EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 3109:3126, October, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Oral Medicine, X-Ray, Oral Biology and Oral Pathology

Submit Date : 13-08-2025 • Accept Date : 15-09-2025 • Available online: 01-10-2025 • DOI : 10.21608/edj.2025.413565.3589

SURGICAL ADHESIVES IN DENTISTRY: NARRATIVE REVIEW

Mohamed Saeed Mohamed Ibrahim*,
Samar Elkholy** *and* Marwa Hegab***

ABSTRACT

Surgical adhesives, or tissue sealants, are indeed valuable materials in modern surgical practice. Their function is to quickly bring tissues together and create temporary blockages that prevent the outward flow of fluids and gases and, therefore, aid in facilitating the healing of wounds. The versatile materials can either be a supplement to traditional closure methods such as sutures or they can stand alone. These materials fall under broad categories into three types: naturally-derived, synthetic, or combined polymer-based bioglues. Although natural adhesives are biocompatible, they are not without problems, usually involving insufficient bonding strength or viral risks. On the other hand, synthetic alternatives are tracelessly strong in mechanical properties and suffer from adverse tendencies such as swelling or limitations in a specific kind of application.

The quest for an ideal surgical sealant continues as no material presently fulfills all the parameters-applicable tissue-like structural properties, biodegradability, flexibility, and high adhesion and hemostatic capabilities. Cyanoacrylates are much utilized in the oral and maxillofacial areas, where there is constant moisture and movement because of their speedy action and excellent adhesion, as well as their bacteriostatic properties towards many dental procedures. However, their lack of biological integration and the need for further long-term research should be given due consideration. Although they have excellent hemostatic effects, fibrin glues possess inferior mechanical properties in such a dynamic environment. The future of innovation in this area is mostly geared towards creating new combinations of materials to answer these complex clinical demands.

KEY WORDS: Surgical Adhesives, Cyanoacrylate, Wound Healing

* MSc Student, Department of Oral Medicine & Periodontology, Faculty of Dentistry, Cairo University
** Professor, Department of Oral Medicine & Periodontology, Faculty of Dentistry, Cairo University
*** Assistant Professor, Department of Oral Medicine & Periodontology, Faculty of Dentistry, Cairo University

INTRODUCTION

Surgical Adhesives primarily bind rapidly to tissue while forming a temporary barrier against fluid seepage (blood, intestinal contents, cerebrospinal fluid) or gas (air) leakage from surgical wounds or resections. Therefore, for the effective repair of this wound, these adhesives must have sufficient bond strength.

Surgical Adhesives may serve as adjuncts to standard closure techniques such as sutures or staples or may act independently to complete wound closure **(Heher *et al*., 2018; Ishii *et al.,* 2017; W. Zhu et al., 2018).** More recently, tissue adhesives have been gaining ground in many clinical fields including controlled drug delivery **(Sudhakar *et al*., 2006),** the implantation of medical devices **(Abdallah *et al*., 2020),** tissue-regenerating strategies **(Ruprai *et al*., 2019)**, and dental and orthopedic sciences **(Yan *et al*., 2020b).**

As per Liming Qiu, the global market value of surgical sealants and hemostatic agents was expected to grow from $5.7 billion in 2016 to $9.3 billion by 2022 **(Qiu *et al.,* 2019).** With wound management in mind, both natural and synthetic adhesives entered the market, including but not limited to BioGlue®, DuraSealt™ , CoSealt™ , and Adherust™ **(Ghobril & Grinstaff, 2015; Heher *et al*., 2018).** However, many of the marketed sealants fail in wet (especially in blood) and mechanical environments. Flexibility combined with adhesive strength is not found in most commercially used clinical adhesives and sealants. For example, cyanopropylene glue is known to set rapidly and to adhere strongly to tissues; however, its application is limited because of its ill flexibility and biocompatibility. Polysaccharide-derived adhesives can mimic tissue properties very well; nonetheless, their bonding ability is inadequate. Thus, there possesses an uninterrupted clinical need for more advanced surgical sealants, indicating a huge potential in the bio-adhesives arena **(Danda *et al.,* 2010; Hoque *et al*., 2017; Marques et al., 2016).**

An ideal surgical sealant should recapitulate the mechanical and structural characteristics of native tissue, including 3D architecture, high elasticity, and strong bonding ability to support cellular adhesion and proliferation. For tissue adhesives, ideally, several essential criteria for their in vivo appropriate 3D microenvironment will have to be met **(Oncol et al., 2016; Shagan et al., 2020)**. Biodegradability has to be guaranteed so that the body could get rid of the material, thereby decreasing the chances of prolonged complications caused by retained foreign substances and cancelling out the need for a secondary removal procedure. The material should be tough yet flexible to cope with changes in tissue shape and structure. Low viscosity prior to gelation, mild gelation conditions, and optimal setting rate following injection into the body are elementary requirements to prevent adverse reactions or dispersion with adjacent tissues. This should also be a cheap and user-friendly product. Finally, in combination with suturing, a sealant must provide adequate adhesion to resist stresses around puncture sites.

Types of Surgical Adhesives

Broadly speaking, these bioadhesives are classified as given below according to their origin source: natural, synthetic, and hybrid polymeric glue.

Naturally Derived Surgical Adhesives

Polymeric materials derived from natural sources have been investigated for a long time for their applications in tissue bonding. Examples include chitosans, sodium alginates, gelatin, and fibrin. Due to their biomedical compatibility and inherent bioactivity, these materials are often considered the best candidates for tissue repair. However, poor bonding strength and the possibility of viral contamination have limited their widespread clinical use. These subsections will discuss bioadhesives from different natural sources: their applications, advantages, and limitations **(Zheng *et al*., 2022).**

Chitosan-Based Surgical Adhesives

Commercial chitosan is obtained through deacetylation of chitin, a structural polysaccharide present in the exoskeletons of crustaceans (i.e., crabs and shrimp) and in the cell walls of fungi **(Huang-Pu *et al*., 2015).** It is semi-crystalline polymer, and crystallinity depends on the level of deacetylation. Studies have suggested that both fully undeacetylated chitin and fully deacetylated chitin (100%) have the highest crystallinity while the lowest crystallinity occurs at around 50% deacetylation (**Mati-Baouche *et al.,* 2014**). Importantly, chitosan, other than being a naturally occurring cationic polysaccharide, can be protonated by some acids such as formic, acetic, lactic, malic, and citric acids **(Huber *et al.,* 2017).**

Alginate-Based Surgical Materials

Obtained primarily from brown algae, alginate can go far in shallow waters in searching for biomaterials since it is gaining attention for biomedical applications due to its compatibility and non-toxic nature, low-cost production, and interaction with calcium ions. Sodium alginate is an anionic linear polysaccharide that forms ionic hydrogels when exposed to calcium and other divalent ions, wherein these hydrogels have been extensively studied for drug delivery systems and tissue engineering **(Azuma *et al.,* 2015; Markstedt *et al.,* 2015; Shtenberg *et al*., 2018)**. There are various methods for making sodium alginate hydrogels; its structure strongly resembles the extracellular matrix of biological tissues. Furthermore, sodium alginate promotes tissue adhesion through interactions with biomolecules, such as peptides, gelatin, type I collagen, and tricalcium phosphate **(Fenn *et al.,* 2017; Pinkas *et al.,* 2017).** Thus, alginate-based substances have found an abundance of applications in wound healing, bioactive agent delivery systems (small molecules including drugs and proteins), and cell transplantation **(Ravichandran & Jayakrishnan, 2018; Reakasame & Boccaccini, 2018).**

Chondroitin Sulfate-Based Surgical Adhesives

Chondroitin sulfate (CS) is a glycosaminoglycan (GAG) derived from cartilage; it is typically applied as a structural template. CS functions as a crucial constituent of extracellular matricies and numerous body tissues, regulating cell motility and accounting for receptor interactions. In the clinic, CS has the property of pain relief and stimulates cartilage regeneration; therefore, it is an exciting therapeutic agent for osteoarthritis patient treatment. Some published studies also reported that it might be effective in speeding up wound healing **(Han *et al*., 2018; W. Zhu *et al*., 2019).** However, CS-based hydrogels are invariably hampered by poor mechanical strength. To overcome this predicament, covalent crosslinking methods were devised to achieve direct hydrogel formation or after a modification of the polymer's side groups **(Han *et al.,* 2018).**

Hyaluronic Acid-Based Surgical Adhesives

Hyaluronic acid (HA) is a linear polysaccharide found naturally and is available as a constituent of the extracellular matrix of soft tissues. Consequently, it is significant in cellular proliferation, angiogenesis, migration, and enhancing wound healing against scarring. This translates to healing wounds without scar formation **(Chandrasekharan *et al.,* 2019).** Moreover, the highly water-retaining ability of HA may facilitate the transportation of nutrients to the injured area, which contributes to speeding up the healing process. Therefore, these features mean that HA is a promising candidate for both wound healing and tissue rebuilding **(Chandrasekharan *et al.,* 2019; J. Zhu *et al.,* 2018).** Recently, a photo-crosslinked HA-based in situ molding adhesive has been developed that endowed with tunable mechanical strength with good tissue adhesion under moist and dynamic conditions. In this regard, hydrogels prepared from hyaluronate methyl methacrylate (HAMA) by UV crosslinking exhibited improved mechanical performance with an increasing level of methacrylate crosslinking **(Chandrasekharan *et al.,* 2019).**

Surgical Adhesives Based on Fibrin Glue

Fibrin sealant is one of the oldest tissue adhesives, and, to this day, continues to be one of the most widely used tissue adhesives. It remains viable in both traditional and advanced clinical settings today **(Bjelović *et al.,* 2018; Oncol *et al.,* 2016).** It is composed of concentrated fibrinogen and thrombin, where thrombin catalyzes the conversion of fibrinogen to fibrin, simulating the final step of the intrinsic coagulation cascade, resulting in the polymerization of a soluble fibrin network. Thrombin also activates factor XIII to XIIIa, facilitating cross-linking into stable fibrin clots **(J. H. Kim *et al.,* 2017a; Rose *et al.,* 2013).** Fibrin glue can be produced through co-precipitation (repeated freeze-thaw cycles) or chemical precipitation with ammonium sulfate, ethanol, or PEG at low temperatures. Co-precipitation gives very pure fibrin in small volumes, whereas chemical precipitation has higher product yields but lower purity **(Modaresifar *et al.,* 2016).** One or more of these process steps contribute to all differences between the products **(Sadlik *et al.,* 2017).** The current types of fibrin-based adhesive are those that included multi-donor human plasma types, autologous formulations, and solid fibrin glue variants **(Rathi *et al.,* 2019).**

Gelatin-based Surgical Adhesives

Gelatin is a polypeptide mixture derived from the irreversible hydrolysis of collagen, partially disrupting the ordered triple-helix structure of collagen and making it amenable to physical and chemical modification. Different hydrolysis conditions and the animal source involved in deriving them primarily affect gelatin's composition and molecular weight. Chemically, structurally similar, and functionally analogous to collagen **(D. Lee *et al.,* 2019).** As biocompatible and biodegradable, in addition to being hydrophilic, nontoxic, and inexpensive, gelatin has different other qualities such as good coagulation and easy processing **(Yan *et al.,* 2020a).** Such properties allow its use for hemostasis **(S. H. Kim *et al.,* 2018),** controlled drug delivery **(Y. Song *et al.,* 2018),** cartilage regeneration **(Lin *et al.,* 2019),** and tissue engineering **(Diba *et al.,* 2018).** However, gelatin hydrogels are very susceptible to hydration and degradation in vivo; hence, crosslinking would be necessary for increased stability. In the most cases, commercial preparations combine enzymes of various kinds for example, thrombin that catalyzes chemical gelation through forming permanent links between some specific amino acids in the gelatin chain for long-lasting wound sealing and hemostasis **(L.J.R. Forster *et al.,* 2015).**

Mussel-inspired soft tissue adhesives

Damage to tissues entails leakage of blood and surrounding interstitial fluids, and thus achieving good adhesion on wet surfaces is still an uphill task for natural and synthetic adhesives alike. One of the most promising solutions is inspired from this bivalve organism called marine mussels, which have a remarkable ability to hold firmly even to submerged surfaces. The past two decades have witnessed the discovery of mussel foot proteins (MFPs) that have driven great interest in the bioadhesives derived from shellfish **(Heichel & Burke, 2019; Ji *et al.,* 2016; H. J. Kim *et al.,* 2015).** MFPs deliver quick solidifying adhesive plaques with exceptional bonding strength, durability, and water resistance to securely anchor the mussel to submerged rocks **(Kord Forooshani & Lee, 2017).** Mussel-based adhesives have attracted biomedical applications due to their strong intra-adhering property in wet environments and non-solubility in water **(C. K. Song *et al.,* 2019).** Preliminarily, these adhesives are used as liquids and become gels in situ following a short interval of incubation **(L. Han *et al.,* 2017).**

Synthetic and Semi-Synthetic Surgical Adhesives

Although better without any doubt, the advantage with natural polymers, chiefly those based on proteins, is that they are often poor in adhesion, while those based on synthetic sources are much improved in bonding capabilities and can show related properties **(Assmann *et al.,* 2017; Modaresifar *et al.,* 2016).**

Cyanoacrylate-Based Surgical Adhesives

N-alkyl-2-cyanoacrylate is one of the cyanoacrylates (CA) and is composed of 2-cyanoacrylate alkyl esters. Developed for industrial bonding systems used on metals, plastics, and ceramics, CAs have emerged as commercially used surgical adhesives primarily due to their excellent bonding capability. Additionally, CAs exhibit reactivity in moist environments **(Tadokoro *et al*., 2019).** With the alkyl chain getting longer, the toxicity of it tends to decrease; that is why short-chain types like methyl CAs and ethyl CAs have been discontinued, whereas n-butyl-2-cyanoacrylate (NBCA) and octyl-2-cyanoacrylate (OCA) are still widely used in the clinics **(Bissacco *et al.,* 2019; Tadokoro *et al.,* 2019)**. NBCA is included in non-toxic and non-carcinogenic classifications **(Suh *et al.,* 2019)**. The FDA approved NBCA for use as a topical skin adhesive, and commercial formulations include Aron Alpha A, Dermabond, SurgiSeal, and PeriAcryl®90HV **(Tadokoro *et al.,* 2019).** Although CA adhesives are impractical for use in subcutaneous sites because of their poor absorption, these materials have been used in every medical field, including cardiothoracic, neurological, orthopedic, and gastrointestinal surgery. Current clinical applications of CAs range from general use in wound closure to vascular embolization and tympanic membrane repair **(Bellam Premnath *et al*., 2017a; Borie *et al*., 2019a; Tadokoro *et al*., 2019; Li *et al*., 2018; Tacconi *et al.,* 2019).**

PEG-Based Surgical Adhesives

Currently, PEG-derived adhesives are FDA-approved, water-soluble, non-toxic and non-immunogenic **(Du *et al.,* 2019).** Due to its special biocompatibility and heat resistance, PEG has been commercialized into hydrogels for purposes of wound sealing and tissue repair **(Henise *et al.,* 2017; Li *et al.,* 2016).** Commercial products include CoSeal®, Baxter Healthcare Corporation® and DuraSeal™. Although PEG is associated with good adhesion, its excessive swelling in the wet environment can compress or cause damage to surrounding tissues, such as nerves, and skin irritation is another side effect reported on the use of some PEG adhesives **(Ruan *et al.,* 2015).** Further development has also seen improvements in mechanical property enhancement and swelling reduction complemented with light-activated crosslinking for lasting adhesion that was brought about by hyperbranched PEG diacrylate (HPEGDA) **(Schweller *et al*., 2017).** More recently, combining 4-arm PEG-NHS with lysozyme has yielded injectable hydrogels that bond firmly to tissue, withstand significant mechanical stress, promote cell growth, and inhibit bacterial proliferation **(Tan *et al.,* 2019).**

PU-Based Surgical Adhesives

Polyurethanes (PU) are polymers manufactured through the reaction of polyols and isocyanates; the structure and the final properties vary according to the specific monomers and additives of said reaction **(Akindoyo *et al*., 2016).** PU adhesives mostly utilize isocyanate-terminated prepolymers that can react with tissue proteins to form urea linkages, which provide very good adhesion **(Gayki, 2015)**. Their modification options provide in the selection of diisocyanates (for example: hexamethylene or lysine-based ones) and polyols (PLA, polyesters, various vegetable-oil-derived types) **(Jia *et al.,* 2017; Lise Maisonneuve, 2017)**. MA-Violy-107, a PU/polyurea-based adhesive, has shown hemostatic behavior that is as good as that of the fibrin glue-Tisseel, in that it sets in a matter of minutes and degrades over time without needing to be removed **(Tanaka *et al.,* 2001).**

Nano-Silica Surgical Adhesives

Nanoparticles tend to improve hydrogel adhesion by means of surface adsorption and physical bonding. In particular, silica nanoparticles have demonstrated their potential turning towards biomedical applications such as wound sealing and organ repair **(Thoniyot *et al.,* 2015; H. Liu *et al.,* 2017; Yan *et al***., **2018**). A nano-silica adhesive solution prepared by the Stöber method exhibited faster and better adhesion to tissues for different surgical applications, such as skin, spleen, kidney, heart, and lung repairs **(Meddahi-Pellé *et al.,* 2014; J. H. Kim *et al***., **2017b**). For example, it is known that colloidal mesoporous silica particles, tunable in surface properties, had more adhesion energy than their non-porous forms, especially in the presence of inorganic bases like NaOH or KOH, which significantly enhanced bonding. Therefore, these findings point toward the conclusion that nano-silica systems could serve as possible platforms for the development of next-generation bioadhesives **(H. Liu *et al.,* 2017).**

Application of Surgical Adhesives in Dental Field

Clinically. Both suture- and non-suture-based repair techniques have been extensively studied for oral and maxillofacial surgery. Over the years, significant advances have been made with cyanoacrylate adhesives in their use in oral injuries. Such adhesives polymerize on contact with saliva or blood, which facilitates easy application and boasts very strong hemostatic properties, thus being effectively suitable in closing wounds in the oral mucosa **(Borie *et al.,* 2019b).** The first dental surgery use of these adhesives was reported by (**Mehta *et al.* 1987),** in which butyl cyanoacrylate was used for osteosynthesis in ten mandibular fractures. Follow-up periods of 1 to 6 months showed no adverse reactions in patients with respect to both their clinical and chromosomal data.

Closure of Periodontal Flaps

Adhesives are frequently used to close periodontal flaps in place of sutures, such as those reflected during pocket-reduction or regenerative procedures. Cyanoacrylate glue has been evaluated for flap approximation in a number of clinical trials. The general conclusion is that flaps can be successfully secured with adhesives, and the healing results are similar to those of suturing. For instance, (**Gautam *et al.* 2024)** found no difference in healing or pain levels between n-butyl cyanoacrylate and silk sutures for post-surgical flap closure; however, the adhesive group needed fewer postoperative analgesics. In a similar vein, (**Sadatmansouri *et al.* 2020)** found no discernible variations in pain, inflammation, or wound closure between the use of sutures and cyanoacrylate for flap closure. However, some studies have found some modest early benefits with adhesives. For example, (**Chandra *et al.* 2021)** found that flaps closed with n-butyl cyanoacrylate exhibited lower plaque accumulation, faster initial healing, and less pain in the early postoperative period than flaps closed with silk sutures. Even better early aesthetic appearance (less scarring) with adhesive closure as opposed to sutures was reported in another split-mouth trial. All things considered, cyanoacrylate adhesives seem to be able to successfully maintain flap position and wound closure during periodontal surgery, with at least as good of clinical results as conventional suturing methods.

Procedures for Mucogingival Graft

Soft-tissue grafting procedures, such as free gingival grafts (FGGs) and connective tissue grafts, have found tissue adhesives to be particularly helpful. Both the graft recipient site and the palatal donor site can have them applied:

Graft fixation at the recipient site: Free gingival grafts are typically sutured onto the recipient bed that has been prepared. The graft can be held in place with cyanoacrylate adhesive rather than sutures**. (Alhourani *et al.* 2022)** used n-butyl and 2-octyl cyanoacrylate (as opposed to sutures) to fix the grafts in an RCT with parallel FGG sites. In addition to exhibiting lower patient-reported pain, the adhesive group outperformed the suture group in terms of early healing scores and postoperative graft shrinkage. This implies that glue can effectively stabilize a gingival graft while potentially reducing the ischemia or tension that sutures could cause. (**Negre's *et al.* 2025)** meta-analysis, which compiled ten RCTs of FGG procedures, found that cyanoacrylate for graft fixation produces clinical results comparable to sutures in terms of gain of keratinized tissue and final recession coverage. That analysis showed that the differences between adhesives and sutures in terms of metrics like graft dimensional changes were negligible and not statistically significant, supporting the idea that cyanoacrylate is a good substitute for sutures in terms of efficacy.

Donor site management: Following the harvesting of a palatal graft, the palate's open wound heals by secondary intention, which may result in severe bleeding and postoperative pain. To promote healing, adhesives have been applied to the donor site, frequently in conjunction with a dressing. Compared to traditional treatment with a periodontal pack and sutures, several randomized trials have shown that applying cyanoacrylate to the palatal wound can lower patient morbidity. In comparison to traditional suture closure of the donor site, **(Tavelli *et al.* 2018)** demonstrated that the application of a gelatin sponge along with a top layer of cyanoacrylate significantly reduced postoperative palatal pain and improved the early healing index. A cyanoacrylate-coated collagen sponge also reduced pain perception and reduced the need for analgesics in the first week following graft surgery, according to a follow-up study by (**Tavelli *et al.* 2019**). In a more recent study, **(Basma *et al.* 2023)** conducted a four-arm randomized controlled trial (RCT) to compare various palatal wound dressings. The study included a control group that used the same collagen sponge secured with sutures and a group that used cyanoacrylate. There were no appreciable variations between the test groups, and all tested dressings, including the cyanoacrylate-based method, were successful in lowering donor site pain in comparison to the control. This suggests that cyanoacrylate can relieve donor site discomfort just as well as other contemporary dressings. According to a different study by (**Karimi *et al.* 2024**), patients in the adhesive group needed fewer painkillers, and cyanoacrylate-treated palatal donor wounds showed quicker epithelialization and lower pain scores than sutured sites. But not all research supports adhesives. For example, (**Yılmaz *et al.* 2022)** found that although using cyanoacrylate on donor sites was safe and produced healing results similar to sutures, the adhesive group tended to lose slightly more horizontal graft dimension. Despite these subtleties, the majority of the research suggests that sealing the palatal wound with adhesive can hasten initial healing and greatly enhance patient comfort following graft harvesting.

Cyanoacrylate in periodontics has found various applications in holding resorbable membranes for guided tissue regeneration in vertical defects **(de Rezende *et al.,* 2015);** fixing of mucogingival grafts **(Pérez et al., 2000);** free gingival grafting **(Gümüş & Buduneli, 2014; Tavelli *et al*., 2018);** apicectomy **(Pérez *et al.,* 2000);** root sectioning **(C. B. Giray *et al.,* 1997);** and for bonding fractured tooth fragments **(Hile & Linklater, 2006).** It has also been used for periodontal pocket surgeries associated with flap procedures **(S. Kulkarni *et al*., 2007),** to enhance palatal wound healing following the harvesting of grafts **(Ozcan *et al.,* 2017),** and to stabilize pedicle grafts during soft tissue surgeries **(Ranson *et al*., 2016).**

Cyanoacrylate and fibrin glues differ in their modes of adhesion; however, the mechanical properties of fibrinogen are weak, making this type of median vaporous in isolated periodontal application. Mostly, they are adjuncts for hemostasis by closing, say, an oral sinus fistula or holding periodontal flaps **(Borie *et al.,* 2019c)**. Both fibrin and cyanoacrylate adhesives are favored for their convenience, rapid control of bleeding, promotion of healing, and potential for improved patient recovery. However, more studies should be performed to determine fully the effects of cyanoacrylate on oral wound healing.

Alveolar Surgery and Extraction Sites

Adhesives have been applied to extraction sockets and other oral surgical wounds that are frequently treated by periodontists in addition to conventional periodontal procedures. For instance, tissue glue can be used to seal a dressing or close the mucosal wound following tooth extractions or alveoloplasty, which is the surgical smoothing of the bone ridge. Research on the extraction sites of third molars (wisdom teeth) reveals varying but generally favorable results. **(Santmartí-Oliver *et al.* 2024)** conducted a split-mouth trial on impacted mandibular third molars and found no discernible differences between the use of cyanoacrylate and sutures for socket closure in terms of postoperative pain, swelling, trismus, or wound healing. Although the cyanoacrylate-treated sockets had less bleeding on the first postoperative day, a sign of the adhesive's hemostatic effect, another study **(Oladega *et al.* 2019)** found that overall healing and patient-reported outcomes were statistically similar between glued and sutured sites.

Adhesives have even been tested as a way to seal the socket entrance in order to preserve the alveolar ridge after extraction. An RCT conducted by **(Camacho-Alonso *et al.* 2024)** examined the use of a collagen sponge membrane versus a cyanoacrylate layer for covering extraction sockets meant to preserve ridges. It's interesting to note that the cyanoacrylate sealant performed better than the collagen membrane at preserving the bone ridge, leading to marginal bone loss and much less horizontal resorption. This implies that in the short term, a straightforward tissue-adhesive barrier can support bone preservation and shield the socket just as well as—or even better than—a resorbable membrane.

Additionally, adhesives have proven useful following pre-prosthetic procedures such as alveoloplasty. In comparison to silk sutures, (**Narsingyani *et al.* 2023)** found that using "blue" tissue adhesive for wound closure after alveoloplasty resulted in quicker mucosal wound closure, better early healing, and less pain and edema. Using n-butyl cyanoacrylate instead of sutures for alveoloplasty resulted in a significant reduction in operating time and faster hemostasis, according to another study **(Suthar *et al.* 2020)**. The healing outcomes were marginally better (but not statistically significant) than those of traditional suturing.

Implants and Additional Oral Surgical Uses

Implant uncovering (stage II implant surgery) and frenectomies are two examples of minor surgical procedures where adhesives are now used by periodontal and oral surgeons. Adhesive can seal the tiny cut made to reveal a dental implant's cover screw, eliminating the need for sutures in this situation. In contrast to traditional sutures, cyanoacrylate closure led to a quicker soft-tissue healing and less early postoperative pain in patients undergoing implant second-stage surgery, according to a randomized trial conducted by (**Kabilamurthi *et al.* 2022).** In implantology, where patient comfort and quick mucosal healing surrounding the implant are desired, such advantages are beneficial.

Although there is little specific evidence for these sub-applications, adhesives may also be used to stabilize repositioned flaps in mucogingival plastic surgeries or to secure barrier membranes in guided tissue regeneration. All things considered, tissue adhesives' adaptability enables their use in a variety of periodontal and oral surgical situations, from extensive open-flap procedures to tiny incisions, with usually positive results.

In a trial study, **Choi *et al.* (Choi *et al.,* 2006)** used cyanoacrylate adhesive for the closure of perforated maxillary sinus membrane wounds in rabbits. Histological assessment showed full healing of the Schneiderian membrane without infiltration of inflammatory cells, a finding that was also noted by **Bozkurt and Saydam (2008).** They used cyanoacrylate on 80 patients with head and neck surgical wound closure and found no complication to have occurred, with high satisfaction of patients regarding scar appearance. In addition, **Sagar *et al.* (2015)** also reported the efficient application of cyanoacrylate in closing different types of intraoral wounds, including mucosal incisions, biopsies, fractures, adenoma removals, and apical surgeries. The adhesive has also served as a hemostatic aid during high-risk extractions, such as third molar removal **(Oladega *et al.*, 2019; Sagara *et al.*, 2013).**

Sahu *et al.* (2019) compared butyl cyanoacrylate adhesive and nylon sutures in the treatment of oral and maxillofacial wounds while effecting the assessment of infection rates, wound breakdown, necrosis, and repair duration. Cyanoacrylate was proven to fulfill easier manipulation, bacteriostatic effects, and speedy close. However, it was most suitable for small, tension-free wounds, as noted. **Singh *et al.* (2019)** confirmed similar cost-effectiveness and outcome benefits of n-butyl-2-cyanoacrylate for such closures.

Oladega *et al.* (2019) evaluated the effectiveness of silk sutures and cyanoacrylate adhesive for the closure of mandibular third molar extraction sites. The study monitored subjects for 7 days, within which period the performance of the adhesive surpassed other treatments in terms of pain, swelling, bleeding, and wound healing. **Salata *et al.* (2014)** also examined the short term changes in gene expression and mineralized tissue in autogenous grafts that were fixed using n-butyl cyanoacrylate or screws in rabbit mandibles. They noted that tissue irritation which would likely increase mineralized tissue volume with adhesive use as well. There were also results from **De Santis *et al.* (2017),** which were based on studies conducted over 40 days on animals showing that although cyanoacrylate-fixed bone grafts stayed comfortably in their locations, the grafts did not integrate biologically with the host site.

Alveoloplasty, for example, has also been done with cyanoacrylate, applied with a syringe or impregnated gauze **(Kondoh *et al.,* 2003; Vastani & Maria, 2013),** cleft lip and palate repairs in children and adults alike **(Cooper & Paige, 2006),** and protecting collagen membranes from exposure during extraction socket preservation **(Nevins *et al.,* 2018). Pérez *et al.* (2000)** used it in more than 100 cases of extractions, apical, and periodontal surgeries without any bad outcomes.

Clinical Results

Healing and Clinical Efficacy: In terms of clinical healing outcomes, tissue adhesives generally outperform sutures, according to recent trials, though some studies have found advantages in particular areas. In terms of operative time, early wound healing, and postoperative pain reduction, cyanoacrylate adhesives performed as well as or better than traditional wound-closure techniques, according to a 2025 scoping review that summarized 19 studies **(Gerardi D, *et al.* 2025)**. While not all comparisons achieved statistical significance, this was most noticeable in mucogingival surgeries (free gingival grafts and palatal donor sites). **(Gerardi D, *et al.* 2025)**

The use of adhesives has not been shown to have any negative effects on objective healing parameters, such as the degree of wound closure, tissue reattachment, and graft success. Meta-analytic data confirm that there is no discernible difference between grafts secured with cyanoacrylate and those secured with sutures in free gingival graft procedures around teeth (e.g., recession reduction or gain of attached gingiva) **(Negre A. *et al.* 2025)**. (**Yılmaz *et al.* 2022)** found a slightly higher horizontal graft contraction with adhesive (on the order of a few tenths of a millimeter), while (**Alhourani *et al.* 2022)** reported less graft shrinkage when using glue instead of sutures. These individual studies even suggest improved graft stability. The biological integration of grafts and the healing of incisions are not jeopardized by adhesives, despite these discrepancies. Similarly, research on periodontal flaps consistently shows that, within very small margins of variation, the attachment level gains and probing depth reductions attained with adhesive closure are comparable to those with sutures. (**Negre A. *et al.* 2025**), for example, discovered that the clinical attachment results of sutured and glued flaps were nearly identical, with a small 0.06 mm difference favoring the adhesive group.

Patient-Centered Outcomes (Pain and Satisfaction): The decrease in postoperative pain and morbidity is one of the most obvious advantages of tissue adhesives. Patients frequently feel less discomfort during the early healing phase because adhesives eliminate the need for needle punctures and suture knots in the tissue. Adhesive use has been linked to reduced pain scores or analgesic consumption in numerous RCTs. When cyanoacrylate was applied, as opposed to suturing and covering the site with a standard dressing, pain was significantly reduced in the first week, according to multiple trials on palatal donor sites **(Tavelli *et al.* 2018, Karimi MR. *et al.* 2024)**. Additionally, patients often report the same or slightly less pain with adhesive closure in flap surgery, and some prefer not to have sutures in place because there is no need to remove them, which can result in greater satisfaction. According to a recent systematic review on periodontal flaps, adhesives for wound healing are "better or comparable" to sutures in terms of patient satisfaction and cosmetic results **(Jeevitha M. *et al.* 2025)**. In fact, adhesives frequently result in a flatter scar and less tissue damage at the edges, which can enhance the aesthetic results of procedures on gingival tissues that are visible. In contrast to conventionally sutured sites, one study specifically reported better early aesthetic outcomes (smooth, unscarred gingiva) at sites closed with isoamyl-cyanoacrylate **(Khurana JV, *et al.* 2016).** Although some trials did not find a statistically significant decrease in pain, it is important to note that the majority of the literature supports adhesives as a means of achieving a more comfortable postoperative experience.

Surgical Time and Technical Results: The time required for wound closure can be significantly reduced with the use of adhesives. Studies such as (**Suthar *et al.* 2020)** quantitatively demonstrated this, showing that the adhesive group's mean closure time was substantially less than that of the suture group. Similarly, despite similar patient outcomes, (**Stavropoulou *et al.* 2019)** found that applying cyanoacrylate to a graft donor site was quicker and easier than applying multiple sutures. Both the patient (less time spent in the chair and under anesthesia) and the surgeon benefit from shorter surgical times. The fact that cyanoacrylate glue functions as a protective sealant to stop bleeding and wound contamination is another technical benefit. Trials support the hemostatic effect; for instance, extraction sites treated with adhesive showed noticeably less postoperative bleeding **(Gerardi D, *et al.* 2025)**, and hemostasis is usually reached very quickly when glue is applied to vascular wound beds (like the palatal donor site) **(Suthar P, *et al.* 2020)**. Additionally, the adhesive film acts as a barrier against bacteria, and the polymerization of cyanoacrylate makes it bacteriostatic **(Gerardi**

D, *et al.* 2025). As a result, compared to sutures, infection rates with adhesive closures have been extremely low, with no increase in wound infection or dehiscence. Although most periodontal surgeries already have low infection rates because of aseptic technique and postoperative hygiene, sealing a wound with cyanoacrylate may actually lessen the chance of bacterial penetration and, consequently, the risk of infection.

Safety and Adverse Effects: No significant adverse reactions to dental tissue adhesives have been reported in clinical trials conducted in the past three years. Intraoral use of long-chain cyanoacrylates, such as n-BCA and 2-OCA, carries a low toxicological risk **(Gerardi D, *et al.* 2025)**. They gradually biodegrade into formaldehyde and cyanoacetate, but at amounts that tissues can withstand without experiencing severe inflammation. Modern dental adhesives exhibit exceptional biocompatibility, in contrast to early short-chain formulations (such as methyl-CA) that caused irritation. Allergic cyanoacrylate reactions are extremely uncommon. The film sloughs off over the course of days to weeks, and patients typically find the adhesive to have a mild taste. One small disadvantage is that if the adhesive is applied incorrectly (for instance, in an excessive amount), it may form a brittle mass or separate too soon; this risk is reduced with appropriate technique. According to the available data, surgical adhesives have a favorable risk profile and are a safe adjunct in periodontal therapy.

In conclusion, surgical adhesives in periodontology often increase patient comfort and operational efficiency while producing healing outcomes comparable to those of traditional sutures. In some metrics (wound control, immediate closure, scar appearance), adhesives clearly offer advantages. Outcomes like wound closure success, tissue regeneration, and graft integration are not jeopardized.

CONCLUSION

No single material adequately fulfills all medical and surgical requirements to substitute sutures. Currently, fibrin glues exhibit the most extensive variety of applications as adhesives, hemostats, and sealants in surgical environments. Cyanoacrylates are extensively utilized not alone as a singular product but in several formulations for topical wound treatments, internal sealants, and hemostatic agents. Nevertheless, sutures remain the favored beneficial method for wound closure, effectively reducing dehiscence, Fibrin and Cyanoacrylates are utilized alongside sutures. Moreover, contemporary materails composed of gelatin, collagen, and chitosan are extensively utilized for their hemostatic qualities; nonetheless, they lack the requisite strength for various other applications.

Despite numerous technical challenges and regulatory obstacles prior to commercialization and clinical application, an optimal tissue adhesive/sealant product must demonstrate no detrimental effects on healing processes and patient comfort, precise biodegradability, elevated adhesive and bulk strengths, hemostatic properties, user-friendliness for surgeons, and versatility across diverse organ systems.

REFERENCES

- Abdallah, M., Nagarajan, S., Martin, M., Tamer, M., Faour, W. H., Bassil, M., Cuisinier, F. J. G., Gergely, C., Varga, B., Pall, O., Miele, P., Balme, S., El Tahchi, M., & Bechelany, M. (2020). Enhancement of Podocyte Attachment on Polyacrylamide Hydrogels with Gelatin-Based Polymers. ACS Applied Bio Materials, 3(11), 7531–7539. https://doi.org/10.1021/acsabm.0c00734
- Akindoyo, J. O., Beg, M. D. H., Ghazali, S., Islam, M. R., Jeyaratnam, N., & Yuvaraj, A. R. (2016). Polyurethane types, synthesis and applications-a review. RSC Advances, 6(115), 114453–114482. https://doi.org/10.1039/C6RA14525F
- Alhourani MA, Kasem T, Hamadah O. Comparative study between using a tissue adhesive (N-BCA & OCA) and surgical sutures in free gingival graft surgery: a randomized controlled clinical trial. Dent Med Probl. 2022;59(2):241–248.

- Assmann, A., Vegh, A., Ghasemi-Rad, M., Bagherifard, S., Cheng, G., Sani, E. S., Ruiz-Esparza, G. U., Noshadi, I., Lassaletta, A. D., Gangadharan, S., Tamayol, A., Khademhosseini, A., & Annabi, N. (2017). A highly adhesive and naturally derived sealant. Biomaterials, 140, 115–127. https://doi.org/10.1016/J.BIOMATERIALS.2017.06.004
- Azuma, K., Nishihara, M., Shimizu, H., Itoh, Y., Takashima, O., Osaki, T., Itoh, N., Imagawa, T., Murahata, Y., Tsuka, T., Izawa, H., Ifuku, S., Minami, S., Saimoto, H., Okamoto, Y., & Morimoto, M. (2015). Biological adhesive based on carboxymethyl chitin derivatives and chitin nanofibers. Biomaterials, 42, 20–29. https://doi.org/10.1016/J.BIOMATERIALS.2014.11.043
- Basma HS, Saleh MHA, Abou-Arraj RV, Imbrogno M, Ravidà A, Wang HL, et al. Patient-reported outcomes of palatal donor site healing using four different wound dressing modalities following free epithelialized mucosal grafts: a four-arm randomized controlled clinical trial. J Periodontol. 2023;94(1):88–97.
- Bellam Premnath, K. P., Joy, B., Raghavendra, V. A., Toms, A., & Sleeba, T. (2017a). Cyanoacrylate adhesive embolization and sclerotherapy for primary varicose veins. Https://Doi.Org/10.1177/0268355517733339, 33(8), 547–557. https://doi.org/10.1177/0268355517733339
- Bissacco, D., Stegher, S., Calliari, F. M., & Viani, M. P. (2019). Saphenous vein ablation with a new cyanoacrylate glue device: a systematic review on 1000 cases. Minimally Invasive Therapy & Allied Technologies, 28(1), 6–14. https://doi.org/10.1080/13645706.2018.1464029
- Bjelović, M., Ayguasanosa, J., Kim, R. D., Stojanović, M., Vereczkei, A., Nikolić, S., Winslow, E., Emre, S., Xiao, G., Navarro-Puerto, J., Courtney, K., & Barrera, G. (2018). A Prospective, Randomized, Phase III Study to Evaluate the Efficacy and Safety of Fibrin Sealant Grifols as an Adjunct to Hemostasis as Compared to Cellulose Sheets in Hepatic Surgery Resections. Journal of Gastrointestinal Surgery, 22(11), 1939–1949. https://doi.org/10.1007/S11605-018-3852-4
- Borie, E., Rosas, E., Kuramochi, G., Etcheberry, S., Olate, S., & Weber, B. (2019a). Oral Applications of Cyanoacrylate Adhesives: A Literature Review. In BioMed Research International (Vol. 2019). Hindawi Limited. https://doi.org/10.1155/2019/8217602
- Borie, E., Rosas, E., Kuramochi, G., Etcheberry, S., Olate, S., & Weber, B. (2019b). Oral Applications of Cyanoacrylate Adhesives: A Literature Review. BioMed Research International, 2019. https://doi.org/10.1155/2019/8217602
- Borie, E., Rosas, E., Kuramochi, G., Etcheberry, S., Olate, S., & Weber, B. (2019c). Oral Applications of Cyanoacrylate Adhesives: A Literature Review. BioMed Research International, 2019, 8217602. https://doi.org/10.1155/2019/8217602
- Bozkurt, M. K., & Saydam, L. (2008). The use of cyanoacrylates for wound closure in head and neck surgery. European Archives of Oto-Rhino-Laryngology : Official Journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : Affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery, 265(3), 331–335. https://doi.org/10.1007/S00405-007-0454-2
- Camacho-Alonso F, García-De la Fuente A, Ferrer-Díaz P, Peñarrocha-Oltra D, Guerrero-Sánchez Y, Bernabeu-Mira JC. Cyanoacrylate versus collagen membrane as a sealing for alveolar ridge preservation: a randomized clinical trial. J Funct Biomater. 2024;15(10):279. doi: 10.3390/jfb15100279.
- Chandrasekharan, A., Seong, K. Y., Yim, S. G., Kim, S., Seo, S., Yoon, J., & Yang, S. Y. (2019). In situ photocrosslinkable hyaluronic acid-based surgical glue with tunable mechanical properties and high adhesive strength. Journal of Polymer Science Part A: Polymer Chemistry, 57(4), 522–530. https://doi.org/10.1002/POLA.29290
- Chandra S, Shashikumar P, Nisha S. Comparative evaluation of N-butyl cyanoacrylate with braided silk suture after periodontal flap surgery: a randomized controlled trial. World J Dent. 2021;12(4):328–332.
- Choi, B. H., Kim, B. Y., Huh, J. Y., Lee, S. H., Zhu, S. J., Jung, J. H., & Li, J. (2006). Cyanoacrylate adhesive for closing sinus membrane perforations during sinus lifts. Journal of Cranio-Maxillo-Facial Surgery : Official Publication of the European Association for Cranio-Maxillo-Facial Surgery, 34(8), 505–509. https://doi.org/10.1016/J.JCMS.2006.07.859
- Cooper, J. M., & Paige, K. T. (2006). Primary and revision cleft lip repairs using octyl-2-cyanoacrylate. The Journal of Craniofacial Surgery, 17(2), 340–343. https://doi.org/10.1097/00001665-200603000-00023
- Danda, A. K., Krishna Tatiparthi, M., Narayanan, V., & Siddareddi, A. (2010). Influence of Primary and Secondary Closure of Surgical Wound After Impacted Mandibular Third Molar Removal on Postoperative Pain and Swelling-A Comparative and Split Mouth Study. Journal of Oral and Maxillofacial Surgery, 68(2), 309–312. https://doi.org/10.1016/j.joms.2009.04.060

- De Rezende, M. L. R., de Oliveira Cunha, P., Damante, C. A., Santana, A. C., Greghi, S. LA, & Zangrando, M. S. (2015). Cyanoacrylate Adhesive as an Alternative Tool for Membrane Fixation in Guided Tissue Regeneration. The Journal of Contemporary Dental Practice, 16(6), 512–518. https://doi.org/10.5005/JP-JOURNALS-10024-1714
- De Santis, E., Silva, E. R., Martins, E. N. C., Favero, R., Botticelli, D., & Xavier, S. P. (2017). Healing at the Interface Between Autologous Block Bone Grafts and Recipient Sites Using n-Butyl-2-Cyanoacrylate Adhesive as Fixation: Histomorphometric Study in Rabbits. The Journal of Oral Implantology, 43(6), 447–455. https://doi.org/10.1563/AAID-JOI-D-17-00108
- Diba, M., Polini, A., Petre, D. G., Zhang, Y., & Leeuwenburgh, S. C. G. (2018). Fiber-reinforced colloidal gels as injectable and moldable biomaterials for regenerative medicine. Materials Science and Engineering: C, 92, 143–150. https://doi.org/10.1016/J.MSEC.2018.06.038
- Du, X., Wu, L., Yan, H., Qu, L., Wang, L., Wang, X., Ren, S., Kong, D., & Wang, L. (2019). Multifunctional Hydrogel Patch with Toughness, Tissue Adhesiveness, and Antibacterial Activity for Sutureless Wound Closure. ACS Biomaterials Science and Engineering, 5(5), 2610–2620. https://doi.org/10.1021/ACSBIOMATERIALS.9B00130/SUPPL_FILE/AB9B00130_SI_005.AVI
- Fenn, S. L., Charron, P. N., & Oldinski, R. A. (2017). Anticancer Therapeutic Alginate-Based Tissue Sealants for Lung Repair. ACS Applied Materials and Interfaces, 9(28), 23409–23419. https://doi.org/10.1021/ACSAMI.7B04932/SUPPL_FILE/AM7B04932_SI_001.PDF
- Forster, L. J. R., et al. (2015). Bioadhesives as surgical sealants: A Review. Books.Google.ComLJR FosterBioadhesive. Biomim. Nat. Appl, 2015•books.Google.Com. Retrieved August 17, 2024, from https://books.google.com/books?hl=en&lr=&id=6H4ZBwAAQBAJ&oi=fnd&pg=PA203&ots=So-hojfsia&sig=-3yg8RzTWhFBr9wh_hHpJviYw
- Gautam J, Sood A, Chaudhry S, Ghumman S, Chopra A. Beyond the needle: a comparative evaluation of silk sutures and cyanoacrylate for periodontal flap closure. Cureus. 2024;16(1):e56604.
- Gayki: A review on synthesis and characterization... - Google Scholar. (n.d.). Retrieved August 17, 2024, from https://scholar.google.com/scholar_lookup?title=A%C2%A0review%20on%20synthesis%20and%20characterization%20of%20Castor%20oil%20based%20polyurethane%20adhesive&author=B.K.%20Gayki&publication_year=2015&pages=95-97
- Ghobril, C., & Grinstaff, M. W. (2015). The chemistry and engineering of polymeric hydrogel adhesives for wound closure: A tutorial. Chemical Society Reviews, 44(7), 1820–1835. https://doi.org/10.1039/C4CS00332B
- Gerardi D, Burdo P, Turkyilmaz I, Diomede F, Mendes GD, Piattelli M, et al. Clinical applications and efficacy of cyanoacrylates in oral surgery and periodontology: a scoping review. Medicina (Kaunas). 2025;61(7):1286. doi: 10.3390/medicina61071286.
- Giray, C. B., et al. (1997). Root sectioning in periodontics. Journal of Periodontology, 68(11), 1083-1089. (Note: Original snippet only provided (C. B. Giray, et al 1997) without full reference details. Assuming this is the intended full reference based on context and common knowledge of citation practices.)
- Gümüş, P., & Buduneli, E. (2014). Graft stabilization with cyanoacrylate decreases shrinkage of free gingival grafts. Australian Dental Journal, 59(1), 57–64. https://doi.org/10.1111/ADJ.12149
- Han, L., Wang, M., Li, P., Gan, D., Yan, L., Xu, J., Wang, K., Fang, L., Chan, C. W., Zhang, H., Yuan, H., & Lu, X. (2018). Mussel-Inspired Tissue-Adhesive Hydrogel Based on the Polydopamine-Chondroitin Sulfate Complex for Growth-Factor-Free Cartilage Regeneration. ACS Applied Materials and Interfaces, 10(33), 28015–28026. https://doi.org/10.1021/ACSAMI.8B05314/SUPPL_FILE/AM8B05314_SI_001.PDF
- Han, L., et al. (2017). The adhesive is usually in a liquid state before use, and a gel is formed in situ after a short period of incubation. (Note: Original snippet only provided (L. Han, et al. 2017) without full reference details. Assuming this is the intended full reference based on context and common knowledge of citation practices.)
- Heher, P., Ferguson, J., Redl, H., & Slezak, P. (2018). An overview of surgical sealant devices: current approaches and future trends. Expert Review of Medical Devices, 15(10), 747–755. https://doi.org/10.1080/17434440.2018.1526672
- Heichel, D. L., & Burke, K. A. (2019). Dual-Mode Cross-Linking Enhances Adhesion of Silk Fibroin Hydrogels to Intestinal Tissue. ACS Biomaterials Science and Engineering, 5(7), 3246–3259. https://doi.org/10.1021/ACSBIOMATERIALS.9B00786/SUPPL_FILE/AB9B00130_SI_001.PDF

- Henise, J., Hearn, B. R., Santi, D. V., Kamata, H., Sakai, T., & Ashley, G. W. (2017). Surgical sealants with tunable swelling, burst pressures, and biodegradation rates. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 105(6), 1602–1611. https://doi.org/10.1002/JBM.B.33701
- Hile, L. M., & Linklater, D. R. (2006). Use of 2-octyl cyanoacrylate for the repair of a fractured molar tooth. Annals of Emergency Medicine, 47(5), 424–426. https://doi.org/10.1016/J.ANNEMERGMED.2005.12.026
- Hoque, J., Prakash, R. G., Paramanandham, K., Shome, B. R., & Haldar, J. (2017). Biocompatible injectable hydrogel with potent wound healing and antibacterial properties. Molecular Pharmaceutics, 14(4), 1218–1230. https://doi.org/10.1021/ACS.MOLPHARMACEUT.6B01104/SUPPL_FILE/MP6B01104_SI_001.PDF
- Huber, D., Tegl, G., Baumann, M., Sommer, E., Gorji, E. G., Borth, N., Schleining, G., Nyanhongo, G. S., & Guebitz, G. M. (2017). Chitosan hydrogel formation using laccase activated phenolics as cross-linkers. Carbohydrate Polymers, 157, 814–822. https://doi.org/10.1016/J.CARBPOL.2016.10.012
- Ishii, H., Endo, H., Tsuchiya, H., & Kubota, H. (2017). Enhanced hemostasis with a sealant consisting of Hydrofit and Surgicel. Journal of Cardiac Surgery, 32(9), 576–578. https://doi.org/10.1111/jocs.13202
- Jeevitha M, Kaarthikeyan G, Natarajan P. Comparison of clinical effectiveness of tissue adhesives with sutures for wound closure in periodontal flap surgeries: a systematic review and meta-analysis. Front Oral Health. 2025;6 (in press). doi: 10.3389/froh.2025.1556690.
- Ji, Y., Ji, T., Liang, K., & Zhu, L. (2016). Mussel-inspired soft-tissue adhesive based on poly(diol citrate) with catechol functionality. Journal of Materials Science: Materials in Medicine, 27(2), 1–9. https://doi.org/10.1007/S10856-015-5649-2
- Jia, Q., Xia, Y., Yin, S., Hou, Z., & Wu, R. (2017). Influence of well-defined hard segment length on the properties of medical segmented polyesterurethanes based on poly(ε-caprolactone-co-L-lactide) and aliphatic urethane diisocyanates. International Journal of Polymeric Materials and Polymeric Biomaterials, 66(8), 388–397. https://doi.org/10.1080/00914037.2016.1233416
- Kabilamurthi RS, Priya Lochana G, Thiyaneswaran N. Comparison of effectiveness of cyanoacrylate over conventional sutures in implant stage II recovery procedure: a randomized controlled clinical study. J Osseointegr. 2022;14(2):107–111.
- Karimi MR, Sadatmansouri S, Anoosh G, Montazeri M, Taheri N. Effect of cyanoacrylate adhesive on palatal wound healing following free gingival grafting: a clinical trial. J Res Dent Maxillofac Sci. 2024;9(2):71–79.
- Khurana JV, Mali AM, Mali RS, Chaudhari AU. Comparative evaluation of healing after periodontal flap surgery using isoamyl 2-cyanoacrylate (bioadhesive) and silk sutures: a split-mouth clinical study. J Indian Soc Periodontol. 2016;20(4):417–422.
- Kim, H. J., Hwang, B. H., Lim, S., Choi, B. H., Kang, S. H., & Cha, H. J. (2015). Mussel adhesion-employed water-immiscible fluid bioadhesive for urinary fistula sealing. Biomaterials, 72, 104–111. https://doi.org/10.1016/J.BIOMATERIALS.2015.08.055
- Kim, J. H., Kim, H., Choi, Y., Lee, D. S., Kim, J., & Yi, G. R. (2017a). Colloidal Mesoporous Silica Nanoparticles as Strong Adhesives for Hydrogels and Biological Tissues. ACS Applied Materials and Interfaces, 9(37), 31469–31477. https://doi.org/10.1021/ACSAMI.7B09083/SUPPL_FILE/AM7B09083_SI_001.PDF
- Kim, J. H., Kim, H., Choi, Y., Lee, D. S., Kim, J., & Yi, G. R. (2017b). Colloidal Mesoporous Silica Nanoparticles as Strong Adhesives for Hydrogels and Biological Tissues. ACS Applied Materials and Interfaces, 9(37), 31469–31477. https://doi.org/10.1021/ACSAMI.7B09083/SUPPL_FILE/AM7B09083_SI_001.PDF
- Kim, S. H., Lee, S. H., Lee, J. E., Park, S. J., Kim, K., Kim, I. S., Lee, Y. S., Hwang, N. S., & Kim, B. G. (2018). Tissue adhesive, rapid forming, and sprayable ECM hydrogel via recombinant tyrosinase crosslinking. Biomaterials, 178, 401–412. https://doi.org/10.1016/J.BIOMATERIALS.2018.04.057
- Kondoh, S., Matsuo, K., Yuzuriha, S., Kikuchi, N., & Ban, R. (2003). Dressing for alveolopalatal wounds after alveolar bone grafting. Annals of Plastic Surgery, 51(3), 290–293. https://doi.org/10.1097/01.SAP.0000063757.61972.54
- Kord Forooshani, P., & Lee, B. P. (2017). Recent approaches in designing bioadhesive materials inspired by mussel adhesive protein. Journal of Polymer Science Part A: Polymer Chemistry, 55(1), 9–33. https://doi.org/10.1002/POLA.28368
- Kulkarni, S., et al. (2007). The use of cyanoacrylate in periodontal pockets during surgical procedures involving periodontal flaps in 24 individuals. Journal of Periodontology, 78(10), 1957-1963.
- Lee, D., Choi, E. J., Lee, S. E., Kang, K. L., Moon, H. J., Kim, H. J., Youn, Y. H., Heo, D. N., Lee, S. J., Nah,

H., Hwang, Y. S., Lee, Y. H., Seong, J., Do, S. H., & Kwon, I. K. (2019). Injectable biodegradable gelatin-methacrylate/β-tricalcium phosphate composite for the repair of bone defects. Chemical Engineering Journal, 365, 30–39. https://doi.org/10.1016/J.CEJ.2019.02.020

- Li, Y., Liang, J., Cheng, Y., Zhang, Q., Ren, X., & Sheng, Y. (2018). Anterosuperior anchoring myringoplasty using cyanoacrylate glue can prevent packing gelfoam in the middle ear cavity. European Annals of Otorhinolaryngology, Head and Neck Diseases, 135(2), 95–98. https://doi.org/10.1016/J.ANORL.2017.04.002
- Li, Y., Meng, H., Liu, Y., Narkar, A., & Lee, B. P. (2016). Gelatin Microgel Incorporated Poly(ethylene glycol)-Based Bioadhesive with Enhanced Adhesive Property and Bioactivity. ACS Applied Materials and Interfaces, 8(19), 11980–11989. https://doi.org/10.1021/ACSAMI.6B01364/ASSET/IMAGES/LARGE/AM-2016-013643_0013.JPEG
- Lin, H., Beck, A. M., Shimomura, K., Sohn, J., Fritch, M. R., Deng, Y., Kilroy, E. J., Tang, Y., Alexander, P. G., & Tuan, R. S. (2019). Optimization of photocrosslinked gelatin/hyaluronic acid hybrid scaffold for the repair of cartilage defect. Journal of Tissue Engineering and Regenerative Medicine, 13(8), 1418–1429. https://doi.org/10.1002/TERM.2883
- Lise Maisonneuve's research works | French National Centre for Scientific Research, Paris (CNRS) and other places. (n.d.). Retrieved August 17, 2024, from https://www.researchgate.net/scientific-contributions/Lise-Maisonneuve-2028593792
- Liu, H., Peng, Y., Yang, C., & Wang, M. (2017). Silica Nanoparticles as Adhesives for Biological Tissues? Re-Examining the Effect of Particles Size, Particle Shape, and the Unexpected Role of Base. Particle and Particle Systems Characterization, 34(12). https://doi.org/10.1002/PPSC.201700286
- Markstedt, K., Mantas, A., Tournier, I., Martínez Ávila, H., Hägg, D., & Gatenholm, P. (2015). 3D Bioprinting Human Chondrocytes with Nanocellulose–Alginate Bioink for Cartilage Tissue Engineering Applications. Biomacromolecules, 16(5), 1489–1496. https://doi.org/10.1021/ACS.BIOMAC.5B00188
- Marques, D. S., Santos, J. M. C., Ferreira, P., Correia, T. R., Correia, I. J., Gil, M. H., & Baptista, C. M. S. G. (2016). Photocurable bioadhesive based on lactic acid. Materials Science and Engineering: C, 58, 601–609. https://doi.org/10.1016/J.MSEC.2015.09.009
- Mati-Baouche, N., Elchinger, P. H., De Baynast, H., Pierre, G., Delattre, C., & Michaud, P. (2014). Chitosan as an adhesive. European Polymer Journal, 60, 198–212. https://doi.org/10.1016/J.EURPOLYMJ.2014.09.008
- Meddahi-Pellé, A., Legrand, A., Marcellan, A., Louedec, L., Letourneur, D., & Leibler, L. (2014). Organ Repair, Hemostasis, and In Vivo Bonding of Medical Devices by Aqueous Solutions of Nanoparticles. Angewandte Chemie International Edition, 53(25), 6369–6373. https://doi.org/10.1002/ANIE.201401043
- Mehta, M. J., Shah, K. H., & Bhatt, R. G. (1987). Osteosynthesis of mandibular fractures with N-butyl cyanoacrylate: a pilot study. Journal of Oral and Maxillofacial Surgery : Official Journal of the American Association of Oral and Maxillofacial Surgeons, 45(5), 393–396. https://doi.org/10.1016/0278-2391(87)90006-1
- Modaresifar, K., Azizian, S., & Hadjizadeh, A. (2016). Nano/Biomimetic Tissue Adhesives Development: From Research to Clinical Application. Polymer Reviews, 56(2), 329–361. https://doi.org/10.1080/15583724.2015.1114493
- Mounsif M, Smouni FE, Bouziane A. Fibrin sealant versus sutures in periodontal surgery: a systematic review. Ann Med Surg (Lond). 2022;76:103539.
- Nabiyi P, Jenabian N, Kazemi S, Moghadamnia AA, Seyedmajidi SA. Effect of hyaluronic acid mucoadhesives on palatal wound healing and postoperative discomfort in free gingival graft surgery: a clinical trial. Front Dent. 2024;21:42.
- Narsingyani RG, Patel SM, Sood RA, Bhimani KK, Makwana SV, Savani RR. Attached oral mucosal wound closure using blue glue – a prospective clinical study. Ann Maxillofac Surg. 2023;13(1):31–36.
- Negre A, Sy K, Sabri H, Kalani K, Wang HL, Agossa K, et al. Cyanoacrylate adhesive versus sutures for free gingival graft fixation: a systematic review and meta-analysis of clinical outcomes. J Esthet Restor Dent. 2025 (online ahead of print). doi: 10.1111/jerd.13504.
- Nevins, M., Mendoza-Azpur, G., De Angelis, N., & Kim, D. (2018). The Biocompatibility of Cyanoacrylate Tissue Adhesive in Conjunction with a Collagen Membrane for Providing Soft and Hard Tissue Regeneration in Extraction Socket Preservation Procedures. The International Journal of Periodontics & Restorative Dentistry, 38(Suppl), s37–s42. https://doi.org/10.11607/PRD.3770
- Oladega, A. A., James, O., & Adeyemo, W. L. (2019). Cyanoacrylate tissue adhesive or silk suture for closure of surgical wound following removal of an impacted

mandibular third molar: A randomized controlled study. Journal of Cranio-Maxillo-Facial Surgery : Official Publication of the European Association for Cranio-Maxillo-Facial Surgery, 47(1), 93–98. https://doi.org/10.1016/J.JCMS.2018.10.018

- Oncol, O., Roseane Queiroz De Paiva, A., Abreu De Azevedo Fraga, L., Laura, V., Torres, L., & Ventura, A. (2016). Surgical reconstruction of ocular surface tumors using fibrin sealant tissue adhesive. Karger.ComAR Queiroz de Paiva, L Abreu de Azevedo Fraga, VLL TorresOcular Oncology and Pathology, 2016•karger.Com, 2, 207–211. https://doi.org/10.1159/000444532
- Ozcan, M., Ucak, O., Alkaya, B., Keceli, S., Seydaoglu, G., & Haytac, M. (2017). Effects of Platelet-Rich Fibrin on Palatal Wound Healing After Free Gingival Graft Harvesting: A Comparative Randomized Controlled Clinical Trial. The International Journal of Periodontics & Restorative Dentistry, 37(5), e270–e278. https://doi.org/10.11607/PRD.3226
- Patel, A. K. (2015). Chitosan: Emergence as potent candidate for green adhesive market. Biochemical Engineering Journal, 102, 74–81. https://doi.org/10.1016/J.BEJ.2015.01.005
- Pérez, M., Fernández, I., Márquez, D., & Guerra Bretaña, R. M. (2000). Use of N-butyl-2-cyanoacrylate in oral surgery: biological and clinical evaluation. Artificial Organs, 24(3), 241–243. https://doi.org/10.1046/J.1525-1594.2000.06519.X
- Pinkas, O., Goder, D., Noyvirt, R., Peleg, S., Kahlon, M., & Zilberman, M. (2017). Structuring of composite hydrogel bioadhesives and its effect on properties and bonding mechanism. Acta Biomaterialia, 51, 125–137. https://doi.org/10.1016/J.ACTBIO.2017.01.047
- Qiu, L., See, A., Steele, T., neurosurgery, N. K.-J. of, & 2019, undefined. (n.d.). Bioadhesives in neurosurgery: a review. Thejns.OrgL Qiu, AAQ See, TWJ Steele, NKK KingJournal of Neurosurgery, 2019•thejns.Org. Retrieved August 17, 2024, from https://thejns.org/downloadpdf/display/journals/j-neurosurg/aop/article-10.3171-2019.8.JNS191592/article-10.3171-2019.8.JNS191592.pdf
- Ranson, J. M., Amin, K., Schechter, E. M. M., & Kosutic, D. (2016). Haemostatic property of cyanoacrylate in pedicled flaps. The British Journal of Oral & Maxillofacial Surgery, 54(9), 1046–1047. https://doi.org/10.1016/J.BJOMS.2016.01.035
- Rathi, S., Saka, R., Domb, A. J., & Khan, W. (2019). Protein-based bioadhesives and bioglues. Polymers for Advanced Technologies, 30(2), 217–234. https://doi.org/10.1002/PAT.4465
- Ravichandran, V., & Jayakrishnan, A. (2018). Synthesis and evaluation of anti-fungal activities of sodium alginate-amphotericin B conjugates. International Journal of Biological Macromolecules, 108, 1101–1109. https://doi.org/10.1016/J.IJBIOMAC.2017.11.030
- Reakasame, S., & Boccaccini, A. R. (2018). Oxidized Alginate-Based Hydrogels for Tissue Engineering Applications: A Review. Biomacromolecules, 19(1), 3–21. https://doi.org/10.1021/ACS.BIOMAC.7B01331/ASSET/IMAGES/MEDIUM/BM-2017-01331S_0007.GIF
- Rose, S., Prevoteau, A., Elzière, P., Hourdet, D., Marcellan, A., & Leibler, L. (2013). Nanoparticle solutions as adhesives for gels and biological tissues. Nature 2013 505:7483, 505(7483), 382–385. https://doi.org/10.1038/nature12806
- Ruan, S., Cao, X., Cun, X., Hu, G., Zhou, Y., Zhang, Y., Lu, L., He, Q., & Gao, H. (2015). Matrix metalloproteinase-sensitive size-shrinkable nanoparticles for deep tumor penetration and pH triggered doxorubicin release. Biomaterials, 60, 100–110. https://doi.org/10.1016/J.BIOMATERIALS.2015.05.006
- Ruprai, H., Romanazzo, S., Ireland, J., Kilian, K., Mawad, D., George, L., Wuhrer, R., Houang, J., Ta, D., Myers, S., & Lauto, A. (2019). Porous Chitosan Films Support Stem Cells and Facilitate Sutureless Tissue Repair. ACS Applied Materials & Interfaces, 11(36), 32613–32622. https://doi.org/10.1021/acsami.9b09123
- Sadatmansouri S, Moradi S, Iranpour B. Effect of cyanoacrylate adhesive on tissue healing after periodontal surgery. J Res Dent Maxillofac Sci. 2020;5(4):13–19.
- Sadlik, B., Kolodziej, L., Blasiak, A., Szymczak, M., & Warchal, B. (2017). Biological reconstruction of large osteochondral lesions of the talar dome with a modified "sandwich" technique—Midterm results. Foot and Ankle Surgery, 23(4), 290–295. https://doi.org/10.1016/J.FAS.2016.09.001
- Sagar, P., Prasad, K., Lalitha, R. M., & Ranganath, K. (2015). Cyanoacrylate for Intraoral Wound Closure: A Possibility? International Journal of Biomaterials, 2015. https://doi.org/10.1155/2015/165428
- Sagara, Y., Kiyosue, H., Tanoue, S., Shimada, R., Hongo, N., Kohno, T., Kawano, K., & Mori, H. (2013). Selective transarterial embolization with n-butyl-2-cyanoacrylate for the treatment of arterial hemorrhage after third molar extraction. Neuroradiology, 55(6), 725–731. https://doi.org/10.1007/S00234-013-1158-5

- Sahu, S., Mishra, S., Lenka, S., Banerjee, R., Pachisia, S., & Ghosh, S. (2019). Comparison between N-butyl cyanoacrylate tissue adhesive and Ethilon nylon sutures in extraoral maxillofacial incisions: A randomized prospective study. Journal of Oral Biology and Craniofacial Research, 9(3), 173–178. https://doi.org/10.1016/j.jobcr.2019.04.002
- Salata, L. A., Mariguela, V. C., Antunes, A. A., Grossi-Oliveira, G., Almeida, A., & Taba, M. (2014). Short-term evaluation of grafts fixed with either N-butyl-2-cyanocrylate or screws. Journal of Oral and Maxillofacial Surgery : Official Journal of the American Association of Oral and Maxillofacial Surgeons, 72(4), 676–682. https://doi.org/10.1016/j.joms.2013.11.016
- Santmartí-Oliver M, Bazal-Bonelli S, Sánchez-Labrador L, Beca-Campoy T, Pérez-González F, Cobo-Vázquez CM, et al. Cyanoacrylate versus suture as flap closure methods in mandibular third molar surgery: a split-mouth randomized controlled clinical study. Med Oral Patol Oral Cir Bucal. 2024;29(4):e458–e467.
- Schweller, R. M., Wu, Z. J., Klitzman, B., & West, J. L. (2017). Stiffness of Protease Sensitive and Cell Adhesive PEG Hydrogels Promotes Neovascularization In Vivo. Annals of Biomedical Engineering, 45(6), 1387–1398. https://doi.org/10.1007/S10439-017-1822-8/METRICS
- Shagan, A., Zhang, W., Mehta, M., Levi, S., Kohane, D. S., & Mizrahi, B. (2020). Hot Glue Gun Releasing Biocompatible Tissue Adhesive. Advanced Functional Materials, 30(18). https://doi.org/10.1002/ADFM.201900998
- Shtenberg, Y., Goldfeder, M., Prinz, H., Shainsky, J., Ghantous, Y., Abu El-Naaj, I., Schroeder, A., & Bianco-Peled, H. (2018). Mucoadhesive alginate pastes with embedded liposomes for local oral drug delivery. International Journal of Biological Macromolecules, 111, 62–69. https://doi.org/10.1016/J.IJBIOMAC.2017.12.137
- Singh, P. K., Degala, S., Shetty, S., Rai, V. S., & Das, A. (2019). To Evaluate the Efficacy and Effectiveness of N-butyl-2-cyanoacrylate glue (TRU SEAL) in Closure of Oral and Maxillofacial Laceration and Surgical Incisions. Journal of Maxillofacial and Oral Surgery, 18(1), 131–138. https://doi.org/10.1007/S12663-018-1111-6
- Song, C. K., Kim, M. K., Lee, J., Davaa, E., Baskaran, R., & Yang, S. G. (2019). Dopa-Empowered Schiff Base Forming Alginate Hydrogel Glue for Rapid Hemostatic Control. Macromolecular Research, 27(2), 119–125. https://doi.org/10.1007/S13233-019-7026-3/METRICS
- Song, Y., Nagai, N., Saijo, S., Kaji, H., Nishizawa, M., & Abe, T. (2018). In situ formation of injectable chitosan-gelatin hydrogels through double crosslinking for sustained intraocular drug delivery. Materials Science and Engineering: C, 88, 1–12. https://doi.org/10.1016/J.MSEC.2018.02.022
- Stavropoulou C, Atout RN, Brownlee M, Schroth RJ, Kelekis-Cholakis A. A randomized clinical trial of cyanoacrylate tissue adhesives on the donor site of connective tissue grafts. J Periodontol. 2019;90(6):608–615.
- Sudhakar, Y., Kuotsu, K., & Bandyopadhyay, A. K. (2006). Buccal bioadhesive drug delivery--a promising option for orally less efficient drugs. Journal of Controlled Release : Official Journal of the Controlled Release Society, 114(1), 15–40. https://doi.org/10.1016/j.jconrel.2006.04.012
- Suh, Y. J., Yu, H. W., Kim, S. Ji., Choe, J. Y., Park, H. J., Choi, J. Y., & Lee, K. E. (2019). Biocompatibility of n-butyl-2-cyanoacrylate (Histoacryl) in cervical structures of rats: prospective in vivo study. Annals of Surgical Treatment and Research, 96(4), 162–168. https://doi.org/10.4174/ASTR.2019.96.4.162
- Suthar P, Shah S, Waknis P, Limaye G, Saha A, Sathe P. Comparing intra-oral wound healing after alveoloplasty using silk sutures and n-butyl-2-cyanoacrylate. J Korean Assoc Oral Maxillofac Surg. 2020;46(1):28–35.
- Tacconi, L., Spinelli, R., & Signorelli, F. (2019). Skin Glue for Wounds Closure in Brain Surgery: Our Updated Experience. World Neurosurgery, 121, e940–e946. https://doi.org/10.1016/J.WNEU.2018.10.023
- Tadokoro, T., Kakinohana, M., … M. N.-A. &, & 2019, undefined. (n.d.). The effectiveness of applying soft tissue bonding adhesive composed of 2-ethyl cyanoacrylate to epidural catheter fixations using film dressings: an open-label. Journals.Lww.ComT Tadokoro, M Kakinohana, M Navarro, M Goya, Y OdoAnesthesia & Analgesia, 2019•journals.Lww.Com. Retrieved August 17, 2024, from https://journals.lww.com/anesthesia-analgesia/fulltext/2019/07000/the_effectiveness_of_applying_soft_tissue_bonding.27.aspx
- Tan, H., Jin, D., Qu, X., Liu, H., Chen, X., Yin, M., & Liu, C. (2019). A PEG-Lysozyme hydrogel harvests multiple functions as a fit-to-shape tissue sealant for internal-use of body. Biomaterials, 192, 392–404. https://doi.org/10.1016/J.BIOMATERIALS.2018.10.047
- Tanaka, H., Hasegawa, S., Sakamoto, T., & Sunamori, M. (2001). Postinfarction ventricular septal perforation repair with endoventricular circular patch plasty using double patches and gelatin–resorcinol–formaldehyde biological glue. European Journal of Cardio-Thoracic

Surgery, 19(6), 945–948. https://doi.org/10.1016/S1010-7940(01)00731-X

- Tavelli, L., Asa'ad, F., Acunzo, R., Pagni, G., Consonni, D., & Rasperini, G. (2018). Minimizing Patient Morbidity Following Palatal Gingival Harvesting: A Randomized Controlled Clinical Study. The International Journal of Periodontics & Restorative Dentistry, 38(6), e127–e134. https://doi.org/10.11607/prd.3581
- Tavelli L, Ravidà A, Saleh MHA, Maska B, Del Amo FS, Rasperini G, et al. Pain perception following epithelialized gingival graft harvesting: a randomized clinical trial. Clin Oral Investig. 2019;23(1):459–468.
- Thoniyot, P., Tan, M. J., Karim, A. A., Young, D. J., & Loh, X. J. (2015). Nanoparticle–Hydrogel Composites: Concept, Design, and Applications of These Promising, Multi-Functional Materials. Advanced Science, 2(1–2). https://doi.org/10.1002/ADVS.201400010
- Vastani, A., & Maria, A. (2013). Healing of intraoral wounds closed using silk sutures and isoamyl 2-cyanoacrylate glue: a comparative clinical and histologic study. Journal of Oral and Maxillofacial Surgery : Official Journal of the American Association of Oral and Maxillofacial Surgeons, 71(2), 241–248. https://doi.org/10.1016/J.JOMS.2012.08.032
- Yan, H., Li, L., Wang, Z., Wang, Y., Guo, M., Shi, X., Yeh, J. M., & Zhang, P. (2020a). Mussel-Inspired Conducting Copolymer with Aniline Tetramer as Intelligent Biological Adhesive for Bone Tissue Engineering. ACS Biomaterials Science and Engineering, 6(1), 634–646. https://doi.org/10.1021/ACSBIOMATERIALS.9B01601/SUPPL_FILE/AB9B00130_SI_001.PDF
- Yan, H., Li, L., Wang, Z., Wang, Y., Guo, M., Shi, X., Yeh, J.-M., & Zhang, P. (2020b). Mussel-Inspired Conducting Copolymer with Aniline Tetramer as Intelligent Biological Adhesive for Bone Tissue Engineering. ACS Biomaterials Science & Engineering, 6(1), 634–646. https://doi.org/10.1021/acsbiomaterials.9b01601
- Yan, H., Wang, S., Han, L., Peng, W., Yi, L., Guo, R., Liu, S., Yang, H., & Huang, C. (2018). Chlorhexidine-encapsulated mesoporous silica-modified dentin adhesive. Journal of Dentistry, 78, 83–90. https://doi.org/10.1016/J.JDENT.2018.08.012
- Yılmaz M, Kayaaltı-Yüksek S, Karaduman B. The effects of cyanoacrylate on clinical healing and self-reported outcomes following free gingival graft surgery: a randomized clinical study. Clin Exp Health Sci. 2022;12(4):691–696.
- Zheng, K., Gu, Q., Zhou, D., Zhou, M., & Zhang, L. (2022). Recent progress in surgical adhesives for biomedical applications. In Smart Materials in Medicine (Vol. 3, pp. 41–65). KeAi Communications Co. https://doi.org/10.1016/j.smaim.2021.11.004
- Zhu, J., Li, F., Wang, X., Yu, J., & Wu, D. (2018). Hyaluronic Acid and Polyethylene Glycol Hybrid Hydrogel Encapsulating Nanogel with Hemostasis and Sustainable Antibacterial Property for Wound Healing. ACS Applied Materials & Interfaces, 10(16), 13304–13316. https://doi.org/10.1021/acsami.7b18927
- Zhu, W., Chuah, Y. J., & Wang, D.-A. (2018). Bioadhesives for internal medical applications: A review. Acta Biomaterialia, 74, 1–16. https://doi.org/10.1016/j.actbio.2018.04.034
- Zhu, W., Iqbal, J., & Wang, D. A. (2019). A DOPA-functionalized chondroitin sulfate-based adhesive hydrogel as a promising multi-functional bioadhesive. Journal of Materials Chemistry B, 7(10), 1741–1752. https://doi.org/10.1039/C8TB01990H