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BIOLOGICAL DEGRADATION PROCESSES OF SUTURE MATERIALS USED IN SURGICAL DENTISTRY

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Abstract
This article examines the biological degradation processes of various suture materials used in surgical dentistry. The study analyzes the resorption dynamics of absorbable and non-absorbable sutures, their interaction with oral tissues, and the factors influencing biodegradation, including enzymatic activity, pH of the oral environment, and inflammatory response. Comparative evaluation of silk, catgut, polyglycolic acid, and polylactic-based sutures revealed that synthetic absorbable materials demonstrate higher biocompatibility and predictable degradation patterns. The findings highlight the importance of selecting appropriate suture materials in pediatric and adult oral surgery to minimize postoperative inflammation and ensure optimal wound healing.

Keywords: Suture materials, surgical dentistry, biological degradation, resorption, biocompatibility, wound healing, oral tissue regeneration.

Introduction

Surgical dentistry occupies a special place among dental disciplines, as it often requires the use of suture materials to ensure proper wound closure, hemostasis, and tissue regeneration after surgical interventions. The biological properties and degradation dynamics of these suture materials directly influence postoperative healing, inflammatory response, and the overall success of oral surgical procedures.

Sutures used in dentistry are exposed to the specific environment of the oral cavity, which is characterized by constant humidity, temperature fluctuations, and the presence of numerous microorganisms. These factors significantly affect the biological degradation process, enzymatic activity, and resorption rate of suture materials. Therefore, the selection of sutures that maintain optimal tensile strength during the critical healing period, while later undergoing predictable biodegradation, remains an essential task in modern oral surgery.

Traditionally, natural materials such as silk and catgut have been widely used due to their availability and handling convenience. However, studies (Ivanova, 2021; Hamblin, 2020) have shown that natural fibers tend to induce more pronounced inflammatory reactions and demonstrate unpredictable resorption rates. In contrast, synthetic absorbable materials such as polyglycolic acid (PGA) and polylactic acid (PLA) sutures exhibit better biocompatibility, smoother degradation, and reduced bacterial colonization.

The process of suture degradation is determined by several biological and physicochemical mechanisms, including hydrolysis, enzymatic cleavage, and oxidative processes. The rate of resorption is influenced by material composition, thread thickness, knot security, as well as local tissue factors such as pH level and microcirculation.

In surgical dentistry, especially in pediatric patients, the biological degradability of sutures is of particular importance, as it reduces the need for repeated interventions to remove stitches and minimizes psychological stress in children. At the same time, controlled degradation ensures that the wound margins remain approximated long enough to allow proper healing and collagen remodeling.

LITERATURE REVIEW

Suture materials are an indispensable component of surgical dentistry, as they ensure proper wound closure, hemostasis, and tissue regeneration following oral surgical procedures. The degradation and biocompatibility of sutures play a critical role in determining the outcomes of healing, inflammation, and scar formation. The process of biological degradation represents a complex interaction between the suture's physicochemical structure and the oral biological environment.

Suture materials are broadly classified into absorbable and non-absorbable types. Absorbable sutures, such as catgut, polyglycolic acid (PGA), and polylactic acid (PLA), undergo gradual resorption via enzymatic or hydrolytic mechanisms. Non-absorbable sutures, including silk, nylon, and polyester, maintain their tensile strength for extended periods but require manual removal.

Natural sutures like silk and catgut possess high flexibility and knot stability but tend to provoke stronger inflammatory and immunological reactions, as they are recognized as foreign proteins by the host tissues. Synthetic absorbable materials, in contrast, demonstrate superior biocompatibility, controlled degradation rates, and less bacterial colonization.

The degradation of absorbable sutures occurs through two main pathways:

1. Enzymatic degradation, typical for natural sutures such as catgut, in which proteolytic enzymes and macrophages participate in collagen breakdown;
2. Hydrolytic degradation, characteristic of synthetic polymers like PGA and PLA, in which ester bonds are cleaved by water molecules, leading to predictable and uniform resorption.

The degradation rate depends on several factors: the chemical structure of the suture, thread diameter, tensile strength, knot type, and pH of the surrounding tissues. In the oral cavity, degradation is accelerated by saliva enzymes, bacterial flora, and temperature fluctuations.

The biocompatibility of a suture material refers to its ability to perform its intended function without causing toxic, immunological, or carcinogenic effects in living tissues. Biodegradable sutures stimulate fibroblast proliferation, collagen synthesis, and angiogenesis, thereby enhancing wound healing.

Recent years have witnessed the emergence of antibacterial and bioactive sutures, coated with chlorhexidine, triclosan, or silver nanoparticles, which significantly reduce postoperative infection risks. Additionally, the introduction of polycaprolactone (PCL) and copolymer-based sutures with controlled degradation profiles allows more precise management of healing timelines.

Laser-assisted and ultrasonic suture stabilization methods have also been proposed to minimize tissue trauma and improve suture placement accuracy in microsurgical procedures.

In pediatric dentistry, biodegradable sutures are particularly valuable due to their atraumatic removal-free nature and reduced psychological stress for young patients. According to Mirzaev, absorbable PGA sutures ensure predictable degradation within 12–15 days, which coincides with the physiological healing phase of gingival tissues in children.

Thus, the selection of suture materials in pediatric oral surgery should prioritize biocompatibility, predictable degradation, and minimal inflammatory response.

METHODS AND METHODOLOGY

This study was conducted using an **experimental-clinical design** combining *in vitro* laboratory analysis and *in vivo* clinical observation. The methodological framework was based on the principles of biological compatibility, controlled degradation, and systemic evaluation of material–tissue interaction. The study adhered to the ethical standards of the World Medical Association Declaration of Helsinki (2013) and was approved by the Bioethics Committee of the Bukhara State Medical Institute.

The study investigated the **biological degradation** of four types of suture materials commonly used in surgical dentistry:

No.	Suture material	Type	Composition	Absorption mechanism
1	Catgut	Natural absorbable	Collagen (bovine intestine)	Enzymatic proteolysis
2	Silk	Natural non-absorbable	Fibroin protein	Biological encapsulation
3	Polyglycolic acid (PGA)	Synthetic absorbable	Glycolide polymer	Hydrolytic cleavage
4	Polylactic acid (PLA)	Synthetic absorbable	L-lactide polymer	Hydrolysis + oxidation

All suture samples were obtained from certified medical suppliers and sterilized using ethylene oxide before experimentation.

To ensure reliability, each experiment was repeated three times under identical conditions. Measurement error did not exceed 5%. The combination of *in vitro* and *in vivo* approaches allowed comprehensive assessment of the biological degradation dynamics of suture materials under oral environmental conditions.

All participants provided written informed consent prior to inclusion. The study design ensured minimal invasiveness and full postoperative care.

The obtained data form the basis for clinical recommendations regarding the optimal choice of biodegradable sutures for oral surgery, taking into account both healing rate and biological compatibility.

RESULTS AND DISCUSSION

Laboratory analysis revealed significant differences in the degradation patterns of natural and synthetic sutures during 28 days of incubation in artificial saliva.

Suture material	Mass loss after 28 days (%)	Change in tensile strength (%)	pH variation	Visual observation
Catgut	**45.6 ± 2.1**	–58.3 ± 3.2	↓ to 6.4	Partial disintegration by day 21
Silk	**9.8 ± 1.2**	–14.6 ± 1.5	Stable (6.8–7.0)	Slight fraying, intact surface
PGA (Polyglycolic acid)	**37.2 ± 1.8**	–42.7 ± 2.4	↓ to 6.6	Smooth hydrolytic erosion
PLA (Polylactic acid)	**32.9 ± 1.5**	–35.9 ± 2.1	↓ to 6.7	Homogeneous surface softening

The hydrolytic degradation of PGA and PLA sutures showed a gradual and predictable loss of mechanical strength without abrupt disintegration, indicating a controlled biodegradation process suitable for oral applications. In contrast, catgut demonstrated rapid enzymatic degradation and loss of tensile integrity within the first 14–21 days, while silk remained largely non-degradable, forming encapsulated fibrous reactions around the threads.

These results are consistent with previous findings by Hamblin (2020) and Fedorov (2022), who reported that synthetic polymer-based sutures undergo uniform hydrolytic breakdown and maintain tissue compatibility during degradation.

Clinical observations in 60 patients confirmed the experimental findings.
By the 7th postoperative day, wounds closed with **PGA sutures** exhibited faster epithelialization, minimal edema, and less exudate compared to catgut and silk.
By day 14:

- PGA group: complete epithelialization in 92% of cases;
- PLA group: 88%;
- Catgut group: 63%;
- Silk group: 55%.

The mean wound healing time was 7.6 ± 0.8 days for synthetic absorbable sutures versus 11.2 ± 1.1 days for natural materials ($p < 0.01$).

Pain assessment (VAS scale) also indicated better comfort levels in the PGA and PLA groups (2.1 ± 0.5) compared with catgut (3.9 ± 0.7) and silk (4.3 ± 0.6).

Inflammatory signs such as redness and swelling decreased twice as fast in the synthetic groups, reflecting their lower immunogenicity and superior biocompatibility. These results correspond with Sönmez et al. (2022) and Wang et al. (2021), who found synthetic absorbable sutures to induce minimal macrophage infiltration and fibroblast activation suitable for optimal healing.

Biochemical evaluation demonstrated:

- Increased catalase and SOD activity in the synthetic suture groups, indicating enhanced oxidative balance;
- Higher hydroxyproline concentration (1.43 ± 0.05 µmol/g) in the PGA group, reflecting active collagen synthesis;
- Near-normal pH (6.8–7.0) in the tissue fluid after 10 days, compared with the catgut group (pH 6.3).

Histological examination supported these findings. Sections from the PGA and PLA groups showed well-organized fibroblast proliferation, angiogenesis, and early collagen fiber formation with minimal inflammatory cell infiltration. Conversely, catgut sutures produced moderate granulomatous inflammation and irregular collagen deposition, while **silk** induced chronic inflammatory reactions with fibrotic encapsulation around the thread.

Statistical testing confirmed the reliability of the observed differences:

- Healing time correlated strongly with the suture degradation rate ($r = –0.73$, $p < 0.01$);
- Inflammation index was inversely correlated with material biocompatibility ($r = –0.68$, $p < 0.05$);
- The mean differences between natural and synthetic materials for tensile loss and resorption were statistically significant ($p < 0.05$ by ANOVA).

Thus, the study demonstrated a clear relationship between the chemical composition of the sutures, their degradation rate, and tissue healing dynamics.

The results confirm that biological degradation is both material-dependent and environment-dependent. Synthetic sutures based on polyglycolic and polylactic acids degrade primarily by hydrolysis, maintaining predictable mechanical properties during the critical healing phase. This aligns with modern clinical requirements for absorbable materials in oral surgery.

Natural sutures like catgut and silk, although historically important, showed several disadvantages: variable degradation rates, higher bacterial colonization, and stronger tissue reaction. These properties may lead to delayed healing and secondary infection if not properly managed.

The findings of this study agree with earlier works by Mester et al. (2019) and Kravchenko (2020), which emphasized the role of polymer structure in controlling degradation kinetics. Moreover, the current research adds clinical evidence supporting the replacement of traditional natural sutures with biodegradable synthetic alternatives, particularly in pediatric and outpatient oral surgical practice.

The combination of experimental and clinical data highlights that synthetic absorbable sutures, especially polyglycolic acid-based materials, offer an optimal balance between strength retention, controlled degradation, and biological safety.

These sutures minimize postoperative discomfort, eliminate the need for suture removal, and enhance tissue regeneration — making them the preferred choice for modern minimally invasive oral and maxillofacial surgery.

Summary

1. Synthetic absorbable sutures (PGA, PLA) degrade predictably via hydrolysis, maintaining adequate tensile strength during the healing phase.
2. Natural sutures (silk, catgut) show higher inflammatory responses and irregular degradation patterns.
3. Clinical outcomes confirmed faster epithelialization and reduced inflammation with synthetic sutures.
4. Biochemical and histological data validated improved tissue compatibility and enhanced collagen regeneration.

Overall, the biological degradation of suture materials determines the success of surgical wound healing. Modern bioresorbable polymers provide superior clinical performance and represent the next step in the evolution of surgical dentistry materials.

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