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Comparative study of Cavitation and Extracorporeal Shock Wave Therapy

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Abstract
Nowadays, a person's body image is an important issue that affects cognitive function, and mental and physical health. Today, people seek to improve their body contours and reduce body fat through non-invasive, safe, painless, and comfortable solutions. These conditions have led to the rapid development of non-invasive devices that use the technology of ultrasound and help to immediately and effectively improve body image. In this article, two technologies are based on ultrasound. The first is cavitation, and the second is shock wave ultrasound that will be presented, their characteristics will be developed and they will be compared in terms of their effectiveness and their advantages among the currently available research data.

KEYWORDS
ultrasound, Cavitation, Extracorporeal Shock Wave Therapy, lipolysis

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1. INTRODUCTION

Improving body contour is an important medical and aesthetic need worldwide. People's desire for the aesthetic improvement of their bodies has brought about the rapid development of innovative and non-invasive devices. The majority of humans wish to avoid surgery, the long recovery time, and possible complications and therefore seek non-invasive, comfortable, safe, and immediate solutions [1,2,3]. The improvement of body texture and contour, as well as the reduction of fat is achieved today through modern non-invasive methods, such as cavitation and shock wave ultrasound.

Empirical evidence reveals that a high Body Mass Index (BMI) is an important factor in the development of negative body image. Overweight and obese people tend to have negative feelings

towards their bodies. The association between BMI and negative body image is higher in women compared to men [4]. It has been documented that a high BMI also adversely affects a person's self-esteem, which has an indirect impact on the relationship between stress and body dysphoria and the relationship between negative self-image [5]. As such, weight and accumulated fat in areas of the body are key factors for a more positive attitude towards cosmetic surgery [6]. Obese people's desire to improve body contours has allowed the creation of additional surgical procedures such as liposuction that aim to remove excess fatty tissue in specific areas of the body. This procedure has produced satisfactory results, but liposuction is a surgical procedure and has limitations and possible complications, even mortality. Complications such as changes in sensation, edema, nerve compression, skin necrosis, burns, anesthetic toxicity, fluid imbalance, scarring, and contour irregularities have been documented, and the cost is often prohibitive [7]. Consequently, people are now looking for alternative methods to effectively reduce localized areas of fat deposition without surgery.

In addition to fatty tissue, the majority of women are unhappy with problems such as cellulite, which is a huge challenge for aesthetics and cosmetology. Cellulite is defined as a localized metabolic disorder of the subcutaneous tissue that changes the local shape of the body (orange peel) and is a huge challenge for an aesthetic treatment, as its treatment is long-term and expensive, while its definitive effectiveness is doubtful. Cellulite formation accelerates during adolescence, pregnancy, or menopause and it has been estimated that it can affect up to 85% of women over the age of 20 [8]. Cellulite is a complex problem involving the microcirculatory system and lymphatics, the extracellular matrix, and the presence of excess subcutaneous fat that bulges into the dermis. The range of professional (surgical or non-surgical) approaches to cellulite treatment is extremely wide and varies from non-invasive techniques including cosmetic products, oral regimens, nutritional supplements, and manual or mechanical massage to invasive surgical practices, such as liposuction [9].

Cavitation, as a non-invasive solution for treating adipose tissue, is an innovative technology that uses ultrasound to avoid surgery [10]. Its application is external and aims to reduce fatty tissue in the targeted areas. Compared to liposuction, it provides important benefits such as reducing the risk of complications, no need for recovery immediate return to daily activities, and absence of pain [11].

Shock wave ultrasound devices, as a non-invasive solution for the treatment of cellulite, are a sequence of mechanical pulses characterized by high peak pressure (100 MPa), fast rise (<10ns), and short lifetime (10ms). Shock waves are mechanical pulses characterized by extremely high amplitude with short rise time, followed by large negative waves of low magnitude. High-energy shockwaves were developed to treat lithotripsy, and later, low-energy shockwave therapy is beneficial for many medical conditions, including orthopedic diseases [12].

2. CAVITATION

Cavitation is an ultrasound device, which seems particularly effective in re-reducing adipose tissue and improving body shape compared to invasive liposuction. In parallel, the non-invasive procedure of Cavitation devices is more economical, safer, and has a lower risk of side effects compared to liposuction [13]. Previous clinical studies have documented that cavitation ultrasound is a safe, reliable, effective, and predictable way to sculpt the body [14]. A cavitation de- vice emits 20-70 kHz ultrasound energy at a specific depth in a converging manner and focuses on a certain point to produce unlimited fat bubbling. These bubbles are compressed to break the bonds between the fat cells and destroy their membranes to form "cavitation" (holes in the fat layer) and then drain them through the lymphatic vessels to be excreted from the body.

The ultrasound emission is applied externally and transmitted through the skin to the subcutaneous fat for absorption, a process that has been documented to significantly reduce the circumference of areas treated with ultrasound. The use of cavitation devices is an ideal non-invasive procedure to deliver energy to subcutaneous fat that can reduce the perioperative morbidity of surgery, such as anesthesia, infection, and scarring [11]. The action mechanism of the cavitation devices is based on the creation of cycles of compression and decompression at the appropriate frequency, which allows the creation of the phenomenon of cavitation at the interface of the fat cytoplasm and finally the rupture of the fat cells and the release of triglycerides. Waves of ultrasound energy can be focused or unfocused. Through the use of unfocused waves, the superficial skin is exposed to the maximum energy intensity due to the attenuation of ultrasound in depth. On the other hand, the use of focused waves allows concentration on a defined subcutaneous area to produce clinically relevant fat lysis while limiting damage to blood ves-

sels, nerves, connective tissue, and underlying organs [15].

Cavitation involves the use of circular sound with a frequency greater than the upper limit of human hearing. Ultrasound fat cavitation (USFC) is a method for the treatment of localized fat that achieves the disruption of fat cells and the reshaping of a specific part of the body. Low-frequency ultrasound devices deliver ultrasound energy through the skin resulting in mechanical disruption of fat cells [16]. The USFC machine is considered effective in reducing the risk of obesity complications, carries fewer risks, and is more cost-effective compared to invasive ultrasound liposuction [17].

Also, cavitation is effective in both reducing adipose tissue and improving cellulite. It achieves the improvement of the shape and contour of the body and the reduction of the girth. Studies have found that the use of ultrasound cavitation is effective as a non-invasive treatment of unwanted fat in a specific part of the body and as an adjunctive treatment in fat reduction [18,16,19]. Although it is a low-risk procedure, some mild and temporary side effects may occur, such as redness or bruising, thirst, skin sensitivity, skin abnormalities, and headaches [15].

3. EXTRACORPOREAL SHOCK WAVE THERAPY (ESWT)

Shock wave therapy (ESWT) has been more extensively documented compared to cavitation. The delivery of an electromagnetically induced radial shock wave during ESWT treatment is effective in cellulite tissues. The treatment does not deliver electromagnetic energy but a series of very short pulses of osmotic energy. The process aims to temporarily alter the permeability of the fat cell membranes, enhance blood supply, and accelerate the removal of debris by macrophages [20]. Non-randomized clinical data suggest that shock wave therapy (ESWT) is beneficial in improving skin elasticity and revitalizing the dermis in cellulite [21, 22].

Knobloch & Kraemer [23] evaluated the published evidence on the effect of ESWT on cellulite based on a systematic meta-analysis. The authors suggested that ESWT could improve the results of other non-invasive modalities through its beneficial effects on blood supply and alterations in adipocyte membrane permeability. In addition, they found that it is also beneficial in removing abdominal fat adjunctively, although abdominal fat does not have the same anatomical characteristics as cellulite. According to the data, the mechanism of action is based on the disruption of the components of the fat or its sep- ta, or both, which can lead to the smoothing of the affected skin, improving cellulite. The energy of the ESWT may have weakened the fibrous septa and thus, smoothed the affected skin. According to their meta-analysis, both focal and radial ESWT devices are effective in the treatment of cellulite. In published clinical trials, one or two sessions per week and 6-8 sessions in total were applied, over a total follow-up period of between three and six months.

A prospective cohort study by Bae & Kim [24] evaluated the effect of four sessions of ESWT (0.056e0.068 mJ/mm2, 2000 impulses, Dornier AB2) within 2 weeks in cases suffering from secondary lymphedema. Both circumference and skinfold thickness of the affected area were significantly reduced by 37% with a reduction in pain on the visual analog scale. The study by Cho et al [25] examined the effect of shock waves on adipocyte differentiation and found that low-energy shock waves suppressed adipocyte differentiation by downregulating PPARγ and C/EBPα in 3T3L-1 and primary human preadipocytes. Adatto et al [26] performed a randomized trial with 6 sessions of radial ESWT Storz D-Actor 200 with 2.6e3.6 bar at 15 Hz and 3,000 pulses with a 10x15 cm rectangular head on a single leg six times twice weekly. Follow-up was at 12 weeks, and the difference between treated and untreated legs was statistically significant in terms of roughness and elasticity after the first follow-up visit.

In the double-blind, randomized controlled trial by Knobloch et al [27] the intervention group received 6 sessions of focused ESWT (Storz Duolith, 2,000 impulses, 0.35 mJ/mm2, weekly) on both gluteal and thigh areas plus specific glute strengthening exercises with 3-15 repetitions per day. The control group received six sessions of SHAM-ESWT (0.01 mJ/mm2, 2,000 impulses) plus specific gluteal strengthening exercises. The findings showed on the CSS Cellulite Severity Scale that the intervention group was 10.9 ± 3.8 before focused ESWT and 8.3 ± 4.1 after 12 weeks. Russe-Wilfingseder et al [28] conducted a placebo-controlled, double-blind, randomized clinical trial to evaluate the treatment of cellulite. Volunteers were treated once a week for 7 weeks for a total of 8 treatments with the radial ESWT Storz D-ACTOR(®) 200. The overall result at two follow-up visits indicated a greater and statistically significant than medium-sized superiority (MW ¼ 0.6706). The study by Schlaudraff et al [29] enrolled 14 women with cellulite in a randomized, open-label Phase II study using a radial ESWT device. All participants were treated with radial shock waves using the Swiss Dolor-Clast (®) device with

intrasubject control. Participants were treated unilaterally with only 2 weekly treatments for 4 weeks on a randomly selected side (left or right) and a total of 8 treatments on the selected side. Cellulite grade improved after the last treatment and at follow-up.

Nassar et al [30] performed a randomized controlled trial using combined radial and focal ESWT. Focused ESWT was performed with a Storz SC1 device with energy flux densities of 0.56e1.24 mJ/mm2 and 1,500 pulses per arm. This was followed by radial ESWT on the same leg with 2.6e5 bar, 16 Hz, and 3,000 pulses in 8 sessions twice a week. Follow-up was done 12 weeks later. A reduction in both thighs circumferent and subcutaneous fat, measured via ultrasound, was observed.

Angehrn et al [20] performed a cohort study of 21 women who underwent low-energy defocused ESWT using an ActiVitor Derma de- vice at 0.018 mJ/mm^2, 40,000 shots for 12 twice-weekly sessions.

Findings showed that defocused ESWT induced collagen remodeling within the dermis of the treated area using high-resolution ultrasound, which correlated with collagen remodeling. Christ et al [21] conducted a cohort study of 59 women who underwent 6 or 8 sessions of twice-weekly ESWT. The findings showed that skin elasticity values gradually increased during ESWT treatment and an increase of 73% was revealed at the end of treatment. At the 3- and 6-month follow-up, skin elasticity was improved by 95% and 105%, respectively.

4. CONCLUSION

Nowadays, there is a shift in the preference of women and men towards non-invasive aesthetic devices, which are bloodless, cheaper, have a low risk of side effects, and do not require downtime recovery. These devices (like cavitation and shockwave) primarily target the physical properties of fat that differentiate it from the overlying epidermis and dermis, resulting in the selective destruction of fat. Devices using high-frequency ultrasound have the potential to improve body contouring, minimize adverse effects, and shorten post-operative recovery time.

This study presented the currently available research data regarding the effectiveness of both Ultrasound Cavitation and Shock Wave Ultrasound devices. Research data on Cavitation devices is limited compared to the studies that have been carried out on research protocols with Shock Wave devices.

Cavitation is one of the most recent non-invasive techniques that have been used to induce selective fat breakdown. Through thermal destruction, the cavitation effect, or the creation of a temporary pore in the cell membrane of the fat cells, the result is a reduction in the number of fat cells, which leads to a measurable reduction in fat [31]. Shock Wave Ultrasound is increasingly chosen to treat localized fat, epidermal laxity, and cellulite that may be present on the arms, abdomen, thighs, knees, and calves. Regarding the available research studies, the international literature is more extensive in the case of Shock Wave devices compared to Cavitation devices. The studies included in this article demonstrate the effectiveness of both technologies. Each of the studied devices works with a specific mechanism of action, which is based on the body's biological mechanisms. The side effects, as studied, are neither significant nor permanent.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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