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ORIGINAL ARTICLE

Effect of capacitive radiofrequency on the dermis of the abdominal region

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Abstract

The purpose of this study is to evaluate the effects of radiofrequency (RF) on sagging skin. This is a case series study with five volunteers who received a single application of capacitive RF (BTL-6000 TR-Therapy Pro®) in the right infraumbilical abdominal region, with epidermal temperature above 40°C, for 10 min (2 min per applicator area), and the skin of the contralateral region was used as control. After 30 days, on average, the skin of the abdominal region was collected for histological analysis and stained with hematoxylin and eosin, Picro-sirus, and Verhoff. The percentage of collagen and elastic fibers found was marked by the Image J®. The statistical analysis was performed in the SPSS program (version 20), with a significance level of 95%. This was registered with the ethics and research comitee of UFTM n 3.461.688 on Jul 12, 2019 and clinical trial registration n. NCT04182542, retrospectively registered. Morphometric analysis demonstrated a remodeling of collagen and elastic fibers on the side treated with RF; however, the morphometry for collagen showed no significant difference, with an average percentage of 60.94 ± 0.32 for the control side and 61.97 ± 2.80 for the treated with p=0.32. Similarly, elastic fibers also showed no significant difference between groups, with a mean percentage of 5.67 ± 2.70 for control and 6.21 ± 2.01 for treated with p=0.19. The RF with the parameters used in this study was able to cause morphological changes in collagen and elastic fibers of the abdominal region skin; however, it showed no change in the percentage of these fibers.

Keywords Radio waves · Radiofrequency therapy · Dermis · Collagen · Elastic tissue

Introduction

The demographic transition currently experienced in society brings us an aging picture of the population in general, with several physiological processes happening, especially in the skin. Over time, the skin becomes thinner and loses elasticity. Collagen fibrils gradually become more rigid, and there is a reduction in the number of elastic fibers and other connective tissue components [1]. This process happens to all individuals, increasing concerns about appearance, considering that the life expectancy of the population has increased [2].

Radiofrequency (RF) is a noninvasive resource capable of stimulating changes in collagen conformation and inducing neocollagenesis by generating controlled thermal energy in deep layers of cutaneous and subcutaneous tissue [3]. This thermal energy is generated through the emission of focused electromagnetic waves that encounter resistance in the tissue, generating heat [4].

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This temperature increase affects the triple structure of the collagen helix, subsequently breaking intramolecular hydrogen bonds, resulting in immediate collagen contracture. Subsequently, neocollagenogenesis and neoelastogenesis occur in the dermis, without interfering with the epidermis, resulting in a visibly compacted and organized dermis [5–7]. RF also causes vasodilation which, in turn, improves tissue trophism and resorption of exceeding intercellular fluid, increasing blood circulation [8].

The term tecartherapy is one of the types of radiofrequency that comes from CPT (capacitive power transfer), having as the main effect of the heat production when flowing through the body. Among the expected benefits of the tecartherapy use is the improvement of the skin appearance by increasing the amount of nutrients and oxygen, in addition to the reduction of fat in the abdomen [9].

There are several studies which demonstrate the efficacy of RF in the face of aging and sagging skin [10, 11]. Its efficacy in reducing "orange skin" in post liposuction treatments, wrinkles, scars, etc. has also been demonstrated. It is also recommended in treatments for excessive hair loss or alopecia, dark circles under the eyes, adiposities, stretch marks, spots, and fibrosis [8].

The aim of this study was to evaluate the effects of RF (tecartherapy) on human skin collagen and elastic fibers, regarding the morphological and morphometric aspects.

Methods

Study design

This is a quasi-experimental case series study with blinding of the evaluatorand convenience sample.

Five women in good general health, who were waiting for abdominoplasty, were selected at the Clinical Hospital of Federal University of Triângulo Mineiro (UFTM) from October 2018 to February 2019. It refers to a convenience sample, in which only these volunteers were invited to participate in the study.

The following exclusion criteria were used: women with sensory and cognitive deficit, under 18 years old, with the presence of metallic implant at the site of application, pacemaker carriers, with signs of infection, circulatory disorders, neoplasia, or any other condition that contraindicates the use of RF.

After being informed about the treatment, they signed the Free and Informed Consent Form. Then, an initial evaluation was performed in which personal data and anthropometric measurements (weight, height, and body mass index—BMI) were collected, as well as the cutaneous phototype following the Fitzpatrick scale.

The project was approved by CEP-UFTM, registration number: 3,461,688 on Jul/12/2019 and registered on the clinical trial platform, registration number: NCT04182542.

Procedures

The volunteers received monopolar radiofrequency with capacitive electrode with a diameter of 50 mm, power of 150 W, and frequency of 0.52 MHz (BTL-6000 TR-Therapy Pro®), in the right abdominal region, with an application time of 10 min (2 min per electrode area), and the left region was used as control. The epidermal temperature above 40°C was maintained, and a single session was performed. These parameters were selected because of the need to verify the effects of different frequencies and types of electrodes on the different tissues.

Approximately 30 days after application, the skin was collected during the surgical procedure, and the controlled and treated fragments were sent for histological analysis.

Sample processing and slide mounting

The fragments removed after surgery were fixed in Metacarn (methanol 60%, chloroform 30%, and acetic acid 10%) for 2 h at room temperature (TA). The slides were made by the general pathology department at the Federal University of Triângulo Mineiro. The samples were dehydrated in ethanol, diaphanized in xylol, and included in paraffin. Histological sections of 5 μm were obtained in microtome (Jung) and positioned on slides pre-covered with polylysine. The histological sections were stained with hematoxylin and eosin, Picro-sirus, and Verhoff. The general morphology of the tissue, Picro-sirus, and the presence and morphology of collagen fibers and Verhoff elastic fibers were analyzed based on hematoxylin-eosin staining.

Microscopic and morphometric analysis

The slides stained with hematoxylin-eosin, Picro-sirus, and Verhoff were visualized with a ×20 lens. The images were captured by a common light microscope and analyzed by the *Axion Vision* Automatic Image Analyzer System.

Thus, the field to be quantified was captured, photographed through a camera coupled to the microscope and to the computer for image scanning. The images were saved in TIFF format. Approximately 20 fields of the slides were photographed and saved.

After the fields were saved, the Image J® program was used to improve them, using the lighting reference so that they all have the same quality.

The percentage of collagen and elastic fibers was registered by the Image J® program and recorded in a Microsoft Excel spreadsheet.

Statistical analysis

The following variables were evaluated: percentage of collagen and elastic fibers. Initially, the normality test was performed with Shapiro Wilk, and the paired *t*-test was performed

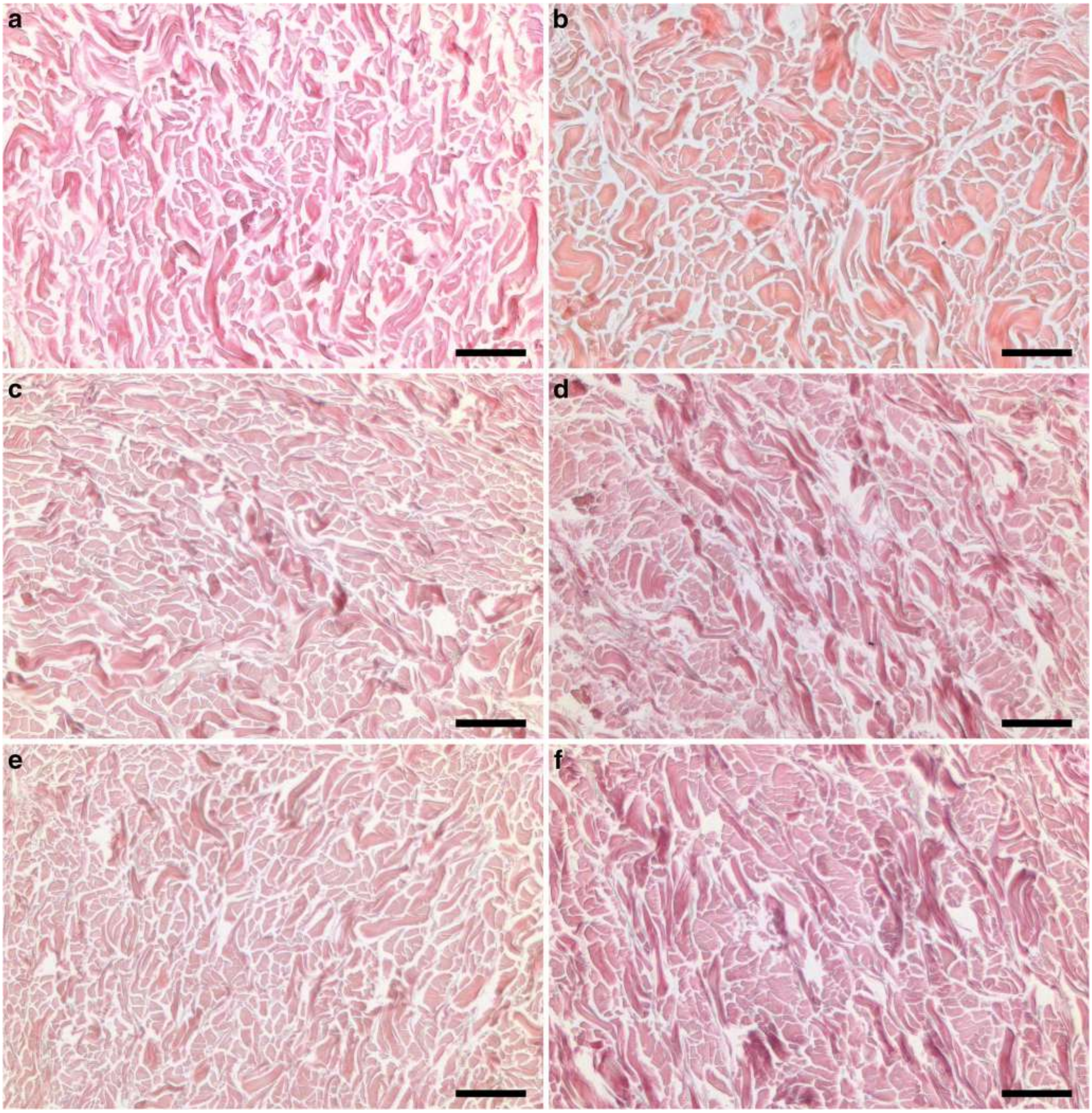

Fig. 1 Collagen fibers: control (**a**, **c**, and **e**) and treated with RF (**b**, **d**, and **f**) (100 μm bar). A reticular dermis with thicker and more organized bundles of collagen fibers can be observed on the treated area (**b**, **d**, and **f**), evidencing collagen remodeling

using the parametric behavior of the data. The differences observed were considered significant when the probability of the null hypothesis rejection was less than 0.05. For this analysis, the SPSS program (version 20) was used.

Results

The final sample consisted of five volunteers, with a mean age of 39.4 ± 10.3 years, mean body mass index of 25.2 ± 3.11 kg/m^2, of which two had skin phototype IV, two phototype V, and one phototype III. No differences were observed in the results related to age and phototype of the volunteers.

Morphological analysis of collagen

Collagen fibers were evaluated by Picro-sirus staining. The comparisons were made in the posttreatment with radiofrequency between the control skin (Fig. 1a, c, and e) and treated one (Fig. 1b, d, and f). Morphologically, in the skin sample of the control group, the extracellular matrix was preserved. The reticular dermis showed, as expected, bundles of delicate fibers arranged in several directions. However, in the histological analysis of the skins treated with RF, the reticular dermis seems to present thicker and more organized bundles of collagen fibers, suggesting a remodeling of the present collagen; no infiltrate of inflammatory cells or tissue lesion was observed (Fig. 1).

Morphometric analysis of collagen

The morphometry for collagen showed no significant difference between the treated side and the control side, with an average percentage of 60.94 ± 0.32 for the control side and 61.97 ± 2.80 for the treated one with p=0.32 (Fig. 2a).

Morphological analysis of elastic fibers

The elastic fibers were evaluated by Verhoff staining. The comparisons were made in the posttreatment with radiofrequency between the control skin (Fig. 3a, c, and e) and treated one (Fig. 3b, d, and f). Histologically, a heterogeneity of the elastic fibers was observed between the controlled and treated skin samples, demonstrating a variation in the increase of these fibers in the analyzed sections. Subtle changes occurred in the radiofrequency-treated skin (Fig. 3).

Morphometric analysis of elastic fibers

As for elastic fibers, no significant difference was observed between the groups, with an average percentage of 5.67 ± 2.70 for the control and 6.21 ± 2.01 for the treated group with p=0.19 (Fig. 2b).

Discussion

Despite several studies have proven the efficacy of radiofrequency in stimulating the synthesis of collagen and elastic fibers of the dermis, in the present study, no statistically relevant morphometric differences were observed between the control side and the treated side; although a morphological difference can be observed between them, by considering this, we can suggest hypotheses for such finding according to the parameters used in the application.

There are differences between radiofrequency equipment regarding the way they work. Some of them are ablative causing dermis lesions for further remodeling, such as fractional radiofrequency and fractionated microneedle radiofrequency; other equipment is non-ablative, that is, they do not cause injury for the remodeling to occur. Still within non-ablative radiofrequencies, we essentially have monopolar and bipolar radiofrequencies, with the use of capacitive or resistive contact electrodes, varying in frequency, in which the higher their frequency is, the more superficial their effects are.

The frequency of RF equipment will determine the depth of treatment, according to the depth equation represented in the study by Belenky et al. [12], in which we have that the depth of penetration of radiofrequency energy in millimeters is inversely proportional to the square root of the frequency. It is then concluded that lower frequencies have higher penetration rates while higher frequencies have lower penetration rates.

Still considering the study by Belenky et al. [12], this fact is proven with the use of an RF device designed to achieve three separate distinct frequencies (0.8 MHz, 1.7 MHz, and 2.45 MHz) and an additional mode that combined the three frequencies in a single pulse, so that it was possible to control the depth of heating according to each treatment objective. The device was used in a study on the skin of domestic pigs and in another study on the skin of healthy women, and for both investigations, the observed heating was deeper with the

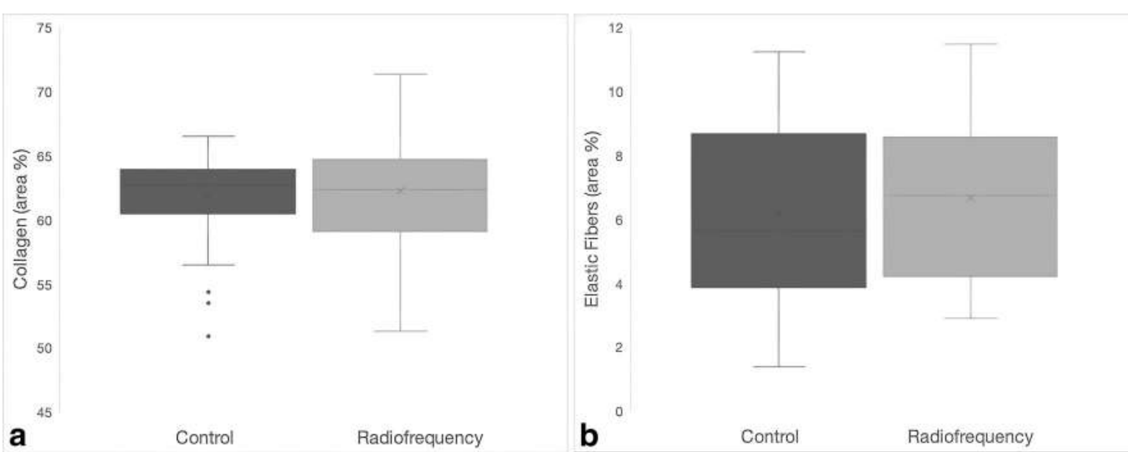

Fig. 2 Morphometry of collagen (**a**) and elastic fibers (**b**), without significant differences between the control area and the treated area, both in collagen fibers and elastic fibers

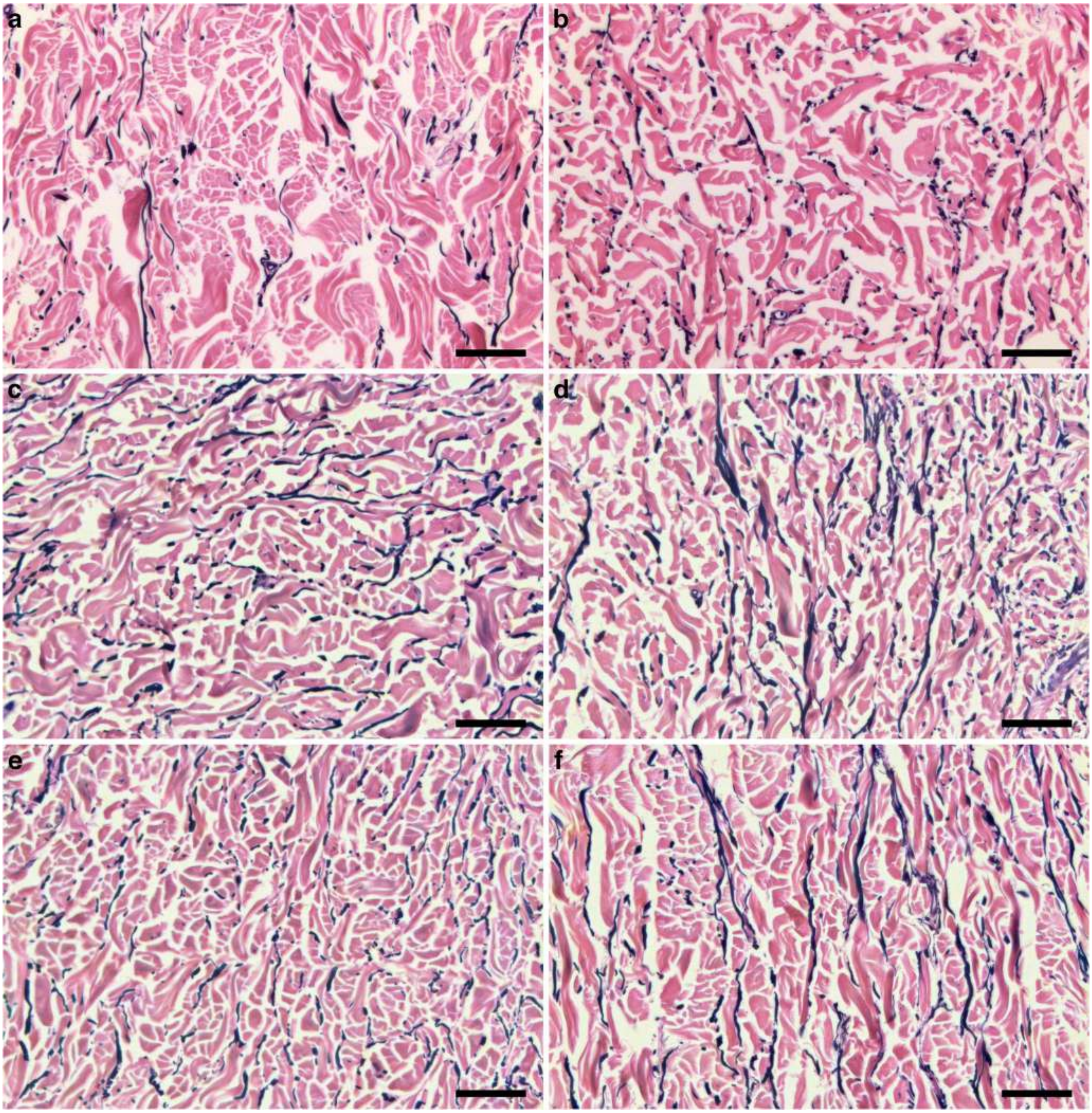

Fig. 3 Elastic fibers: control (**a**, **c**, and **e**) and RF treated (**b**, **d,** and **f**) (100 μm bar); subtle changes can be observed on the RF-treated area

lowest frequency of 0.8 MHz and more superficial with the highest frequency of 2.45 MHz.

In the study by Trelles et al. [13], different frequencies (0.6 MHz and 2.4 MHz) were also applied on the skin of thirty women in order to heat several tissue layers. They also concluded that the higher frequency (2.4 MHz) heated the most superficial tissues and the lower frequency (0.6 MHz) heated deeper tissues. Both studies then show that if the treatment objective is in the dermal layer, higher frequencies should be used, whereas for the subcutaneous layer lower frequencies should be used.

Franco et al. [14] have reported that at relatively low frequencies, energy deposition is more uniform in relation to a larger volume, resulting in uniform heating of large volumes of tissue. Therefore, high frequencies are suitable for the treatment of smaller areas, whereas low frequencies are appropriate for larger areas.

Other authors have also reported that the lower the frequency, the lower the depth of action [15, 16], and this may be one of the hypotheses through which this study has not demonstrated significant effects on the synthesis of collagen and elastic fibers, since the frequency used was 0.52 MHz, that is, with more significant results in deeper tissues.

Another factor that interferes in the RF heating is the type of electrode; Gorgu et al. [16] have observed that the heat generated by the monopolar head was deeper compared to the bipolar and tripolar heads, and this effect has also been observed by Belenky et al. [12] and Beasley and Weiss [17]. In the present study, the monopolar electrode was used; this may have been another factor that led the heating to being deeper as well as the effects on the dermis to being smaller.

According to Belenky et al. [12], the calculation of the evaluated penetration depth of the monopolar RF energy would be half the size of the active electrode: for example, a 10–mm electrode can penetrate at a depth of approximately 5 mm. In the present study, the electrode used measured 50 mm; taking into account this equation, its depth was approximately 25 mm, therefore much deeper than necessary for dermal treatment; this may be another hypothesis which may explain why the findings of this study are less relevant in the dermis.

The RF application mode (capacitive or resistive) also interferes with depth. Kumaran and Watson [18] have demonstrated faster heating and deheating in RF capacitive mode, associating this to its fairly superficial nature of penetration, whereas in the resistive mode, there was greater heat retention and lower decrease in posttreatment temperature, suggesting a greater energy penetration. In the present study, the capacitive mode was used, which according to the authors, although it is more superficial, it presents a faster thermal decrease; this may have interfered in the results of this study, since to trigger the effects of collagen synthesis, high temperatures are necessary [11].

Elman et al. [11] and Pinheiro et al. [19] have observed that, in order for the desired effects on the dermis to occur, it is necessary to reach and maintain a minimum temperature of 40°C in the epidermis during the entire RF application time, and this thermal parameter is used by most authors [13, 16, 18]. Regarding temperature, this was the same one used in this study, so we do not believe that the results are related to temperature, except for the fact that the faster cooling that occurs in capacitive mode may have interfered.

The number of sessions directly interferes with the result. However, in this study, we used a single session due to the reduced sample size and to avoid sample loss due to the volunteers' support. It seems that this is not a relevant factor to the results found in this study, since similar treatment was conducted in another study in which the authors reported increased collagen [19], though this is a difficult parameter to compare with the literature, since a lot of authors do not mention the number of sessions performed.

Considering what has been exposed, it seems that the equipment parameters used in this study have a higher conformity with deep tissues, since studies with higher frequencies, different electrodes, and application modes have showed increased synthesis of collagen and/or elastic fiber [6, 10] compared to studies that have used low frequencies and also demonstrated minimal effect on the dermis [12, 13] corroborating the present study.

As a restriction of this study, we can mention the reduced sample number due to the cosmetic surgery scheduling, which in this case were performed in the teaching hospital, whose priority is emergency surgeries, which restricted the number of abdominoplasties during the study period. Another restriction is the lack of information on the parameters used in previous studies, such as the application time, temperature reached, number of sessions, and power and frequency of the RF apparatus. We know that these data are extremely relevant to evaluate the results obtained, making it difficult to compare the findings of this study with those in the literature.

Conclusion

We conclude that RF with the parameters used in the present study was able to exert effects on the dermis with small histological changes of elastic and collagen fibers, though without morphometric changes. It is likely that the low frequency (0.52 MHz) used in this study will produce better effects on deeper tissues.

Code availability Not applicable.

Author contribution All authors contributed to the study conception and design: Effect of capacitive radiofrequency on the dermis of the abdominal region. Material preparation, data collection, and analysis were performed by Gabriela Laguna Monaretti, Maria Clara Fonseca Costa, Lenaldo Branco Rocha, Mariana Molinar Mauad Cintra, Nanci Mendes Pinheiro, and Adriana Clemente Mendonça. The first draft of the manuscript was written by Marco Túlio Rodrigues da Cunha, Andreia Noites, and Adriana Clemente Mendonça, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability Not applicable.

Declarations

Ethics approval The project was approved by CEP-UFTM, registration number: 3.461.688, and registered on the clinical trial platform, registration number: NCT04182542.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent for publication The authors of this article consent to the publication.

Conflict of interest The authors declare no competing interests.

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