EJPMR, 2026, 13(8), 417-422 **Research Article** **Impact Factor: 8.158**

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

ISSN (O): 2394-3211
ISSN (P): 3051-2573
Coden USA:EJPMAG

HYDROLYTIC DEGRADATION AND LOSS OF MECHANICAL STRENGTH OF POLYDIOXANONE THREADS: IMPLICATIONS OF EXPOSURE TO HYALURONIC ACID IN AESTHETIC PROCEDURESHYDROLYTIC DEGRADATION AND LOSS OF MECHANICAL STRENGTH OF POLYDIOXANONE THREADS: IMPLICATIONS OF EXPOSURE TO HYALURONIC ACID IN AESTHETIC PROCEDURES

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DOI: https://doi.org/10.5281/zenodo.21785949

How to cite this Article: [1]*Dra. Kelly Christiane Ricca Martins, [2]Dr. Carlos Ruiz da. Silva, [3]Dr. Joy Martins. (2026). Hydrolytic Degradation and Loss of Mechanical Strength of Polydioxanone Threads: Implications of Exposure to Hyaluronic Acid in Aesthetic ProceduresHydrolytic Degradation and Loss of Mechanical Strength of Polydioxanone Threads: Implications of Exposure to Hyaluronic Acid in Aesthetic Procedures. European Journal of Pharmaceutical and Medical Research, 13(8), 417–422.

Article Received on 05/07/2026 **Article Revised on 25/07/2026** **Article Published on 01/08/2026**

ABSTRACT

Introduction: Polydioxanone (PDO) threads are synthetic, biodegradable, and absorbable biomaterials widely used in minimally invasive procedures for rejuvenation and tissue support. Their ability to provide mechanical support depends on the temporary maintenance of the polymer's structural integrity, which undergoes progressive degradation primarily through hydrolysis. The increasing combined use of PDO threads and injectable biomaterials containing hyaluronic acid raises questions regarding potential interactions that could alter the degradation and mechanical properties of these threads. **Objective:** To experimentally evaluate the tensile strength of PDO threads after prolonged exposure to physiological saline or a formulation containing non-cross-linked hyaluronic acid, and to discuss the potential biomechanical and clinical implications of these findings for combined aesthetic procedures. **Methods:** Thirty barbed PDO threads were distributed into three experimental groups (n=10): control, kept in the original packaging at room temperature; physiological saline, with threads immersed in 15 mL of 0.9% saline solution; and NCTF135HA, with threads immersed in 15 mL of a formulation containing non-cross-linked hyaluronic acid at 5 mg/mL. The groups subjected to immersion were kept at 37.5°C for 30 days. Subsequently, all threads underwent tensile strength testing. Statistical analysis employed the Kruskal-Wallis test, followed by Dunn's post hoc test with Benjamini-Hochberg correction and a significance level of $p<0.05$ **Results:** Tensile strength was 2.39 ± 0.41 kgf in the control group, 0.84 ± 0.44 kgf in the physiological saline group, and 1.044 ± 0.47 kgf in the NCTF135HA group. Both groups subjected to immersion showed significantly lower strength than the control group ($p<0.05$), with no statistically significant difference between the physiological saline and NCTF135HA groups. **Conclusion**: Prolonged exposure of PDO threads to aqueous media, under the experimental conditions evaluated, resulted in a significant reduction in tensile strength. Although previous studies suggest a possible role of hyaluronic acid in accelerating PDO degradation, the results of this experiment did not demonstrate a significant difference between the formulation containing hyaluronic acid and physiological saline. The findings indicate that hydrolysis resulting from exposure to the aqueous medium represents a relevant mechanism for the progressive loss of PDO mechanical Properties.

KEYWORDS: Polydioxanone; suspension threads; hyaluronic acid; hydrolysis; tensile strength; biomaterials; facial rejuvenation.

1. INTRODUCTION

Facial aging is a multifactorial biological process characterized by progressive changes in the skin, soft tissues, and supporting structures, contributing to the development of laxity, ptosis, and alterations in facial contours (Rezaee Khiabanloo et al., 2019; Cobo, 2020).

In this context, minimally invasive procedures aimed at supporting and repositioning soft tissues have gained increasing importance. Among these, suspension threads offer mechanical support combined with a secondary biological response resulting from the presence of the biomaterial within the tissues (Kim et al., 2017; Cobo, 2020).

Threads used for aesthetic procedures can vary in composition, configuration, and anchoring mechanisms. Notable absorbable materials include polydioxanone (PDO), poly-L-lactic acid, and polycaprolactone. PDO is of particular interest due to its biocompatibility, biodegradability, and history of use as an absorbable material (Albuquerque et al., 2021; Marinho et al., 2023; Hong et al., 2024).

In suspension procedures, the initial efficacy of barbed threads depends fundamentally on their mechanical properties. Anchoring structures enable physical interaction with the tissues, while the thread body must retain sufficient strength to withstand the forces to which it is subjected (Aitzetmueller et al., 2019; Bucci et al., 2023; Hong et al., 2024).

Polydioxanone is a polyester susceptible to hydrolytic degradation. The entry of water molecules into the polymer matrix progressively promotes the cleavage of ester bonds in the chain, reducing the polymer's molecular weight. As this process progresses, the material's physical and mechanical properties—including its tensile strength—become compromised (Quirino et al., 2023; Song et al., 2018).

This characteristic is particularly relevant given the use of combined aesthetic therapies. Absorbable threads may be used in patients undergoing procedures involving hyaluronic acid and other injectable biomaterials, whether at different times or in different anatomical regions (da Silva et al., 2023; Ziade et al., 2024).

Previous experimental studies have observed structural changes in PDO threads exposed to hyaluronic acid, leading to the hypothesis that certain conditions could alter or accelerate their degradation. However, understanding regarding the mechanical impact of this interaction—and, above all, its clinical relevance—remains limited (Suárez et al., 2019a; Suárez et al., 2019b).

Thus, the aim of this study was to evaluate the tensile strength of barbed PDO threads following experimental exposure to physiological saline and a formulation containing non-crosslinked hyaluronic acid, comparing them with threads maintained under control conditions.

2. MATERIALS AND METHODS

2.1 Experimental design

An *in vitro* experimental study was conducted to investigate changes in the mechanical strength of PDO threads following prolonged exposure to different liquid media.

Thirty barbed PDO threads of the same model were used, distributed into three experimental groups of ten units each.

The experimental design employed 19G × 100 mm cannulated barbed threads (with a 160 mm thread length), subjected to standardized conditions prior to mechanical testing.

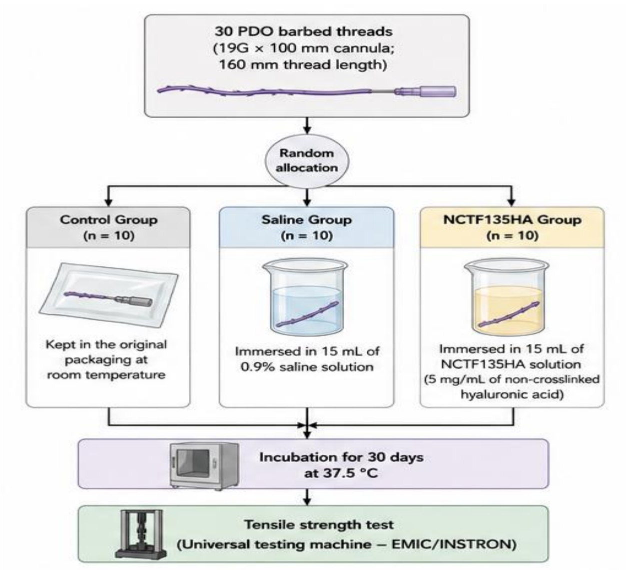

Figure 1: Experimental design of the study.

2.2 Experimental groups

The threads were assigned to the following groups:

- Control Group (n=10): kept in their original packaging and stored at room temperature;
- Saline Solution Group (n=10): immersed in 15 mL of 0.9% saline solution;
- NCTF135HA Group (n=10): immersed in 15 mL of a formulation containing non-cross-linked hyaluronic acid at a concentration of 5 mg/mL.

The groups subjected to immersion were kept in an incubator at 37.5°C for 30 days.

2.3 Tensile strength test

Following the experimental period, the threads were individually subjected to tensile strength testing using a properly calibrated EMIC/INSTRON universal mechanical testing machine.

The tests were conducted by a single trained operator to minimize variability associated with the execution of the procedure.

2.4 Statistical analysis

Data were analyzed using the non-parametric Kruskal-Wallis test. In the event of overall statistical significance, Dunn's post-hoc test was used for multiple comparisons, with probability values adjusted via the Benjamini-Hochberg correction.

The significance level adopted was 5% ($p<0.05$).

3. RESULTS

Exposure of the PDO threads to the two liquid media for 30 days resulted in a significant reduction in tensile strength compared to the control group.

The control group exhibited a mean strength of 2.39 ± 0.41 kgf. The group subjected to physiological saline showed 0.84 ± 0.44 kgf, while the group exposed to NCTF135HA showed 1.044 ± 0.47 kgf.

Both experimental groups showed values significantly lower than those observed in the control group ($p<0.05$). However, no statistically significant difference was identified between the physiological saline and NCTF135HA groups. Using the means as a descriptive reference, the observed strength corresponded to approximately 35% of the control value in the physiological saline group and 44% in the NCTF135HA group. These percentages represent a descriptive comparison of the means and not a direct measure of the polymer's degradation rate.

The results therefore demonstrate that keeping the threads in a heated aqueous environment during the experimental period was associated with a significant compromise of their mechanical properties.

4. DISCUSSION

The main finding of this study was the significant reduction in the tensile strength of PDO threads after 30 days of exposure to both physiological saline and the formulation containing non-crosslinked hyaluronic acid. The influence of hydrolytic degradation on the structural and mechanical properties of polydioxanone is consistent with the behavior described for this biomaterial in the literature (Quirino et al., 2023; Suárez et al., 2019a).

This result is relevant to understanding the biomechanical behavior of PDO. As a biodegradable polyester, polydioxanone possesses chemical bonds susceptible to hydrolysis. Exposure to water promotes the progressive cleavage of ester bonds, fragmenting polymer chains and reducing their molecular mass (Quirino et al., 2023; Song et al., 2018).

The expected biomechanical consequence of this process is a gradual loss of material strength—a property of particular importance when the polymer is used to provide mechanical support to tissues (Bucci et al., 2023; Park et al., 2024).

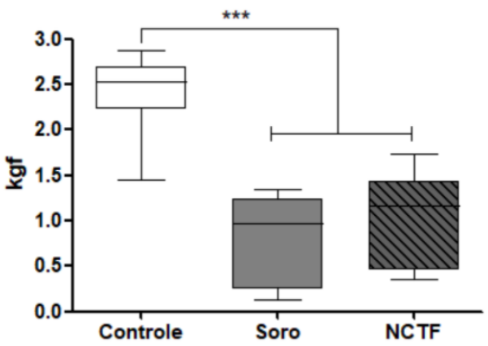

Figure 1: Tensile strength of the experimental groups.

Where: kgf: kilogram-force
*** $p<0.005$, compared to the control group.

4.1 Hydrolysis as the central mechanism

A fundamental aspect of the results is that the reduction in strength was not limited to the group exposed to the hyaluronic acid-containing formulation; the same phenomenon occurred in the group kept in physiological saline.

This finding reinforces the interpretation that prolonged exposure to an aqueous environment—combined with the experimental temperature conditions—played a significant role in the observed mechanical degradation, given the well-known susceptibility of polydioxanone to hydrolytic degradation (Quirino et al., 2023).

Water progressively penetrates the polymer structure, promoting the cleavage of ester bonds. Chain fragmentation reduces the polymer's molecular weight even before a complete macroscopic loss of mass occurs (Quirino et al., 2023; Song et al., 2018).

Consequently, a thread may remain physically present while its mechanical performance is already compromised. Thus, the persistence of the biomaterial should not necessarily be interpreted as the full preservation of its biomechanical properties (Quirino et al., 2023).

This concept is particularly relevant to aesthetic practice: the physical presence of the biomaterial and its functional structural support capacity are not necessarily equivalente.

4.2 The role of hyaluronic acid

Previous studies have suggested that contact between PDO and hyaluronic acid could promote microstructural changes in the polymer. Earlier research reported structural modifications and increased interlaminar spaces following experimental exposure to hyaluronic acid (Suárez et al., 2019a; Suárez et al., 2019b).

Suárez et al. (2019a) observed structural changes in PDO threads incubated with hyaluronic acid, leading to the hypothesis that the degradation process might be accelerated. Microscopic and clinical evidence regarding the interaction between these biomaterials was also subsequently discussed by the authors (Suárez et al., 2019b).

However, the results of the present experiment require careful interpretation.

Although the NCTF135HA group exhibited significantly lower resistance than the control, the physiological saline group showed similar behavior, and there was no statistically significant difference between the two immersion media.

Therefore, the results do not demonstrate that NCTF135HA caused greater mechanical degradation than physiological saline under the conditions evaluated.

This does not rule out a potential specific interaction between hyaluronic acid and PDO, but it indicates that future studies should control for variables such as pH, osmolarity, hyaluronic acid concentration and molecular weight, degree of cross-linking, and the composition of the formulations used.

4.3 An important issue regarding the experimental design

NCTF135HA is not a solution composed exclusively of hyaluronic acid. The formulation used in the experiment contains non-cross-linked hyaluronic acid combined with various other components.

Consequently, any effect observed in this group cannot be attributed solely to the hyaluronic acid.

To specifically determine whether hyaluronic acid accelerates PDO degradation, future experimental designs should compare control solutions with hyaluronic acid alone at various concentrations and molecular weights, as well as compare cross-linked and non-cross-linked formulations and complete commercial products.

This approach would allow for distinguishing the effect of the polymer's exposure to an aqueous environment from any potential specific physicochemical effect of the hyaluronic acid.

4.4 Clinical implications

The findings are potentially relevant for planning combination treatments, but extrapolation to humans must be done with caution. Previous studies demonstrate growing interest in the combination or interaction of lifting threads and hyaluronic acid in aesthetic procedures (da Silva et al., 2023; Ziade et al., 2024). The experiment demonstrates the material's behavior under specific *in vitro* conditions. The human biological environment is more complex and is not fully replicated by experimental immersion models.

Therefore, the results do not justify the claim that the clinical application of hyaluronic acid inevitably reduces the longevity of PDO threads.

However, they raise a relevant scientific question: biomaterials used in the same anatomical region may exhibit interactions that warrant specific investigation, especially considering previous experimental findings involving PDO and hyaluronic acid (Suárez et al., 2019a; Suárez et al., 2019b).

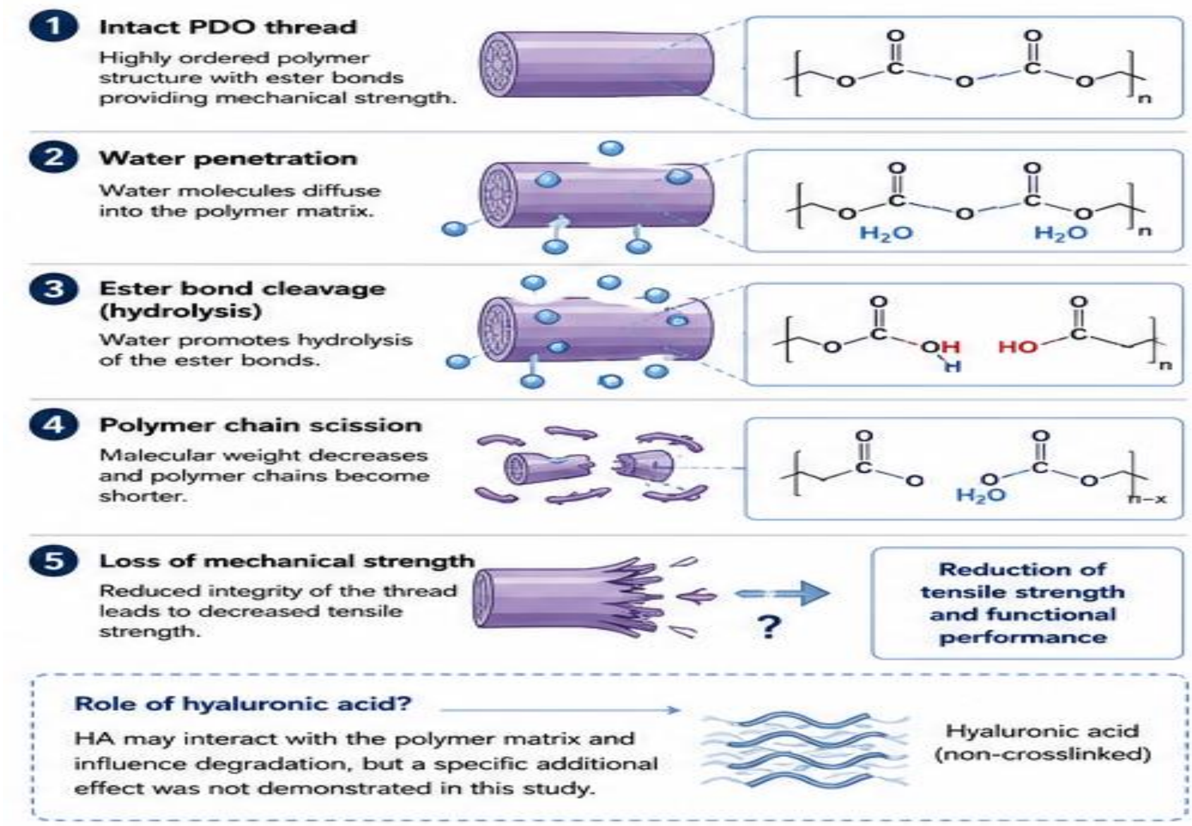

Figure 3: Proposed mechanism of hydorlytic degradation of polydioxanone (PDO).

4.5 Mechanical strength and clinical outcome

Tensile strength is an essential property of threads intended for structural support, being directly related to the material's ability to withstand mechanical loads (Bucci et al., 2023; Park et al., 2024).

The progressive reduction of this strength may diminish the capacity.ability of the thread to withstand mechanical loads. However, the clinical outcome of thread treatment does not depend solely on the polymer's strength (Aitzetmueller et al., 2019; Hong et al., 2024).

Barb geometry, insertion technique, anatomical plane, and traction vector can also influence tissue behavior and the procedure's outcome (Braun et al., 2020; Rezaee Khiabanloo et al., 2019; Hong et al., 2024).
In addition to the mechanical component, the biological response triggered by thread implantation may contribute to the results observed while the biomaterial remains in the tissues (Kim et al., 2017).

Thus, the reduction in mechanical strength observed in this study is an important indicator of material behavior, but it cannot be directly translated into an equivalent percentage of clinical loss of the lifting effect.

5. LIMITATIONS

This study has limitations that should be considered.

First, it is an *in vitro* model that does not fully replicate the human biological environment.

Second, only a 30-day experimental period was evaluated. Including multiple evaluation periods would allow for the establishment of a time-course curve for mechanical strength loss and its correlation with structural changes previously described during PDO degradation (Suárez et al., 2019a).

Another important limitation is the lack of complementary characterization of the polymer structure using techniques such as scanning electron microscopy, thermal analysis, or molecular weight determination. Microscopic analysis has proven relevant in previous studies for identifying structural changes associated with thread degradation (Suárez et al., 2019a; Suárez et al., 2019b).

Furthermore, the NCTF135HA formulation contains multiple components, making it impossible to attribute any specific effect exclusively to hyaluronic acid. Finally, the sample size of ten threads per group limits more in-depth analyses regarding mechanical variability between units.

6. PERSPECTIVES FOR FUTURE STUDIES

Based on the results obtained, future studies should combine mechanical testing with structural and physicochemical analyses, allowing for the correlation of strength loss with microscopic changes in the polymer (Suárez et al., 2019a; Park et al., 2024).

It would be particularly relevant to longitudinally investigate the relationship between exposure time, structural changes, and the loss of mechanical strength in PDO.

It would also be important to compare different classes of absorbable threads, given that different materials exhibit distinct physicochemical and mechanical properties (Hong et al., 2024).

Prospective clinical studies could subsequently investigate whether performing combined procedures in adjacent anatomical planes effectively interferes with the clinical duration of the lifting effect.

7. CONCLUSION

Under the experimental conditions evaluated, exposing barbed polydioxanone threads to physiological saline or a formulation containing non-crosslinked hyaluronic acid for 30 days at 37.5°C resulted in a significant reduction in tensile strength compared to control threads.

The absence of a significant difference between the two immersed groups suggests that exposure to an aqueous environment and the resulting polymer hydrolysis are relevant factors in the observed loss of mechanical strength—an interpretation consistent with the hydrolytic degradation mechanisms described for polydioxanone (Quirino et al., 2023).

Although previous studies have hypothesized that hyaluronic acid might accelerate PDO degradation (Suárez et al., 2019a; Suárez et al., 2019b), the data from this experiment alone do not confirm a specific effect of hyaluronic acid that exceeds the effect caused by exposure to physiological saline. These findings contribute to the understanding of the biomechanical degradation of PDO threads and reinforce the need for experimental and clinical investigations into potential interactions between biomaterials used in combined aesthetic procedures.

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