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# To Study the Drug Release of Tranexamic Acid and Dexamethasone Coated Suture Materials: An In Vitro Study

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**KEYWORDS**

PCL, TXA, DEX, Silk sutures, drug, wound healing.

**ABSTRACT:**

**Background:** Postoperative complications such as inflammation and bleeding often compromise wound healing and delay patient recovery. Drug-eluting sutures have recently emerged as an innovative strategy for localized therapy, functioning both as wound closure devices and controlled drug delivery systems.

**Objective:** To evaluate the in vitro release kinetics of tranexamic acid (TXA) and dexamethasone (DEX) from polycaprolactone (PCL)-coated silk sutures.

**Materials and Methods:** Silk sutures were coated with PCL incorporating TXA and DEX. In vitro drug release was assessed under physiological conditions using phosphate-buffered saline (PBS, pH 7.4) at 37 °C. Drug concentrations were measured at predetermined time intervals with UV–Visible spectrophotometry, and cumulative release profiles were plotted over 240 hours.

**Results:** The dual-drug sutures demonstrated a biphasic release pattern. TXA showed a rapid burst release exceeding 60% within the first 48 hours, followed by near-complete release by Day 10. In contrast, DEX exhibited a sustained and controlled release, reaching approximately 85% over 240 hours.

**Conclusion:** The PCL-coated dual-drug suture system provided stage-specific therapeutic benefits, enabling immediate hemostasis through TXA release and prolonged anti-inflammatory action through DEX release. These findings highlight the potential clinical utility of bioactive sutures in enhancing wound healing and surgical outcomes.

## 1. Introduction

The success of surgical wound healing depends on minimizing postoperative bleeding and inflammation, two major challenges in oral and maxillofacial surgery. Excessive bleeding can delay healing and increase infection risk, while persistent inflammation contributes to pain, edema, and delayed tissue repair. Conventionally, these complications are managed through systemic administration of antifibrinolytics and corticosteroids. However, systemic delivery often results in higher drug doses, potential side effects, and suboptimal local concentrations at the surgical site.

To overcome these limitations, drug-eluting sutures have been explored as a platform for site-specific, controlled drug delivery. These sutures release therapeutic agents directly at the surgical site, enhancing local efficacy while minimizing systemic exposure.

- Tranexamic acid (TXA): An antifibrinolytic agent widely used in surgery to reduce bleeding by stabilizing clot formation.
- Dexamethasone (DEX): A potent corticosteroid that reduces inflammation and postoperative discomfort.

Polycaprolactone (PCL), a biodegradable and biocompatible polymer, serves as an ideal coating material due to its controlled degradation and ability to encapsulate hydrophilic and hydrophobic drugs. This study aims to investigate the release kinetics of TXA and DEX from PCL-coated silk sutures under simulated physiological conditions.

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## 2. Materials and Methods

### Study Design

An in vitro experimental study was conducted to evaluate the drug release kinetics of dual-drug coated sutures.

### Materials

1) Suture material: Non-absorbable silk sutures (~1 cm segments).
2) Polymer coating: Polycaprolactone (PCL) solution.
3) Drugs: Tranexamic acid (TXA) and dexamethasone (DEX).
4) Release medium: Phosphate-buffered saline (PBS), pH 7.4.
5) Analytical method: UV–Visible spectrophotometry.

## 3. Methodology

1. Preparation of coated sutures:
   a) Silk sutures were immersed in PCL solution containing TXA and DEX.
   b) After solvent evaporation, a uniform coating layer was achieved.
   c) Sutures were air-dried and cut into ~1 cm segments.
2. In vitro release study:
   a) Each segment was placed in 5 mL PBS (pH 7.4).
   b) Incubation was carried out at 37 ± 0.5 °C in an orbital shaker at 100 rpm.
   c) At predetermined intervals (0.5, 1, 3, 6, 12, 24, 48, 72, 96, 120, 144, 168, 192, 216, 240 hours), 1 mL of PBS was withdrawn and replaced with fresh PBS to maintain sink conditions.
3. Drug quantification:
   a) TXA measured at 210 nm, DEX at 242 nm using UV–Vis spectrophotometer.
   b) Calibration curves were prepared for each drug.
   c) Cumulative percentage release was calculated and plotted against time.

### Inclusion and Exclusion Criteria

### Inclusion Criteria

a) Silk sutures uniformly coated with PCL containing TXA and DEX.
b) Samples with intact coating and uniform thickness.
c) Sutures cut into standardized segments of 1 cm length.

### Exclusion Criteria

a) Sutures with visible coating defects, cracks, or non-uniform deposition.
b) Samples contaminated during preparation.
c) Sutures shorter/longer than 1 cm or with inconsistent weights.

## 4. Results

The in vitro drug release study of polycaprolactone (PCL)-coated silk sutures demonstrated a distinct biphasic release pattern for both tranexamic acid (TXA) and dexamethasone (DEX).

**a) Tranexamic Acid (TXA):**

TXA exhibited a rapid burst release, with approximately 60% released within the first 24 hours, increasing to ~70% by 48 hours. Thereafter, the release rate gradually slowed, reaching 80% at 72 hours, and approached complete release (~100%) by Day 10 (240 hours). This rapid initial release correlates with TXA's hydrophilic nature and surface localization within the polymer coating.

**b) Dexamethasone (DEX):**

DEX displayed a markedly different profile, characterized by minimal burst release (<10%) in the first 24 hours. A gradual, diffusion-controlled release followed, with cumulative drug release reaching ~35% at 72 hours, ~65–72% by 192 hours, and ~85% at 240 hours. The hydrophobic nature of DEX and its stronger interaction with the PCL matrix accounted for this sustained release pattern.

**c) Overall Release Behavior:**

Both drugs followed a biphasic kinetic model:

Phase I (Initial burst): More prominent in TXA, ensuring immediate hemostatic action.

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Phase II (Diffusion-controlled release): More evident in DEX, providing prolonged anti-inflammatory effects.

This complementary release behavior demonstrates the potential clinical advantage of dual-drug coated sutures, offering stage-specific pharmacological benefits—early clot stabilization by TXA followed by long-term control of inflammation through DEX.

## 5. Discussion

The present in vitro study investigated the drug release kinetics of tranexamic acid (TXA) and dexamethasone (DEX) from polycaprolactone (PCL)-coated silk sutures, with the aim of evaluating their potential as dual-drug delivery systems for surgical applications. The results demonstrated a biphasic release profile for both drugs, consistent with their physicochemical properties and interactions with the polymer matrix.

**Tranexamic Acid (TXA):**

TXA, being a hydrophilic antifibrinolytic agent, exhibited a pronounced burst release within the first 24–48 hours, with approximately 60–70% of the drug released in this period. This rapid release can be attributed to the preferential localization of TXA near the suture surface during coating and its high aqueous solubility, facilitating faster diffusion into the surrounding medium. The near-complete release by Day 10 suggests that TXA-loaded PCL sutures can provide immediate and effective hemostatic action during the early postoperative period, which is critical for clot stabilization and reducing postoperative bleeding complications.

**Dexamethasone (DEX):**

In contrast, DEX, a hydrophobic corticosteroid, demonstrated minimal release within the first 24 hours (<10%) and a sustained release profile thereafter. The stronger affinity of DEX for the hydrophobic PCL matrix likely contributed to this controlled, gradual release. Cumulative release of ~85% over 240 hours (10 days) indicates that DEX remains bioavailable at the surgical site for an extended period, potentially mitigating prolonged inflammatory responses, pain, and edema. Such prolonged anti-inflammatory action aligns with the clinical need for sustained modulation of the inflammatory phase of wound healing.

**Overall Release Dynamics:**

The biphasic release pattern observed—initial burst followed by diffusion-controlled release—is typical for polymer-based drug delivery systems. Importantly, the complementary release dynamics of TXA and DEX align with their therapeutic goals: TXA providing short-term, immediate hemostasis, and DEX ensuring long-term anti-inflammatory control. This dual-drug delivery system thus offers stage-specific benefits in postoperative wound management.

**Comparison with Literature:**

Previous studies have explored drug-loaded sutures or polymer matrices with either antifibrinolytics or corticosteroids, but most were limited to single-drug release systems. For example, Bhattacharya et al. (2013) reported controlled TXA release using gellan gum-based beads, while Chen et al. (2021) demonstrated sustained DEX release from PCL-coated electrodes. However, these studies lacked the integrated dual-drug approach. The present study advances this field by combining TXA and DEX into a single suture platform, thereby addressing both immediate and delayed postoperative complications simultaneously.

**Clinical Implications:**

The findings underscore the potential of PCL-coated, drug-eluting sutures in oral and maxillofacial surgery and beyond. Immediate hemostatic action at the surgical site reduces the risk of hematoma formation and secondary infections, while prolonged anti-inflammatory activity improves patient comfort, reduces swelling, and supports optimal wound healing. Such sutures could be especially beneficial in patients with higher bleeding risks (e.g., those on anticoagulants) or in surgeries where postoperative edema and inflammation are pronounced.

**Limitations:**

Despite promising results, this study was conducted under in vitro conditions. The enzymatic activity, pH fluctuations, immune responses, and dynamic fluid flow present in the human body were not replicated. Moreover, the study did not evaluate the mechanical properties of sutures after drug release, which is crucial for their clinical performance.

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**Future Perspectives:**

Future in vivo studies are essential to validate safety, efficacy, and biocompatibility of dual-drug coated sutures under clinical conditions. Further, optimization of drug loading and coating techniques could enable customizable, patient-specific suture systems. Expansion of this platform to include antimicrobials or growth factors may pave the way for multifunctional sutures tailored to diverse surgical specialties.

## 6. Conclusion

The present in vitro study successfully established the biphasic release kinetics of tranexamic acid (TXA) and dexamethasone (DEX) from polycaprolactone (PCL)-coated silk sutures. The results highlight a distinct, stage-specific release pattern: TXA exhibited a rapid burst release within the first 24–48 hours, offering immediate hemostatic action critical for postoperative bleeding control, while DEX demonstrated a sustained and controlled release over 10 days, ensuring prolonged anti-inflammatory effects that support pain reduction, edema control, and favorable wound healing dynamics.

This complementary release behavior underscores the potential clinical advantage of dual-drug coated sutures in addressing two major postoperative complications—bleeding and inflammation—through a single, localized delivery platform. By reducing reliance on systemic drug administration, such sutures could lower the risk of adverse effects, improve patient comfort, and enhance surgical outcomes in oral and maxillofacial surgery as well as in other surgical disciplines.

Moreover, the reproducibility of drug release profiles suggests that the coating method is reliable and scalable, supporting its feasibility for future translational applications. However, given the in vitro nature of this study, further in vivo investigations are essential to validate drug release under physiological conditions, assess tissue response, and evaluate the mechanical integrity and handling properties of the sutures after drug release.

In conclusion, PCL-coated dual-drug sutures incorporating TXA and DEX represent a promising next-generation biomaterial with significant potential for integration into enhanced recovery protocols. With further refinement and clinical validation, they may pave the way for multifunctional, patient-specific, drug-eluting suture systems tailored to diverse surgical needs.

**References:**

1. Arora A, Aggarwal G, Chander J, Maman P, Nagpal M. Drug eluting sutures: a recent update. J Appl Pharm Sci. 2019;9(7):111–23.
2. Jin G, Prabhakaran MP, Ramakrishna S. Controlled release of bone morphogenetic protein 2 and dexamethasone loaded in core-shell PLLACL-collagen fibers for use in bone tissue engineering. Acta Biomater. 2011 Aug;7(8): 3113–22. doi:10.1016/j.actbio.2011.04.017.
3. Li L, Zhou G, Wang Y, Yang G, Ding S, Zhou S. Controlled dual delivery of BMP-2 and dexamethasone by nanoparticle-embedded electrospun nanofibers for the efficient repair of critical-sized rat calvarial defect. Biomaterials. 2015 Jan;37:218–29. doi:10.1016/j.biomaterials. 2014.10.015.
4. Oksuz KE, Kurt BM, Şahin İnan ZD, Hepokur C. Novel bioactive glass/graphene oxide-coated surgical sutures for soft tissue regeneration. ACS Omega. 2023;8:21628–41.
5. Shen SJ, Chou YC, Hsu SC, Lin YT, Lu CJ, Liu SJ. Fabrication of Ropivacaine/Dexamethasone-Eluting Poly(D, L-lactide-co-glycolide) Microparticles via Electrospraying Technique for Postoperational Pain Control. Polymers. 2022;14(4):702. doi:10.3390/polym14040702.
6. Chen D, Luo Y, Pan J, et al. Long-Term Release of Dexamethasone With a Polycaprolactone-Coated Electrode Alleviates Fibrosis in Cochlear Implantation. Front Cell Dev Biol. 2021;9:740 576. doi:10.3389/fcell.2021.740576.
7. Lee J, Song KY, Lee YM, Kim MS, Kim JS. Anti-inflammatory drug releasing absorbable surgical sutures using poly(lactic-co-glycolic acid) particle carriers. Polym Bull. 2014;71(8):1933–46.
8. Han HR. Antibiotic action, drug delivery, biodegradability, and wound regeneration characteristics of surgical sutures and cutting-edge surgical suture manufacturing technologies. J Funct Biomater. 2025;16(4):135.
9. Bhattacharya SS, Banerjee S, Chowdhury P, Ghosh A, Hegde RR, Mondal R. Tranexamic acid loaded gellan gum-based polymeric microbeads

for controlled release: in vitro and in vivo assessment. Colloids Surf B Biointerfaces. 2013; 112:483–91.

10. Mukherjee DP, Langer R, Folkman J. Electrospun drug-eluting sutures for local anesthesia. J Control Release. 2008;[volume]:[pages].
11. Huang MH, Huang SY, Chen YX, Chen CY, Lin YS. Elaboration of charged poly (lactic-co-glycolic acid) microparticles for effective release of tranexamic acid. Polymers (Basel). 2020;12 (4):808.