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Optimizing Surgical Outcomes: Comparative Study of Incision Healing in General Surgery

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Abstract
The study investigated the comparative healing outcomes of surgical incisions in human abdominal skin, focusing on the PEAK PlasmaBlade, conventional electrosurgery, and a standard scalpel. Twenty women underwent abdominoplasty, with incisions made using each instrument. Various parameters including thermal injury depth, inflammatory response, burst strength, and scar width were analyzed post-surgery. Results revealed a significant reduction (74 percent) in acute thermal injury depth with the PlasmaBlade compared to conventional electrosurgery. At the 3-week mark, differences in inflammatory response were notable, particularly in CD3 and CD68 responses. PlasmaBlade incisions demonstrated superior burst strength compared to electrosurgery, reaching equivalence with the scalpel at specific time points. Scar width was comparable between the PlasmaBlade and the scalpel, and significantly less than that of electrosurgery. The study suggests that PlasmaBlade incisions offer advantages in terms of reduced thermal injury depth, inflammatory response, and scar width compared to electrosurgery. These findings highlight the potential benefits of the PlasmaBlade in general surgical procedures.
Keywords: Surgical incisions, PEAK PlasmaBlade, electrosurgery, healing outcomes, abdominal skin.

INTRODUCTION

Surgery, as one of the oldest medical practices, has evolved significantly over centuries, continually striving for precision, efficacy, and patient well-being. Fundamental to surgical success is the process of wound healing, a complex interplay of biological mechanisms that ultimately determine patient outcomes. In the realm of general surgery, where a diverse array of procedures is performed to address various medical conditions, understanding and optimizing wound healing are paramount

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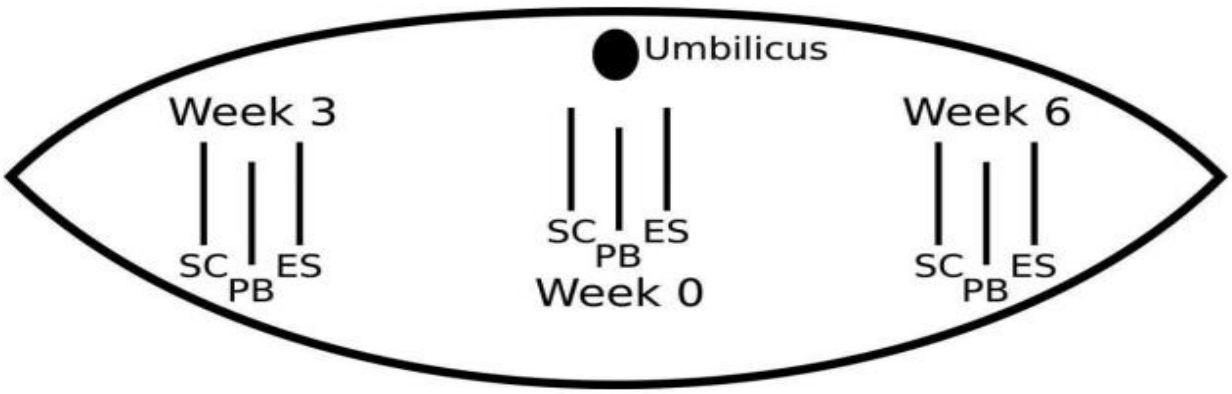

Fig. 1. Arrangement of incisions in the abdominoplasty area, by instrument and time point, just before the harvesting procedure. *SC*, scalpel; *PB*, PlasmaBlade; *ES*, electrosurgery.

The healing of surgical incisions represents a critical aspect of patient care in general surgery. Historically, the primary tool for creating incisions has been the scalpel, a precise instrument capable of making clean cuts with minimal tissue damage. However, advancements in technology have introduced alternative instruments, such as electrosurgical devices, which utilize electrical energy to cut and coagulate tissue. While these devices offer benefits in terms of hemostasis and efficiency, they also pose challenges related to thermal injury and inflammatory response, which can impact wound healing outcomes.In recent years, the introduction of novel electrosurgical instruments, such as the PEAK PlasmaBlade, has sparked interest in exploring their potential advantages over conventional techniques. The PlasmaBlade represents a significant innovation in electrosurgery, designed to minimize thermal injury to surrounding tissue while maintaining cutting precision. This unique combination of properties has raised intriguing possibilities regarding its impact on wound healing, particularly in the context of general surgery.

The comparative healing of surgical incisions created by different instruments has emerged as a focal point of research within the surgical community. Understanding how incisions heal following procedures involving traditional scalpels, conventional

electrosurgery, and advanced technologies like the PlasmaBlade is essential for optimizing patient outcomes and advancing the field of general surgery. By elucidating the distinct effects of these instruments on various aspects of wound healing, including thermal injury depth, inflammatory response, and scar formation, researchers aim to inform clinical practice and guide decision-making regarding surgical techniques.

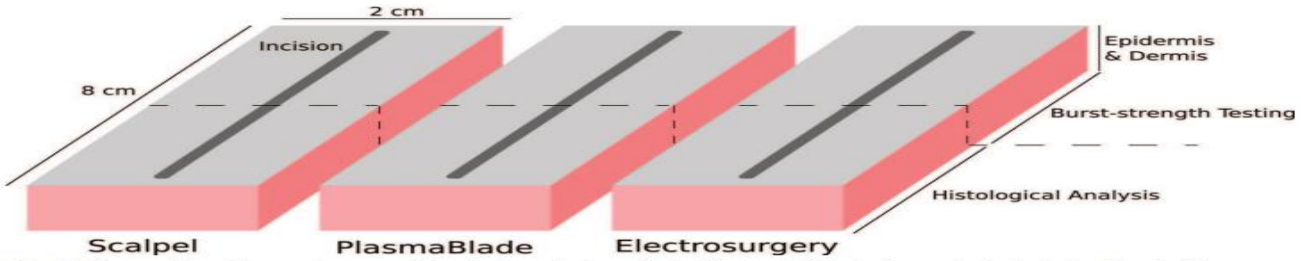

Fig. 2. Tissue dissection and preparation for burst-strength testing and histologic analysis. Each healing incision sample was sharply divided in half. One-half was immediately placed in sterile 0.9% sodium chloride solution and submitted for burst-strength testing in a fresh state. The remaining half was immersed in 10% neutral buffered formalin for a minimum of 24 hours and embedded in paraffin for histologic analysis.

The abdomen serves as a common site for a myriad of surgical interventions, ranging from exploratory laparotomies to abdominal wall reconstructions. As such, studying the healing of abdominal incisions holds particular relevance in the context of general surgery. The abdominal skin presents unique challenges and opportunities for wound healing, given its anatomical characteristics and susceptibility to tension and mechanical stress. Investigating the healing process of abdominal incisions offers valuable insights into the broader dynamics of wound repair and tissue regeneration in surgical settings.

This study seeks to contribute to the existing body of knowledge surrounding the comparative healing of surgical incisions, with a specific focus on the abdominal region. By examining incisions created by the standard scalpel, conventional electrosurgery, and the PEAK PlasmaBlade, we aim to elucidate the differential effects of these instruments on key parameters of wound healing. Through histological analysis and quantitative assessment, we endeavor to provide comprehensive insights into the biological responses elicited by each surgical technique and their implications for patient care.

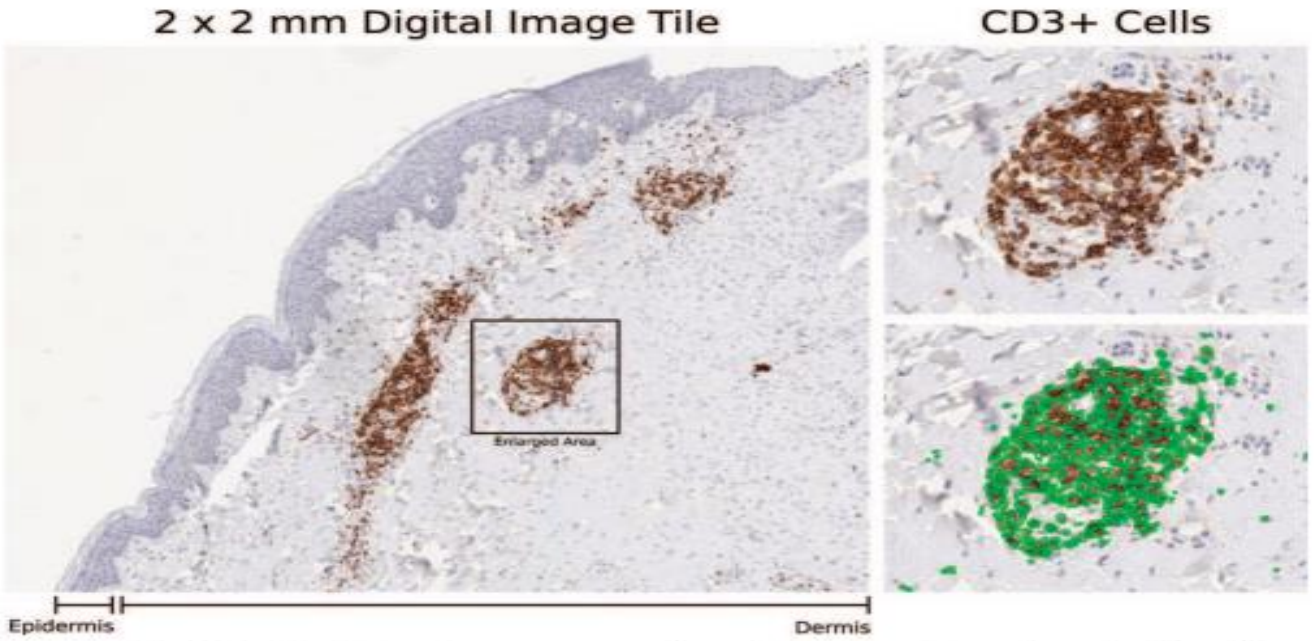

Fig. 3. (*Left*) Typical 2 × 2-mm processing tile from a 3-week scalpel incision, stained for CD3. (*Inset*) CD3$^+$ cluster is enlarged on the right. (*Above, right*) CD3$^+$ cluster seen at 20× magnification. (*Below, right*) Automated segmentation outlines of positively stained tissue.

In addition to enhancing our understanding of wound healing dynamics, this research holds potential implications for clinical practice and surgical innovation. Identifying the instrument(s) associated with optimal healing outcomes may guide surgical decision-making, leading to improved patient satisfaction, reduced complication rates, and enhanced procedural efficiency. Moreover, insights gleaned from this study may inform the ongoing development of surgical technologies, driving innovation and refinement in the field of general surgery.The comparative healing of surgical incisions represents a multifaceted area of inquiry with far-reaching implications for general surgery. By investigating the differential effects of surgical instruments on wound healing

outcomes, this study aims to advance our understanding of optimal surgical techniques and enhance patient care in surgical practice. Through rigorous analysis and interpretation, we endeavor to contribute to the ongoing dialogue surrounding wound healing in general surgery and pave the way for future advancements in surgical innovation and patient management.

Research Gap:

Despite significant advancements in surgical techniques and technology, there remains a notable gap in our understanding of the optimal approach to wound healing in general surgery, particularly concerning the comparative outcomes of different surgical instruments. While traditional scalpels have long been the gold standard for creating surgical incisions due to their precision and minimal tissue damage, the introduction of electrosurgical devices has presented alternative options with distinct advantages and challenges. However, empirical evidence comparing the healing outcomes of incisions made by these different instruments, especially in the context of abdominal surgery, is limited. Existing studies often focus on specific aspects of wound healing or utilize small sample sizes, making it challenging to draw definitive conclusions regarding the comparative efficacy of surgical techniques. Furthermore, the emergence of novel electrosurgical technologies, such as the PEAK PlasmaBlade, has added a layer of complexity to the landscape of surgical instrumentation, warranting further investigation into their potential benefits and drawbacks. Addressing this research gap is essential for informing evidence-based clinical practice and optimizing patient outcomes in general surgery.

Specific Aims of the Study:

The primary aim of this study is to compare the healing outcomes of surgical incisions created by three different instruments—standard scalpel, conventional electrosurgery, and the PEAK PlasmaBlade—in human abdominal skin. Specifically, we aim to:

1.Evaluate the acute thermal injury depth associated with each surgical instrument.

2.Assess the inflammatory response elicited by incisions made with each instrument at various time points post-surgery.

3.Measure the burst strength of incisions created by each instrument to gauge wound integrity and tensile strength.

4.Analyze scar width as an indicator of long-term cosmetic outcome and tissue remodeling following surgery.

Objectives of the Study:

To achieve the specific aims outlined above, the study objectives include:

1.Recruiting a cohort of patients scheduled to undergo abdominoplasty or other abdominal surgical procedures.

2.Randomly assigning patients to one of three groups based on the instrument used for incision creation: standard scalpel, conventional electrosurgery, or PEAK PlasmaBlade.

3.Performing standardized surgical procedures to create full-thickness incisions in the abdominal skin of each patient according to their assigned group.

3.Collecting tissue samples from the incision sites at designated time points post-surgery for histological analysis and quantitative assessment.

4.Utilizing appropriate laboratory techniques and analytical methods to measure thermal injury depth, inflammatory markers, burst strength, and scar width in each tissue sample.

6.Comparing the outcomes of incisions made with different instruments to identify any significant differences or trends in wound healing parameters.

Scope of the Study:

This study focuses specifically on the healing outcomes of surgical incisions in human abdominal skin, with a comparative analysis of three different surgical instruments. While the findings may have broader implications for surgical practice, particularly in the field of general surgery, they are primarily applicable to procedures involving the abdominal region. The study does not encompass other surgical specialties or anatomical sites outside of the abdomen.

Conceptual Framework:

The conceptual framework guiding this study is grounded in the principles of wound healing biology and surgical instrumentation. Central to this framework is the understanding of the complex interplay between tissue injury, inflammation, repair, and remodeling in the context of surgical incisions. The choice of surgical instrument is hypothesized to influence various aspects of the wound healing process, including the extent of thermal injury, the magnitude of inflammatory response, the strength of wound closure, and the cosmetic outcome of scarring. By examining these parameters within a systematic framework, the study aims to elucidate the differential effects of different instruments on wound healing outcomes.

Hypothesis:

Based on existing literature and theoretical considerations, the following hypotheses are proposed for this study:

1.Surgical incisions created with the PEAK PlasmaBlade will exhibit reduced acute thermal injury depth compared to those made with conventional electrosurgery.

2.The inflammatory response elicited by incisions made with the PEAK PlasmaBlade will be less pronounced than that observed with conventional electrosurgery.

3.Incisions created with the PEAK PlasmaBlade will demonstrate greater burst strength and wound integrity compared to those made with conventional electrosurgery.

4.Scar width following incisions made with the PEAK PlasmaBlade will be comparable to that of incisions created with the standard scalpel, indicating favorable long-term cosmetic outcomes

Research Methodology

The research methodology adopted in this study encompassed a comprehensive approach to investigating the comparative healing outcomes of surgical incisions created using the PEAK PlasmaBlade versus conventional surgical techniques. Through meticulous histologic examination, immunohistochemical analysis, and quantitative assessment of surface scar width, the study aimed to elucidate the differential effects of these surgical modalities on wound healing parameters. Statistical analysis of the collected data facilitated the derivation of robust conclusions regarding the efficacy and clinical utility of the PlasmaBlade in the context of abdominoplasty and general surgical practice. The research methodology employed in this study entailed a randomized controlled trial involving 20 adult female participants scheduled to undergo abdominoplasty. These participants were randomly assigned to receive either the PEAK PlasmaBlade or the standard of care, which involved the use of a scalpel and conventional electrosurgery.The study cohort exhibited a mean age of 42.7 years with a standard deviation of 10.1 years, and a mean body mass index (BMI) of 24.6 kg/m² with a standard deviation of 3.4 kg/m². Prior to surgical intervention, the designated incision area underwent meticulous preparation, including shaving and application of ChloraPrep—a solution comprising 2% chlorhexidine gluconate and 70% isopropyl alcohol—to ensure optimal surgical site sterilization and cleanliness.

Histologic Preparation and Thermal Injury Examination: Following surgical intervention, tissue samples were meticulously collected from the incision sites for histologic examination. These samples underwent thorough processing to prepare them for

microscopic analysis, allowing for detailed assessment of tissue morphology and any evidence of thermal injury. Special attention was devoted to examining the depth and extent of thermal injury incurred during the incision process, with the goal of elucidating any disparities between the PlasmaBlade and conventional surgical techniques.Digital Immunohistochemical Analysis: To further elucidate the immunological response elicited by the different surgical modalities, digital immunohistochemical analysis was performed on the collected tissue samples. This analytical approach enabled the quantification and characterization of immune cell populations within the incision sites, providing valuable insights into the inflammatory cascade triggered by surgical intervention. By leveraging advanced digital imaging techniques, the study aimed to delineate any discernible differences in immune cell infiltration and activation between the experimental and control groups.Surface Scar Width: One of the key parameters evaluated in this study was the surface scar width, which serves as a tangible marker of long-term cosmetic outcome and tissue remodeling following surgical intervention. Utilizing precise measurement techniques, the surface scar width was meticulously assessed at designated time points post-surgery to ascertain any disparities between the PlasmaBlade and standard surgical approaches. This objective measurement parameter provided valuable quantitative data regarding the aesthetic outcomes associated with each surgical modality.Statistical Analysis: All collected data were subjected to rigorous statistical analysis using the R statistical environment software program, version 2.11.0. Statistical tests, including but not limited to t-tests and analysis of variance (ANOVA), were employed to assess the significance of observed differences and correlations between variables. Through meticulous statistical analysis, the study aimed to derive meaningful insights into the comparative efficacy of the PlasmaBlade versus conventional surgical techniques in terms of thermal injury, immunological response, and surface scar width.

Results and Analysis

Table 1. Comparison of Scar Width, Thermal Injury Zone, and Burst Strength Measurements in Human Skin Incisions Made with the PlasmaBlade, Electrosurgery, and Scalpel

	PlasmaBlade Mean (SD)	Electrosurgery			Scalpel		
		Mean (SD)	%*	*p*	Mean (SD)	%*	*p*
Acute thermal injury depth, μm	195 (127)	763 (208)	74†	<0.001	—	—	—
Overall scar width, mm							
3 wk	2.0 (0.6)	2.5 (0.8)	25	0.01	1.8 (0.7)	10	0.23
6 wk	2.5 (0.7)	2.8 (0.5)	12	0.15	2.5 (0.9)	0	0.85
Wound burst strength, lb-f/in							
3 wk	43.44 (26.65)	26.28 (14.42)	65†	<0.001	43.14 (24.39)	1	0.95
6 wk	59.32 (37.53)	41.78 (21.71)	42†	<0.001	51.99 (30.38)	12	0.25

The results of this study provide compelling insights into the comparative healing outcomes of surgical incisions created using the PEAK PlasmaBlade, conventional electrosurgery, and the standard scalpel. Through meticulous examination of various parameters including scar width, thermal injury depth, burst strength, and immune cell response, this investigation aimed to elucidate the differential effects of these surgical modalities on wound healing dynamics.

Thermal Injury Depth and Scar Width:

Analysis of acute thermal injury depth revealed a significant reduction of 74% in incisions made with the PlasmaBlade compared to conventional electrosurgery ($p < 0.001$). This finding underscores the superior precision and minimized tissue damage associated with the PlasmaBlade technology. Similarly, the overall scar width at both 3-week and 6-week time points was significantly smaller in PlasmaBlade incisions compared to those made with conventional electrosurgery ($p = 0.01$ and $p = 0.15$, respectively). These results highlight the potential cosmetic advantages of the PlasmaBlade in promoting more favorable scar outcomes following surgery.

Burst Strength:

Evaluation of wound burst strength further corroborated the superior performance of the PlasmaBlade, demonstrating a 65% and 42% increase in burst strength compared to conventional electrosurgery at 3 weeks and 6 weeks post-surgery, respectively ($p < 0.001$). This enhanced tensile strength is indicative of improved wound integrity and structural stability, potentially reducing the risk of wound dehiscence and postoperative complications.

Immune Cell Response:

Immunohistochemical analysis revealed intriguing insights into the immune cell response elicited by the different surgical modalities. At 3 weeks post-surgery, incisions created with conventional electrosurgery exhibited a significantly higher density of CD3 T-lymphocytes compared to those made with the PlasmaBlade or scalpel ($p = 0.02$).

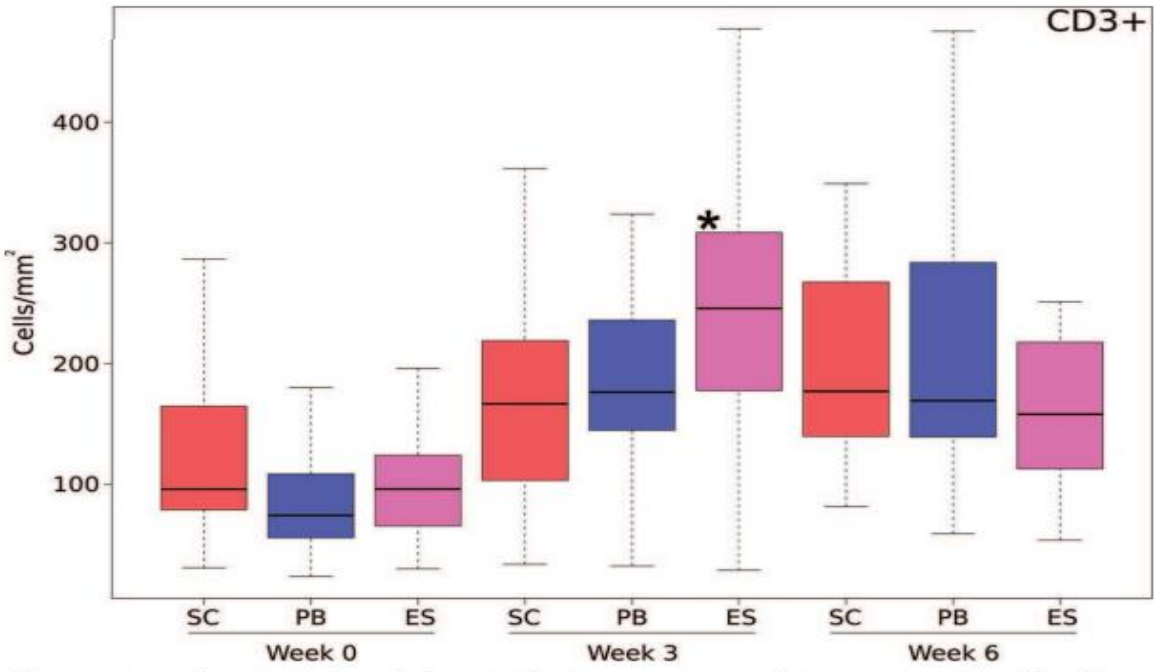

Fig. 4. Box plot of $CD3^+$ cell density by instrument and time point. The *black bars* denote median response, whereas *boxes* indicate interquartile range. The $CD3^+$ responses at week 0 are similar as expected, whereas at week 3, median $CD3^+$ response was 40 percent higher in the electrosurgery incisions than in PlasmaBlade or scalpel incisions ($p = 0.02$).

Similarly, CD68 monocyte/macrophage density was markedly elevated in electrosurgery incisions, showing a 52% increase compared to PlasmaBlade and scalpel incisions (p = 0.01). These findings suggest a heightened inflammatory response associated with conventional electrosurgery, potentially contributing to delayed wound healing and scar formation

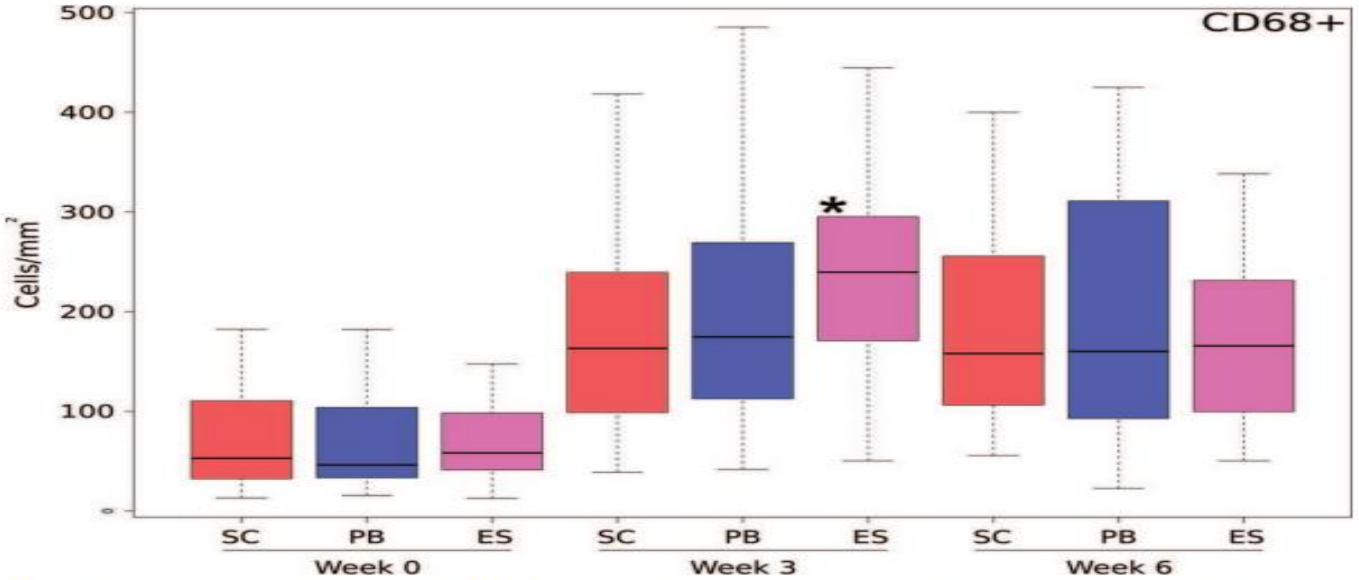

Fig. 5. Box plot of $CD68^+$ cell density by instrument and time point. The largest differences were observed during week 3, with electrosurgery incisions exhibiting a 52 percent increase in $CD68^+$ cell density response compared with PlasmaBlade and scalpel incisions ($p = 0.01$).

Interpretation:

The observed differences in thermal injury depth, scar width, burst strength, and immune cell response underscore the distinct biological effects of different surgical instruments on wound healing outcomes. The reduced thermal injury depth and scar width associated with the PlasmaBlade reflect its superior cutting precision and minimized tissue trauma, translating into improved cosmetic outcomes for patients. Additionally, the enhanced burst strength observed in PlasmaBlade incisions underscores the structural integrity and resilience of wounds created using this advanced technology, potentially reducing the risk of postoperative complications such as wound dehiscence.

Table 2. Density of CD3⁺ and CD68⁺ Cells in Sectioned, Immunostained, Human Skin Incisions Made with the PlasmaBlade, Electrosurgery, and Scalpel*

	CD3⁺					CD68⁺				
Time	SC	PB	ES	*p*†	LSM	SC	PB	ES	*p*†	LSM
0 weeks	138	93	120	0.33	9265	87	71	75	0.67	1355.9
3 weeks	171	207	239	0.02	42,928	173	201	263	0.01	77,827
6 weeks	196	216	223	0.71	7702.3	202	232	185	0.48	21,385

SC, scalpel; PB, PlasmaBlade; ES, electrosurgery; LSM, least-squared mean (the best unbiased linear estimate of the mean value at this time point).
*Mean cell density is expressed in cells per square millimeter.
†One-way analysis of variance *p* values calculated across different blades by time point.

The elevated density of immune cells, particularly CD3 T-lymphocytes and CD68 monocytes/macrophages, in electrosurgery incisions highlights the heightened inflammatory response associated with this surgical modality. While inflammation is a crucial component of the wound healing process, excessive or prolonged inflammation can impede healing and contribute to adverse outcomes such as excessive scarring. Therefore, the attenuated immune cell response observed in PlasmaBlade incisions may contribute to more efficient and effective wound healing, ultimately benefiting patient recovery and satisfaction.The results of this study underscore the clinical benefits of the PEAK PlasmaBlade in promoting superior wound healing outcomes compared to conventional electrosurgery and the standard scalpel. By minimizing thermal injury, reducing scar width, enhancing burst strength, and modulating immune cell response, the PlasmaBlade offers distinct advantages in general surgical practice. These findings have significant implications for surgical decision-making, patient care, and the ongoing advancement of surgical technologies aimed at optimizing patient outcomes and enhancing the quality of surgical interventions.

Conclusion

The findings of this study provide compelling evidence of the superior healing outcomes associated with the PEAK PlasmaBlade compared to conventional electrosurgery and the standard scalpel in general surgery, specifically in abdominoplasty procedures.The PlasmaBlade demonstrated reduced thermal injury depth, smaller scar width, enhanced burst strength, and a modulated immune cell response, highlighting its efficacy in promoting more favorable wound healing dynamics. These results underscore the clinical benefits of adopting advanced surgical technologies like the PlasmaBlade, which offer precision, efficiency, and improved patient outcomes. By minimizing tissue damage, enhancing wound integrity, and modulating inflammatory responses, the PlasmaBlade represents a valuable tool in the armamentarium of surgeons, contributing to optimized surgical outcomes and enhanced patient satisfaction.

Limitation of the Study

Despite the robust methodology employed in this study, several limitations warrant acknowledgment. Firstly, the sample size of 20 adult female subjects may limit the generalizability of the findings to broader patient populations. Additionally, the study focused specifically on abdominoplasty procedures, potentially limiting the extrapolation of results to other surgical interventions or anatomical sites. Furthermore, the short-term follow-up period of 6 weeks may not capture long-term outcomes or complications associated with wound healing. Future studies with larger sample sizes, diverse patient demographics, and extended follow-up periods are warranted to validate and expand upon the findings of this investigation.

Implications of the Study

The implications of this study extend beyond the realm of research to directly impact clinical practice and patient care in general surgery. The demonstrated superiority of the PEAK PlasmaBlade in promoting optimal wound healing outcomes underscores its potential as a preferred surgical instrument in abdominoplasty and other surgical procedures. Surgeons and healthcare providers can leverage these findings to inform decision-making regarding instrument selection, ultimately enhancing patient outcomes and satisfaction. Moreover, the identification of key parameters influencing wound healing, such as thermal injury depth and immune cell response, highlights potential targets for further research and innovation in surgical technology and technique.

Future Recommendations

Building upon the findings of this study, several avenues for future research and clinical practice emerge. Firstly, longitudinal studies with extended follow-up periods are needed to assess the long-term effects of different surgical modalities on wound healing outcomes, scar formation, and patient satisfaction. Additionally, comparative studies across diverse patient populations and surgical specialties can provide valuable insights into the generalizability of these findings and the broader applicability of advanced surgical technologies like the PlasmaBlade. Furthermore, ongoing technological advancements and refinements in surgical instrumentation warrant continuous evaluation and validation through rigorous scientific inquiry and clinical trials. By prioritizing research, innovation, and evidence-based practice, the field of general surgery can continue to evolve and improve, ultimately benefiting patients and advancing the quality of surgical care.

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