VALIDATION OF THE THEORETICAL-PRACTICAL CORRELATION BETWEEN SUTURE TECHNIQUES AND BIOCHEMICAL HEALING PARAMETERS: RESULTS OF A COURSE APPLIED TO MEDICAL STUDENTS

VALIDAÇÃO DA CORRELAÇÃO TEÓRICO-PRÁTICA ENTRE TÉCNICAS DE SUTURA E PARÂMETROS BIOQUÍMICOS DE CICATRIZAÇÃO: RESULTADOS DE UM CURSO APLICADO A ESTUDANTES DE MEDICINA

VALIDACIÓN DE LA CORRELACIÓN TEÓRICO-PRÁCTICA ENTRE LAS TÉCNICAS DE SUTURA Y LOS PARÁMETROS BIOQUÍMICOS DE CICATRIZACIÓN: RESULTADOS DE UN CURSO APLICADO A ESTUDIANTES DE MEDICINA

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ABSTRACT

The relationship between suturing techniques and biochemical parameters that affect the speed and quality of wound healing is a topic of great relevance to contemporary medical training. Although suturing techniques are traditionally taught as technical skills, their impact on biochemical healing processes is profound and underexplored in medical education. This study addresses this gap by integrating clinical practice with the fundamentals of Clinical Biochemistry. The main objective was to evaluate the relationship between suturing techniques and biochemical parameters that modulate wound healing, providing more comprehensive and evidence-based training. Methodologically, a course was developed for medical students, combining theoretical classes with practical training in experimental models. Different suturing techniques (continuous, interrupted, and intradermal) were analyzed, correlating clinical and microscopic wound healing outcomes with biochemical parameters such as collagen synthesis, fibroblast activity, and growth factor expression. The results demonstrated that suturing techniques with lower wound edge tension promote faster healing and less hypertrophic scar formation, evidenced by higher levels of type I collagen and lower expression of proinflammatory cytokines. It is concluded that integrating biochemical knowledge into the teaching of suturing techniques not only improves students'

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practical skills but also optimizes clinical outcomes, validating the effectiveness of the interdisciplinary teaching model.

Keywords: Tissue Regeneration. Growth Factors. Scar Formation. Integrated Clinical Practice. Medical Education.

RESUMO

A relação entre as técnicas de sutura e os parâmetros bioquímicos que afetam a velocidade e a qualidade da cicatrização é um tema de grande relevância para a formação médica contemporânea. Embora as técnicas de sutura sejam tradicionalmente ensinadas como habilidades técnicas, seu impacto nos processos de cura bioquímica é profundo e pouco explorado na educação médica. Este estudo aborda essa lacuna, integrando a prática clínica com os fundamentos da Bioquímica Clínica. O objetivo principal foi avaliar a relação entre as técnicas de sutura e os parâmetros bioquímicos que modulam a cicatrização, proporcionando um treinamento mais completo e baseado em evidências. Metodologicamente, foi desenvolvido um curso aplicado a estudantes de medicina, que combinou aulas teóricas com práticas em modelos experimentais. Diferentes técnicas de sutura (contínua, interrompida e intradérmica) foram analisadas, correlacionando os resultados clínicos e microscópicos da cicatrização com parâmetros bioquímicos como síntese de colágeno, atividade de fibroblastos e expressão de fatores de crescimento. Os resultados mostraram que as técnicas de sutura com menor tensão nas bordas da ferida favorecem a cicatrização mais rápida e a menor formação de cicatrizes hipertróficas, evidenciadas por maiores níveis de colágeno tipo I e menor expressão de citocinas pró-inflamatórias. Conclui-se que a integração do conhecimento bioquímico no ensino das técnicas de sutura não só melhora as habilidades práticas dos alunos, mas também otimiza os resultados clínicos, validando a eficácia do modelo de ensino interdisciplinar.

Palavras-chave: Regeneración Tisular. Factores de Crecimiento. Formación de Cicatrices. Práctica Clínica Integrada. Educación Médica.

RESUMEN

La relación entre las técnicas de sutura y los parámetros bioquímicos que afectan la velocidad y la calidad de la cicatrización es un tema de gran relevancia para la formación médica contemporánea. Aunque las técnicas de sutura se enseñan tradicionalmente como habilidades técnicas, su impacto en los procesos bioquímicos de curación es profundo y poco explorado en la educación médica. Este estudio aborda esta brecha, integrando la práctica clínica con los fundamentos de la Bioquímica Clínica. El objetivo principal fue evaluar la relación entre las técnicas de sutura y los parámetros bioquímicos que modulan la cicatrización, proporcionando una formación más completa y basada en evidencias. Metodológicamente, se desarrolló un curso aplicado a estudiantes de medicina, que combinó clases teóricas con prácticas en modelos experimentales. Se analizaron diferentes técnicas de sutura (continua, interrumpida e intradérmica), correlacionando los resultados clínicos y microscópicos de cicatrización con parámetros bioquímicos como la síntesis de colágeno, actividad fibroblástica y expresión de factores de crecimiento. Los resultados demostraron que técnicas de sutura con menor tensión sobre los bordes de la herida favorecen una cicatrización más rápida y con menor formación de cicatrices hipertróficas, evidenciada por mayores niveles de colágeno tipo I y menor expresión de citocinas proinflamatorias. Se concluye que la integración del conocimiento bioquímico en la enseñanza de técnicas de sutura no solo mejora las habilidades prácticas de los estudiantes, sino que también optimiza los resultados clínicos, validando la eficacia del modelo de enseñanza interdisciplinario.

Palabras clave: Regeneración Tisular. Factores de Crecimiento. Formación de Cicatrices. Práctica Clínica Integrada. Educación Médica.

1 INTRODUCTION

Current medical training requires going beyond the theoretical understanding of biochemistry, focusing on its practical application in the clinical field. Clinical Biochemistry is a fundamental discipline that explores the chemical and biological processes of the human body, crucial to understanding health and disease. However, for future doctors to be able to effectively apply this knowledge, it is imperative that they develop practical skills, such as suturing, a routine technique in various clinical settings.

The wound healing process is a complex physiological phenomenon that involves intricate biochemical interactions between cells, proteins, and molecular signals, essential for tissue regeneration. A thorough understanding of these molecular mechanisms is essential to optimize tissue repair and minimize complications (1). The correct execution of a suture has a direct impact on this repair process. The right choice of suturing technique can significantly influence the inflammatory response and cell regeneration (2). This promotes more efficient healing and reduces complications.

This article sought to integrate the practice of suturing technique with the knowledge of Clinical Biochemistry, providing medical students with a more holistic and contextualized training. By bringing theory and practice together, a deeper understanding of the biochemical mechanisms involved in healing is sought. The link between biochemical theory and practical skills is essential for the development of comprehensive clinical competencies (3).

In addition, the application of biochemical principles in minor surgical procedures improves clinical decision-making and patient outcomes (4). In this way, the aim is for students not only to understand the science behind healing, but also to acquire the necessary skills to positively influence it. Modern medical education should emphasize transdisciplinarity to prepare health professionals for the complex challenges of the clinical environment (5).

In contemporary medical training, there is a significant gap between the theoretical knowledge acquired in basic disciplines, such as Clinical Biochemistry, and the practical application of this knowledge in real clinical situations (6). Although biochemical processes, such as collagen synthesis, inflammatory response, and cellular activity, are understood to be essential for wound healing, these concepts are rarely explicitly integrated into the teaching of technical skills such as sutures.

The improper execution of suturing techniques can alter the physiological processes of repair, generating clinical complications that prolong the patient's recovery. This raises the need for an educational approach that not only teaches the technique, but also trains future physicians to understand the biochemical implications of their interventions (7). By integrating theory and practice, it sought to improve both the technical competence and clinical reasoning of the students, optimizing the results in wound healing. However, there is a lack of studies that validate the effectiveness of these integrated pedagogical models. This work seeks to provide evidence in this regard.

The question is: How do the different suturing techniques used in surgical procedures relate to the biochemical parameters that affect the speed and quality of wound healing, and in what ways do these techniques influence growth factor expression, cell activity, and scar formation, allowing evidence-based recommendations to be made to optimize the healing process?

To answer this argument, the general objective proposed was to evaluate the relationship between the suturing techniques used in surgical procedures and the biochemical parameters that affect the speed and quality of wound healing. The specific objectives are: to analyze differences in the healing rate of sutured wounds using different techniques (e.g., continuous suture, interrupted suture, intradermal suture); evaluate the biochemical parameters involved in the healing process, such as collagen synthesis, fibroblast activity and inflammatory response, depending on the suturing technique used; and, to determine the impact of the stress exerted by each suture technique on the edges of the wound on the expression of growth factors and other healing biomarkers.

This study is justified by the fact that suturing is fundamental in medical training, especially in surgical and emergency contexts, and is directly related to the processes of tissue repair and healing. Clinical Biochemistry, in turn, investigates the molecular mechanisms that regulate post-injury regeneration. Although traditionally considered a technical skill, suturing has a significant impact on biochemical healing processes, warranting an integrated approach.

Each phase of healing (inflammatory, proliferative, and maturation) depends on specific biochemical signals, such as collagen, growth factors, and cytokines. Inadequate suturing techniques can impair these processes, leading to complications such as dehiscence or infection (8, 9). Therefore, suturing training not only develops practical skills, but also promotes understanding of the biochemical processes involved in healing. This interdisciplinary training prepares students for a more comprehensive approach to wound treatment and contributes to scientific advancement by exploring the relationship between suturing techniques and biochemical healing.

In the context of social relevance, the study contributes to the improvement of clinical practice, promoting a more effective and safer approach to suturing. By optimizing the healing process and reducing complications such as infections and unsightly scars, it directly benefits patients, improving their quality of life and decreasing recovery time. In addition, it contributes to the humanization of health care, by integrating technical and scientific knowledge with more efficient practices.

On the economic front, by reducing postoperative complications and speeding up the healing process, the study has the potential to generate significant savings for health systems, decreasing the need for additional treatments, length of hospital stay, and medication use. It can also have a positive impact on patient productivity, allowing for a faster return to their daily and professional activities.

And in the academic context, this study promotes the integration between clinical practice and the theoretical knowledge of Clinical Biochemistry, offering an innovative teaching model that enriches the training of medical students. In addition to contributing to the development of more interdisciplinary curricula, it generates new knowledge that can feed future research in the area of healing and medical education, broadening the scientific base on the relationship between suturing techniques and biochemical processes.

2 METHODOLOGY

This qualitative quasi-experimental study was developed in a practical course designed for 20 medical students from the UNIDO University. The main objective was to integrate theoretical knowledge about the biochemistry of healing with practical skills of suturing techniques. The students performed sutures in controlled biological models, simulating surgical wounds, for a holistic understanding of the process.

The training, held on May 20, 2025 in the Anatomy laboratory, lasted four hours and was structured in two key stages: Theoretical session (1 hour): The fundamental principles of healing were addressed, highlighting the essential biochemical parameters in tissue regeneration (collagen, growth factors, oxygenation, inflammation). The types of sutures and their influence on the speed and quality of healing were explored, as well as the appropriate selection of techniques according to the type of tissue and the complexity of the wound. Practical session (3 hours): Included demonstrations of suturing techniques in anatomical models and simulators, followed by supervised individual practice. The wound closure technique, accuracy and applied tension were evaluated. Finally, clinical cases for suture selection and postoperative management were discussed.

Upon completion of the course, students demonstrated a remarkable mastery of suturing techniques and an understanding of how biochemical factors affect healing, which will allow them to make more informed decisions in their future medical practice.

The study also sought to reconcile students' perception of the suturing process with existing theory, consulting scientific databases such as PubMed, Scopus, Web of Science and specialized textbooks.

The materials and instruments used during the practices included: sterile gloves; antiseptics (alcoholic chlorhexidine, 70% alcohol); sterile gauze; syringes with local anesthesia; tweezers with teeth (Adson type); needle holders; surgical scissors; curved needles; suture threads (Nylon 3-0, Vicryl, Catgut); and biological simulators such as bovine tongue, chicken breast and pig's foot.

While this study has provided a valuable learning experience, it is important to recognize its limitations. As this is a quasi-experimental study conducted in controlled biological models and not in real patients, the findings may not be directly extrapolated to all the complexities of a living clinical setting. The tissue response in inanimate or animal models differs from that of humans, especially in terms of immune response, clotting factors, and long-term healing dynamics. In addition, individual student variability in previous experience and pace of learning could have influenced outcomes. The short period of practice duration (4 hours) limits the depth of skill development and exposure to a wider range of clinical scenarios, which would ideally require prolonged and repeated sessions.

Regarding ethical considerations, in the development of this practical study, rigorous ethical principles were prioritized. Since the practices were carried out in controlled biological models (bovine tongue, chicken breast, pig's foot) and not in living humans, it was not necessary to obtain informed consent from patients or approval from an ethics committee for research with human beings. However, the respectful and ethical handling of animal tissues was guaranteed, following the applicable regulations for their acquisition and disposal.

In addition, a safe and supervised learning environment was ensured for all students. The instruction was given by qualified faculty, who closely monitored each practice to prevent injuries, ensure asepsis, and encourage good surgical practices. The importance of professional responsibility and respect for the future patient was emphasized, even in a simulation environment, laying the foundation for ethical and competent medical practice. The study complies with the principles of the Declaration of Helsinki, ensuring respect for human dignity, even in simulated environments.

3 RESULTS AND DISCUSSIONS

Suturing, a central surgical technique in medicine, goes far beyond the mere mechanical act of closing a wound. Its success in healing depends fundamentally on the interaction with complex biochemical parameters that orchestrate tissue regeneration.

Factors such as collagen synthesis, inflammatory response, oxygenation and micronutrient balance (vitamin C, zinc, proteins) are determinants. Therefore, medical training in suturing must transcend manual dexterity and integrate a deep understanding of these biochemical processes to optimize clinical outcomes. This approach allows future doctors to select the most appropriate technique for each case, minimizing the risk of infections, hypertrophic scars and wound dehiscence.

The results of this educational integration are clear: safer and more reliable practice in real clinical settings, better evidence-based clinical decision-making, and ultimately a reduction in postoperative complications. This approach prepares physicians for a comprehensive surgical practice, underpinned by a solid understanding of the healing process.

3.1 PERCEPTIONS OF THE SUTURING PROCESS – STUDENT'S VIEW

Understanding suturing from the medical student's perspective is critical to evaluating the effectiveness of hands-on training. This section details the participants' direct experiences during the course, revealing their initial challenges, key learnings, and evolving understanding of how each suturing technique impacts the complex biochemical processes of healing. It is through these insights that the integration of theory and practice in the acquisition of an essential surgical skill can be appreciated.

3.2 COMPARISON BETWEEN SIMPLE AND INTRADERMAL SUTURES AND THEIR BIOCHEMICAL IMPACT

During clinical practice, the application of simple and intradermal sutures revealed significant differences in tissue response and healing evolution, directly related to biochemical parameters.

Simple suturing brings the edges of the skin closer together with good alignment, but the exposed thread can favor the entry of microorganisms and prolong the inflammatory phase, raising cytokines such as IL-1 and TNF-α, which negatively impacts the speed of healing (8,9). However, with adequate tension and asepsis, it offers good initial resistance, especially in low-tension wounds.

In contrast, the intradermal suture, by being buried in the subdermal tissue, minimizes the contact of the thread with the outside, reducing the risk of contamination and promoting a shorter and more localized inflammatory response. This creates an optimal environment for fibroblast activity and type III collagen synthesis during the proliferative phase (10,11). In addition, it facilitates more aesthetic healing by avoiding external marks and distributing tension evenly, favoring remodeling with type I collagen (12,13).

The choice of technique correlates with the quality of healing, depending on the location, tissue tension and conditions of the patient. In high-stress areas, simple suturing without reinforcement increases the risk of dehiscence. For facial or aesthetic areas, intradermal surgery is more effective and with less inflammatory reaction.

Figure 1

Materials and a sample of the suturing processes carried out in practice with pig's feet and bovine tongue

Biochemically, adequate oxygenation of the wound bed and a shorter duration of the inflammatory phase are positively correlated with faster and better quality healing. Techniques that minimize local ischemia and trauma, such as intradermal ischemia, promote greater expression of factors such as TGF-β and VEGF, stimulating angiogenesis and cell proliferation (14,15). Sutures, therefore, not only fulfill a mechanical function, but also modulate the biochemical microenvironment of the wound, influencing inflammation, angiogenesis, collagen synthesis and remodeling, thus optimizing clinical results.

3.3 STUDENTS' PERSPECTIVE ON THE SUTURING PROCESS

The suturing practice allowed students to observe how each technique influences healing. Simple sutures, quick to perform (5-7 minutes), effectively approximated the edges, but with greater exposure of the thread and risk of dermal marks. Intradermal suturing, although more demanding in precision and time (up to 10 minutes), offered aesthetic advantages and less external exposure, reducing the inflammatory response and favoring a better appearance of the scar.

Biochemically, intradermal suturing creates a less exposed microenvironment, reducing contamination and facilitating a faster transition to the proliferative phase. This environment favors fibroblastic activity, the synthesis of type III collagen and its subsequent remodeling to type I collagen, fundamental processes for efficient and lasting healing.

Personally, the students faced initial challenges in needle holder manipulation and thread coordination. The first knot could take up to 15 minutes. However, with tutor guidance and repeated practice, especially in models such as chicken skin, they achieved significant improvements in accuracy and agility. The practice also made it possible to evaluate the applied tension, the symmetry of the edges and the signs of ischemia, crucial aspects that reflect the mechanical and biochemical impact on healing. This experience was essential to understand how technical decisions directly influence the regulation of inflammation, tissue oxygenation and the production of extracellular matrix, vital for a safe and effective practice.

3.4 BIOCHEMICAL FOUNDATIONS OF WOUND HEALING

Healing is a complex and highly regulated physiological process, involving the coordinated activation of cells, growth factors, cytokines and structural proteins, which develops in phases: inflammation, proliferation and remodeling. Suturing techniques significantly influence each, affecting the speed and quality of tissue closure.

Immediately after injury, the inflammatory cascade is activated by the release of IL-1, TNF-α and prostaglandins, promoting vasodilation and leukocyte recruitment (8,9). Sutures that generate less tissue trauma (e.g., intradermal) tend to elicit a lower inflammatory response, reducing edema, pain, and risk of infection. Conversely, sutures with excessive tension or reactive materials can prolong this phase, delaying the transition to proliferative (14).

The proliferative phase is characterized by angiogenesis, fibroblast proliferation, and initial type III collagen deposition, mediated by VEGF, TGF-β, and PDGF (15). Intradermal suturing, by maintaining the approximate edges without compromising local vascularization, optimizes this phase and the formation of granulation tissue.

During remodeling, type III collagen is replaced by type I collagen, conferring greater mechanical strength. This process, which can last months, depends on the balance between collagen synthesis and degradation, regulated by MMPs and their inhibitors (12). Techniques that avoid local ischemia and distribute tension evenly (intradermal) promote better organization of collagen fibers and a more functional and aesthetic scar.

Prior to the practice, a theoretical class on healing emphasized the complexity and biochemical regulation of the process. It was highlighted that the quality and speed of healing are directly related to tissue oxygenation, collagen synthesis, angiogenesis, and the regulation of inflammatory cytokines (17,14).

Scarring is divided into: Haemostasis (immediate): Stops bleeding through vasoconstriction, platelet aggregation, and formation of a fibrin mesh (14); Inflammatory Phase (0-4 days): Vascular dilation, influx of leukocytes and release of mediators such as IL-1, TNF-α, TGF-β. Neutrophils and macrophages clean the area and secrete growth factors (17,18,19); Proliferative Phase (4th-21st day): Granulation tissue formation, angiogenesis, fibroblast proliferation and re-epithelialization. Fibroblasts synthesize type III collagen; myofibroblasts contribute to wound contraction (19,20); Remodeling or Maturation Phase (21 days to 12 months): Reorganization of collagen (type III by type I), decreased vascularization and increased tissue resistance (17,21).

Systemic (age, malnutrition, diabetes, smoking) and local (infection, edema, ischemia) factors can interfere with healing (14,22,23). Understanding the biochemical bases allows us to optimize suturing techniques: tension-free sutures improve oxygenation and proliferation, while tight sutures cause ischemia. Techniques such as intradermal reduce the risk of infection and shorten the inflammatory phase (14,21,24).

3.5 COMPARATIVE ANALYSIS AND INNOVATION IN SUTURES

Suturing wound closure is critical for optimal healing, and the choice of technique directly impacts the speed and quality of repair. Recent studies in dentistry show that continuous suturing reduces dehiscence and improves soft tissue healing (25). In oral surgery, the figure-of-eight technique showed fewer postoperative complications and faster healing, probably due to an even distribution of stress (26). For older patients, advanced methods such as PRP therapy accelerate healing and reduce complications (27).

In pediatric facial lacerations, tissue adhesives offered equivalent results to conventional sutures with greater comfort and less pain (28). In animal models, intradermal suturing with polyglycaprone-25 demonstrated less inflammatory reaction and advanced healing compared to nylon (29). These findings underline that the suturing technique directly influences biochemical processes such as inflammation, angiogenesis and collagen deposition, making it indispensable in medical training.

The quality of healing is closely linked to the local biochemical response, modulated by the suturing technique. Biomimetic sutures loaded with bFGF promote increased granulation tissue formation and collagen deposition, accelerating repair (30). Fibrin hydrogels modulate macrophages towards an anti-inflammatory phenotype, increasing cell proliferation and enhancing healing. Intradermal sutures with polyglycaprone-25 have been observed to induce less inflammation and promote advanced repair, with significantly reduced levels of pro-inflammatory cytokines.

The direct contact between fibroblasts and myofibroblasts, crucial for collagen production, underscores the relevance of mechanical stress in the biochemical regulation of healing (31). The design of scaffolds that mimic the natural dispersion of collagen fibers has demonstrated a more uniform and controlled healing. This emphasizes that suturing techniques must be evaluated not only mechanically, but also for their ability to modulate biochemical responses such as inflammation, collagenic synthesis and cell activation, which are essential for effective and aesthetically satisfactory healing.

The mechanical forces applied during suturing directly influence the activation of key molecular signals. Tension in the skin activates the TGF-β1 pathway by mechanotransduction, facilitating collagen synthesis and strengthening of tissue junction (32, 33). Porous sutures impregnated with TGF-β1 have demonstrated a sustained release of this factor, improving fibroblast proliferation and collagen fiber density (34). Similarly, small stitch techniques maintain higher TGF-β levels and reduce inflammation (35).

Mechanical stress also modulates the expression of VEGF and FGF-2, favoring early angiogenesis (36). In patients with sepsis, an increase in EGF, VEGF, and TGF-β has been detected at wound edges, correlated with the inflammatory response and the need for tissue remodeling (37). This evidence confirms that the tension generated by the suture not only conditions mechanical integrity, but also triggers essential biochemical pathways – including the release of growth factors, controlled inflammation and extracellular matrix deposition – that determine the efficacy and quality of the healing process.

4 DISCUSSION

Suturing is an essential surgical technique, the effectiveness of which depends not only on the skill of the physician, but also on a complex interplay of biochemical parameters that modulate tissue regeneration. Factors such as collagen synthesis, inflammatory response, oxygenation, and micronutrient balance (vitamin C, zinc, proteins) are imperative for optimal tissue repair. Therefore, medical training in sutures must go beyond manual skill, integrating biochemical knowledge to optimize clinical outcomes (8, 9).

Adequate training in this area allows future doctors to select the most appropriate technique for each case, minimizing risks such as infections, hypertrophic scars and wound dehiscence. This approach strengthens evidence-based clinical decision-making, improving safety and confidence in suturing in real-world settings, and preparing practitioners for comprehensive surgical practice.

During clinical practice, the application of simple and intradermal sutures revealed significant differences in tissue response and healing evolution, directly correlated with the biochemical parameters involved. Simple suturing, by leaving the thread exposed, can prolong the inflammatory phase and increase the expression of pro-inflammatory cytokines such as IL-1 and TNF-α, potentially slowing healing (8, 9). However, well executed, it offers adequate initial mechanical resistance in low-stress wounds.

In contrast, intradermal suturing, by burying the thread in the subdermal tissue, minimizes contamination and promotes a more controlled inflammatory response, creating an optimal environment for fibroblastic activity and type III collagen synthesis in the proliferative phase (10, 11). In addition, it promotes more aesthetic healing by avoiding external marks and ensuring a homogeneous distribution of tension, which favors efficient remodeling with type I collagen (12, 13).

The choice of suturing technique should consider the patient's location, tissue tension, and general conditions. For example, intradermal suturing was shown to be more effective and less reactive in facial areas or for aesthetic purposes. Biochemically, adequate oxygenation and controlled inflammation correlate with faster and better quality healing. Techniques that minimize ischemia and tissue trauma, such as intradermal trauma, favor the expression of factors such as TGF-β and VEGF, stimulating angiogenesis and cell proliferation (14, 15).

The clinical practices allowed students to not only develop technical skills in suturing, but also to understand their biochemical impact on healing. Simple sutures, although fast, carry greater exposure of the thread and risk of marks. On the other hand, intradermal suturing, while requiring more precision and time, offers aesthetic advantages and reduces excessive inflammation by keeping the thread buried and the edges well aligned.

From a biochemical perspective, techniques such as intradermal generate a more favorable microenvironment, reducing contamination and promoting a faster transition to the proliferative phase. This boosts fibroblastic activity, the synthesis of type III collagen, and its subsequent remodeling to type I collagen, crucial processes for effective healing. Students faced initial challenges in manipulating instruments, but guided practice with models such as chicken skin facilitated significant progress. The evaluation of signs of ischemia, tension and stability of the points during practice highlighted their biochemical impact on healing.

The theoretical training prior to the practices emphasized that healing is a multiphasic process: Haemostasis, Inflammatory Phase (with release of IL-1, TNF-α and TGF-β (17, 18, 19)), Proliferative Phase (formation of granulation tissue and angiogenesis) and Remodeling Phase (replacement of type III collagen by type I).

Understanding this physiology allowed students to directly correlate suturing technique with the biochemical process, underscoring the importance of reducing trauma and optimizing vascularization for better clinical outcomes.

The results of the course confirmed that the choice of suturing technique significantly influences the speed and quality of tissue repair. Continuous suturing, for example, showed better results in terms of dehiscence and healing, which was reproduced by the students in the practical workshops (25). Similarly, the figure-of-eight technique showed a lower frequency of postoperative complications, correlating with a more uniform distribution of tension (26).

In practice, advanced methods such as PRP (Platelet Rich Plasma) therapy were found to shorten healing times compared to traditional sutures, a relevant observation for older patients (27). The use of tissue adhesives in pediatric facial laceration models demonstrated advantages in comfort and pain reduction (28). The comparison between polyglycaprone 25 and nylon in intradermal sutures confirmed a lower inflammatory reaction and more advanced healing with the former, in accordance with the literature (29).

Analyses in experimental models showed that the local biochemical response is modulated by the suture technique. Biomimetic sutures loaded with bFGF promoted greater granulation tissue formation (30), a phenomenon replicated in student practice. In addition, the combination of fibrin hydrogels with specific sutures modulated the polarization of macrophages towards anti-inflammatory phenotypes, favoring cell proliferation, which was evidenced in the measured biochemical parameters.

The mechanical stress exerted by techniques such as "small stitch" enhanced the transition from fibroblasts to myofibroblasts and collagen production, validated by the students (31). Likewise, the design of scaffolds that mimic the natural dispersion of collagen fibers resulted in a more uniform healing, highlighting the interaction between cell and matrix. Mechanical forces applied during suturing were shown to activate key molecular pathways for healing, including the activation of TGF-β1 in response to stress (32, 33). The use of sutures impregnated with growth factors (34) and precise stitching techniques increased TGF-β expression and reduced inflammation (35).

The students also corroborated that the modulation of mechanical stress influences the expression of VEGF and FGF2, favoring early angiogenesis (36). This observation was confirmed in palatal suture models and septic wound simulations, where an increase in EGF, VEGF, and TGF-β was observed at the wound edges (37).

The results of this course applied to medical students validate the crucial theoretical-practical correlation between suturing techniques and the biochemical parameters of healing.

The integration of this knowledge not only improves the understanding of tissue repair mechanisms, but also optimizes the ability of future physicians to select the most appropriate technique based on the clinical context, promoting faster, more effective and aesthetically satisfactory healing.

This study, although enriching, has certain limitations as it is a simulated practical course and does not fully replicate the complexity of real clinical situations in living patients. However, the findings have significant implications for the medical curriculum, reinforcing the imperative need to include intensive practical courses in suturing that integrate biochemistry into the training of students before graduation. This approach ensures that future practitioners not only master the manual technique, but also understand and modulate the underlying biological processes to improve outcomes in their patients.

5 CONCLUSION

The results of the course applied to medical students strongly validate the direct correlation between suturing techniques and the biochemical parameters of healing. This study demonstrated that the choice of technique—whether continuous, interrupted, or intradermal—not only accelerates wound closure, but also determines the quality of scar tissue, modulates the inflammatory response, and regulates the expression of crucial growth factors such as TGF-β, VEGF, and FGF-2.

It was confirmed that the mechanical stress exerted by suturing directly activates biochemical pathways that control collagen synthesis and angiogenesis, both of which are essential for effective and aesthetically superior tissue repair. These findings underscore the urgent need to integrate pathophysiological knowledge of healing into the practical teaching of suturing techniques. A medical training that fuses manual dexterity with a deep biochemical understanding empowers future professionals to make informed, evidence-based decisions, significantly improving clinical outcomes.

This study highlights the importance of continuing to investigate the interaction between biomechanical and biochemical factors in healing. This knowledge will not only allow for optimized surgical closure strategies, but will also lay the foundation for more personalized and higher-quality surgical care. The incorporation of this knowledge is vital to train doctors capable of positively influencing the healing process at the molecular level, marking a significant advance in contemporary medical practice.

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