracted from brown algae – a biodegradable and crucial photosynthesizer – our approach promotes an environmentally responsible design and may eventually contribute to medical waste and contaminant reduction associated with synthetic adhesives.

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Conclusion

Kelserra, a brown algae-inspired biomimetic adhesive composed of alginate, xanthan gum, phloroglucinol and calcium ions, is a potential alternative for minimally invasive surgical wound closure. Our preliminary results suggest that the optimized Kelserra formulation has a higher uniaxial strength compared to its lap shear strength, which remains a challenge for translation of all bioadhesives to clinical use. We also observed no significant differences in strength under air curing compared to curing under wet physiological conditions, suggesting that the curing medium has no effect on the adhesive's strength. Overall, our results are preliminary and further characterization is required to establish clinical value of this formulation, the current data lacks sufficient statistical power to support definitive conclusions. Though this investigation is broad and preliminary in nature, it is meant as an opening into the investigation of alginate-based biomimetic adhesives as a potential surgical tool. Future work should focus on enhancing wet-state adhesion, improving long-term stability and validating *in vivo* efficacy to strengthen Kelserra's viability as an alternative to current closure methods.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S2977905726100195

Data availability statement. The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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Note

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