

Comparative Effects Of Absorbable Monofilament (Polyglecaprone), Absorbable Multifilament (Polyglactin 910), And Non-Absorbable Multifilament (Silk) Sutures On Collagen And Fibroblast Density In Primary Tracheal Repair: An Experimental Study In New Zealand Rabbits.

Dissa Yulianita Suryani^{a,*}, Sahudi^b, and Marjono Dwi Wibowo^b

^aDepartement of surgery, Faculty of Medicine, Airlangga University/ dr. Soetomo Hospital, Surabaya, Indonesia

^bDivision of Head and Neck Surgery, Departement of surgery, Faculty of Medicine, Airlangga University/ dr. Soetomo Hospital, Surabaya, Indonesia

*Corresponding author Tel.: +62 812-5260-5918

*E-mail: dr.dissays@gmail.com

ABSTRACT

Background: tracheal injury may result in impaired airway healing and fibrotic stenosis. Primary tracheal repair commonly relies on sutures, and the choice of suture material may influence local tissue response during wound healing. Comparative histologic data regarding different suture materials in tracheal repair remain limited.

Methods: This experimental randomized controlled trial involved 30 male New Zealand white rabbits randomly allocated into three groups (n = 10 each): non-absorbable multifilament silk (control), absorbable monofilament polyglecaprone, and absorbable multifilament polyglactin 910. A standardized full-thickness tracheal defect was created and repaired using simple interrupted sutures. On postoperative day 7, tracheal specimens were harvested for histopathological analysis. Collagen density was evaluated using Masson's trichrome staining, while fibroblast density and fibroblast count were assessed using hematoxylin–eosin staining. Statistical analyses were performed to compare outcomes among groups.

Results: Baseline characteristics were comparable across groups. Significant differences were observed in collagen density, fibroblast density, and fibroblast count among the three suture materials. The silk group demonstrated the highest collagen deposition and fibroblast proliferation, whereas the polyglactin 910 group showed the lowest values. The polyglecaprone group exhibited intermediate results. All differences were statistically significant ($p < 0.05$).

Conclusion: Suture material significantly affects histologic tissue response following primary tracheal repair. Absorbable sutures, particularly polyglactin 910 and polyglecaprone, were associated with lower collagen deposition and fibroblast proliferation compared with silk. These findings suggest that suture selection plays an important role in modulating tracheal wound healing and may influence the risk of excessive fibrotic response.

Keywords: Tracheal repair; Suture materials; Collagen density; Fibroblast density; Wound healing; New Zealand rabbit

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Introduction

Tracheal injury—traumatic, iatrogenic, or congenital—remains clinically critical because airway disruption can rapidly compromise ventilation and lead to long-term morbidity. The trachea's integrity depends on the coordinated function of its epithelial barrier, submucosa, and cartilaginous framework; injury to these deeper layers often triggers maladaptive repair and luminal narrowing.¹ Severe injuries healing by secondary intention increase the risk of excessive scarring and fibrotic airway stenosis.^{1,2} Local observations at Dr.

Soetomo General Hospital and reports from H. Adam Malik General Hospital confirm that beyond immediate stabilization, optimizing surgical repair is vital to prevent downstream complications such as restenosis and infection.³

While relatively uncommon, tracheobronchial injuries carry high mortality and diagnostic challenges.⁴⁻⁶ A substantial portion of cases requiring reconstruction are iatrogenic, often related to tracheostomy or endotracheal intubation.⁷⁻¹⁰ Early recognition is central to preventing adverse outcomes, and while imaging is a common

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starting point, fiberoptic bronchoscopy remains the diagnostic gold standard for direct visualization.^{6,7,11} Management strategies span conservative and operative approaches, including primary closure or end-to-end anastomosis.^{6,12–15} However, even technically successful reconstructions can result in anastomotic granulation, restenosis, or dehiscence, highlighting that the biologic response at the repair site is as critical as surgical technique.^{8,16,17}

The choice of suture material is a modifiable factor that influences tissue reaction and healing outcomes.⁵ Silk, a non-absorbable multifilament, offers favorable handling but may amplify local inflammation due to its architecture.^{8,18} Conversely, absorbable synthetic sutures like polyglecaprone (monofilament) and polyglactin 910 (multifilament) provide predictable degradation and minimal tissue reaction.^{5,11,17} Despite the clinical relevance of these material properties, comparative evidence focusing on histologic healing markers in tracheal repair remains limited.

The biologic basis of post-repair stenosis is tied to the wound healing cascade: hemostasis, inflammation, proliferation, and remodeling.^{12,13,16,19–21} Fibroblasts drive this process by synthesizing collagen to restore mechanical integrity; however, excessive deposition leads to fibrotic stenosis.^{12,13} Therefore, fibroblast and collagen densities are key histologic endpoints for evaluating how suture selection shapes airway repair.^{8,12,16,22} Mechanistic evaluation is best achieved through animal models, specifically the New Zealand rabbit (*Oryctolagus cuniculus*), due to structural similarities to the human trachea and well-characterized biology.^{10,19,24–26} Male rabbits are chosen to reduce hormonal variability, and the simple interrupted suturing technique is used to allow for controlled approximation and localized tissue response evaluation.^{10,24}

Given the clinical burden of airway complications, this study investigates the comparative tissue response between absorbable monofilament polyglecaprone and absorbable multifilament polyglactin 910 in primary tracheal repair. By quantifying collagen and fibroblast density, this research aims to provide evidence for precise suture selection to improve surgical outcomes and reduce the risk of stenosis following tracheal injury repair.

Method

This experimental study employed a randomized controlled trial design using male New Zealand white rabbits (*Oryctolagus cuniculus*). All animals were

acclimatized for 7 days under standardized housing and feeding conditions before intervention. A total of 30 rabbits were included and randomly allocated into three groups using permuted block randomization: a control group receiving silk sutures, a polyglecaprone group, and a polyglactin 910 group, with 10 animals in each group. All procedures used the simple interrupted suturing technique. A full-thickness tracheal defect measuring 2 cm was created at the level of the 6th to 9th tracheal rings using a scalpel, taking care to avoid laryngeal injury. Primary tracheal repair was performed using simple interrupted sutures with either silk (control), absorbable monofilament polyglecaprone, or absorbable multifilament polyglactin 910 (all 4-0, round needle). Skin closure was completed using nylon 4-0 sutures.

On postoperative day 7, corresponding to the proliferative phase of wound healing, animals were anesthetized and euthanized aseptically. Tracheal specimens were harvested from the surgical site, measuring 1 cm craniocaudally and including both healthy and injured tissue, with full-thickness depth. Samples were fixed in 10% neutral buffered formalin, processed into paraffin blocks, and prepared for histopathological evaluation. Fibroblast expression was assessed on hematoxylin–eosin–stained sections at 400× magnification and recorded as ratio data, with fibroblast density additionally graded using an ordinal scoring system (0–4). Collagen density was evaluated using Masson’s trichrome staining at 100× magnification and graded on the same ordinal scale.

Histopathological assessments were performed by an anatomical pathologist blinded to group allocation. Data were analyzed after confirming homogeneity. Fibroblast expression was compared between groups using independent *t*-tests, while collagen density was analyzed using the Mann–Whitney *U* test. Ethical approval was obtained from the Animal Care and Use Committee, Faculty of Veterinary Medicine, Universitas Airlangga, and all procedures adhered to institutional guidelines for animal welfare. The study was conducted at Dr. Soetomo General Hospital, Surabaya, over a period of seven months.

Results

Baseline Characteristics of the Experimental Animals

A total of 30 male New Zealand white rabbits were included in the analysis. Baseline characteristics, including age, body weight before surgery, and body weight after surgery, were comparable between the control and treatment groups. The mean age of rabbits in

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the control group was 7.73 ± 1.08 months, while that of the treatment group was 7.74 ± 1.06 months, with no statistically significant difference between groups ($p = 0.93$).

The mean preoperative body weight was $2,220 \pm 262.7$ g in the control group and $2,266 \pm 244.5$ g in the treatment group ($p = 0.791$). Postoperative body weight also did not differ significantly between groups, with mean values of $2,179 \pm 262.8$ g in the control group and $2,221 \pm 276.2$ g in the treatment group ($p = 0.93$). These findings indicate that the experimental groups were homogeneous prior to intervention

Variable	Control (Mean \pm SD)	Treatment (Mean \pm SD)	<i>p</i> value
Age (months)	7.73 ± 1.08	7.74 ± 1.06	0.93
Body weight before surgery (g)	$2,220 \pm 262.7$	$2,266 \pm 244.5$	0.791
Body weight after surgery (g)	$2,179 \pm 262.8$	$2,221 \pm 276.2$	0.93

Table 1. Baseline characteristics of the experimental animals

Collagen Density

Collagen density was assessed histopathologically and graded on an ordinal scale. In the control group repaired with silk sutures, 9 samples showed grade 3 collagen density, while 1 sample showed grade 2 density. In the polyglecaprone (Monocryl) group, 2 samples demonstrated grade 3 density, 6 samples grade 2, and 2 samples grade 1. In the polyglactin 910 (Vicryl) group, 2 samples exhibited grade 3 density, 2 samples grade 2, and 6 samples grade 1.

The mean collagen density score was highest in the silk group (2.9 ± 0.31), followed by the Monocryl group (2.0 ± 0.67) and the Vicryl group (1.6 ± 0.84). Statistical analysis revealed a significant difference in collagen density among the three groups ($p = 0.001$).

Table 2. Distribution of collagen density scores

Group	Grade 1	Grade 2	Grade 3
Silk	0	1	9
Monocryl	2	6	2
Vicryl	6	2	2

Fibroblast Density

Fibroblast density was evaluated using an ordinal scoring system. In the control group, 5 samples demonstrated grade 3 fibroblast density and 5 samples showed grade 2

Comparison of Collagen and Fibroblast Density Among Groups

density. In the Monocryl group, 7 samples exhibited grade 2 density and 3 samples grade 1 density. In the Vicryl group, most samples showed grade 1 density, with only 3 samples demonstrating grade 2 density.

The mean fibroblast density score was 2.5 ± 0.53 in the silk group, 1.7 ± 0.48 in the Monocryl group, and 1.3 ± 0.48 in the Vicryl group. Differences in fibroblast density among the three groups were statistically significant ($p = 0.002$).

Table 3. Distribution of fibroblast density scores

Group	Grade 1	Grade 2	Grade 3
Silk	0	5	5
Monocryl	3	7	0
Vicryl	7	3	0

Fibroblast Count (Proportion Analysis)

Fibroblast counts were assessed by counting fibroblast cells in five microscopic fields. In the silk group, 3 samples had 50 fibroblasts, 2 samples had 45 fibroblasts, and 5 samples had 40 fibroblasts. In the Monocryl group, 7 samples showed 40 fibroblasts and 3 samples showed 20 fibroblasts. In the Vicryl group, 3 samples demonstrated 40 fibroblasts, while the remaining 7 samples demonstrated 20 fibroblasts.

The mean fibroblast count was highest in the silk group (44 ± 4.5 cells), followed by the Monocryl group (34 ± 9.6 cells) and the Vicryl group (26 ± 9.67 cells). Statistical analysis showed a significant difference in fibroblast count among the three groups ($p = 0.001$).

Table 4. Fibroblast count per group

Group	Mean \pm SD (cells)	<i>p</i> value
Silk	44 ± 4.5	0.001
Monocryl	34 ± 9.6	
Vicryl	26 ± 9.67	

Table 5. Comparison of collagen and fibroblast density among groups

Group	Collagen Density (Mean \pm SD)	<i>p</i> value	Fibroblast Density (Mean \pm SD)	<i>p</i> value
Silk	2.9 ± 0.31	0.001	2.5 ± 0.53	0.002
Monocryl	2.0 ± 0.67		1.7 ± 0.48	
Vicryl	1.6 ± 0.84		1.3 ± 0.48	

Comparative analysis demonstrated that both collagen density and fibroblast density were significantly higher

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in the silk group compared to the Monocryl and Vicryl groups. The lowest collagen and fibroblast density values were observed in the Vicryl group.

Discussion

Suture materials can be broadly classified based on absorbability, filament structure, material origin, and tensile strength. These characteristics influence not only handling properties during surgery but also the biological response of surrounding tissues during wound healing.²⁷ Absorbable sutures offer the practical advantage of not requiring removal; however, they may induce varying degrees of tissue reaction depending on their degradation mechanism, such as hydrolysis, enzymatic digestion, or phagocytosis.²⁸ In contrast, non-absorbable sutures are generally associated with lower acute tissue reactivity but persist as foreign material within the tissue.²⁸

In the present study, significant differences were observed in both collagen density and fibroblast density among tracheal repairs performed using silk, polyglecaprone (Monocryl), and polyglactin 910 (Vicryl). The silk group demonstrated the highest mean collagen density and fibroblast density, while the Vicryl group showed the lowest values. These findings suggest that suture material plays a substantial role in modulating the cellular and extracellular matrix response during tracheal wound healing.

Silk is a non-absorbable, braided suture material derived from natural protein fibers. Although widely used due to its strength and favorable handling characteristics, the braided structure of silk may facilitate surface debris retention and bacterial accumulation, potentially contributing to sustained local inflammation.²⁹ Persistent foreign material can provoke prolonged fibroblast recruitment and collagen deposition, which may explain the higher collagen density and fibroblast counts observed in the silk group in this study. Such a response, while potentially beneficial for early mechanical stability, may also predispose to excessive fibrosis and subsequent airway stenosis in the long term.

Vicryl (polyglactin 910), an absorbable multifilament synthetic suture, is known to maintain predictable tensile strength during early healing and to elicit lower tissue reaction compared with natural absorbable sutures such as surgical gut.¹¹ In this study, however, the Vicryl group exhibited the lowest collagen density and fibroblast proliferation. This may reflect a reduced and more transient inflammatory response during the early proliferative phase of wound healing, resulting in lower

fibroblast activity and collagen deposition at day 7 post-repair.

Monocryl (polyglecaprone 25), an absorbable monofilament synthetic suture, showed intermediate results between silk and Vicryl. Monocryl is primarily designed for soft tissue and skin closure and retains most of its tensile strength during the first week before undergoing gradual absorption over approximately 3–4 months. The monofilament structure limits bacterial adherence and tissue drag, which may explain the moderate fibroblast density and collagen deposition observed. These findings align with previous observations that monofilament sutures generally induce less tissue reaction than braided materials.¹⁸

The present results are consistent with findings by Yaltirik et al., who reported that monofilament materials and Vicryl induced lower tissue reactions compared with silk, a braided suture.¹⁸ However, other studies have reported contrasting results. Behrend and Klemppauer found no fundamental difference in inflammatory response between absorbable monofilament (polyglecaprone) and absorbable multifilament sutures (polyglactin 910 and polypropylene) in an ovine tracheal reconstruction model.³⁰ These discrepancies may be attributed to differences in animal models, tissue type, surgical technique, evaluation time points, and outcome parameters assessed.

Fibroblast density and absolute fibroblast counts in this study also differed significantly among groups. The silk group showed the highest fibroblast counts, followed by Monocryl and Vicryl. Fibroblasts are central mediators of wound healing, responsible for extracellular matrix synthesis and remodeling. Elevated fibroblast proliferation may indicate a more pronounced inflammatory and reparative response, but excessive or prolonged fibroblast activity can contribute to pathological fibrosis. The lower fibroblast density observed in the Vicryl group may reflect a more controlled healing response, potentially reducing the risk of excessive scar formation.

The biological behavior of absorbable sutures is strongly influenced by their degradation pathway. Synthetic absorbable sutures primarily undergo hydrolysis, a process associated with lower tissue reactivity compared with enzymatic degradation.³⁰ Hydrolytic degradation leads to a gradual and predictable loss of tensile strength, allowing tissue to progressively assume mechanical load. In contrast, non-absorbable sutures elicit a chronic foreign-body response characterized by fibroblast

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encapsulation and frustrated phagocytosis involving macrophages and multinucleated giant cells.¹¹ This mechanism may account for the higher fibroblast activity observed around silk sutures in this study.

Absorbable monofilament polyglactone offers optimal tracheal healing because its smooth, single-strand structure facilitates tissue penetration, minimizes friction-induced trauma, and lacks the capillarity—or "wicking" effect—characteristic of multifilament sutures. While multifilament sutures provide superior flexibility and knot security, their braided design can harbor microorganisms and fluids, increasing the risk of infection and dehiscence. These findings align with Taylor et al. (2013), who demonstrated the inferiority of polyglactin (Vicryl) to polyglactone (Monocryl), and Deters et al. (2010), who highlighted the increased risks of inflammation and wicking associated with multifilament structures. Consequently, monofilament sutures are the preferred choice for tracheal repair to achieve superior tissue healing with minimal inflammatory reaction.

Clinically, these findings have important implications for suture selection in tracheal surgery. While silk sutures demonstrated higher collagen and fibroblast responses, which may enhance early wound strength, this heightened response could also increase the risk of excessive fibrosis and airway narrowing. Conversely, absorbable sutures, particularly Vicryl and Monocryl, may offer a more balanced healing response with reduced fibroblast proliferation and collagen deposition, potentially lowering the risk of postoperative tracheal stenosis. Nevertheless, absorbable sutures carry the trade-off of reduced long-term mechanical support and a transient inflammatory response during degradation.³¹

This study has several limitations. The evaluation was limited to a single postoperative time point corresponding to the proliferative phase of wound healing, which restricts assessment of long-term remodeling and scar maturation. Additionally, inflammatory markers beyond fibroblast density and collagen deposition were not assessed. Future studies incorporating longer follow-up periods and additional molecular or immunohistochemical markers of inflammation and fibrosis would provide a more comprehensive understanding of tissue responses to different suture materials in tracheal repair.

Conclusion

This study concludes that absorbable monofilament (polyglactone) provides the most superior tracheal

healing, as evidenced by significantly higher collagen and fibroblast densities compared to absorbable multifilament (polyglactin 910) and non-absorbable multifilament (silk), while polyglactin 910 exhibited the poorest outcomes. Consequently, polyglactone is clinically recommended for optimal tracheal repair; however, further research with extended observation periods and additional inflammatory markers is necessary to more comprehensively evaluate long-term tissue responses and remodeling.

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