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Effects of prolonged immersion in artificial saliva on mechanical properties of indonesian made silk sutures: An in vitro study

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Abstract

Objective: This study aimed to evaluate the mechanical properties of Indonesian-made silk sutures after immersion in artificial saliva for varying durations (0, 1, 7, and 14 days).

Material and Method: An in vitro experimental study was conducted using 20 sterile silk suture specimens (4-0 gauge). Five specimens were tested in their dry state (control), while the remaining specimens were immersed in artificial saliva for 1, 7, and 14 days at 37°C. Tensile load, tensile strength, and elongation were assessed using a Universal Testing Machine. Statistical analysis was performed using ANOVA and Tukey's post hoc test.

Results: Prolonged immersion significantly impacted the sutures' mechanical properties. Tensile load and tensile strength decreased progressively, with the lowest values observed on Day 7 (7.23 ± 0.99 N and 409.46 ± 55.77 MPa, respectively). Conversely, elongation (%) increased significantly, peaking on Day 14 (45.08 ± 4.53%).

Conclusion: Indonesian-made silk sutures exhibit reduced tensile strength and load but increased elongation with prolonged exposure to artificial saliva. The sutures meet the minimum tensile strength requirements of the Indonesian National Standard (SNI), however their performance under prolonged immersion need improvement, Further research should focus on improving their resistance to degradation and performance in the oral environment.

Keywords: ongation, Indonesian silk suture, Mechanical properties, Saliva, Tensile
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Introduction

Surgical sutures are fibers used to unite wounds, allowing the collagen produced by the body to close the wound.1 The ideal suture should be easy to manipulate, applicable to various types of surgeries, possess high tensile strength and knot security, not cause tissue damage, sterile, non-allergenic, biocompatible, and affordable.[1-3] Suturing in dentistry differs from suturing in other parts of the body due to the type of tissue involved, the constant presence of saliva, the high vascularization of tissues, and factors related to speech, chewing, and swallowing. Proper sutures require good tensile strength, dimensional stability, knot security, and sufficient flexibility to avoid damage to the oral mucosa.[2,4]

The strength of sutures primarily lies in their ability to close wounds, which depends on the mechanical properties of the suturing technique and materials used.[5] Tensile strength needs to be maintained, as suture threads are likely to lose 70-80% of their strength over time.6 Suture elasticity is the ability of the thread to return to its original shape and length after being stretched. High elasticity allows the suture to stretch as the wound swells without injuring the tissue edges and then regain its normal shape and length as the swelling subsides. These mechanical properties maintain proper tissue apposition during healing.[2,7]

The presence of saliva in the oral cavity affects the quality of surgical sutures. Saliva increases the degradation of surgical sutures, leading to a reduction in tensile strength. Previous studies indicate that the tensile strength of surgical sutures decreases more significantly when soaked in saliva compared to soaking in saline, soybean, or milk solutions.[8] Surgical sutures commonly used in dentistry (intraoral) include silk, nylon, e-PTFE, polyglactin (PGA), and chromic gut.[3,9] Silk is a natural, braided, and colored suture thread that facilitates handling and offers excellent visibility.[10] It is one of the easiest suture materials to handle, with high tensile strength and an affordable price. As a result, silk serves as a benchmark for comparing the characteristics of other surgical sutures. This makes silk the most widely used suture material in Indonesia.[11-14]

Despite its extensive usage, Indonesia relies heavily on imported sutures, with 94% of surgical sutures used by clinicians being imported as of 2015, according to the Director General of Pharmaceutical and Medical Device Development.[15] Domestic production of surgical sutures is limited to only two or three companies, despite the significant cost savings offered by locally produced sutures, which are sold at 30-40% lower prices compared to their imported counterparts. Additionally, many clinicians

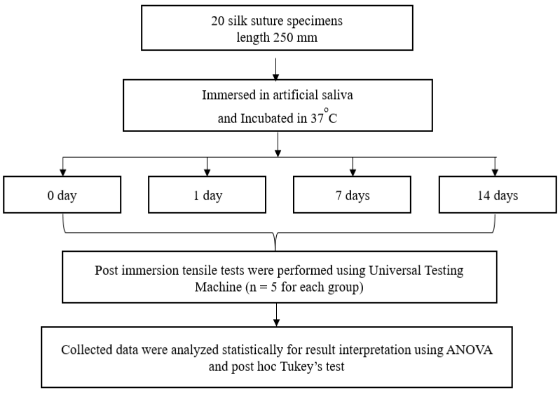

Figure 1. Flow chart of the study protocol.

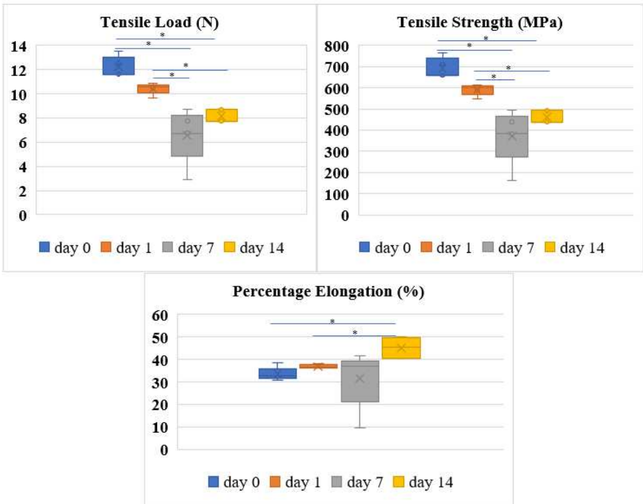

Figure 2. Boxplot diagram represented the tensile load, tensile strength, and elongation.

are unaware of Indonesian-made sutures, limiting their usage in oral procedures.

To the best of our knowledge, limited data are available comparing the tensile strength of Indonesian-made silk sutures under simulated oral conditions. Thus, this study aims to evaluate and compare the tensile properties and elasticity of locally produced silk sutures at different immersion times in artificial saliva, providing insights into their suitability for use in dentistry.

Material and Methods

This in-vitro experimental study used natural braided multifilament silk suture materials produced in Indonesia by PT. Triton Manufacture. The suture evaluated was 4-0 size, chosen due to their common use in oral surgeries.

A total of 20 suture specimens, sourced from sterile, unexpired commercial packs, were prepared. Each suture was cut to a uniform length of 250 mm. Five specimens from each group were tested for tensile properties in a dry state, serving as the control group, while the remaining specimens were divided into three groups and immersed in artificial saliva for 1, 7, and 14 days. All specimens were incubated at 37°C. The study protocol is illustrated in figure 1.

The suture specimens were tested using a Universal Testing Machine (Instron®, USA) which was connected to a computer for digital readout. During the process, the surgical suture was placed on the upper part of the machine, precisely below the top plate. The sample was then secured by turning the handwheel to ensure the clamp was firmly tightened to prevent slippage. Each suture specimen was assessed at a speed of 300 ± 10 mm/min following ASTM D2256 standards. The specimen was stretched until the material broke, and the maximum load required to break the suture was recorded in Newtons (N).

The Universal Testing Machine (UTM) was utilized to determine both the maximum tensile load required to break the suture and the percentage elongation at the point of failure. Tensile strength (s) was calculated using the formula: $s = P/a$.

Where s is the tensile strength (MPa), P is the maximal force required to break (N), and a is the cross-sectional area (mm2). The P was the maximal tensile load that noted using the UTM machine. The cross-sectional area was calculated using the formula πr^2, where r is the radius of the suture. Based on the literature, the diameter of the 4-0 suture was 150 mm, making the r = 75 mm (3). The tensile strength was then calculated using the above formula based on the recorded values.

The collected data was organized and analyzed statistically. Intergroup comparisons of means for continuous variables were conducted using analysis of variance (ANOVA), followed by Tukey's post hoc test. The analysis was performed using the Statistical Package for Social Sciences (SPSS, version 27.0, IBM Corporation, New York, NY, USA).

Results

The tensile load, tensile strength, and elongation of the silk sutures across four immersion periods (0, 1, 7, and 14 days) in artificial saliva were summarized on the diagram figure 2. The tensile load and tensile strength showed a decreasing trend with prolonged immersion, indicating a significant reduction in the material's ability to bear force and resist breaking. Conversely, elongation (%) increased over time with immersion. Statistical analysis (ANOVA) confirmed that the changes in all parameters were significant ($p<0.05$). The boxplot diagram includes annotations for significant differences of the group based on the different of the immersion time using the post hoc Tukey's test.

The tensile load decreases significantly with immersion time. The highest tensile load is observed on Day 0 (12.18 N ± 0.85N), which decreases to 10.48 ± 0.46 N on Day 1, and drops significantly to 7.23 ± 0.99 N on Day 7. By Day 14, there is a slight recovery, with the tensile load increasing to 8.12 ± 0.53 N. Statistical significance is observed between Day 0 and all other days, as well as between Days 1, 7, and 14, as indicated by the asterisks (*).

Tensile strength also shows a decreasing trend over time. On Day 0, the tensile strength is the highest (689.71 ± 48.33 MPa), which significantly decreases to 590.74 ± 26.10 MPa on Day 1. A further reduction is observed on Day 7 (409.46 ± 55.77 MPa), followed by a modest increase to 459.96 ± 29.77 MPa on Day 14. The boxplot highlights statistically significant (*) differences between Day 0 and all subsequent days, as well as between Day 1, Day 7, and Day 14.

In contrast to tensile load and strength, elongation increases with immersion time. Day 0 exhibits the lowest elongation (33.44 ± 3.01 %), followed by a slight increase on Day 1 (36.80 ± 0.85 %). By Day 7, elongation rises further (35.52 ± 4.71 %), reaching the highest value on Day 14 (45.08 ± 4.53 %). Significant differences are observed between Day 14 and all preceding days, with no significant differences between Day 0 and Day 1 or between Day 1 and Day 7.

Discussion

This study evaluated the mechanical properties of Indonesian-made silk sutures after immersion in artificial saliva for varying durations, providing insights into their performance under simulated oral conditions. The results revealed significant trends in tensile strength, tensile load, and elongation, highlighting the impact of prolonged exposure to saliva on the sutures' mechanical integrity.

The tensile strength and tensile load exhibited a consistent decline with increasing immersion time, suggesting that the sutures' structural integrity diminishes under prolonged exposure in the saliva. On day 0, the sutures demonstrated their highest tensile load (12.18 ± 0.85N) and tensile strength (689.71 ± 48.33 MPa). These values significantly decreased by Day 7 (7.23 ± 0.99 N and 409.46 ± 55.77 MPa), respectively and showed only slightly increase by Day 14 (8.12 ± 0.53 N and 459.96 ± 29.77 MPa). This trend aligns with previous studies, such as Khiste et al. (2013), which highlighted the degradative effects of saliva on suture materials, and Nayak (2018). Both studies showed similar result which, the tensile strength did not show significant decrease in 24 hours immersion in saliva, and decreased significantly after 7 and 14 days.[8] However, even though the tensile properties of the Indonesian made silk suture in this study decreased over time, it is still meet the criteria based on Indonesian National Standard (SNI no.16-3346-1994) for nonabsorbable suture (size 4-0), which is 4.5 N.[15]

The reduction in tensile properties may be attributed to enzymatic and chemical breakdown of the silk fibers, compromising the sutures' ability to resist applied forces.17,18 Lashab (2021) stated that the mixing of saliva and human serum appears to improve suture degradation, resulting in a significant decrease in tensile strength.[15] The research by Mathew (2018) also suggested that 4-0 silk sutures showed maximum deterioration of tensile strength, hence it can be used in minor surgical procedures (including frenectomy, vestibuloplasty) where the suture material need to retain for one week.[15]

In contrast, elongation increased over time, with the highest values observed on Day 14, 45.08 ± 4.53 %, which significantly higher than on Day 0, 33.44 ± 3.01 %. This trend indicates enhanced ductility, which may result from the softening or weakening of the material matrix during prolonged immersion. In tensile testing, elongation is defined as the percentage increase in a material's length when subjected to tensile force. This parameter is crucial for evaluating a material's ductility and its capacity to stretch and deform prior to breaking. It is important to assess a material's performance, because it shows whether material can withstand the required stress and deformation without failure. The higher the elongation, the greater the material's flexibility and ductility.[15] It is also suggested that higher elongation could be beneficial in cases where significant postoperative edema is anticipated.[15]

The implications of these findings are significant for the use of Indonesian-made silk sutures in oral surgeries. The observed reduction in tensile properties over time raises concerns about their long-term performance in intraoral applications. However, the increased elongation may offer advantages in scenarios where flexibility is critical, such as during wound swelling. To enhance their performance, modifications to the material, such as the application of protective coatings or the incorporation of biocompatible additives, could be considered to improve resistance to degradation while maintaining flexibility.

Several limitations of the study should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of the results. Second, while artificial saliva was used to simulate oral conditions, it does not fully replicate the complexity of the oral cavity, including variations in pH, enzymatic activity, and temperature fluctuations.

Future research should address these limitations by exploring the performance of other commonly used suture materials, such as nylon, PTFE, or polyglactin, under similar conditions. Investigating the effects of specific enzymes, pH variations, and longer immersion durations would provide a more comprehensive understanding of the degradative processes affecting sutures in oral environments. Furthermore, the application of protective coatings to silk sutures should be explored to enhance their resistance to enzymatic degradation while maintaining their mechanical properties. By addressing these limitations and pursuing future research directions, it will be possible to enhance the quality and applicability of Indonesian-made silk sutures. These efforts will not only improve their suitability for oral surgical applications but also reduce dependency on imported sutures, supporting domestic healthcare needs more effectively.

These findings are significant for the development of locally produced silk sutures in Indonesia. Although the sutures meet the minimum tensile strength requirements of the Indonesian National Standard (SNI), their performance under prolonged immersion suggests areas for improvement, particularly in enhancing durability and resistance to degradation. The differences in mechanical properties between immersion periods emphasize the need for further research and development to optimize the quality and performance of domestic sutures.

Conclusion

The mechanical properties of Indonesian-made silk sutures are significantly influenced by immersion time in artificial saliva. Prolonged immersion reduces tensile load and tensile strength, compromising the sutures' structural integrity, while increasing elongation, reflecting enhanced ductility. These findings highlight the susceptibility of silk sutures to degradation in the oral environment, emphasizing the need for careful consideration of their mechanical performance over time.

Despite these limitations, Indonesian-made silk sutures meet the minimum tensile strength requirements outlined by the Indonesian National Standard (SNI) and exhibit comparable performance to imported sutures. This underscores their potential to support domestic healthcare needs while reducing dependency on imported products. Further research should focus on optimizing the manufacturing process and material composition to achieve these goals.

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Conflict of Interest

The authors report no conflict of interest.

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