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ORIGINAL ARTICLE

Immediate inelastic compression garment for swelling management after total knee arthroplasty: a feasibility study

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ABSTRACT

Background: Swelling after total knee arthroplasty (TKA) peaks between days 3 and 8. Peak swelling is associated with decreased strength and function.
Aim: The aim of the study was to investigate the feasibility and initial efficacy of an inelastic compression garment on attenuating peak swelling when applied immediately after TKA (immediate compression garment [ICG]).
Methods: The ICG group (n = 14) had the inelastic compression garment applied in the operating room after surgery and wore it for 12 h/day while awake for 21 days. The historical comparison group (n = 16) wore the same garment, which was donned 3 – 4 days after surgery (delayed compression garment). ICG feasibility outcomes at day 21 were safety, satisfaction, and adherence. Initial efficacy outcomes at days 4, 7, 14, 21, and 42 were swelling, quadriceps strength and activation, and pain. Hedges' g effect sizes (ES) were calculated.
Results: One participant was removed from the study on day 7 due to deep vein thrombosis. Median satisfaction with ICG was 5/5, that is, very satisfied. On average, participants wore the garment for 11 h/day. ES favoring ICG were found for: (i) swelling at days 4 (ES = 0.26) and 14 (ES = 0.17) only; (ii) quadriceps activation at days 21 (ES = 0.77) and 42 (ES = 0.72); and (iii) pain at days 14 (ES = 0.43), 21 (ES = 0.57), and 42 (ES = 0.42).
Conclusion: The use of an ICG after TKA appears feasible, though its effect on peak swelling (days 4 and 7) is unclear. All ES should be interpreted with caution due to the small sample size.
Relevance for Patients: Donning the garment immediately in the operating room demonstrates promising trends toward improved quadriceps activation and pain.

1. Introduction

Patients experience significant swelling after total knee arthroplasty (TKA). Swelling increases 10%/day, on average, for the first 3 days after surgery and then peaks at 25 – 47% between post-operative days 3 – 8 [1,2]. Even 90 days after surgery, swelling remains 11% higher than pre-operative values [1]. Swelling after TKA is associated with lower patient satisfaction [3] and is one of the most frequent reasons for emergency department visits shortly after surgery [4,5]. In addition, swelling after TKA is associated with decreased quadriceps strength and functional performance, such as reduced gait speed [1,6,7]. It is thought that the relationship between swelling and functional performance is mediated by quadriceps strength [1,6].

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Quadriceps strength loss after TKA is also significant, with patients experiencing up to a 60% loss in the 1st month after surgery [8-10]. Pre-operative quadriceps strength levels are typically not regained for 6 months [9,10], and, perhaps most concerning, strength may never reach the levels of aged-matched peers without any history of knee pathology [11-15]. Early quadriceps strength loss after TKA is thought to be predominately due to the inability to fully activate the quadriceps muscle voluntarily, also known as arthrogenic muscle inhibition (AMI) [8,16,17]. AMI accounts for 65% of the variance in acute quadriceps strength loss after TKA and is thought to impede the effectiveness of voluntary strengthening during rehabilitation [8,17]. This could explain why even high-intensity, progressive resistance protocols after surgery have failed to mitigate quadriceps strength loss [18,19]. The mechanisms underlying AMI are not fully understood, but joint pain [8,16,20] and swelling [21-24] have been implicated. Pain and swelling may reduce the excitability of the quadriceps by affecting the afferent discharge of the joint sensory receptors [21].

Researchers and clinicians alike have attempted to mitigate swelling after TKA with little success. The use of cryotherapy has mixed findings, which may be due to variations in study methodology [25-29]. Similarly, the effect of kinesiotape [29-33], manual lymphatic drainage [33-36], or a combination of both [37] has been inconclusive. The use of elastic compression bandages, including modified Robert Jones bandages, has also proven ineffective after TKA [38-42]. Conversely, the use of an inelastic compression garment has recently displayed promise [36,43]. Carmichael *et al.* [36] found up to 54% less swelling in the first 21 days after TKA when compared to a control group that wore standard elastic, non-adjustable thromboembolic deterrent (T.E.D.) hose only. In this study, however, the inelastic compression garment was not applied until 3 – 4 days after surgery, potentially limiting its ability to maximally mitigate peak swelling. Peak swelling, not cumulative swelling, has been associated with decreased quadriceps strength and functional performance [7]. Applying the same inelastic garment immediately after surgery could further attenuate peak swelling and consequently improve patient recovery.

Therefore, the purpose of this study was to evaluate the feasibility of an inelastic compression garment donned in the operating room immediately after TKA (i.e., immediate compression garment [ICG]). In addition, we sought to investigate the initial efficacy of ICG on peak swelling, quadriceps activation, strength, and pain as compared to the Carmichael *et al*. [36] study that used the same garment applied 3 – 4 days after surgery (i.e., delayed compression garment [DCG]). We hypothesized that ICG would be feasible, and, when compared to DCG, it would have lower peak swelling, superior quadriceps activation and strength, and reduced pain.

2. Methods

2.1. Study design and participants

This was a prospective feasibility study with a comparison to a historical cohort (DCG). The ICG and DCG cohorts had the same inclusion and exclusion criteria. Participants between the ages of 50 and 85 years, who were undergoing a primary unilateral TKA secondary to end-stage osteoarthritis, were consecutively recruited. They were excluded if they had any of the following: (i) discharge to a location other than home after surgery; (ii) history of heart failure, lymphatic insufficiency, hepatic disease, pre-existing pitting edema, varicose vein ligation, or any other condition associated with chronic swelling of either lower extremity; (iii) uncontrolled diabetes; (iv) body mass index (BMI) >40 kg/m^2; (v) no caregiver or the inability to touch toes, which may affect donning/doffing the compression garment; or (vi) any ongoing neurologic, cardiac, or other unstable orthopedic conditions that limit the function or ability to participate in outcome measures testing. ICG participants were recruited from April 2021 to July 2022 by two orthopedic surgeons from one institution in the Denver metro area.

2.2. Interventions

2.2.1. Inelastic compression garment

Both ICG and DCG cohorts were measured with the inelastic compression garment 1 – 2 weeks before surgery as part of their baseline testing session. The garment (CircAid Juxtafit upper leg and knee garment combined with a lower leg garment; Medi USA, United States of America [USA]) has adjustable straps that enable quick and precise setting of various compression ranges using a standardized garment tensioning tool (Figure 1). Throughout the intervention period, the garment straps were applied using gradient compression to promote venous and lymphatic return using the following pressures: 40 mmHg (lower leg), 30 mmHg (knee), and 20 mmHg (thigh). Participants were trained in garment donning/doffing preoperatively. They were asked to wear the garment for 12 waking hours each day, removing it at night to sleep. They could remove the garment for brief periods throughout the day for hygiene and rehabilitation, as needed. Finally, they were asked to wear the garment until post-operative day 21.

Figure 1. Inelastic compression garment

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2.2.2. Timing of initial garment donning

The DCG group did not don the garment until 3 – 4 days after surgery. The ICG group donned the garment immediately after surgery in the operating room, assisted by an orthopedic physician assistant, a surgical assistant, or a professional research assistant. Approximately 2 h later, a research assistant assessed the participant to ensure proper garment application and to answer any participant questions. The participant was instructed to leave the garment on until the following evening (i.e., bedtime of post-operative day 1) and then to wear it for 12 waking hours per day.

2.2.3. Rehabilitation

Participants in both groups were instructed in a home exercise program designed to promote frequent pumping of calf and thigh musculature to aid in (i) venous and lymphatic return and (ii) knee range of motion (ROM). Participants were asked to perform ankle pumps for 1 min, a minimum of 5 times daily. In addition, they were asked to perform 10 repetitions of a knee flexion exercise, a minimum of 5 times daily. The knee flexion exercise was chosen by the participant from one of the following, with the option to choose a different exercise at any time: heel slides, floor scrubs, or stair stretch (Table S1). These exercises were performed with the garment in place, but the participant could loosen select straps around the knee joint to allow more ROM, if necessary. Finally, all participants also received standard-of-care outpatient rehabilitation separate from this study.

2.3. Outcome measures

Feasibility of ICG was assessed by safety, average daily wear time of the garment, adherence to the prescribed garment wear time of 12 h/day, and participant satisfaction with the garment. To investigate initial efficacy, ICG and DCG were both tested at baseline (1 – 2 weeks preoperatively) and postoperatively on days 4, 7, 14, 21, and 42 (Figure 2).

2.3.1. Safety

Safety was assessed by recording serious adverse events related to the ICG protocol (e.g., deep vein thrombosis, infection, skin necrosis, delayed wound healing, or manipulation under anesthesia to address knee ROM limitations) throughout the study, that is, 42 days.

2.3.2. Daily wear time and adherence

Average daily wear time and adherence were determined by self-report logs that were collected weekly to increase the accuracy of reporting. Average daily wear time was calculated by dividing the sum of the hours the garment was worn each day by the total number of possible days during the intervention period, that is, 21 days. Adherence to the prescribed daily wear time of 12 h was calculated from 0 to 100% by dividing the total number of days the garment was worn for at least 12 h by the total number of possible days during the intervention period. Both were then reported as the mean, standard deviation (SD), and the 95% confidence interval (CI).

2.3.3. Satisfaction

Satisfaction with the garment was measured on completion of the intervention period using a five-point Likert survey, including completely dissatisfied (1), somewhat dissatisfied (2), neither dissatisfied nor satisfied (3), somewhat satisfied (4), and completely satisfied (5). It was then reported as median and range.

2.3.4. Swelling

The swelling was measured at days 4, 7, 14, 21, and 42 days after surgery by a single frequency bioelectrical impedance assessment (SF-BIA) using an RJL Systems Quantum® (USA) device, as further described in the study by Carmichael *et al.* [36] SF-BIA is a reliable and responsive measure of total limb swelling after TKA [44]. The device delivers a 2.5 μA alternating current at a frequency of 50 kHz. The level of impedance met by the current will fluctuate with the presence of swelling in the lower extremity. Lower levels of impedance represent greater levels of swelling. Using a ratio of the impedance of the involved limb to the uninvolved limb accounts for body composition, fluid shifts, and hydration status, allows any changes in impedance between time points to be attributed to changes in limb swelling. Therefore, swelling values at each time point are presented as the percent difference between limbs and calculated as:

$$\text{Swelling} = \left(1 - \frac{\text{involved bioelectrical impedance assessment}}{\text{uninvolved bioelectrical impedance assessment}}\right) \times 100 \quad \text{(I)}$$

Given that swelling is known to peak at 3 – 8 days after surgery, swelling measurements at days 4 and 7 were used to specifically consider ICG's effect on peak swelling.

2.3.5. Quadriceps strength and activation

Quadriceps strength and activation were evaluated on days 21 and 42. Quadriceps strength was assessed by

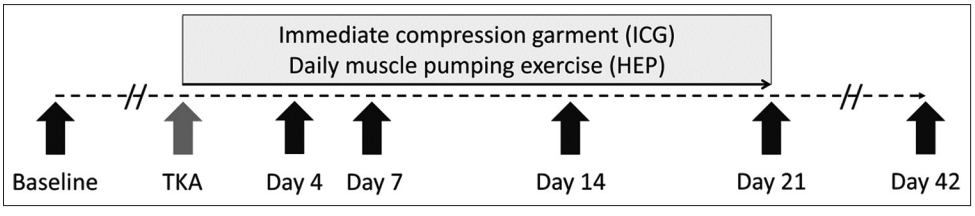

Figure 2. Immediate compression garment intervention and testing timeline
Abbreviations: HEP: Home exercise program; TKA: Total knee arthroplasty

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maximum voluntary isometric contraction (MVIC) using an electromechanical dynamometer (HUMAC NORM; CSMi, USA) at 60° of knee flexion. To ensure maximal strength was recorded, testing was repeated, with 1 min rest between trials, until the readings from two trials were within 5% of each other. The trial with the highest torque was utilized for data analysis, after normalization [45]. Data were collected with a BIOPAC Data Acquisition System (Biodex Medical Systems Inc, USA) at 2000 samples/s and analyzed with Acknowledge software, version 5.0 (Biodex Medical Systems Inc, USA). Voluntary activation of the quadriceps was assessed using the doublet interpolation technique, where a supramaximal stimulus is applied (Grass S48 stimulator and SIU8T stimulus isolation unit, Grass Instruments Co, USA) during quadriceps MVIC testing and again immediately afterward while the muscle is at rest [45]. Stimulus parameters were two pulses, a pulse duration of 600 μs, and a frequency of 100 pulses/s. Full voluntary activation of the quadriceps is 100%, whereas anything less than this represents an activation deficit. As this laboratory assessment of quadriceps activation is not feasible early after surgery, the quadriceps activation battery (QAB) was conducted on day 4 [46]. The QAB consists of the following three clinical tests, each scored from 0 to 2: Isometric quadriceps contraction, straight leg raise, and quadriceps extension lag. Isometric quadriceps contraction was tested with the participant in supine and the surgical knee in full available extension ROM. It was scored as 0 (unable to initiate any contraction), 1 (poor contraction with no superior patellar movement), or 2 (strong contraction with visible superior movement of the patella). Straight leg raise was tested with the participant in supine, the surgical knee in full available extension ROM, and the contralateral knee bent to 90°. It was scored as 0 (unable to lift the heel off the table), 1 (able to lift the heel two feet off the table, but unable to maintain knee in full available extension ROM), or 2 (able to lift the heel off the table and maintain the knee in full available extension ROM). The quadriceps extension lag was tested with the participant sitting upright at the edge of a table. The surgical knee was passively extended by the tester to <5° the available extension ROM. The participant was then instructed to hold this position while the tester withdrew support. It was scored as 0 (unable to keep the surgical knee from bending without tester support), 1 (able to maintain knee extension but for <1 s and able to slow the leg's descent into further flexion without tester support), or 2 (able to maintain knee in extension for >1 s). The total score is the sum of the three tests ranging from 0 to 6. Scoring ≤ 3 on the QAB 4 days after surgery is significantly related to: (i) poorer quadriceps activation 1 month after surgery; and (ii) poorer strength and functional performance 1 – 2 months after surgery [46].

2.3.6. Pain

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is one of the most commonly utilized patient-reported outcome measures after TKA [47]. It can assess three components of TKA recovery: pain, stiffness, and function. In this study, the self-reported pain of the surgical knee was assessed using the WOMAC pain sub-score on days 14, 21, and 42. The WOMAC pain sub-score includes five questions, each scored as 0 (none), 1 (mild), 2 (moderate), 3 (severe), or 4 (extreme). The total pain sub-score ranges from 0 to 20, with a lower score indicating less pain.

2.4. Power and sample size

A large effect size (ES) (>1.0) was found for DCG on swelling compared to controls without an inelastic compression garment [36]. The anticipated ES of ICG on swelling compared to DCG was unknown, but we believed that it would be at least 0.3. Given this anticipated ES (>0.3), 80% power, and type I error rate of 0.05, Whitehead *et al.* [48] recommended a minimum of 10 participants per cohort in a pilot study to more precisely estimate the variability of a treatment effect. Therefore, we set our minimum sample size for ICG to 10 participants.

2.5. Data analysis

The ICG and DCG groups were compared at baseline for age, BMI, swelling, quadriceps strength and activation, and WOMAC pain using the Wilcoxon rank sum test. The differences between all post-operative time points and baseline were calculated for the same outcomes and assessed for normality statistically using the Shapiro–Wilk test and visually using histograms. Initial efficacy for ICG was assessed with Hedges' g ES for total limb swelling, quadriceps strength, quadriceps activation, and WOMAC pain. ESs were classified as small if $g \leq 0.2$, as medium if $0.21 \leq g \leq 0.79$, or as large if $g \geq 0.8$ [49]. The proportion of participants in each group scoring ≤ 3 and ≥ 4 on the QAB were compared using Fisher's exact test.

3. Results

Participant baseline characteristics can be found in Table 1. A total of 14 participants were enrolled in the ICG protocol (62.3 ± 8.3 years; nine females). One participant self-selected to wear the garment only while sleeping during the third post-operative week due to claustrophobia. An additional participant was instructed by a non-study provider during the third post-operative week to only wear the garment while sleeping due to poor ROM progress. Therefore, the data from days 21 and 42 were not included in the analysis for these two participants. Finally, one participant was removed from the study during the second post-operative week due to deep vein thrombosis (DVT), resulting in no data available for days 14, 21, and 42. There were 16 participants in the DCG group (64.7 ± 7.1; 12 females).

No significant differences were found between groups at baseline for age, BMI, swelling, or quadriceps strength (Table 1). ICG had statistically significantly lower quadriceps activation than DCG at baseline with median values of 57.9% and 84.6%, respectively ($p = 0.01$). The ICG group also had statistically significantly higher WOMAC pain than DCG at baseline with median values of 9.0 and 7.5, respectively ($p = 0.03$).

3.1. Feasibility of ICG

In addition to the DVT reported above, it should be noted that the two participants who wore the garment during sleeping hours

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Table 1. Participant baseline characteristics

Characteristic	ICG		DCG		p-value[a]
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	
Age, years	64.5 (15.0)	62.3 (8.3)	65.0 (10.0)	64.7 (7.1)	0.40
BMI (kg/m^2)	29.5 (9.4)	28.6 (5.2)	28.9 (7.3)	29.8 (4.9)	0.66
Swelling (%)	0.6 (8.4)	0.3 (8.0)	−1.7 (5.0)	-2.5 (4.9)	0.35
Quadriceps strength (Nm/kg)	0.9 (0.4)	1.1 (0.5)	1.0 (0.6)	1.2 (0.5)	0.72
Quadriceps activation (%)	57.9 (31.9)	61.3 (18.4)	84.6 (14.5)	79.6 (16.4)	0.01[b]
WOMAC pain	9.0 (5.0)	9.6 (3.7)	7.5 (2.5)	7.4 (2.6)	0.04[b]

Note: [a]p-value, Wilcoxon rank sum; [b]statistically significant at $p<0.05$.
Abbreviations: ICG: Immediate compression garment; DCG: Delayed compression garment; IQR: Interquartile range; SD: Standard deviation; BMI: Body mass index; WOMAC: Western Ontario and McMaster Universities osteoarthritis index.

underwent manipulation under anesthesia (MUA) to address knee ROM limitations. On average, participants indicated they wore the garment for 11 ± 2 h/day (95% CI: 10 – 12). They were only adherent to wearing the garment for the prescribed 12-h wear time, on average, 64 ± 37% of the time (95% CI: 43–85%). Median satisfaction with the garment was 5/5 (i.e., very satisfied) on the five-point Likert scale (range: 4 – 5).

3.2. Initial efficacy

The mean and SD for all outcomes at all-time points are listed in Table S2. A summary of ES at all-time points can be found in Table 2**.** For swelling, a medium and a small ES were found in favor of ICG at days 4 and 14, respectively. Conversely, ES for swelling at days 7, 21, and 42 were found in favor of DCG. ES for all other outcomes and time points favored ICG. Small ES were found for quadriceps strength and medium ES for quadriceps activation at days 21 and 42. Medium ES was found for WOMAC pain on days 14, 21, and 42. A significantly greater proportion of ICG scored ≥ 4 on the QAB compared to DCG (100% vs. 63%, respectively; p = 0.02).

4. Discussion

This study evaluated the feasibility and initial efficacy of applying an inelastic compression garment in the operating room immediately after TKA. The effect of immediate application (ICG) on peak swelling remains unclear, but this study supports the use of an inelastic compression garment to mitigate total limb swelling in the first 3 weeks after surgery. The immediate application demonstrated promising trends toward improved early quadriceps activation and pain. Future research is warranted to conclusively evaluate efficacy as our small sample size was not designed to do so.

The ICG appears feasible after TKA. All ICG participants indicated they were completely or somewhat satisfied with the compression garment, that is, 4 – 5/5 on the Likert scale, which is consistent with the satisfaction reported in DCG [36]. Average adherence to the prescribed wear time of 12 hours per day over the intervention period was only 64% for ICG. Instead, participants recorded wearing the garment for 10.9 hours on average per day, with some indicating that they were simply not awake for 12 hours. The 12-hour wear time was chosen arbitrarily based on an estimate of the amount of time that participants would be awake each day with the surgical limb in a gravity-dependent position and potentially accumulating swelling. Our findings suggest that a 12-hour wear time may not be feasible, but also that 12 hours may not be necessary, since swelling mitigation in ICG was similar to that found in DCG. Future studies should consider a shortened daily wear time to better accommodate participants' natural daily waking hours and to improve adherence. While it is unfortunate that one participant experienced DVT while enrolled in this study, it is not appropriate to assume a causal relationship between the two. DVT after TKA occurs at a rate of 0.5% – 0.9% [50,51], suggesting that this event may be due to chance alone. Similarly, rates of MUA after TKA range from 0.6% to 4.2% [52,53]. Both of the participants in this study who wore the garment while sleeping went on to have MUA, but this does not imply causality. In addition, no DVTs or MUAs occurred in the DCG group [36]. Nevertheless, future studies should report adverse event rates with particular attention to DVT and MUA.

The ES for swelling at days 4 and 14 favored ICG, while the remaining time points favored DCG. When looking at the raw data, the ICG and DCG groups appear similar in their ability to mitigate swelling compared to a historical control cohort that only wore elastic T.E.D. hose (Figure 3) [2,36]. While it is unclear if ICG was able to mitigate peak swelling to a greater extent than DCG, our findings demonstrate the effect that an inelastic garment can have on swelling after TKA. In addition, early application would still be preferred in future studies, given the trend toward improved activation and the ease of donning the garment while the patient is still within their surgical episode of care. Applying the garment 3 – 4 days after surgery necessitates a clinic visit, which may not align with typical care pathways.

There appears to be a trend towards better WOMAC pain scores for ICG than DCG, with medium ES ranging from 0.42 to 0.57 for days 14 – 42 (Table 2). This should be interpreted with caution, as ICG had significantly higher pain scores at baseline than DCG (mean: 9.6 vs. 7.4, respectively) (Table 1), suggesting that ICG had more room for improvement. Future research should also examine narcotic pain medication usage to better assess the relationship between ICG and pain amelioration.

The ICG does not appear to have had a significant effect on quadriceps strength with small between-group mean differences

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Table 2. Effect size estimates at post-operative days 4, 7, 14, 21, and 42

Outcome	Time point	ICG			DCG			Hedges' g effect size[c] (95% CI)	Between-group mean difference (95% CI)[d]
		n	Mean difference[a]	SD	n	Mean difference[b]	SD		
Swelling (%)	Day 4	14	27.20	10.65	16	30.27	12.17	0.26 (−0.44 to 0.96)	−3.08 (−11.69 to 5.53)
	Day 7	11	22.20	10.71	16	21.71	8.98	−0.05 (−0.79 to 0.70)	0.49 (−7.34 to 8.32)
	Day 14	13	16.50	12.65	16	18.53	10.72	0.17 (−0.54 to 0.88)	−2.03 (−10.93 to 6.87)
	Day 21	11	17.03	10.84	16	14.55	7.60	−0.27 (−1.01 to 0.48)	2.48 (−4.81 to 9.77)
	Day 42	11	18.84	11.46	15	18.26	9.27	−0.06 (−0.81 to 0.70)	0.58 (−7.81 to 8.97)
Quadriceps strength (Nm/kg)	Day 21	11	−0.41	0.34	16	−0.46	0.39	0.13 (−0.61 to 0.88)	0.05 (−0.25 to 0.35)
	Day 42	11	−0.21	0.30	15	−0.24	0.40	0.07 (−0.68 to 0.83)	0.03 (−0.27 to 0.32)
Quadriceps activation (%)	Day 21	11	12.23	12.16	15	−3.24	23.20	0.77 (−0.01 to 1.56)	15.47 (0.91 to 30.03)
	Day 42	11	16.86	13.08	13	7.20	12.99	0.72 (−0.09 to 1.52)	9.66 (−1.42 to 20.73)
WOMAC pain	Day 14	10	−1.60	4.55	16	0.13	3.40	0.43 (−0.34 to 1.21)	−1.73 (−4.95 to 1.50)
	Day 21	11	−2.73	4.17	16	−0.63	3.16	0.57 (−0.19 to 1.33)	−2.10 (−5.01 to 0.80)
	Day 42	11	−3.64	4.18	16	−2.06	3.21	0.42 (−0.33 to 1.17)	−1.57 (−4.50 to 1.35)

Note: [a]mean difference=ICG post-operative day x – ICG baseline; [b]mean difference=DCG post-operative day x – DCG baseline; [c]for clarity, effect sizes have been standardized so that positive values favor ICG and negative values favor DCG; [d]between-group mean difference = (ICG mean difference) – (DCG mean difference). Abbreviations: ICG: Immediate compression garment; DCG: Delayed compression garment; SD: Standard deviation; CI: Confidence interval; WOMAC: Western Ontario and McMaster universities osteoarthritis index.

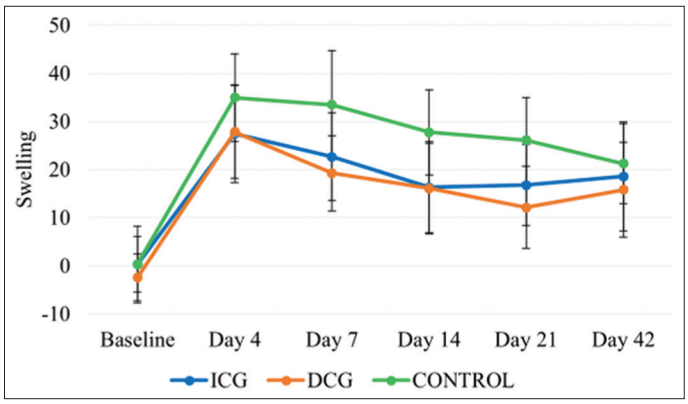

Figure 3. Changes in swelling over time for immediate compression garment, delayed compression garment, and elastic thromboembolism-deterrent garment

and ES noted at days 21 and 42 (Table 2). However, there appears to be a trend toward greater quadriceps activation for ICG at both of these time points (ES = 0.77 and 0.72, respectively). Notably, ICG had significantly lower activation compared to DCG at baseline and, thus, more room for improvement. However, this trend is possibly corroborated by the QAB data collected 4 days after surgery, revealing that 100% of ICG scored ≥ 4 compared to only 63% for DCG. Interestingly, Bade *et al.* [46] found that only 46% of participants scored ≥ 4 on the QAB 4 days after surgery when they received no specific intervention to address swelling or activation (e.g., no compression garment). This suggests that the inelastic compression garment might positively affect quadriceps activation in the acute post-operative period theoretically by minimizing swelling and quadriceps AMI. Future research is warranted to conclusively determine the impact that improved early activation may have on quadriceps strength and function.

Finally, there is a need to determine the impact of an inelastic compression garment on other outcomes that have been associated with swelling after TKA, for example, patient satisfaction [3] and early emergency department visits [4,5]. Dissatisfaction after TKA is between 8% and 19%, with actual rates possibly higher than reported in the literature [54]. In addition, in the first 90 days after TKA, the incidence of emergency department visits is between 10.8% and 13.8%, with swelling of the surgical limb being one of the most common reasons for seeking medical care [4,5]. It remains to be determined whether minimizing swelling in the early post-operative period can impact (i) long-term residual swelling and satisfaction, and (ii) the incidence of emergency department visits and healthcare costs following TKA.

Nonetheless, the study had several limitations. The primary aim of this study was to assess the feasibility of ICG among a small sample of TKA recipients. Thus, the study was not adequately designed to definitively evaluate the efficacy of ICG compared to DCG. All ESs presented should be interpreted in light of this limitation. The 95% CI for all ES includes 0, indicating that the true ES could favor either group for all outcomes. In addition, since we used a historical control (DCG), there were statistically significant baseline differences between groups for quadriceps activation and WOMAC pain. Future research should focus on randomized controlled trials with appropriate power to definitively evaluate efficacy and minimize baseline differences between groups.

5. Conclusion

The ICG appears feasible after TKA. The effect of immediate application on peak swelling remains unclear, but this study supports the use of an inelastic compression garment to mitigate total limb swelling in the first 3 weeks after surgery. The immediate application demonstrated promising trends toward improved early quadriceps activation and pain. Based on these results, a future full-scale study will be conducted with sufficient power to conclusively evaluate the efficacy of ICG on peak swelling after TKA.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethics Approval and Consent to Participate

This study was registered on ClinicalTrials.Gov (NCT04841356) and was approved by Colorado Joint Replacement's institutional review board, the CommonSpirit Health Research Institute Institutional Review Board (1722208-1). All study procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration. Informed written consent was obtained, and participants' rights were protected.

Consent for Publication

Consent for publication was obtained for every individual's data included in this experimental study.

Availability of Data

All data are available within this manuscript or online as supplementary material.

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ORIGINAL ARTICLE

Immediate inelastic compression garment for swelling management after total knee arthroplasty: a feasibility study

Supplementary File

Table S1. Home exercise program

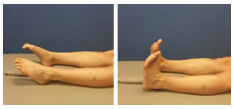
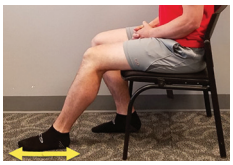
Exercise	Demonstration
Ankle pumps: Perform for 1 min; 5+times per day	
Knee flexion exercise (choose any): Perform 10 repetitions; 5+times per day Heel slides	
Floor scrubs	
Stair stretch	

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Table S2. Statistics at all time points

Time point	Statistic	Swelling (%)		Quadriceps strength (Nm/kg)		Quadriceps activation (%)		WOMAC pain	
		ICG	DCG	ICG	DCG	ICG	DCG	ICG	DCG
Baseline	n	14	16	14	16	14	16	14	16
	Mean	0.3	−2.5	1.1	1.2	61.3	79.6	9.6	7.4
	SD	8.0	4.9	0.5	0.5	18.4	16.4	3.7	2.6
Day 4	n	14	16	-	-	-	-	-	-
	Mean	27.5	27.8	-	-	-	-	-	-
	SD	10.1	9.7	-	-	-	-	-	-
Day 7	n	11	16	-	-	-	-	-	-
	Mean	22.6	19.3	-	-	-	-	-	-
	SD	9.1	7.8	-	-	-	-	-	-
Day 14	n	13	16	-	-	-	-	12	16
	Mean	16.3	16.1	-	-	-	-	7.0	7.5
	SD	9.5	9.4	-	-	-	-	2.0	2.6
Day 21	n	11	16	11	16	11	15	11	16
	Mean	16.8	12.1	0.6	0.7	72.3	76.3	5.8	6.8
	SD	8.5	8.6	0.3	0.3	14.1	15.8	2.6	2.5
Day 42	n	11	15	11	15	11	13	11	16
	Mean	18.6	15.8	0.8	0.9	77.0	88.0	4.9	5.3
	SD	11.3	9.9	0.3	0.4	10.5	6.7	2.2	2.7

Abbreviations: WOMAC: Western Ontario and McMaster universities osteoarthritis index; ICG: Immediate compression garment; DCG: Delayed compression garment; SD: Standard deviation.

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