Lasers Med Sci (2018) 33:461–467
https://doi.org/10.1007/s10103-017-2351-2

ORIGINAL ARTICLE

Efficacy of long pulse Nd:YAG laser versus fractional Er:YAG laser in the treatment of hand wrinkles

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Received: 6 August 2017 / Accepted: 1 October 2017 / Published online: 8 October 2017

Abstract There are different modalities for hand rejuvenation. Fractional Er:YAG laser and long pulse Nd:YAG laser were introduced for treating hand wrinkles. We plan to compare fractional Er:YAG laser and long pulse Nd:YAG laser in a randomized controlled double-blind design with multiple sessions and larger sample size in comparison with previous studies. Thirty-three participants with hand wrinkles entered this study. They were randomly allocated to undergo three monthly laser treatments on each hand, one with a fractional Er:YAG laser and the other with a long pulse Nd:YAG laser. The evaluations included assessment of clinical improvement determined by two independent dermatologists not enrolled in the treatment along with measuring skin biomechanical property of hands using a sensitive biometrologic device with the assessment of cutaneous resonance running time (CRRT). Moreover, potential side effects and patients' satisfaction have been documented at baseline, 1 month after each treatment, and 3 months after the final treatment session. Clinical evaluation revealed both modalities significantly reduce hand wrinkles (p value < 0.05), with no significant difference between two lasers. Mean CRRT values also decreased significantly after the laser treatment compared to those of the baseline in both laser groups. There was no serious persistent side effect after both laser treatments. Both fractional Er:YAG and long pulse Nd:YAG lasers show substantial clinical improvement of hand skin wrinkles with no serious side effects. However, combination treatment by these lasers along with the other modalities such as fat transfer could lead to better outcomes in hand rejuvenation. Trial registration: IRCT2016032020468N4

Keywords Erbium:YAG laser · Hand rejuvenation · ND:YAG laser · Skin aging

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Introduction

Hand rejuvenation is intended to restoring soft tissue volume, decreasing skin laxity, and reversing extrinsic aging [1]. For the appearance of the hand, the dorsum is the most frequently viewed non-clothed body part. In patients who have had facial rejuvenation treatments, an inconsistency between a youthful face and aged hands often becomes relevant and proves a patient's true age [2]. Common findings in the aged hand include atrophy with prominent bones, tendons, and inter-metacarpal spaces as well as large, visible veins and rhytides, solar lentigines, actinic keratosis, and seborrheic keratosis [3]. Hand rejuvenation can be achieved using a variety of techniques, including ablative dermabrasion, chemical peels, and ablative laser resurfacing, intense pulsed light, radiofrequency, and photodynamic therapy, autologous fat transfer, hyaluronic acid, calcium hydroxylapatite, and poly-L-lactic acid injections [2–4].

Laser technology is widely used for cosmetic surgery. Tissue ablation and thermal coagulation of the dermis stimulate dermal remodeling. The effect of laser resurfacing is more powerful with the ablative fractional laser than with non-ablative laser devices, although there has been growing demand for the short downtime and minimal side effects associated with ablative lasers, which has incited development of non-ablative lasers. When handling non-facial locations, there is a greater risk of a lengthy recovery period, infection, dyschromia, and scarring because of the small number of pilosebaceous structures and lesser vascular supply in those areas. With the introduction of fractional photothermolysis, we could reach significant clinical results with promising side effect profile and shorter down time. Fractional ablative lasers like fractional CO_2 and Er:YAG lasers can be used safely on the hands, create columns of vaporized tissue, and coagulation necrosis. Healing begins quickly from the adjacent untreated tissue, dermal fibroblasts, and adnexal structures [2, 5].

Non-ablative laser devices exert their effects by inducing dermal collagen production while sparing the epidermis. One type of non-ablative lasers used for photo rejuvenation is the 1064-nm neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. The long pulse Nd:YAG laser has also been developed in the past decades. Long pulse duration is considered safer than short-pulse duration and cause less adverse effects including dyspigmentation or purpura. Long pulse Nd:YAG lasers have been commonly used in photo-rejuvenation, and some investigations have also shown its considerable effect on collagen remodeling [6, 7].

We found no evidence of the comparative assessment of efficacy and safety of these laser modalities on the hand rejuvenation. Therefore, we planned this study to compare fractional Er:YAG and long pulse Nd:YAG lasers in terms of their effect on the hand rejuvenation, side effect profile, and patient satisfaction.

Materials and methods

Study design

We performed a randomized controlled double-blind trial. The present study was conducted on 33 volunteers presenting to our office for hand rejuvenation between November 2015 and May 2016. The subjects were between 43 and 69 years of age. This study was approved by the Ethical Committee of Shahid Beheshti University of Medical Sciences and was performed according to the principles of the Declaration of Helsinki. All of the subjects signed a written informed consent after explanation of the procedure. The protocol was approved by the Iranian Registry of Clinical Trials (IRCT ID2016032020468N4). We have no conflict of interest to declare. This study was funded by Skin Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Patients with any active skin disease within the treatment area (e.g., cancer, autoimmune disease, or active infection), pregnancy, history of isotretinoin use in the year before laser treatment, coagulation disorders or anticoagulant treatment, history of keloid scarring, known allergy to topical lidocaine anesthetic, history of photosensitizing medications, or any cosmetic procedure in areas of treatment in the last 12 months were excluded from the study.

Technical data

The Er:YAG 2940-nm laser used in this study has a fractional handpiece (LotusII; Laseroptek Co., Ltd., Sungnam, Gyenggido, Korea). We used short pulse (350 μs) mode with a spot size of 7 mm, the fluence of 3.12 J/cm^2, pulse energy of 1–1.2 J, and repetition rate of 3–5 Hz. We also used the long pulse Nd:YAG 1064-nm laser (Hyperion; Laseroptek Co., Ltd., Sungnam, Gyenggido, Korea) along with cryogen cooling with a spot size of 7 mm, pulse duration of 5 ms and fluence of 10–20 J/cm^2 to reach an obvious erythema following the laser procedure.

Treatment protocol

The treatment area was thoroughly cleansed before the procedure with a gentle skin cleanser.

Lidocaine/prilocaine cream was applied to the dorsal hand at least 30 min before the treatment. After wiping off this cream with gauze, acetone was used to completely wipe it off. The patients were advised to keep their eyes closed, and the eyes were covered with moist gauze held in place by an assistant during the entire procedure. On the basis of a randomization table that was generated by an external statistician not otherwise involved in the study, each hand has undergone a different laser resurfacing treatment. Zinc oxide ointment was applied to the treatment areas immediately after the procedure. Participants were instructed to gently cleanse their hand with normal saline and to reapply zinc oxide ointment as needed.

Participants were assigned to receive three monthly treatments for each hand, one with a long pulse Nd:YAG laser and the other with a fractional Er:YAG laser. Photographs were taken with a Canon digital camera (Power Shot S110 with 12.1 megapixels high-sensitivity CMOS sensor; Canon, Inc., Japan) at baseline, before each treatment session, and 3 months after the final treatment. Two board-certified dermatologists were asked to score the clinical outcome regarding the improvement of wrinkles, skin texture, and clinical appearance in a blinded fashion. The wrinkle improvement was calculated with the use of the visual analog scale (VAS). The degree of clinical improvement was defined as the percentage of improvement: no response (less than 10%), mild response (10–25%), moderate response (25–50%), good response (50–75%), and excellent response (more than 75%). Outcomes were evaluated by investigators at each session and 3 months after the third treatment.

Patients were asked to specify their level of satisfaction to the statements in the questionnaire by marking a position along a continuous black line between two endpoints measuring 10 cm, which served as a visual analog scale (VAS). Patients were asked to come for the checkup 1 week after the first treatment session, and all undesired effects of the procedures such as pain, erythema, edema, hypopigmentation, or hyperpigmentation were recorded. We also asked the patient to declare the laser system that they have experienced more discomfort with.

Skin biomechanical properties

We used Multi-Probe Adaptor (MPA 9; Courage & Khazaka Electronic GmbH, Köln, Germany) System to assess skin biomechanical properties. MPA-9 has several handpieces to assess various skin biophysical properties such as stratum corneum hydration, skin erythema, trans-epidermal water loss (TEWL), and cutaneous resonance running time (CRRT). We have only measured cutaneous resonance running time (CRRT) with a Reviscometer® RVM 600 handpiece that allows for the evaluation of the biomechanical properties of the skin by measuring the propagation time of a shear wave between two sensors placed on the skin surface; one is transmitting an acoustical shockwave and the other is the receiver. The time the wave needs to propagate from transmitter to recipient is the measured parameter that is defined as cutaneous resonance running time (CRRT). It determines the mechanical properties of the skin and the direction of collagen and elastic fibers. The CRRT is expressed in arbitrary units (AU). CRRT is mainly influenced by collagen fibers in the papillary layers of the dermis and correlates negatively with skin stiffness. Directional changes of CRRTs in the specific diseases or after skin procedures have been reported in some studies, which could reflect the dermal biomechanical property at various conditions [8].Two sensors are applied to the skin surface in supine position. The mean CRRT over the four axes (0°, 180°, 90°, and 270°) was calculated for the hands. These measurements were conducted at room temperature 24–26 °C with a relative humidity of 50 ± 3%. These measurements were recorded for each patient at baseline, before each treatment session, and 3 months after the final treatment.

Statistical analysis

All data were analyzed using the Statistical Package for Social Sciences (SPSS) program (version 20.0 f or Windows). Comparison of outcome variables between any two-time points was done by Wilcoxon signed-rank test and Mann-Whitney *U* test. The trend of measures for the grade of wrinkles as an ordinal variable was investigated using Friedman' test statistic. The significance level was set at $p < 0.05$. Descriptive statistics were also calculated (mean, standard deviation, median, minimum, maximum, numbers, and percentage rate).

Table 1 Mean improvement, patient satisfaction, and CRRT measurements at each follow-up visit

	Baseline		*p* value	1 month after first treatment		*p* value	1 month after second treatment		*p* value	3 months after third treatment		*p* value
	Nd:YAG	Er:YAG		Nd:YAG	Er:YAG		Nd:YAG	Er:YAG		Nd:YAG	Er:YAG	
Mean clinical improvement (%)				16.97 ± 4.79	16.52 ± 4.05	0.71	24.69 ± 5.42	25.30 ± 5.29	0.67	31.02 ± 5.01	31.38 ± 5.96	0.83
Mean patient satisfaction (%)				35.60 ± 24.45%	36.36 ± 23.75%	0.86	49.64 ± 24.07%	49.64 ± 23.76%	0.84	56.50 ± 24.39%	55.75 ± 20.14%	0.79
Mean CRRT (AU)	238.09 ± 324.92	211.96 ± 244.61	0.82	156.25 ± 142.13	141.94 ± 82.35	0.83	147.27 ± 129.28	154.81 ± 144.14	0.72	121.43 ± 72.27	137.30 ± 99.06	0.65

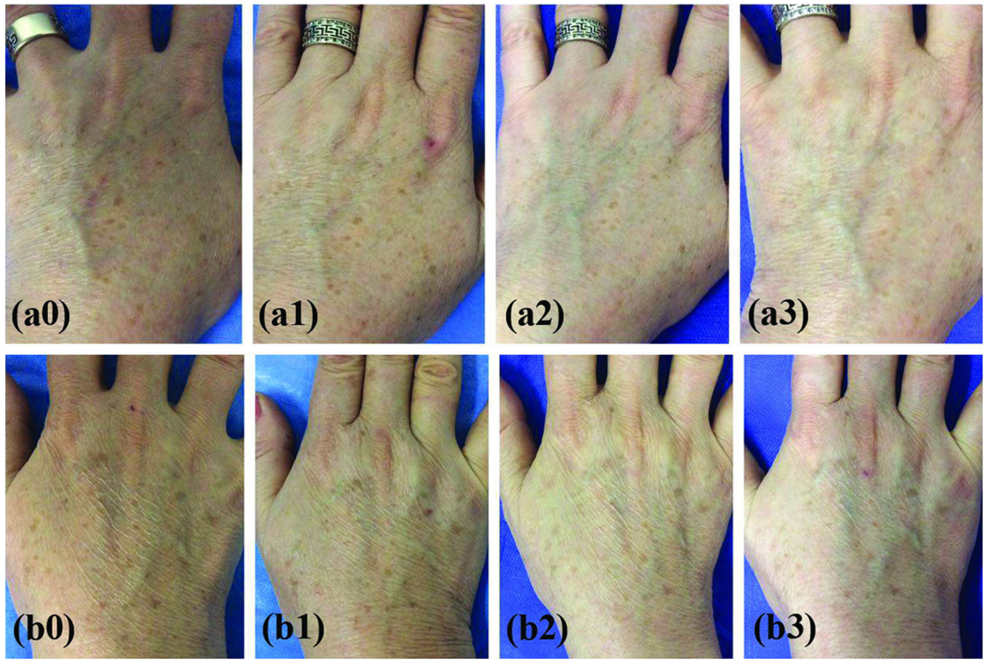

Fig. 1 Moderate improvement of hand skin wrinkle and appearance after laser in a 60-year-old woman, left hand [(**a**) long pulse Nd:YAG], right hand [(**b**) fractional erbium:YAG laser]. 0 before treatment, 1 1 month after first treatment, 2 1 month after second treatment, and 3 3 months after final treatment

Results

The mean age of the participants was 54.94 (+ 6.48) years. Standardized images of the hands taken at baseline and at each follow-up visits were evaluated. Among 33 female volunteers, 27 subjects completed the study, while 6 participants did not come for the last follow-up visit. Mean wrinkle improvement for fractional Er:YAG laser 1 month after the first treatment, 1 month after the second treatment, and 3 months after the final treatment was 16.52 ± 4.05, 25.30 ± 5.29, and 31.38 ± 5.96%, respectively, with significant improvement in comparison with the baseline condition (p value < 0.001). Mean wrinkle improvement for long pulse Nd:YAG laser 1 month after the first treatment, 1 month after the second treatment, and 3 months after the final treatment was 16.97 ± 4.79, 24.69 ± 5.42, and 31.02 ± 5.01%, respectively, with significant improvement in comparison with the baseline condition (p value < 0.001) (Table 1; Figs. 1 and 2).There was no significant difference in efficacy between two lasers 1 month after the first treatment, 1 month after the second treatment, and 3 months after the final treatment (p value > 0.05) (Fig. 3). Three months after the final treatment, 22 (81.5%) of the subjects treated with long pulse

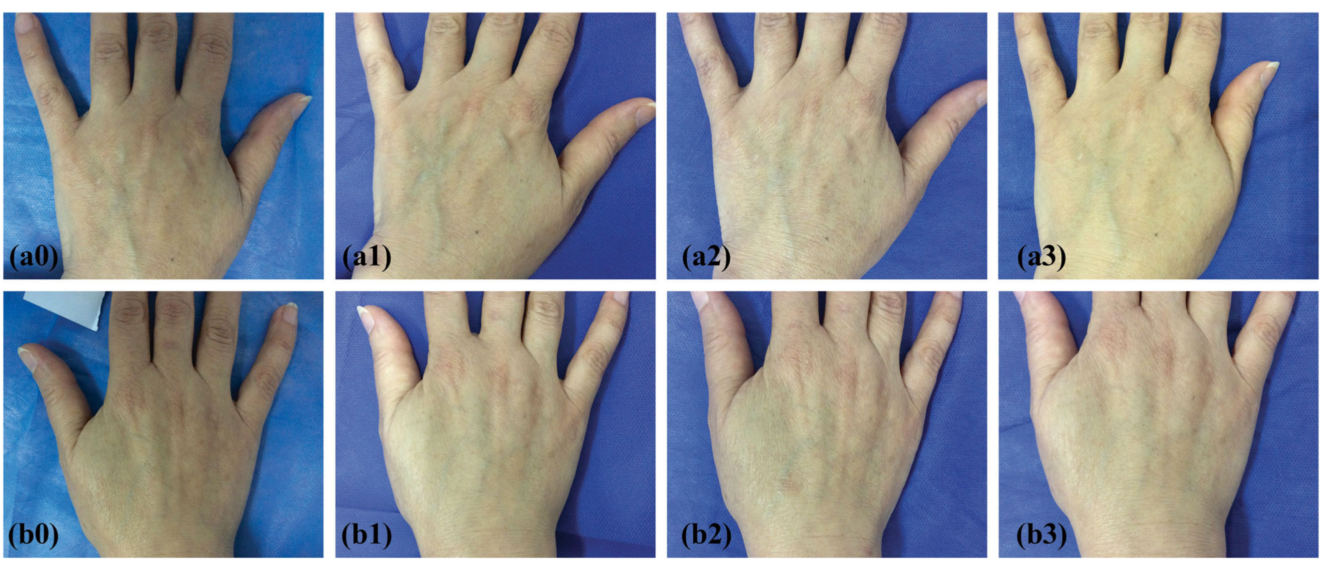

Fig. 2 Moderate improvement of hand skin wrinkle and appearance after laser in a 48-year-old woman, left hand [(**a**) long pulse Nd:YAG], right hand [(**b**) fractional erbium:YAG laser]. 0 before treatment, 1 1 month after first treatment, 2 1 month after second treatment, and 3 3 months after final treatment

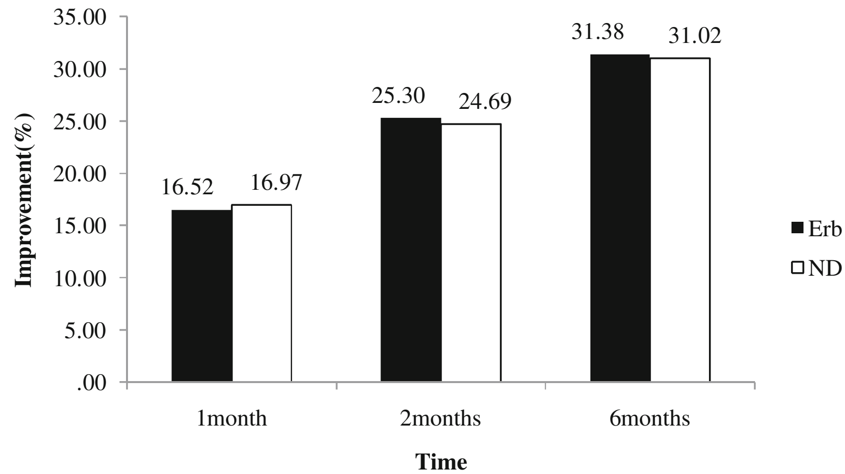

Fig. 3 Mean wrinkle improvement by lasers at each follow-up visit

Nd:YAG laser and 20 (74.1%) participants treated with fractional Er:YAG laser showed a moderate response (Table 2).The patients showed considerable satisfaction with both laser methods with no statistically significant difference ($p > 0.05$) (Table 1).

Skin biomechanical properties

The mean CRRT at the baseline, before each treatment session, and 3 months after the final treatment is shown in Table 1. It showed a significant decrease of mean CRRT at each visit in comparison with the baseline measurements in both laser systems. Mean CRRT showed a significant decrease in both the long pulse Nd:YAG-treated site ($p = 0.000$) and fractional Er:YAG-treated site ($p = 0.005$) 3 months after the final treatment (Fig. 4). However, there was no significant difference in CRRT measurements between two lasers (Table 1).

Side effects

No serious or persistent complications, such as prolonged erythema, pain, dyspigmentation, and scarring developed in the participants with both lasers. Some subjects mentioned discomfort during the procedure especially with long pulse Nd:YAG laser due to the pain during laser performance but it resolved during some minutes after laser.

Discussion

Regardless of great improvements in facial rejuvenation over the past 10 years, considerable progression in hand rejuvenation has remained a relative challenge [2].The skin of the hand is thin and has fewer pilosebaceous units. Thus, there is a greater risk of a prolonged recovery period, possibility of infection, dyschromia, and scarring after treatment settings that in the facial skin would normally be accepted [3].Non-ablative resurfacing usually has shorter downtime and a lower risk of adverse effects [9, 10].However, there are limited studies that compare different laser systems such as fractional Co_2, fractional Er:YAG, and long pulse Nd:YAG lasers in skin rejuvenation [11–13]. Moreover, few studies have specifically investigated the use of these lasers for the treatment of photoaging of the hands [2].In this study, we performed a randomized controlled double-blinded trial comparing the efficacy and safety of long pulse Nd:YAG laser versus fractional Er:YAG laser in the treatment of hand wrinkles on 33 volunteers in three treatment sessions. Previous data on their efficacy and safety in hand rejuvenation were mostly few and almost not comparative [10, 14–16].

Oktem et al. conducted a comparative trial of Nd:YAG laser and Nd:YAG laser-intense-pulsed light (IPL) in photo-rejuvenations of the skin of the hand. IPL-Nd:YAG laser combination treatment surpasses Nd:YAG laser treatment in

Table 2 Degree of wrinkle improvement compared to baseline

	One month after first treatment Number of participants (%)		One month after second treatment Number of participants (%)		Three months after third treatment Number of participants (%)	
	Nd:YAG	Er:YAG	Nd:YAG	Er:YAG	Nd:YAG	Er:YAG
No response	5 (15.2%)	4 (12.1%)	–	–	–	–
Mild response	27 (81.8%)	27 (81.8%)	21 (63.6%)	21 (63.6%)	5 (18.5%)	7 (25.9%)
Moderate response	1 (3%)	2 (6.1%)	12 (36.4%)	12 (36.4%)	22 (81.5%)	20 (74.1%)
Good response or greater	–	–	–	–	–	–

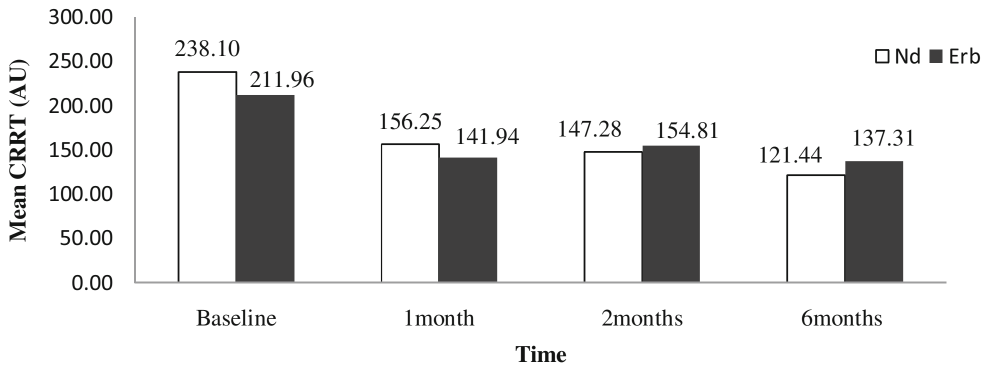

Fig. 4 Mean CRRT at each follow-up visit

improvement scores of pigment distribution, fine wrinkles, sallowness, and pigment tone parameters, which was statistically significant ($p < 0.001$) [14]. Sadick et al. showed the 1320-nm Nd:YAG laser with cryogen cooling can be effective for rejuvenation of photoaged hands with mild to moderate improvement [15]. Maruyama showed IPL could be an effective choice for hand rejuvenation by using appropriate parameters with specific cutoff filters and dark-toned and flat senile lentigines could be treated effectively with a small number of treatments, but it declared preliminary by the author [16].

Our study showed significant improvement of skin wrinkles with no considerable difference between long pulse Nd:YAG laser versus fractional Er:YAG laser in the improvement of skin wrinkles in an experimental setting with randomized, blind allocation of treatment sites in a split-design and an additive objective assessment of skin biomechanical property. Both laser systems caused no serious long-standing side effects and seem to be well-tolerated by the participants, but the discomfort was somewhat more pronounced after long pulse Nd:YAG laser. However, the clinical outcome can be changed based on the parameters used for each laser. In this study, we only compare the outcome using the provided laser parameters and the results might be different if alternative parameters are used for each laser. Moreover, recent studies suggest that combination therapy including non-ablative and fractional lasers, chemical peeling, cryotherapy, fat transfer, and sclerotherapy could be more beneficial to improve different aspects of hand rejuvenation such as restoring the volume of the hands, vein removal, and dermal rejuvenation [17, 18].

Measurement of cutaneous resonance running time (CRRT) is a non-invasive method to evaluate skin biophysical property. CRRT, which is generally influenced by collagen fibers in the papillary layers of the dermis, associates adversely with skin stiffness. It seems that CRRTs vary with age, body sites, and gender [19]. Some systemic diseases like diabetes or keratoconus could also affect CRRT values [8, 20]. It seems that these discrepancies of CRRT values could give us some evidence to evaluate skin biomechanical property more accurately. Therefore, we used CRRT assessment as an additive measure beside the clinical evaluation of laser efficacy. In our study, mean CRRT values declined meaningfully after treatment in both laser groups. These changes in CRRT values could suggest some variations of skin stiffness and elasticity, but outlining a precise association between these factors is relatively challenging [8, 12]. Nevertheless, the alterations of CRRT after laser treatment could give use some additive objective clues for better assessment of laser efficacy in this study. Therefore, our study seems to be distinctive in the literature as a prospective, randomized study used skin biomechanical evaluation along with clinical assessment to compare the efficacy of long pulse Nd:YAG laser and fractional Er:YAG laser on hand rejuvenation.

In conclusion, we find in our study that both long pulse Nd:YAG laser and fractional Er:YAG laser seem to be effective and safe in hand rejuvenation. Therefore, we suggest both laser systems for hand rejuvenation. But hand rejuvenation might need different treatment modalities such as lasers, chemical peeling, and fat transfer to improve the different aspects of hand aging including dyspigmentation, wrinkles, and volume loss. The long pulse Nd:YAG and fractional Er:YAG lasers seem to improve the hand wrinkle and skin tightness. However, future studies with larger sample size, different rejuvenation procedures, and histopathology evaluation of neocollagenesis after these treatments would be more beneficial to elucidate any possible difference in the efficacy of long pulse Nd:YAG laser, fractional Er:YAG laser, and other rejuvenation procedures in skin resurfacing of the hands.

Role of funding source This study has been funded by Skin Research Center, Shahid Beheshti University of Medical Sciences with grant number of 94/141.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Ethical approval This study was approved by the Ethical Committee of Shahid Beheshti University of Medical Sciences with number of *Ir.sbmu.ram.rec.1394.414.* This project was performed according to the principles of the Declaration of Helsinki. The protocol was approved by the Iranian Registry of Clinical Trials (IRCT ID2016032020468N4).

Informed consent All of the subjects signed a written informed consent after explanation of the procedure.

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