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Title: Effects of mechanical stimulation on mastectomy scars within 2 months of surgery: a single-center, single-blinded, randomized controlled trial

ABSTRACT

Background: One common complication after mastectomy is thickened scars at the surgical site that impair shoulder function. This study aimed to investigate the effects of mechanical stimulation on scar appearance, arm function, and quality of life of breast cancer survivors after mastectomy.

Methods: This was a single-center, single-blinded (assessor), randomized controlled trial with a 3-month follow-up. Women who had undergone mastectomy in the preceding 6 weeks for breast cancer were randomly allocated to an experimental group and a control group by permuted block randomization (block size=6). The experimental group received conventional treatment (mobilization and strengthening exercises) and mechanical stimulation applied to the mastectomy scar twice a week for 6 weeks (12 sessions). The control group received 12 sessions of conventional treatment only. Primary outcome measures included the Vancouver Scar scale (VSS) to assess scar quality. The secondary outcomes were spectrophotometry, the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire; shoulder range of motion; the Numeric Pain Rating scale; hand grip strength; and Functional Assessment of Chronic Illness Therapy–Breast Cancer (FACT-B).

Results: One hundred and eight participants were equally randomized to 2 groups. All follow-up assessments were completed in September 2018. Intention-to-treat analysis revealed a significant group × time interaction on the VSS ($\eta^2 = 0.161$, $p < 0.001$), DASH ($\eta^2 = 0.060$, $p = 0.003$), and FACT-B functional well-being scores ($\eta^2 = 0.033$, $p = 0.034$), indicating that the experimental group (n=54) showed greater improvement in these outcomes than the control group (n=54). Post-hoc analysis showed that the improvements in the VSS and DASH scores remained apparent at the 3-month follow-up. Other outcomes did not yield significant group × time interaction. No adverse effects were reported.

Conclusion: The addition of mechanical stimulation to a conventional intervention program improved scar appearance, arm function, and functional well-being compared with conventional intervention alone.

Keywords: mechanical stimulation, mastectomy scars, upper limb function, quality of life

Trial registration: www.clinicaltrials.gov (reference number: NCT02702050).

Funding: The Hong Kong Polytechnic University PhD studentship

Abbreviations

ANOVA	Analysis of variance
DASH	Disabilities of the Arm, Shoulder and Hand questionnaire
FACT-B	Functional Assessment of Chronic Illness Therapy–Breast Cancer
ICC	Intraclass correlation coefficient
MDC	Minimal Detectable Change
NPRS	Numeric Pain Rating Scale
QoL	Quality of life
ROM	Range of motion
VSS	Vancouver Scar scale

INTRODUCTION

Breast cancer is the most common cancer among women [1]. Mastectomy is a common treatment for breast cancer. Scarring, as an intrinsic process of wound healing, is reported to be one of the most common complications following mastectomy [2]. Thickened mastectomy scars and soft tissue adhesions can cause pain [3], loss of function [3, 4], compromised quality of life (QoL) [4, 5],loss of shoulder range of motion (ROM) [3-5] and other psycho-social problems [5]. Given the undesirable consequences of thickened mastectomy scars, there is a need to identify effective scar management strategies.

Previous studies have found mechanical massage (e.g., effleurage, petrissage, friction, lengthening and rolling, 10-30 min/session, 2 sessions per week, 3 weeks-3 months) has a positive effect on surgical scars or radiation-induced fibrosis, [6, 7] probably because mechanical stimulation (horizontal and vertical pressure) on elastin fibers could assist skin tone restoring by enhancing the production of elastic fibers and collagens. [8, 9] Mechanical stimulation (tension, compression and osmotic) could also prevent scar over-formation by relieving the tension around wounds. [10, 11]

The treatment of post-mastectomy scars is an under-studied area. Conventional post-mastectomy physiotherapy focuses primarily on active and active-assisted upper limb exercises [3, 4, 12]. A review examining morbidity after breast cancer treatment [13] suggested that adherent scars post-mastectomy can be treated with transverse maneuvers [14] as well as circular friction maneuvers and rotational kneading procedures [13]. The positive effect of using a hand-held device that transferred pressure and shear forces to scar tissue on shoulder mobility and perception of disability post-mastectomy was

demonstrated in a retrospective, single-group study only [3]. Given the adverse influence of post-mastectomy scars on cosmetic, functional, and psychological outcomes [3, 5] and a lack of robust evidence for interventions, more research is needed to determine effective mastectomy scar management [15].

A randomized controlled study was undertaken to investigate the efficacy of mechanical stimulation in (i) alleviating scar appearance (pigmentation, vascularity, pliability, and thickness), (ii) improving arm function (reduction in pain and improvement in ROM, strength, and functional ability), and (iii) enhancing QoL of women who have undergone mastectomy for breast cancer. Mechanical stimulation delivered via an electrical device was studied because this method is not labor-intensive and produces consistent and replicable massage maneuvers [7]. It was hypothesized that when compared with conventional physiotherapy alone, a combination of mechanical stimulation and conventional physiotherapy intervention for scar management in post-mastectomy women would result in better outcomes in terms of scar appearance (i.e., pigmentation, vascularity, pliability, and thickness), arm impairment and function (i.e., shoulder pain, ROM, muscle strength, and functional ability), and QoL.

METHODS

Study Design

This study was a single-center, single-blind, randomized controlled study. The study is reported according to the CONSORT checklist for non-pharmaceutical intervention studies.

Ethical considerations

The study protocol was reviewed and approved by the Hospital Authority Kowloon Central Cluster Research Ethics Committee (reference no. KC/KE-15-0186/FR-3) and the Institutional Review Board of the Hong Kong Polytechnic University (reference no. HSEARS20150326001-02). The study was also registered at www.clinicaltrials.gov (reference number: NCT02702050). Written informed consent was obtained from potential participants before their enrollment.

Participants

A convenience sampling method was used. The participants were recruited from women attending the physiotherapy breast care clinic at a local hospital between March 2016 and April 2018. The inclusion criteria were: (1) women over 18 years of age who (2) had undergone mastectomy in the preceding 6 weeks and (3) were able to attend physiotherapy treatment follow-ups. The exclusion criteria were: (1) altered mental state, (2) unable to provide informed consent, (3) presenting with signs and symptoms of mastectomy scar infection or inflammation, (4) unhealed mastectomy wounds, (5) history of lymphedema, (6) bilateral breast cancer, (7) unstable medical or cardiovascular conditions, (8) pre-existing arm impairments or dysfunctions that would affect the testing or exercising of the affected arm, (9) undergoing radiotherapy during the study period, (10) known sensitivity to mechanical stimulation, (11) skin cancer on the treatment area or unclear margins of the cancer, (12) cancer with known metastasis to other areas, and (13) human immunodeficiency virus positive status.

Sample Size Estimation

An a priori power analysis was performed using the statistics software G*Power 3.1.92 for Windows (Heinrich-Heine-Universität Düsseldorf, Kiel, Germany) [16]. We took the reference values from studies that examined the effects of massage therapy on scar tissue in other patient populations [17, 18]. The standardized effect size (Hedge's g) for these studies was -0.4 for pigmentation, -1.4 for pliability, and -1.9 for thickness [17, 18]. Therefore, a more conservative approach was adopted by using the smallest effect size (Cohen's d = 0.4; equivalent to F = 0.2 for ANOVA). With an alpha of 0.017 (to adjust for multiple comparisons) and a power of 0.9, a total of 70 participants would be required. Assuming a 20% attrition rate, the minimum sample size needed would be 90 (45 in each group).

Randomization

After the physiotherapist in the breast care clinic had performed the initial screening and obtained consent from women 3-4 weeks after surgery, group allocation was done by an independent research assistant who had not been involved in the recruitment process. The participants were randomly allocated to either the experimental (mechanical stimulation + conventional physiotherapy) group or the control (conventional physiotherapy only) group by permuted block randomization, with a block size of 6 and an allocation ratio of 1:1, using sequentially numbered opaque sealed envelopes.

Intervention

Participants in both groups received an educational booklet before the commencement of the

program. The educational booklet provided information about the breast cancer rehabilitation program, strategies to prevent shoulder morbidities, skin care, scar massages and home exercises. It was specified in the pamphlet that participants should perform the home exercises 3 times per day. The physiotherapists who provided the intervention also reinforced the importance of home exercises to participants in both the experimental and control groups at each intervention session.

At 6 weeks post-mastectomy, the experimental and control groups received their respective intervention twice weekly for 6 consecutive weeks (i.e., total of 12 sessions). This treatment frequency and duration were chosen because, according to 2 previous studies that investigated the treatment effect of mechano-stimulation on scars, a positive treatment effect was found after an average of 9 to 14 biweekly treatment sessions [3, 8].

In each treatment session, both groups of participants underwent a comprehensive exercise program. Each session included 20 minutes of shoulder mobilization exercises (pendulum, wall climbing, and reciprocal pulley exercises) and 20 minutes of arm and grip strengthening exercises using a dumbbell and an arm ergometer. The exercises were supervised by 1 of the 2 experienced physiotherapists who had worked in the breast care clinic for more than 3 years to ensure that the delivery of exercise intervention was standardized. Five minutes of general stretching exercises were performed before and after the training program (a total of 10 minutes) as warm-up and cool-down exercises, respectively.

Participants in the experimental group received additional mechanical stimulation treatment immediately after each exercise session described above. To ensure consistency of the treatment

delivered, the mechanical stimulation treatment was administered by a third physiotherapist who had more than 20 years of experience in managing patients with breast cancer (approximately 200 breast cancer cases per year) and had undergone a one-week training course run by the manufacturer on the theory and practical use of the mechanical stimulator (LPG Cellu M6 Integral, Valence, France). A pre-set protocol installed on the mechanical stimulator for scar management was selected. This protocol included maneuvers of sequential grasp (2 minutes), bouncing and opposition (6 minutes), and stretching (2 minutes), in accordance with previous reports [6, 8]. The suction force was adjusted according to each participant's tolerance.

For quality assurance purposes, the physiotherapy department of the hospital underwent an internal audit to ensure adherence of care providers to the protocol.

Outcome Measurements

All the outcome measurements were performed by 3 physiotherapists who had 4 to 10 years of work experience at the breast care clinic. To ensure that these practitioners were blinded to group allocation, none of them were involved in delivering the intervention. All participants were evaluated at baseline (T1, 6 weeks post-mastectomy), immediately after the 6-week intervention (T2, 3 months post-mastectomy), and 3 months after the end of the intervention period (T3, 6 months post-mastectomy).

Relevant demographic and clinical data (age, height, weight, past medical history, diagnosis, characteristics of the mastectomy, and adjunct therapy) were collected from medical records. The use of compression therapy, silicone gel sheets, and other scar treatments was documented as reported by

the participants.

Primary outcome

The Vancouver Scar Scale (VSS), the primary outcome, was administered to assess overall scar quality. The VSS is a common tool for scar assessment [19] and includes assessments of the thickness, pliability, pigmentation, and vascularity of a scar. The former 2 items are rated on ordinal scales, while the latter 2 are presented in a descriptive manner. The VSS score ranges from 0 (normal scar) to 13 (most severe scar). The VSS has been shown to have excellent inter-rater reliability in a burn scar population (intraclass correlation coefficient [ICC] = 0.81) [19]. When used post-mastectomy, it also has acceptable internal consistency, with a Cronbach's alpha of 0.79. The inter-observer's ratings showed strong correlations (Spearman's correlation coefficients=0.66, $p < 0.001$); and the association of ratings for pliability (Spearman's $\rho = 0.37$, $p = 0.004$) and color of scars (Spearman's $\rho = 0.42$, $p = 0.001$) between tester and patient were found to be moderate [20]. In a study of hypertrophic scars, a strong and statistically significant correlation was found between pigmentation and vascularity scores on the VSS and two color measurements by spectrophotometer: lightness (Spearman's $\rho = -0.83$ to -0.80, $p < 0.01$) and redness (Spearman's $\rho = 0.72$ to 0.75, $p < 0.01$) [21].

Secondary Outcomes

Spectrophotometry: A spectrophotometer (MiniScan EZ 45/0 SAV; HunterLAB, Reston, Virginia, USA) was used to objectively measure scar color [21]. In a spectrophotometry measurement, the level

of redness indicates vascularization, and pigmentation represents the amount of melanin deposited in a scar [22]. Before each measurement, the spectrophotometer was checked and calibrated according to the standardized instructions provided by the manufacturer. All of the assessments took place in the same room with the same amount of lighting. With the participant in the supine position, the spectrophotometer was placed onto the midline of the scar while the spectrophotometry data were registered. The test-retest reliability was demonstrated to be moderate to high (ICC = 0.95–0.99) [21, 23]. The pigmentation of a scar and the skin were reported in terms of lightness (L), redness (a), and yellowness (b). These measurements are consistent with the international expression of the Commission Internationale de l'Eclairage (CIE) [24], which is considered to be the most accurate scar color evaluation standard [25, 26].

The Numeric Pain Rating Scale (NPRS) is valid, reliable, and appropriate for use in a clinical setting with good test-retest reliability (ICC = 0.67-0.83) [27, 28]. Using this scale, pain is rated from 0 (no pain) to 10 (the worst pain possible). The minimal clinically important difference using this scale is 1.1 points [28]. The participants were asked to describe their level of pain in the breast region from 0 to 10.

Active shoulder flexion and abduction ROM on the operated side were evaluated as follows. The participants were asked to maintain an upright standing position and perform an active shoulder flexion on the operated side. The maximum ROM attained was measured with a universal plastic goniometer [29, 30]. The participants were then asked to perform an active shoulder abduction movement [13, 29, 30] in the same standing position, and the goniometer reading was recorded [29,

30]. Excellent intra-rater reliability (ICC = 0.96–0.97, standard error of measurement (SEM) = 2.5°-2.9°, minimal detectable difference (MDC) = 7°-8°) and inter-rater reliability (ICC = 0.88–0.93) for shoulder flexion goniometric measurement has been established for individuals with unilateral shoulder pathology [31].

Hand grip strength was evaluated using the JAMAR Hydraulic Hand Dynamometer (JAMAR 5030J1; Patterson Medical Limited, Warrenville, Illinois, USA) [4, 29] according to the standard procedures recommended by the American Society of Hand Therapists [32]. The participants were instructed to perform 3 trials of the hand grip strength test. Mean strength, measured in kilogram-force (kgf), from these trials was recorded for analysis. The SEM and MDC are 1.51-1.98 (kgf) and 4.18 to 5.47(kgf) respectively in individuals with primary osteoarthritis of the hand [33].

The Chinese version of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was used to evaluate upper extremity disabilities and symptoms. The DASH is a self-administered questionnaire that can be completed in under 15 minutes [34]. The participants were asked to consider the week before the questionnaire was administered and rate the degree of difficulty and severity of pain when performing various activities on a 5-point Likert scale. The total DASH score ranges from 0 (no disability) to 100 (most severe disability). The test-retest reliability (ICC = 0.77) and internal consistency (Cronbach's alpha = 0.94) for the 30-item Disability/Symptom scale are good [34]. The associations of the DASH scores with unilateral grip strength (r = -0.43–0.44, p < 0.01) and the physical functioning score from SF-36 (r = -0.43, p < 0.01) were found to be moderate [35]. The minimal clinically important change in the DASH score is 12.4 points [36].

The fourth version of the Functional Assessment of Chronic Illness Therapy–Breast Cancer (FACT-B), a traditional Chinese questionnaire, was used to measure quality of life in women with breast cancer [37, 38]. This tool includes the FACT-G (physical, social/family, emotional, and functional well-being) instrument and a breast cancer sub-scale. In this study, the questionnaire was self-administered by the participants. The total FACT-B score ranges between 0 and 144 points, reflecting the lowest to highest health-related quality of life [39]. The test-retest reliability (ICC = 0.88) and internal consistency (Cronbach's alpha = 0.87–0.91) of the Chinese version of FACT-B are high [39]. The minimal clinically important difference in the FACT-B score is 7–8 points [40].

Prior to actual data collection, the intra-rater reliability of the physiotherapist responsible for assessing a given outcome was established. The tests were performed on 5 women on 2 consecutive days. Reliability was good, with ICC values ranging from 0.70 to 0.95 (Supplementary file: 1).

Attendance and Safety

Attendance at the treatment sessions was recorded by the physiotherapist who delivered the interventions. The same physiotherapist also monitored the participants' responses during each treatment session. Any adverse events were noted.

Data Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) 24.0 for Windows (IBM Corp., Armonk, NY, USA). The baseline characteristics of the 2 groups were

compared using independent samples t tests, Mann-Whitney U tests, or chi-square tests, depending on the kind of data. A two-way repeated-measures analysis of variance (ANOVA) (mixed design; within-subject factor: time [3 levels]; between-subject factor: group [2 levels]) was used to compare the outcome measures between the 2 groups across time. Post-hoc tests were used for group comparisons if significant results were found by the ANOVA. Effect size was indicated by the eta-squared value (η^2). Eta-squared values of 0.01, 0.06, and 0.14 were considered to represent small, medium, and large effect sizes, respectively [41]. The level of significance (alpha) was set at 0.05, except for the post-hoc analysis, in which the alpha was adjusted according to the number of comparisons made (Bonferroni's correction). Spearman's ρ was used to analyze the correlation between improvement in quality of life and other functional outcomes, and the outcomes that showed a significant treatment effect (i.e., a significant time × group interaction). An intention-to-treat analysis was conducted, with the missing data replaced using the last-observation-carried-forward method. This was followed by per-protocol analysis.

RESULTS

A total of 183 women who had undergone mastectomy for breast cancer were screened between March 2016 and April 2018 at the breast care clinic. Of these, 75 women were excluded for various reasons. In total, 108 individuals who fulfilled the inclusion criteria were enrolled in the study (Figure 1). Fifty-four individuals were randomly allocated to the experimental (conventional physiotherapy + mechanical stimulation) group and another 54 to the conventional physiotherapy group at 3-4 weeks after surgery. The intervention protocols for the 2 groups during the implementation stage were the

same as those described in the Methods section. All follow-up outcome assessments were completed in September 2018.

The overall drop-out rate was 13.9% (experimental group = 7, control group = 8), which was lower than the estimated attrition rate in our original sample size calculation (20%). No adverse effects relating to the experimental or control treatments were reported during the treatment or the follow-up periods.

The demographic characteristics of the participants are shown in Table 1. No significant differences were found between the groups in terms of demographic characteristics or in terms of any of the primary or secondary outcome variables at baseline (Table 2).

Scar characteristics

Photographs of 2 representative participants from each treatment group are shown in Figure 2. At 6 months post-mastectomy, the appearance of the scars in the experimental group was pinker and suppler than that in the control group.

A statistically significant group × time interaction effect was identified for the VSS total ($F = 20.41$, $\eta^2 = 0.161$, $p < 0.001$), vascularity ($F = 6.32$, $\eta^2 = 0.056$, $p = 0.002$), pigmentation ($F = 6.40$, $\eta^2 = 0.057$, $p = 0.003$), and pliability ($F = 13.60$, $\eta^2 = 0.114$, $p < 0.001$) scores. As shown in Table 3, post-hoc analysis showed that the reduction in the VSS total, vascularity, pigmentation, and pliability scores in the experimental group was significantly greater ($p < 0.017$) than that in the control group immediately after the treatment period (T2) and at the 3-month follow-up (T3).

The group × time interaction effect for the VSS height scores was marginal ($p = 0.062$), indicating a trend towards a better improvement after the experimental treatment compared with the control

treatment (Table 2). As shown in Table 2, no significant group × time interaction or time effects were found for the measurements of skin lightness, redness, and yellowness (spectrophotometry).

Physical Function and Quality of Life

A significant time effect ($p < 0.05$) was found for all the secondary outcomes except the FACT-B social well-being score. However, the group × time interaction effect was only significant for the DASH ($F = 6.82$, $\eta^2 = 0.060$, $p = 0.003$) and FACT-B functional well-being scores ($F = 3.65$, $\eta^2 = 0.033$, $p = 0.034$), indicating that these 2 outcomes showed more improvement in the experimental group than in the control group.

Post-hoc comparisons found that the change in the DASH scores from baseline (T1) to follow-up (T3) was significantly greater ($p = 0.002$) in the experimental group than in the control group. Additionally, although both groups showed improvement in the DASH scores ($p < 0.017$) at the completion of the intervention (T2), only the experimental group demonstrated ongoing significant improvement in the DASH scores during the follow-up period ($p < 0.017$). Overall, the changes in the participants' DASH scores from baseline (T1) to follow-up (T3) were positively correlated with the changes in scar pliability ($\rho = 0.41$, $p < 0.001$) during the same period (Table 4).

Post-hoc analysis showed that there was a greater change in the FACT-B functional well-being scores in the experimental group ($p = 0.024$) than in the control group from baseline to the 6-month follow-up. As shown in Table 4, these changes in the FACT-B functional well-being scores were significantly related to the changes in the VSS total ($\rho = 0.37$, $p < 0.001$) and DASH scores ($\rho = 0.39$,

$p < 0.001$).

The above intention-to-treat analyses were followed by per-protocol analyses, and similar results were obtained (Supplementary file: 2 and 3). Scatter plots of the results shown in Table 4 are provided in Supplementary file: 4 and 5.

DISCUSSION

The experimental group showed significantly more improvement over time in various aspects related to scar features than the control group. The improvement in scar appearance (mainly reflected in vascularity and pliability scores) in the experimental group was maintained for at least 3 months after the termination of treatment. The improvement in upper limb function, as indicated by the DASH scores, was also significantly greater in the experimental group than in the control group at follow-up.

Scar Characteristics

The major finding of this study was that the addition of mechanical stimulation to a conventional physiotherapy intervention program effectively improved scar appearance, as reflected in the VSS vascularity (medium effect size), pigmentation (medium effect size), pliability (medium to large effect size), and total scores (large effect size), compared with conventional physiotherapy alone. This is consistent with a previous histology study [8] that showed that mechanical stimulation restored vascularization in scar tissue. It is also consistent with a study that found reduced erythema after mechanical stimulation was applied to radiated breast tissues [7]. The improved vascularity could be due to improved circulation and lymphatic drainage after mechanical stimulation [42, 43], which may

enhance the wound-healing process. The improvement in scar pliability may be due to the stimulation of elastin fibers, disruption of fibrotic tissues, and reduction of mechanical tension around the scars after mechanical stimulation [8-11, 44]. The treatment effect on the VSS height score did not quite reach statistical significance (p = 0.062). This may be because none of the mastectomy scars in our patient population were hypertrophied or showed keloid formation. These results suggest that additional mechanical stimulation treatment may not lead to a significant reduction in the height of the scars.

The same reason may also explain why the scar color analysis, as measured by spectrophotometry (skin lightness, redness, and yellowness), yielded no significant results. Previous research has found that spectrophotometry is a good method for differentiating hypertrophied scars from normal skin in terms of pigmentation and vascularity (skin lightness, redness, and yellowness) [21], While the redness values of our participants' scars were somewhat close to what can be expected in hypertrophied scars, the lightness and yellowness of our participants' scars at baseline were close to those found in healthy skin [21].

Upper limb pain, function and quality of life

The treatment effect on pain was similar in the 2 groups. This could be partially explained by the floor effect [45], as the pain scores obtained at baseline were already quite low (2.0 points and 1.7 points in the experimental and control groups, respectively).

The improvement of shoulder flexion (T2: 15°, T3: 21°) and abduction (T2: 15°, T3: 22°) ROM observed in the experimental group was close to the mean change in shoulder flexion (12°) and abduction (20°) after an average of 9 weeks (SD=7) of physiotherapy including

mechanical massage, as reported in a pilot study without a control group [3]. However, the improvement in our experimental group was similar to that observed in the control group, although the former group showed greater improvement in VSS pliability score. As both groups were instructed to perform home exercises and self-scar massage as described in the educational pamphlet, it is possible that the between-group difference in these factors may have confounded the results on ROM.

The experimental group had better DASH outcomes than the control group at 6 months post-mastectomy, reflecting less disability (medium effect size). The change in DASH scores in the experimental group (15.4 points) surpassed the minimal important change (12.4 points) defined by van Kampen et al. (2013) in individuals with orthopedic shoulder problems [36].

The improvement in FACT-B total scores in both groups post-intervention, with no significant between-group differences, is consistent with 2 studies of breast cancer survivors who had undergone mixed types of surgeries (breast-conserving, mastectomy, and axillary dissection) with adjunct therapy (e.g., radiotherapy and chemotherapy): these women also reported similar improvements in the FACT-B total scores after physiotherapy interventions that included education and therapeutic exercises [46, 47]. Among the various FACT-B domains, only the improvement in the functional well-being domain demonstrated a significant group × time interaction effect (small to medium effect size). This may be attributable to the greater improvement in scar status (VSS) and arm function (DASH) in the experimental group, as shown in the correlation analysis.

Intriguingly, the experimental group had a better improvement in DASH and functional well-being

despite the lack of between-group differences in shoulder joint ROM, pain and muscle strength after treatment. The improvement in scar characteristics (as measured by VSS) may be a contributing factor to the observed improvement in DASH and functional well-being. Indeed, our correlational analysis revealed that those whose scar characteristics improved more tended to have greater improvements in FACT-B. We also cannot rule out the possibility of a placebo effect arising from the mechanical stimulation, which may also partly account for the greater improvement in DASH and FACT-B functional well-being scores (both are self-rated measures).

Limitations of the Study

This study has several limitations. First, the findings of the current study can only be extrapolated to women who have undergone mastectomy for breast cancer and have demographic and clinical characteristics similar to our study participants. As the results of mechanical stimulation on hypertrophied mastectomy scars might be different, further studies involving individuals with hypertrophied or keloid mastectomy scars are warranted. As this study was a single-center trial, the external validity is somewhat limited to allow for widespread changes in clinical practice in post-mastectomy scar management [48]. Multicenter studies are required to replicate the findings before mechanical stimulation can be incorporated into clinical practice guidelines for the treatment of post-mastectomy scars.

Second, the sample size calculation was based on the VSS, which is only an ordinal scale (score range from 0 to 13). The study may have been underpowered to detect the effects of the experimental

intervention on other outcomes. Third, the effects of other scar treatments may have influenced the results. According to their medical records, none of the participants had applied silicone gel sheets for mastectomy scar management. However, the frequency and duration of manual self-massage and home exercises were not documented. Moreover, the side effects of adjunct therapies, such as chemotherapy, might have prolonged the effects on the overall mental and physical health status of the participants, and this was not assessed in the current study. Nevertheless, the randomization in the group allocation process may have minimized the potential confounding effects of the above factors.

Participants were not blinded to the intervention. To better account for a potential placebo effect, future studies could consider providing sham mechanical massage as a control by putting the stimulator on the scar but with no, or with minimal, actual mechanical stimulation. However, this should have no major impact on the results of the VSS and spectrophotometry because they were determined by a blinded researcher, rather than the participants themselves.

There may be a potential confounding effect of self-scar-massage. However, the frequency and duration of self-scar-massage was documented. Scar massage was included in the education pamphlet given to participants in both groups. The randomized controlled design should also have minimized any systematic bias.

Lymphedema was not used as an exclusion criterion. Lymphedema after mastectomy is more common as time progresses and among those who receive radiotherapy. Since the participants in the current study were newly diagnosed with breast cancer, the surgical intervention was done within 6 weeks, and those who had received radiotherapy were excluded, the overall incidence of lymphedema

among the study participants should be very low. Therefore, the potential confounding effect of lymphedema should be minimal, if any.

Conclusion

This study showed that adding mechanical stimulation to conventional physiotherapy for women who have undergone mastectomy for breast cancer was safe and produced additional benefits in the form of improvements in scar vascularity and pliability, arm function, and functional well-being as compared with conventional scar treatment. The results suggest that mechanical stimulation can be used as a long-term adjunct treatment alongside conventional physiotherapy to further improve scar recovery and upper limb function in women post-mastectomy. Further studies that aim to identify the optimal amount of stimulation and the potential mechanisms of mechanical stimulation in scar management are warranted.

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Declaration of Interest: none.

The data and full trial protocol can be accessed from the corresponding author upon well-justified request.

Figure captions

Figure 1: Participant flow and loss at follow-up

Figure 2: Clinical photographs of mastectomy scars in both groups at different time points

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