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Original Article


# Mirror Therapy for Total Knee Arthroplasty: A Pilot Study

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## Abstract

***Background:*** *One in five patients experience persistent pain and disability after total knee arthroplasty (TKA), often driven by increased sensitization of the nervous system and pain. Pain and a sensitized nervous system are major barriers to postoperative rehabilitation impeding improved movement, and function.*

***Objective:*** *To determine if mirror therapy following TKA yields any positive shifts in self-reported pain, active range of motion (ROM) and nerve sensitivity (pressure pain thresholds - PPT).*

***Design****: Case series with pre- and immediate post-intervention measurements.*

***Methods:*** *A convenience sample of patients who just underwent TKA was recruited for the study. Prior to mirror therapy, self-reported pain, active knee flexion ROM and PPTs were measured. In hook lying, a mirror was placed between the legs, separating the surgical and non-surgical legs. Patients performed 3 sets of 10 supine heel slides with the non-surgical leg while watching the leg in the mirror, mimicking active knee flexion of the surgical leg.*

***Results:*** *Eighteen patients (9 female), with a mean age of 65.94 years and mean time since TKA of 7.83 days participated in the study. Immediately following mirror therapy, mean active knee flexion improved by 3.84 degrees ($p = 0.001$), with 10 patients exceeding minimal detectable change. Self-reported pain ($p = 0.08$), PPT of the surgical knee ($p = 0.95$), PPT of the non-surgical knee ($p = 0.21$) and PPT of the upper trapezius ($p = 0.23$) failed to show any significant improvement after mirror therapy.*

***Conclusion:*** *The results of this study show that mirror therapy immediately following TKA may have some benefit in improving ROM, but not pain or sensitivity of the nervous system. This is the first study exploring the immediate effects of mirror therapy in postoperative TKA.*

## Introduction

IWith Baby-Boomers living longer, the older adult population in the United States (US) is becoming a larger representation of the overall population ratio. Older adults experience increased healthcare issues associated with aging [1]. One such example is aging of joints, or osteoarthritis, which is estimated to affect 13% of the US population [2]. With problematic age-related joint changes, pain and disability, corrective surgery is often suggested including total knee arthroplasty (TKA) for knee osteoarthritis [3]. Singh, et. al reported that more than 1 million TKA's are performed in the US annually and between 2020 and 2030 this rate will increase 56% [3]. Unfortunately, it is estimated that one in five patients following TKA still experience significant pain and disability [4, 5], which adds additional challenges to postoperative rehabilitation, as well as quality of life [6].

In light of the high rates of persistent pain and disability following TKA, researchers started exploring various comorbid preoperative issues predictive of poor outcomes. It is suggested that recognition of these factors may either be used to steer a patient away from TKA, or warrant additional non-surgical treatment prior to surgery, i.e., cognitive behavioral medicine [7]. One example is fear-avoidance, which has been shown to powerfully predict outcomes for surgical and non-surgical conditions [6,8,9]. Another factor associated

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with poor outcomes following TKA is pain catastrophizing [10,11]. In a large scale systematic review and meta-analysis, it was shown that there is a statistically significant association between preoperative pain catastrophizing and development of chronic post-surgical pain [10]. In line with this growing body of evidence implicating psychosocial variables' impact on TKA, strategies for addressing fear-avoidance, general anxiety and pain catastrophizing has been developed. In a randomized clinical trial of patients scheduled for TKA, it was shown that a preoperative program focusing on coping skills for patients with elevated pain catastrophizing has superior outcomes 2 months post-TKA in regards to pain severity, postoperative catastrophizing and function compared to the non-trained group [12].

One additional area of interest pertaining to TKA outcomes that is gaining interest is the sensitivity of the peripheral and central nervous system of the patient undergoing TKA. It is now well-established that the years of knee pain and inflammation accompanying knee OA result in sensitization of the nervous system around the affected knee (peripheral sensitization), as well as a sensitization of the person's entire central nervous system (central sensitization) [5,13,14]. Both of these factors have been linked to poor outcomes following TKA and added challenges during postoperative rehabilitation [5,13,14]. In line with this research it is now not uncommon for patients scheduled for TKA to be placed on membrane stabilizers such as Pregabalin and Gabapentin preoperatively to ensure a calming effect on the nervous system in the perioperative period [15-17]. Non-pharmacologically, therapeutic interventions such as pain neuroscience education have been tested and shown to decrease sensitization of the patient's knee prior to TKA [18]. In the postoperative rehabilitation realm, strategies to ease sensitization of the peripheral and central nervous system are not well studied. Postoperatively, therapists are charged with helping patients maximize range-of-motion (ROM), function and pain control primarily with using various movement-based strategies, but not specifically aiming to decrease sensitization of the nervous system. The aim of this pilot study is to determine if a central nervous system-focused treatment of mirror therapy to patients who have undergone a TKA yields any postoperative benefits.

## Methodology

### Study

Prior to the study, institutional review board approval was obtained from Southwest Baptist University. Participants were asked to provide written consent for participation in the study and the study followed the Helsinki declaration of ethics for medical research. The study was a case series with pre- and immediate post intervention measures with no personal identifiable information collected.

### Participants

In line with the objectives of the study, hospital outpatient departments and private practices agreed for the study to take place in their facility. All patients attending outpatient physical therapy for their first postoperative visit after the TKA were eligible to participate in the study. Participation was entirely voluntary and patients who agreed signed a written consent. Inclusion criteria included having had a TKA previously and not received postoperative physical therapy yet; adult (aged 18 and above); fluent in writing and reading the English language; exhibit and report no contraindications for postoperative rehabilitation. Exclusion criteria was any patient who is blind (cannot use mirror therapy), under the age of 18, not able to read or write English or have ROM limitation set by the surgeon (i.e., not to exceed a certain ROM after surgery). The attending physical therapists were well-versed in the proposed treatment protocol, having completed a post-professional certification and/or residency, including extensive training in the treatment plan consisting of mirror therapy.

### Intervention

One therapeutic strategy that has been shown to help calm down the peripheral and central nervous system is graded motor imagery [19,20]. Graded motor imagery is a collective series of treatments aimed at restoring body maps of affected painful areas of the body [19,20]. It has been shown that patients who experience pain exhibit different cortical body maps than non-painful individuals and when these maps are restored pain and sensitivity of the nervous system eases [19]. Clinicians find evidence for possible changes in cortical mapping by performing various clinical tests. When patients have altered two-point discrimination, an impaired ability to accurately identify where they are being touched (localization), or an impaired ability to determine left versus right (lafterality), an impairment in the body map is suspected [21-23]. Graded motor imagery uses techniques aimed specifically at restoring these deficits and includes laterality training (left/right judgement tasks), motor imagery, sensory discrimination and mirror therapy [23]. Even though it has been suggested that graded motor imagery use a sequence of the aforementioned techniques, it's now also been shown that stand-alone parts of the graded motor imagery can be beneficial. For example, Louw, et. al. showed that a 5-minute localization treatment for patients attending physical therapy for knee pain yielded immediate, significant improvements in knee flexion [24]. Similarly, it has been shown that a brief mirror therapy session for patients attending physical therapy for shoulder pain yields immediate changes in ROM, self-reported pain, pain catastrophizing and fear-avoidance [25].

In this study patients underwent a single session of mirror therapy with the head of the bed raised to support the patients in a long sitting position. The patient then performed knee flexion in a hook lying position with the involved leg supported to optimize patient comfort. The patient performed 3 sets of 10 repetitions of supine heel slides (knee flexion active ROM) with the uninvolved lower extremity, while looking at that extremity in a long mirror placed between the legs, with the mirror hiding the involved limb (Figure 1). The patient was instructed to look at the reflection of the limb and imagine that they are looking at the involved limb. The patient was asked to move slowly into knee flexion and knee extension with a heel slide exercise, continuing to look at the reflection and imagine that they are moving the involved limb. Patients performed three sets of 10 repetitions with a brief break in between sets. If the subject stopped looking in the mirror during the set, they were kindly reminded to watch the limb in the mirror and imagine that it is the involved limb.

### Outcomes

Prior to formal pre- and post-intervention measures, patients were asked to complete a demographics questionnaire, with no identifiable information being collected. Demographic information included age, gender, involved limb (left or right), days of hospitalization, days of sub-acute rehabilitation, if they

***Figure 1.*** *Example of mirror therapy for knee pain and limited ROM*

received home-health physical therapy and days postoperative Formal measures done only once prior to intervention to describe the cohort included:

## Outcomes

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- **Disability (Lower Extremity Functional Scale – LEFS)**: The lower extremity functional scale (LEFS) is a 20-item valid patient-rated outcome measure for measuring lower extremity function for adults. The questionnaire rates several functional tasks from "Extreme Difficulty" to "No Difficulty." The maximum score is 80 points. The higher the score, the higher the function.
- **Kinesiophobia (Tampa Scale of Kinesiophobia – TSK):** To evaluate the participant's pain-related fear of movement and (re)injury the original 17-item Tampa Scale of Kinesiophobia (TSK) was used [26,27]. Each item is scored on a four-point Likert-type scale that ranges from strongly agree [1] to strongly disagree [4]. Total scores range from 17 to 68, and higher scores indicate more fear of movement and/or (re)injury.
- **Central Sensitization (Central Sensitization Inventory – CSI):** The CSI includes 25 questions related to central sensitization. The individual scores each item on a scale of 0 (never) to 4 (always). If the total score is greater than 40, this is considered to indicate the presence of CS [28-30]. The CSI is considered a useful and valid measure to screen for patients with CS. It is reported to have strong test-retest reliability as well [28,29]. The internal consistency of the CSI is excellent, with Cronbach's a value ranging from 0.87 to 0.91, and test-re-test reliability has been found to be high [31,32]. Scores obtained with the CSI showed concurrent validity with a range of relevant measures, including measures of resilience and negative affect, anxiety, pain catastrophizing, duration and severity of pain, lateralization of pain [33,34].

Prior to, and immediately following intervention a series of measures were taken to assess the efficacy of the proposed mirror therapy intervention:

- **Self-reported pain rating (Numeric Pain Rating Scale – NPRS):** Knee pain was measured using an NPRS, as it has been used in various musculoskeletal pain studies [35-37]. The minimal clinical important difference (MCID) for the NPRS for the lower extremity is reported to be 3 [38].
- **Active knee flexion:** Active knee flexion ROM was assessed by another therapist with a standard goniometer with the patient in a supine position. To ensure consistency of pre- and post-treatment measurements, skin marks were placed for the goniometric measurements. There is good evidence for the reliability and validity of goniometric knee ROM measurements [39]. The MDC for knee pain is reported to vary between 3-5 degrees, while the MCID is reported at 10 degrees [40,41].
- **Nerve Sensitivity (Pressure Pain Thresholds -PPT):** To assess the sensitivity of the nervous system, pressure algometry was used. PPT followed standardized protocols [42,43] and was measured in kilograms (kg) using a pressure-pain algometer at:
  - Web space of the dominant hand
  - Posterior midline of the knee with a TKA
  - Dominant arm upper trapezius

In knee OA, the MDC for PPT has been reported as 3.44 kg and the standard error of measurement as 1.49 kg [44].

## Statistical analysis

Upon completion of the study, participant intake forms from pre- and post-intervention were collected for analysis. There was no attrition during the study and all participants were accounted for in post-treatment analysis. Summary statistics were generated for a wholistic viewpoint of the study sample. Two primary forms of analysis were used: (1) a series of student's paired, one-sample t-tests with df = 17 were used to test for significant differences in Self-reported Pain Rating, Active Knee Flexion, and Nerve Sensitivity, and (2) count data was generated to examine the proportion of the study sample who achieved either MDC or MCID. A pre-defined significance level of a = 0.05 was used in this study for all analyses. Post-hoc power analysis showed that with n = 18, a = 0.05, and effect size of 0.8. The results of the paired, one-sample t-tests yielded power at 0.892, suggesting that the results of these tests can be reasonably generalized to a larger population which is demographically like the study sample.

# Provisional Results

The authors have no conflicts of interest to declare.

## Patients

Eighteen patients following knee arthroplasty participated in the study (Table 1).

***Table 1.*** *Patient demographics*

| Characteristic | Patients (n = 18) |
|---|---|
| Female (%) | 9 (50) |
| Mean age - years (range) | 65.94 (47-83) |
| Left leg surgery | 11 (61.1%) |
| Mean days of hospitalization | 0.78 |
| Mean days of sub-acute rehabilitation | 0.72 |
| Received home health physical therapy (%) | 1 (5.6%) |
| Days since surgery | 7.83 |
| Mean Tampa Scale of Kinesiophobia<br>— Exceed high score cut off (>37) (%) | 37.5<br>8 (44.4) |
| Mean Central Sensitization Inventory<br>— Exceed high score cut off (≥ 40) (%) | 29<br>3 (16.7) |
| Mean Lower Extremity Functional Scale | 19.5 |

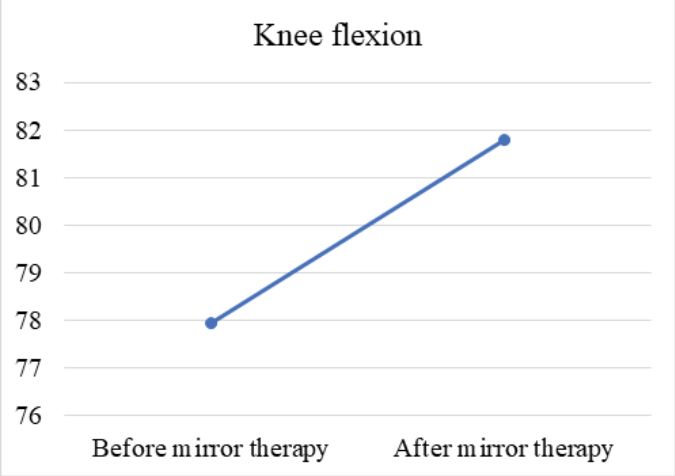


***Figure 2.*** *Knee flexion active ROM before and after mirror therapy*

## Knee range of motion

Immediately following mirror therapy, mean knee flexion improved by 3.84 degrees (p = 0.001), which is within the range for MDC, but failed to reach MCID (Figure 2). Ten patients (55.6%) knee flexion improved beyond MDC after mirror therapy, while three patients (16.7%) met the MCID of 10 degrees flexion improvement.

## Self-reported pain rating

Mean self-reported pain rating before mirror therapy was 3.97. Immediately following mirror therapy, self-reported pain improved to a mean score of 3.28 but failed to reach significance (p = 0.08). Three patients (16.7%) did meet the MCID for acute pain following mirror therapy.

## Pressure pain thresholds

Immediately following mirror therapy, PPT measurements failed to reach any significant changes on the involved knee (p = 0.95), uninvolved knee (p = 0.21) and remote/upper trapezius site (p = 0.23).

# Discussion

The results of this study show that mirror therapy immediately following TKA may have some benefit in improving ROM, but not pain or sensitivity of the nervous system. This is the first study exploring the immediate effects of mirror therapy in postoperative TKA.

The main positive finding from this study shows that a brief postoperative mirror therapy session can positively influence active knee flexion ROM. This immediate shift in active ROM after mirror therapy concurs with the shoulder study by Louw, et. al., of which nearly half (49.3%) of the subjects were postoperative [25]. Numerous studies have been undertaken to predict outcomes of TKA, including various preoperative and postoperative measurements, including knee ROM. Knee ROM in the perioperative period (preoperative > postoperative) has been shown to be a predictor of recovery following TKA, which underscores the potential value of this pilot study [45-48]. In this study nearly half of the attendees presented with kinesiophobia scores above the cut-off, which has been shown to negatively impact outcomes and rehabilitation [8,27]. This

study did not set out to see if mirror therapy positively change kinesiophobia or fear-avoidance, but with the immediate shift on active knee flexion ROM it can be argued that this novel, brief and non-threatening (moving the uninvolved side) therapy may have potential benefit for patients following TKA, especially those who are fear-avoidant.

The result from this study concurs with the growing evidence supporting the notion of subgrouping of patients attending rehabilitation. In this study, a sub-group of patients exhibited high levels of kinesiophobia and CSI scores indicative of potential presence of central sensitization. The results showed that mean active knee flexion ROM was significantly improved, and a sub-group met the MDC and MCID for knee active flexion ROM. Additionally, a sub-group of patients met the MCID for self-reported knee pain. In contrast to the previous shoulder study using mirror therapy, which showed significant reduction in pain after mirror therapy, it is worth noting this cohort was seen in therapy approximately 8 days after surgery (acute phase), whereas the shoulder cohort mean duration of pain was 28 months with a large range from acute to chronic [25]. This difference in self-reported pain after mirror therapy in different phases (acute, sub-acute and chronic) and surgical versus non-surgical patients should be further explored. Mirror therapy, as part of graded motor imagery, is designed primarily as an intervention for more complex patient cases, i.e., hyperalgesia, allodynia, fear-avoidant, etc. The reduction in pain for a sub-group tie into emerging evidence for mirror therapy to yield a positive influence on self-reported pain in complex clinical conditions [49,50]. Also of interest is that mirror therapy is often associated with neuropathic conditions [49,50], whereas the results from this study fuel the speculation along with other studies that treatments such as mirror therapy may have potential benefit in nociceptive-dominant orthopedic cases as well [25].

The overall results indicate that mirror therapy has no effect on the sensitivity of the nervous system after TKA, as measured by PPT. This result was surprising, since it has been proposed that mirror therapy (as part of graded motor imagery) aims to normalize altered cortical maps of body parts which have been tied to increased sensitization [19,20,49]. To date, very little information is available on mirror therapy improving pressure pain thresholds on the affected and remote areas. This may be due to the fact that the majority of mirror therapy research typically focus on complex neuropathic conditions such as complex regional pain syndrome or phantom limb pain, which often presents with allodynia, which prohibits pressure algometry in the area and is usually in the chronic phase, versus this study's acute, postoperative period. Future studies will need to further explore the use of PPT in mirror therapy and graded motor imagery in postoperative pain.

This study contains various limitations. First, the case series design is commonly used in exploratory studies, but the results are limited given there is no control group for comparison purposes. Second, the outcomes were only measured immediately following intervention with no intermediate or long-term follow-up, which is needed to determine true efficacy of the intervention. Third, very little is known about the optimal dosage for mirror therapy. This study utilized a short, brief intervention and it is not known if it was optimal – future studies should explore this further. Finally, this study may have yielded more insightful results if the sample consisted of patients only with high levels of kensiophobia, clinical presence of central sensitization and abnormal PPT scores.

## Conclusion

Mirror therapy in the immediate postoperative period is able to improve active knee flexion ROM in TKA, with little effect on self-reported pain and nerve sensitivity. Future studies should explore mirror therapy post-TKA with more robust trials including long-term outcomes.

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