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Histological comparison of the action of CO2 laser and plasma in abdominal skin

Comparação histológica da ação do laser de CO2 e plasma na pele abdominal

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ABSTRACT

Histological data on microscopic treatment zones are essential for evaluating procedure safety and effectiveness. To date, no studies have histologically compared low-temperature plasma with other techniques. In this study, two square areas on the patient's abdomen, referred to as area A and area B, were with low-temperature plasma and fractional CO_2 laser, respectively. A biopsy was taken immediately after treatment. When applied to thinner skin regions, plasma technology appears to result in fewer complications, a faster recovery, and fewer side effects during the application period. However, further studies are needed to confirm these findings.

Keywords: Laser Therapy; Histology Comparative; Plasma Skin Regeneration; Gas Lasers.

RESUMO

Dados histológicos das zonas de tratamento microscópico são importantes para estudar a segurança do procedimento e a eficácia do tratamento. Ainda não existem estudos envolvendo o plasma com outras técnicas. Selecionamos duas áreas no abdome de um paciente, denominada área A e área B, aplicando o plasma de baixa temperatura e o laser de CO_2 fracionado. Logo após, foram realizadas biopsias. Quando utilizada em regiões mais finas de pele, a tecnologia de plasma garantiria menos complicações durante o período de aplicação, recuperação mais rápida e menos efeitos colaterais. No entanto, mais estudos são necessários para confirmar nossos achados.

Palavras-chave: *Terapia a Laser; Histologia Comparada; Regeneração da Pele por Plasma; Lasers de Gás.*

Case report

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INTRODUCTION

CO_2 laser (CO_2L) is one of the most widely used treatments in dermatology. However, due to its associated complications, nonablative fractional lasers (NAFL) were introduced.[1,2] Following NAFL, ablative fractional lasers (AFL) were developed, emitting narrow, high-energy beams that destroy columns of tissue. Around these ablated columns, an adjacent ring of thermal damage forms, known as microscopic treatment zones (MTZs).[3] Within the MTZs, columns of uninjured tissue contribute to the clinical response to treatment.

The skin retraction and neocollagenesis observed with AFL result from two primary effects—ablation and injury.[3,4] AFLs allow greater control over treatment depth, more selective thermal damage, and consequently, a significant reduction in side effects.[1]

Over the past decade, medicinal plasma has emerged as a powerful tool for biomedical applications, particularly in therapies for delicate tissues.[5] Low-temperature plasma (LTP), which operates below 40°C, has been evaluated for treating conditions requiring tissue retraction, such as blepharochalasis syndrome, tissue laxity, and scarring. Additionally, LTP has demonstrated effectiveness in treating cutaneous neoplasms, viral infections, and biofilm-related infections.[5]

Histological data on MTZ dimensions—depth, diameter of ablation, coagulation, and necrosis—are crucial for assessing procedure safety and effectiveness, as well as for optimizing treatment combinations based on individual patient needs.[6] However, no studies have yet histologically compared LTP with other techniques. According to Baroni, compared to conventional radiofrequency and ablative treatments, LTP promotes better healing and superior aesthetic outcomes.

METHODS

A woman scheduled for abdominoplasty in 3 months consented to participate in this study. Two squared areas of approximately 4 cm^2 were selected on her abdomen, designated as Area A and Area B, where plasma application and fractional CO_2L were performed, respectively.

In Area A, LTP was applied using the Surgical Derm device from the SOLON® platform (LMG – Laser Medical Group Ltda., Guaxupé, MG, Brazil). In Area B, Dual Deep® fractional CO_2L (Lutronics, Gyeonggi-do, South Korea) was applied with the following parameters: wavelength 10,600 nm, pulse energy 50 mJ, and static mode.

Immediately after the procedures, a 4 mm punch biopsy was performed. The two tissue samples were fixed in a 10% formaldehyde solution before processing for light microscopy, which included dehydration, paraffin embedding, and sectioning. Hematoxylin and eosin stains were used to visualize and analyze the depth and diameter of the coagulation channel. Histological sections were examined under 100× magnification with a polarized light source, using an Olympus BX41 trinocular microscope coupled to an Olympus C-35DA-2 camera.

RESULTS

The histopathological analysis of Area A (Figure 1), subjected to LTP, revealed a central coagulation zone measuring 0.6 mm in diameter, with a depth ranging from 0.15 mm to 0.25 mm, excluding the epidermis. The papillary dermis surrounding this area exhibited edema and a reduction in elastic tissue, confirmed by Verhoeff stain. Masson's trichrome staining did not reveal any significant findings.

In Area B (Figure 2), two small coagulation zones of similar dimensions were observed. One, located eccentrically, was more prominent, measuring 0.13 mm to 0.15 mm in diameter, with a depth of 0.5 mm, excluding the epidermis. In the surrounding papillary dermis, a slight reduction in elastic tissue was noted.

DISCUSSION

Since its first description, CO_2L has gained considerable recognition in the aesthetic field, stimulating neocollagenesis depending on the amount of heat supplied and the depth of its dermal and epidermal penetration.[7,8] Additionally, the longer the ablation column, the greater the stimulus for dermal remodeling in deeper scar regions, resulting in improved outcomes for fine lines, acne scars, and photodamaged skin.[9,10] Fractionated CO_2L pulse energy has been identified as a critical factor in determining the extent and depth of ablation, thermal damage, and collagen remodeling.[11,12] Baumann et al. concluded differences in the properties of ablative zones are not directly proportional to the total amount of energy applied.[12] Thus, studies evaluating ablation columns resulting from different therapeutic methods are of great interest.

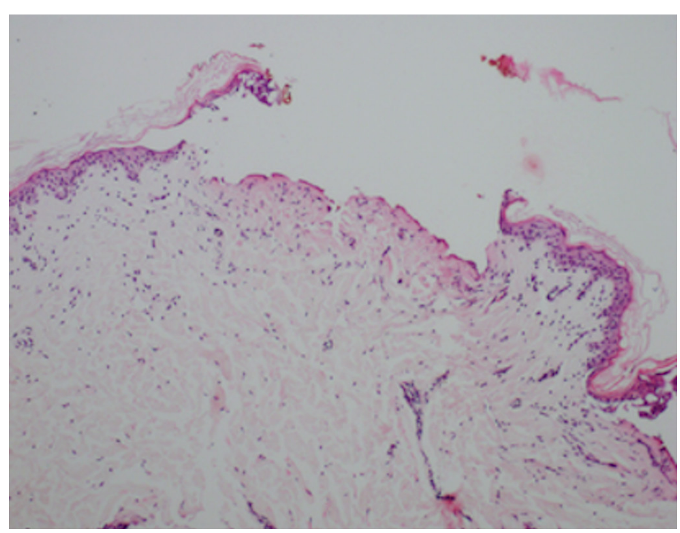

FIGURE 1: Area A (100× magnification) – Central coagulation zone measuring 0.6 mm in diameter, with a depth ranging from 0.15 mm to 0.25 mm

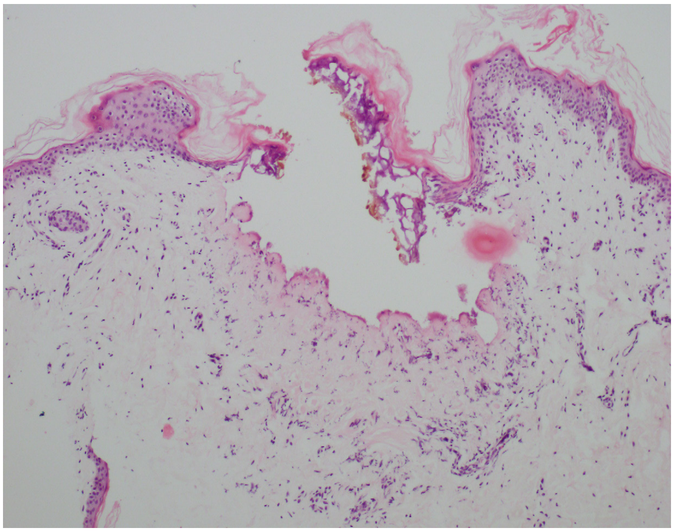

FIGURE 2: Area B (100× magnification) – Two small coagulation zones, one eccentrically located and more prominent, measuring 0.13 mm to 0.15 mm in diameter, with a depth of 0.5 mm

Arisa and Ortiz et al.[2] demonstrated treatment with fractionated CO_2L produced greater ablation columns compared to the surgical method. The increased ablation depth led to more significant skin retraction, resulting in better final aesthetic outcomes for scars.[4] In contrast, LTP technology has gained prominence, particularly in noninvasive blepharoplasty. Its mechanism of action involves inducing the expression of key genes such as type I collagen, transforming growth factors (TGF-β1 and TGF-β2), and alpha-smooth muscle actin (α-SMA). Plasma treatment triggers a coordinated response of transcription factors essential for wound healing, promoting re-epithelialization, angiogenesis, and oxidation of the lipid layer.[13]

The plasma spark generated by LTP sublimates the superficial skin layers without causing excessive thermal damage by coagulating dermal vessels, maintaining controlled heating. The energy is concentrated in small areas (~1 mm in diameter), allowing for precise and targeted tissue action while minimizing damage to deeper layers.[14]

Our findings revealed variations in coagulation column measurements: the diameter produced by LTP was approximately four times larger than that achieved with CO_2L, whereas CO_2L reached an ablation depth twice that of plasma. Considering areas with low dermal thickness, such as the eyelids, this shallower penetration combined with greater surface coverage may explain the increasing popularity of LTP in nonsurgical blepharoplasty. Such histological differences suggest each technology offers distinct yet complementary therapeutic possibilities, supporting individualized treatment approaches.

According to Baroni, the advantages of LTP include high precision, short procedure time, absence of bleeding, minimal collateral tissue damage, rapid formation of a postoperative protective layer, fast wound healing, and an immediate return to daily activities, with fewer unwanted effects.[14] Our findings suggest when applied to thinner skin regions, LTP provides greater protection for deeper layers, more precise and controlled heating, fewer complications during application, faster recovery, and fewer side effects compared to CO_2L.

However, further studies comparing the histological characteristics of MTZs across these techniques, along with their clinical outcomes, are necessary to validate these findings.

CONCLUSION

Studies on CO_2L ablation layers associate greater depth with improved results. However, there is a lack of studies comparing CO_2L with LTP. Our findings suggest that the greater diameter and shallower depth of the ablation column are key characteristics that support the use of plasma, particularly in areas with delicate skin. These properties contribute to fewer complications during and after the procedure, faster recovery, and excellent aesthetic outcomes. Nonetheless, further studies are required to confirm this relationship. ●

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Statistical analysis; approval of the final version of the manuscript; study conception and design; manuscript drafting and writing; data collection, analysis, and interpretation; active participation in research supervision; intellectual contribution to the propaedeutic and/or therapeutic management of studied cases; critical literature review; critical manuscript review.

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