

Integrating Clinical Anatomy and Tissue Engineering for Abdominal Wall Repair in Ruminants

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ABSTRACT

Abdominal wall defects, particularly hernias, pose significant challenges in veterinary medicine due to high recurrence rates and complications associated with traditional repair methods. This study introduces the BioBridge approach, a novel tissue engineering technique utilizing bioscaffolds (BioGrafts) to facilitate abdominal wall repair in ruminants. This study evaluated the clinical efficacy of BioScaffolds (BioGrafts) for repairing large abdominal wall defects in ruminants, introducing the innovative BioBridge approach. Twelve ruminants with abdominal wall defects (hernias) were treated at the Department of Veterinary Clinical Complex, Veterinary College, Shivamogga. Animals were implanted with plain and chitosan-treated scaffolds (n=6 each). Complete healing was achieved by the 15th postoperative day. Ultrasonography revealed proper tissue apposition, decreased wound gap and progressive bridging of tissues with adequate muscular tissue regeneration, without complications. Results were supported by physiological, clinical-hematological analysis, and enhanced wound healing properties of ECM-CS (Bioscaffolds/BioGrafts). Ultrasonography showed gradual increases in implanted ECM size and neovascularization, indicating chitosan-treated scaffolds' potential for clinical application. These scaffolds demonstrated non-immunogenicity, sufficient mechanical strength, and improved biocompatibility without complications. The BioBridge approach, leveraging BioGrafts' non-immunogenicity, mechanical strength, and biocompatibility, demonstrates potential to revolutionize abdominal wall repair in veterinary medicine, offering enhanced wound healing and tissue regeneration.

Key words: BioGraft, Abdominal Wall Repair, Tissue Engineering, Clinical Anatomy & Ruminant Surgery

INTRODUCTION

The surgical management of abdominal wall defects in ruminants presents significant challenges, especially when dealing with large hernias or defects characterized by substantial tissue loss. Traditional repair techniques frequently involve the use of synthetic meshes. However, these materials can be expensive and are associated with potential complications such as infection, fistula formation, and pain (Bachman & Ramshaw, 2008).

Umbilical hernia is the most commonly seen abdominal defect in calves. It occurs due to genetic or may be acquired such as weakening of abdominal wall caused by abscess or infection, cutting the umbilicus off close to the body wall and excessive traction applied to an oversized foetus during delivery. Small umbilical hernias with smaller ring and reducible contents can be repaired by primary closure but repair of large hernias poses clinical challenge to the surgeons due to large sized hernial

rings and immense distortion of hernial margin. Reconstructive surgery is the only method to restore the integrity of the abdominal wall and prevent incarceration and strangulation of herniated contents. Hernial ring size exceeding 3cm in diameter requires the use of prosthetic material for hernioplasty (Vilar *et al.*, 2009). Recurrence in these cases occurs frequently and the deformity gets even worse because of inadequate tissue at the site to enable a satisfactory closure (Mohsina *et al.*, 2014). In such cases, hernioplasty with implantation of animal origin biomaterials is indicated (Park and Lakes, 1992). The use of synthetic materials for abdominal wall reinforcement in field conditions is particularly problematic due to the heightened risk of infection, especially in contaminated surgical fields (Bachman & Ramshaw, 2008). Recognizing these limitations, recent research has emphasized the need for alternative solutions, suggesting bioscaffold implants due to their potential to resist infection and facilitate tissue regeneration (Dhoolappa *et al.* 2022). Various biomaterials have been explored for bioscaffold development, including decellularized extracellular matrices (Yuvaraj *et al.*, 2023). Despite their promise, the

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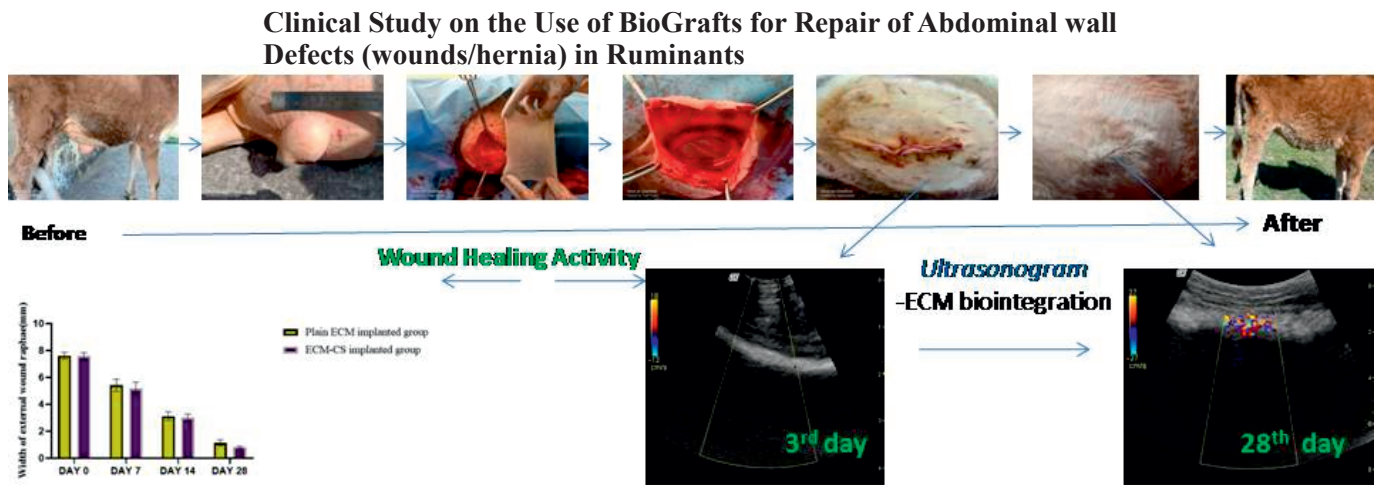


Fig. 1. Graphical representation of the clinical study on the use of BioGrafts for repair of abdominal wall wounds/hernia in ruminants

application of bioscaffolds in ruminants remains largely unexplored. This study addresses this research gap by evaluating the clinical efficacy of a specific type of bioscaffold (BioGrafts) for repairing large abdominal wall defects in ruminants. Furthermore, the study introduces the innovative "BioBridge" approach to this repair technique.

MATERIAL AND METHODS

Preparation and Characterization of BioGrafts

BioGrafts were prepared from fresh rumen samples of food animal origin, as previously described by Dhoolappa *et al.* (2017). Briefly, the samples were cut into larger sizes (10x15cm) and treated with chitosan to produce extracellular matrix-chitosan (ECM-CS) sheets. The bioscaffolds underwent morphological characterization; including scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR) analysis, to evaluate their structure and composition.

Biocompatibility studies were conducted using a zebra fish embryo model to assess the prepared bioscaffolds' suitability for clinical applications in ruminants. The studies were performed according to standard protocols, and the results were analyzed using mixed-effect analysis followed by Tukey's post hoc test (GraphPad Prism software, version 9.3.1).

The clinical study was conducted on 12 ruminants with hernias / wounds / traumatic injuries, presented to the Department of Veterinary Clinical Complex, Veterinary College, Shivamogga (Fig.1). The clinical cases were randomly divided into two groups (n=6 each): plain ECM and chitosan-treated ECM. The study was approved by the Institutional

Animal Ethics Committee (IAEC) of Veterinary College, Shivamogga (approval no: VCS/IAEC/SA-LA-84/ 2022-23, dated 06.08.2022).

The surgical procedure involved implanting plain ECM or chitosan-treated ECM using the underlay technique, with proper sterilization prior to implantation, as described by de Vries Reilingh *et al.* (2004).

The healing of wound was evaluated by gross clinical examination of wound and ultrasonography. Hematological parameters & clinical parameters were also recorded.

The following outcome measures were evaluated:

1. Gross clinical examinations: external wound healing (planimetry), degree of swelling and warmth (Kumar *et al.*, 2012), and exudation (Singh *et al.*, 2018).

Statistical analysis was performed using GraphPad Prism software (version 9.3.1). The values were expressed as mean $\pm$ SE. One-way ANOVA was used for morphological characterization of ECM, while mixed-effect analysis followed by Tukey's post hoc test was used for biocompatibility studies. $P < 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Planimetry analysis revealed increased wound contraction, granulation tissue formation, and antibacterial activity in the chitosan-treated group compared to the plain-ECM group. Normal abdominal wall integrity was observed without postoperative complications or rejection of ECM (Fig.1).

The chitosan-treated group showed faster wound contraction, with a marked decline in wound width from 7.60 ± 0.24 mm (day 0) to 0.82 ± 0.07 mm (day 28). The plain-ECM group also showed significant wound contraction, but at a slower rate. These findings are consistent with previous studies (Kumar *et al.*, 2012).

Non-significant differences were observed in heart rate and respiration rate between groups. A significant decrease in rectal temperature was observed in both groups up to day 4, attributed to decreased metabolic rate and muscular activity (Lumb and Jones, 1984).

Increased total leukocyte count, monocyte, and neutrophil counts were observed up to day 7, indicating an inflammatory response to surgical trauma. These findings are consistent with previous studies (Gangwar *et al.*, 2006).

Ultrasonography revealed gradual increases in implanted ECM size and neovascularization, indicating tissue regeneration and integration of ECM with host tissue. Chitosan-treated ECM showed better integration and neovascularization compared to plain ECM.

The findings of study demonstrate the potential of bioscaffolds (BioGrafts) for abdominal wall repair in ruminants. The chitosan-treated ECM showed improved wound healing, tissue regeneration, and biocompatibility. These results are consistent with existing literature, highlighting the benefits of bioscaffolds in tissue engineering and regenerative medicine.

CONCLUSION

This study demonstrates the efficacy of BioGrafts/bioscaffolds (decellularized ECMs) in promoting early wound healing and tissue regeneration in ruminants. Chitosan-treated ECM showed enhanced wound contraction, granulation tissue formation, and antibacterial activity compared to plain ECM. The implants were biocompatible, and no tissue rejection or complications were observed. These findings suggest that bioscaffolds, particularly chitosan-treated ECM, have significant potential for repairing abdominal wall wounds, hernias, and skin injuries in veterinary medicine.

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