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Effects of therapeutic ultrasound and paraffin with or without vacuum massage on biomechanical properties of grafted skin after burn: a randomized controlled trial

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SUMMARY

OBJECTIVE: This study aimed to compare the effects of therapeutic ultrasound and paraffin with or without vacuum massage on the biomechanical properties of grafted skin after a burn.

METHODS: A total of 44 patients with deep second- and third-degree burns, with a mean age of 35.89 (±11.53) years, who visited the Hospital Burn Unity, were included in the study. The therapeutic interventions were randomly defined by drawing lots, with a crossover design (crossover), and a minimum interval of 7 days (washout) between interventions. Skin biomechanical parameters such as distensibility (R0) and viscoelasticity (R6) were noninvasively evaluated by Cutometer before and after 0, 10, 20, and 30 min of intervention with therapeutic ultrasound and paraffin alone, as well as associated with negative pressure therapy of the skin (vacuum therapy). In this study, all groups showed increased distensibility (R0) in the period immediately after the application of the resources and a progressive reduction in the effects in the consecutive tests. Participants with skin grafts showed a decrease in viscoelasticity (R6) in all groups, except therapeutic paraffin and therapeutic ultrasound and vacuum massage.

CONCLUSION: The biomechanical properties of grafted skin after a burn are altered after therapeutic intervention with ultrasound alone or associated with vacuum massage, such as intervention with paraffin associated with vacuum massage, for both parameters evaluated, skin distensibility (R0) and skin viscoelasticity (R6). However, the same did not occur for the intervention with isolated paraffin. There was no significant difference between the interventions therapeutic ultrasound and therapeutic paraffin.

KEYWORDS: Skin transplantation. Burns. Physical therapy modalities. Ultrasonic therapy.

INTRODUCTION

Therapeutic interventions in the burned individual aim at reducing sequelae and disability, involving an increase in the distensibility of he patient and a consequent increase in functionality[1]. The healing process that occurs post-burn is known to cause a reduction in tissue flexibility. Even in grafted areas, retractions are common in particular regions, resulting in contractures. Although burned skin does not exhibit the same biomechanical characteristics as normal skin, therapeutic approaches may help to minimize these sequelae, improving the quality of life for these patients[2].

The rehabilitation of burned patients involves specific behaviors in both the prevention and recovery of certain movements, using different therapeutic techniques[3,4]. Therapeutic ultrasound (TU) is used in the rehabilitation of scar tissue when there is a high concentration of collagen. There is a thermal effect, promoting an increase in the extensibility of the collagen, increasing the distensibility of the skin and the range of motion of the affected joints[5,6]. This effect is also attributed to the use of therapeutic paraffin (TP), which increases superficial blood flow and the extensibility of collagen fibers, improving tissue mobility[7]. Vacuum massage is a noninvasive mechanical massage technique performed with a device that lifts the skin using suction. This is thought to promote mobilization of the skin, increasing tissue distensibility[8,9]. This technique produces additional stretching of the skin when combined with heating using either ultrasound or paraffin. Therapeutic interventions with ultrasound often precede other therapeutic modalities

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such as kinesiotherapy as well as manual and assisted massage, aiming to increase tissue distensibility first. However, the durability of the effects seen with therapeutic interventions has not yet been established.

The importance of mobilization of the burned patients in the rehabilitation process is known; however, if performed inappropriately, it can produce lesions in the areas affected by the burn, which are naturally rigid, increasing the recovery period. Thus, it is important to know the effects of those therapeutic interventions on tissue distensibility[10,11]. Therefore, the objective of this study was to compare the effects of TU and TP with or without vacuum massage on the biomechanical properties of skin and grafted skin after a burn.

METHODS

Study design and ethical aspects

A randomized controlled trial was conducted at the Burn Unity of the Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo, Brazil. The protocol was approved by the University's Institutional Ethic Committee for the research (13386/2011) and registered in Clinical Trials (NCT02185950). Patients were duly informed about the procedures used in the study and signed the consent form.

Inclusion criteria were patients aged between 18 and 60 years presenting burns in the upper limbs, with at least 3 months of postoperative healing of a skin graft (0.2 mm thick), normal skin site in the contralateral limb, without signs of infection, and with no limitations of upper limb movements. Noninclusion criteria were burn patients aged over 60 years and infection (fever in the last 24 h) and limitation of upper limb movements.

In this study, the Cutometer 580® (Courage-Khazaka electronic GmbH, Cologne, Germany) was used to assess the biomechanical characteristics of the skin, such as distensibility and viscoelasticity. Participants and their skin graft areas were divided into four groups according to the different therapeutic interventions applied: Group 1, TU—therapeutic ultrasound; Group 2, TP—paraffin therapy; Group 3, TUV—therapeutic ultrasound and vacuum massage; and Group 4, TPV—therapeutic paraffin and vacuum massage.

The design of this study of therapeutic interventions was a crossover, and the evaluated areas were submitted to all therapeutic procedures with the application of the resources randomly assigned, with an interval of 7 days (washout) to avoid interference between each intervention. The sample was calculated using the software *Ene*, version 3.0 (Autonomous University of Barcelona, Barcelona, Spain).

Therapeutic methods

Therapeutic interventions with ultrasound (TU) and paraffin (TP) alone or associated with vacuum massage (TUV and TPV) were applied in delimited areas with a size of 9×5 cm, followed by evaluations immediately after the applications and after 10, 20, and 30 min. The TU was applied for 4 min at a frequency of 3 MHz, the intensity of 1 W/cm^2, in continuous mode with the transducer in a circular motion. Paraffin was applied in four layers, heated to 38.5°C in specific equipment (Carci, São Paulo, Brazil), and remaining for 20 min in the place to be evaluated.

For TUV and TPV, the vacuum massage was performed with the Dermotonus Slim® equipment (IBRAMED, Amparo, São Paulo, Brazil), with continuous negative pressure of 250 mmHg and a 1.8-cm diameter glass accessory for 4 min with longitudinal slips.

Biomechanical properties of the skin

The biomechanical properties of the skin were evaluated in areas with skin sheet grafting at least 3 months postoperative in the upper limbs of the patient. The evaluations were carried out in a controlled environment, in the supine position, always in the morning, to avoid chronobiological interference in the skin characteristics[12].

Biomechanical characteristics of the skin were evaluated before the application of the resources in both areas: the area of the scar (grafted) and in the control area (contralateral intact, normal skin) and after 0 (P0), 10 (P10), 20 (P20), and 30 (P30) min after intervention. The evaluation of the biomechanical properties of the skin, such as distensibility and viscoelasticity, was performed with the Cutometer MPA 580® equipment (Courage-Khazaka electronic GmbH, Cologne, Germany), calibrated with a 2-mm diameter probe and a 500 mbar (375 mmHg) vacuum. The probe was attached to the area to be evaluated with 1 s of suction and 1 s of relaxation, in three cycles, configuring three tissue deformation curves. The vertical deformation was evaluated in mm using constant negative suction. The parameters R (relative) are automatically calculated in mm, where R0 corresponds to distensibility and represents the passive behavior of the skin to force, with low values representing greater firmness, and R6 to viscoelasticity.

Statistical analyses

The data for the variables, distensibility and viscoelasticity, were normalized by the Shapiro-Wilk test. The Friedman test was used for intragroup comparisons over time, and the Kruskal-Wallis test followed by the Dunn post-hoc test was used for intergroup comparisons between the different interventions and had a significance level of 5% ($p<0.05$). All processing was performed in the *Statistical Package for Social Sciences (SPSS)*, version 17.0 (Chicago, IL, USA).

RESULTS

A total of 44 burned patients participated in the study, with a predominance of men (59.1%) and a mean age of 35.8 (±11.5) years. We evaluated 140 areas with skin grafts with p<0.05, stimulated with different therapeutic interventions: intervention with ultrasound (UT), intervention with paraffin (PT), intervention with ultrasound and vacuum (TUV), and intervention with paraffin and vacuum (TPV).

Although controversial, factors that may interfere in the assessment of the biomechanical characteristics of the skin, such as color, age, and sex, are pointed out[13-16]. Skin color showed no significant difference for variables R0 (0.31±0.08, 0.30±0.09, and 0.3±0.1, p=0.44) and R6 (0.5±0.08; 0.4±0.1, and 0.4±0.1, p=0.43), considering the control group for black, brown, and white, respectively.

A significant increase in total distensibility was observed in the normal skin of the TU group immediately after application (P0), when compared to the pre-intervention; however, there was a reduction in this variable over time (P30) (Table 1). The TPV treatment group showed a significant difference between pre-intervention and immediately after application (P0) in normal skin, with increased skin distensibility. However, a significant decrease in distensibility was found between P10 and P20 when compared to the data collected at P0 (Table 1). There was a progressive reduction in the values at all times observed for all groups, in the area of the skin graft (P0, P10, P20, and P30). However, this post-intervention reduction was significant only in the TUV treatment group when comparing P30 with that immediately after the intervention (Table 1).

The viscoelasticity of the normal skin for the TU and TP groups showed a significant increase from pre-treatment to shortly after the application of the intervention (P0). Furthermore, a significant increase for the TU treatment group between P20 and P30 compared to P0 was also observed. The TUV and P10 treatment groups had a significant increase (Table 2). For skin graft areas, there was a significant decrease between pre-intervention and P0 in viscoelasticity observed in the TU and TPV groups. Furthermore, in the TUV and TPV groups, a significant increase in viscoelasticity was observed for P30 and P10, respectively (Table 2). In general, it can be observed that for both parameters, skin distensibility (R0) and skin viscoelasticity (R6), both for the normal area and the skin graft area, there was no significant difference between the interventions (Table 3).

DISCUSSION

The rehabilitation of the burned individual is complex and challenging, whose main objective is to promote functionality, which is often compromised due to biomechanical changes in the scar tissue, with consequent movement limitation. The results of this study show the effects produced after the application of the therapeutic intervention with TU and TP on the biomechanical properties of the skin, such as skin distensibility and viscoelasticity.

It is established that the application of TU in a continuous mode increases the tissue temperature, associated with an increase in the distensibility of collagen in scar tissue[5]. This justifies the use of TU to increase tissue distensibility[17]. Previously, the effect of TU has been evaluated on the scars and skin grafts of burn victims, and although the authors did not find a significant increase in distensibility

Table 1. Comparison of tissue distensibility values in control and skin graft area at different times.

Area	Group	Pre	P0	P10	P20	P30
Normal skin	TU (n=39)	0.32 (0.27–0.38)	0.36[a] (0.31–0.45)	0.35 (0.29–0.40)	0.33 (0.30–0.40)	0.31[b] (0.29–0.38)
	TP (n=38)	0.30 (0.25–0.36)	0.31 (0.27–0.37)	0.34 (0.26–0.39)	0.34 (0.28–0.38)	0.32 (0.26–0.38)
	TUV (n=32)	0.35 (0.27–0.42)	0.36 (0.30–0.44)	0.33 (0.30–0.41)	0.34 (0.28–0.40)	0.31[b] (0.26–0.40)
	TPV (n=32)	0.33 (0.25–0.38)	0.35[a] (0.27–0.40)	0.32[b] (0.27–0.37)	0.30[b] (0.26–0.36)	0.32 (0.26–0.37)
Skin graft area	TU (n=39)	0.13 (0.10–0.16)	0.14 (0.10–0.19)	0.13 (0.10–0.18)	0.12 (0.09–0.17)	0.13 (0.09–0.16)
	TP (n=38)	0.11 (0.09–0.16)	0.13 (0.10–0.16)	0.12 (0.10–0.16)	0.11 (0.10–0.14)	0.12 (0.10–0.16)
	TUV (n=32)	0.13 (0.10–0.16)	0.14 (0.09–0.18)	0.11 (0.08–0.16)	0.12 (0.09–0.16)	0.11[b] (0.08–0.15)
	TPV (n=32)	0.11 (0.09–0.16)	0.13 (0.10–0.17)	0.10 (0.08–0.15)	0.10 (0.08–0.15)	0.11 (0.09–0.16)

TU: ultrasound group; TP: paraffin group; TUV: ultrasound and vacuum massage group; TPV: paraffin and vacuum massage group and vacuum. [a]It differs from Pre (p<0.05); [b]It differs from P0 (p<0.05). Tissue distensibility values (R0, in mm), pre-intervention (Pre), immediately (0 min, P0), 10, 20, and 30 min after intervention (P10, P20, and P30). Values presented in median (first quartile-third quartile).

Table 2. Comparison of relative values for viscoelasticity, in control and skin graft area at different times.

Area	Group	Pre	0	10	20	30
Normal skin	TU (n=39)	0.45 (0.40–0.50)	0.36[a] (0.31–0.42)	0.42 (0.37–0.48)	0.44[b] (0.38–0.50)	0.45[b] (0.36–0.50)
	TP (n=38)	0.47 (0.43–0.50)	0.42[a] (0.37–0.47)	0.43 (0.40–0.50)	0.44 (0.39–0.49)	0.46 (0.38–0.53)
	TUV (n=32)	0.43 (0.38–0.48)	0.39 (0.32–0.45)	0.43[b] (0.40–0.51)	0.48[b] (0.41–0.53)	0.50[b] (0.39–0.55)
	TPV (n=32)	0.45 (0.39–0.49)	0.44 (0.36–0.47)	0.46[b] (0.42–0.53)	0.47[ab] (0.43–0.52)	0.47 (0.39–0.54)
Skin graft area	TU (n=39)	0.59 (0.53–0.71)	0.53[a] (0.45–0.64)	0.59 (0.48–0.69)	0.57 (0.51–0.67)	0.63 (0.48–0.72)
	TP (n=38)	0.57 (0.50–0.71)	0.55 (0.50–0.64)	0.55 (0.51–0.63)	0.56 (0.52–0.67)	0.55 (0.49–0.66)
	TUV (n=32)	0.60 (0.50–0.73)	0.50 (0.43–0.59)	0.57 (0.50–0.71)	0.59 (0.49–0.65)	0.67[b] (0.53–0.82)
	TPV (n=32)	0.58 (0.55–0.66)	0.52[a] (0.42–0.59)	0.60[b] (0.51–0.70)	0.60 (0.52–0.71)	0.58 (0.49–0.63)

TU: ultrasound group; TP: paraffin group; TUV: ultrasound and vacuum massage group; TPV: paraffin and vacuum massage group and vacuum. [a]It differs from Pre ($p<0.05$); [b]It differs from P0 ($p<0.05$). Viscoelasticity (R6), pre-intervention (Pre), immediately (0 min, P0), 10, 20, and 30 min after intervention (P10, P20, and P30). Values presented in median (first quartile-third quartile).

Table 3. Comparison of values related to tissue distensibility, control area, and skin graft in the different resources.

Area	Time (min)	TU	TP	TUV	TPV
Normal skin	Pre	0.32 (0.27–0.38)	0.30 (0.25–0.36)	0.35 (0.27–0.42)	0.33 (0.25–0.38)
	0	0.36 (0.31–0.45)	0.31 (0.27–0.37)	0.36 (0.30–0.44)	0.35 (0.27–0.40)
	10	0.35 (0.29–0.40)	0.34 (0.26–0.39)	0.33 (0.30–0.41)	0.32 (0.27–0.37)
	20	0.33 (0.30–0.40)	0.34 (0.28–0.38)	0.34 (0.28–0.40)	0.30 (0.26–0.36)
	30	0.31 (0.29–0.38)	0.32 (0.26–0.38)	0.31 (0.26–0.40)	0.32 (0.26–0.37)
Skin graft area	Pre	0.13 (0.10–0.16)	0.11 (0.09–0.16)	0.13 (0.10–0.16)	0.11 (0.09–0.16)
	0	0.14 (0.10–0.19)	0.13 (0.10–0.16)	0.14 (0.09–0.18)	0.13 (0.10–0.17)
	10	0.13 (0.10–0.18)	0.12 (0.10–0.16)	0.11 (0.08–0.16)	0.10 (0.08–0.15)
	20	0.12 (0.09–0.17)	0.11 (0.10–0.14)	0.12 (0.09–0.16)	0.10 (0.08–0.15)
	30	0.13 (0.09–0.16)	0.12 (0.10–0.16)	0.11 (0.08–0.15)	0.11 (0.09–0.16)

Pre: pre-intervention; 0: immediately after; 10: after 10 min; 20: after 20 min; 30: after 30 min. No significant difference ($p>0.05$) in the comparisons. Tissue distensibility (R0, in mm), TU (ultrasound group); TP (paraffin group); TUV (ultrasound and vacuum massage group); TPV group (paraffin and vacuum massage group). Values presented in median (first quartile-third quartile).

with TU, they found a significant improvement in the active and passive amplitude of the movement[7]. These results can be related to tissue distensibility and therefore support the results of this study.

Despite this, TU is frequently used in therapeutic interventions, the ineffectiveness indicates that the wrong parameters are being used, such as the size of the treated area, duration, intensity, frequency, tissue type, transducer movement, and the "therapeutic window"[5,18].

The literature about the use of paraffin therapy and vacuum massage, including the specific parameters such as temperature, time, or type of application, is scarce[6,19]. It has been found previously that different methods of applying paraffin therapy may influence the depth of heating, having different responses in different pathologies[20,21]. Previously, it has been observed that an increase in the elasticity of a burn scar that was treated with TP could remain for 4 h[18]. In this study, the maintenance of the effect did not remain for 30 min.

The vacuotherapy or vacuum massage applied to the skin leads to mechanical stress on the biological structures that make them up[22]. It is thought that the combination of interventions with vacuum massage can produce an impact on the collagen found in scar tissue and elastic fiber remodeling[23]. However, different from other studies, in this study, with only one application of the intervention, no significant increase was noted for distensibility of both the normal and skin graft for either combination therapy, TUV and TPV[8,9].

Despite no significant difference being seen in this study between normal skin and skin graft after the intervention, it should be considered that the distensibility pre-intervention of the skin graft was on average 0.12 mm, corresponding to an increase of 0.01–0.02 mm post-intervention, which is a 10% increase in the total distensibility. With the mean thickness of 0.20-mm grafts[24] and that in the evaluated period, between 3- and 6-month postoperative, the complete maturation of this scar had not yet occurred[25], a distensibility around 0.12 mm may in fact correspond to more than 50% of the initial thickness of the graft.

All groups evaluated in this study demonstrated a profile of increased distensibility in the period immediately after the application of the intervention, with a progressive reduction in the effects over time, most likely due to the probable "therapeutic window." There was no significant difference found between normal and skin graft, though, with values approximately 50% lower for scar skin. These results highlight the need for a distensibility gain in scar tissue, showing changes in the biomechanics properties of scar tissue in relation to normal skin.

Additionally, the effect of the interventions can increase the elastic properties more than the viscoelastic properties of normal skin, considering it was found that the viscoelasticity diminished immediately after the intervention. The viscoelasticity changes had no durability and did not remain more than 10 min after both TUV and TPV. In the skin graft, the viscoelasticity was observed to decrease in all the groups, except after intervention with TP, which showed practically no change. These data showed that TUV and TPV are more associated with changes in the elastic properties of the skin than the viscoelastic properties of the scar tissue.

In this study, it was observed that intervention with TU presented significant results in both normal and skin graft (between pre-intervention and P0), with a decrease in viscoelasticity. The skin graft areas that received the TP did not show significant differences at any time (P0, P10, P20, and P30). However, 30 min after the application of TUV to the skin graft, a return to the pre-intervention state was seen, which is characteristic of the elastic property of the tissue. It could be hypothesized that the nonsignificant changes in the distensibility and the viscoelasticity of the skin graft studied may be due to the intervention being carried out on a tissue type that already has greater rigidity.

The nonuniform behavior of the responses found in this study may be due to the anisotropic and nonlinear responses of the skin in terms of its biomechanical characteristics. The skin under stretching stress exhibits a nonlinear behavior[26]. The skin is complacent and large deformations can occur with a relatively low applied load. This is because a large portion of the fibers is not aligned, and the stiffness of the skin gradually increases as the fibers line up in the direction of the applied load.

CONCLUSION

Therapeutic intervention with ultrasound or paraffin alone or associated with vacuum massage alters the biomechanical properties of distensibility and viscoelasticity of the grafted skin after burns.

AUTHORS' CONTRIBUTIONS

ACG: Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **RRJG:** Methodology, Software, Writing – original draft, Writing – review & editing. **LAR:** Methodology, Resources, Writing – review & editing. **JAFJ:** Methodology, Writing – review & editing. **CSC:** Visualization, Writing – original draft. **APF:** Visualization, Writing – original draft, Writing – review & editing. **ECOG:** Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

REFERENCES

1. Roshangar L, Soleimani Rad J, Kheirjou R, Reza Ranjkesh M, Ferdowsi Khosroshahi A. Skin burns: review of molecular mechanisms and therapeutic approaches. Wounds. 2019;31(12):308-15. PMID: 31730513
2. Goel A, Shrivastava P. Post-burn scars and scar contractures. Indian J Plast Surg. 2010;43(suppl):S63-71. https://doi.org/10.4103/0970-0358.70724
3. de Jesus Guirro RR, Oliveira Lima Leite Vaz MM, das Neves LMS, Dibai-Filho AV, Carrara HHA, de Oliveira Guirro EC. Accuracy and reliability of infrared thermography in assessment of the breasts of women affected by cancer. J Med Syst. 2017;41(5):87. https://doi.org/10.1007/s10916-017-0730-7
4. Anthonissen M, Daly D, Janssens T, Van den Kerckhove E. The effects of conservative treatments on burn scars: a systematic review. Burns. 2016;42(3):508-18. https://doi.org/10.1016/j.burns.2015.12.006
5. Ward RS, Hayes-Lundy C, Reddy R, Brockway C, Mills P, Saffle JR. Evaluation of topical therapeutic ultrasound to improve response to physical therapy and lessen scar contracture after burn injury. J Burn Care Rehabil. 1994;15(1):74-9. https://doi.org/10.1097/00004630-199401000-00014

6. Draper DO. Ultrasound and joint mobilizations for achieving normal wrist range of motion after injury or surgery: a case series. J Athl Train. 2010;45(5):486-91. https://doi.org/10.4085/1062-6050-45.5.486
7. Riaz HM, Ashraf Cheema S. Paraffin wax bath therapy versus therapeutic ultrasound in management of post burn contractures of small joints of hand. Int J Burns Trauma. 2021;11(3):245-50. PMID: 34336391
8. Moortgat P, Anthonissen M, Meirte J, Van Daele U, Maertens K. The physical and physiological effects of vacuum massage on the different skin layers: a current status of the literature. Burns Trauma. 2016;4:34. https://doi.org/10.1186/s41038-016-0053-9
9. Meirte J, Moortgat P, Anthonissen M, Maertens K, Lafaire C, De Cuyper L, et al. Short-term effects of vacuum massage on epidermal and dermal thickness and density in burn scars: an experimental study. Burns Trauma. 2016;4:27. https://doi.org/10.1186/s41038-016-0052-x
10. Brancalion Catapani L, da Costa Gonçalves A, Morano Candeloro N, Rossi LA, Caldeira de Oliveira Guirro E. Influence of therapeutic ultrasound on the biomechanical characteristics of the skin. J Ther Ultrasound. 2016;4:21. https://doi.org/10.1186/s40349-016-0065-8
11. Turner SM, Powell ES, Ng CS. The effect of ultrasound on the healing of repaired cockerel tendon: is collagen cross-linkage a factor? J Hand Surg. 1989;14(4):428-33. https://doi.org/10.1016/0266-7681(89)90161-7
12. Tsukahara K, Takema Y, Moriwaki S, Fujimura T, Imokawa G. Dermal fluid translocation is an important determinant of the diurnal variation in human skin thickness. Br J Dermatol 2001;145(4):590-6. https://doi.org/10.1046/j.1365-2133.2001.04430.x
13. Ryu HS, Joo YH, Kim SO, Park KC, Youn SW. Influence of age and regional differences on skin elasticity as measured by the cutometer. Skin Res Technol. 2008;14(3):354-8. https://doi.org/10.1111/j.1600-0846.2008.00302.x
14. Inforzato HCB, Carbonel AAF, Simões RS, Sasso GRDS, Lima PDA, Soares-Júnior JM, et al. Histomorphometric analysis of the skin of women during the reproductive period. Clinics (Sao Paulo). 2018;73:e387. https://doi.org/10.6061/clinics/2018/e387
15. Naik PP, Farrukh SN. Influence of ethnicities and skin color variations in different populations: a review. Skin Pharmacol Physiol. 2022;35(2):65-76. https://doi.org/10.1159/000518826
16. Baker KG, Robertson VJ, Duck FA. A review of therapeutic ultrasound: biophysical effects. Phys Ther. 2001;81(7):1351-8. PMID: 11444998
17. Rawlings AV. Ethnic skin types: are there differences in skin structure and function? Int J Cosmet Sci. 2006;28(2):79-93. https://doi.org/10.1111/j.1467-2494.2006.00302.x
18. Draper D, Mallipudi RM. Therapeutic ultrasound: myths and truths for non-portable in-clinic and portable home use ultrasound. MOJ Sports Med. 2020;4(4):115-6. PMID: 33442669
19. Mir-Bonafé JF, Serra-Baldrich E, Rozas-Muñoz E, Puig L. Paraffin wax baths for the treatment of chronic hand eczema. Actas Dermosifiliogr. 2017;108(3):261-4. https://doi.org/10.1016/j.ad.2016.09.019
20. Santacreu ES, Cabezas NV, Graupera AB. Combined treatment with paraffin, manual therapy, pegboard and splinting in a patient with post-traumatic stiff hand. Arch Physiother. 2016;6:14. https://doi.org/10.1186/s40945-016-0028-y
21. Ordahan B, Karahan AY. Efficacy of paraffin wax bath for carpal tunnel syndrome: a randomized comparative study. Int J Biometeorol. 2017;61(12):2175-81. https://doi.org/10.1007/s00484-017-1422-1
22. Holavanahalli RK, Helm PA, Kowalske KJ, Hynan LS. Effectiveness of paraffin and sustained stretch in treatment of shoulder contractures following a burn injury. Arch Phys Med Rehabil. 2019;101(1S):S42-9. https://doi.org/10.1016/j.apmr.2019.08.482
23. Nicoletti G, Perugini P, Bellino S, Capra P, Malovini A, Jaber O, et al. Scar remodeling with the association of monopolar capacitive radiofrequency, electric stimulation, and negative pressure. Photomed Laser Surg. 2017;35(5):246-58. https://doi.org/10.1089/pho.2016.4180
24. Gomes RC, Guirro ECO, Gonçalves AC, Farina Junior JA, Murta Junior LO, Guirro RRJ. High-voltage electric stimulation of the donor site of skin grafts accelerates the healing process: a randomized blinded clinical trial. Burns. 2018;44(3):636-45. https://doi.org/10.1016/j.burns.2017.10.006
25. Gould DJ, Reece GP. Skin graft vascular maturation and remodeling: a multifractal approach to morphological quantification. Microcirculation. 2012;19(7):652-63. https://doi.org/10.1111/j.1549-8719.2012.00200.x
26. Joodaki H, Panzer MB. Skin mechanical properties and modeling: a review. Proc Inst Mech Eng H. 2018;232(4):323-43. https://doi.org/10.1177/0954411918759801