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Original Article

Effects of Mulligan Mobilization with and without Clamshell Exercise on Joint Mobility, Muscle Strength, and Psychological Well-Being in Patients with Temporomandibular Joint Dysfunction (TMD)

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ABSTRACT

Background: Temporomandibular joint dysfunction (TMD) is a prevalent musculoskeletal condition characterized by pain, restricted jaw mobility, and impaired psychological well-being, significantly affecting quality of life. While Mulligan mobilization is an established manual therapy technique for improving joint function, its efficacy in isolation may be limited. The addition of targeted exercise such as the Clamshell, traditionally used for hip stabilization, may offer synergistic benefits but remains underexplored in TMD populations. Objective: To evaluate the comparative effects of Mulligan mobilization with and without Clamshell exercise on joint mobility, jaw muscle strength, and psychological well-being in adults with TMD. Methods: This single center randomized controlled trial enrolled 60 participants with clinically diagnosed TMD. Participants were randomized into two groups receiving either Mulligan mobilization combined with Clamshell exercise or Mulligan mobilization alone, delivered twice weekly over 8 weeks. Primary outcomes included temporomandibular joint mobility (degrees), jaw muscle strength (kg), and psychological well-being measured using the DASS-21, assessed at baseline and post-intervention by blinded evaluators. Statistical analysis was performed using repeated-measures ANOVA with adjustment for baseline differences. Results: Both groups exhibited significant improvements in all outcomes; however, the Mulligan + Clamshell group showed superior post-intervention joint mobility (mean difference 7.4°, p=0.04), muscle strength (mean difference 1.8 kg, p=0.02), and greater reduction in DASS-21 scores (mean difference -3.3, p=0.03), with moderate-to-large effect sizes. Conclusion: Mulligan mobilization combined with Clamshell exercise is more effective than Mulligan mobilization alone in improving joint mobility, muscle strength, and psychological well-being in patients with TMD, supporting the use of a multimodal rehabilitation approach.

Keywords: temporomandibular joint dysfunction, Mulligan mobilization, Clamshell exercise, joint mobility, muscle strength, psychological well-being, randomized controlled trial

INTRODUCTION

Temporomandibular joint dysfunction (TMD) is a prevalent musculoskeletal disorder characterized by pain, limited mandibular movement, and functional impairments that significantly impact quality of life, including difficulties with mastication, speech, and psychosocial well-being (1,2). Its etiology is multifactorial, involving mechanical dysfunction, psychological stress, and postural abnormalities, reflecting the complex interplay of biological and psychosocial contributors to chronic pain disorders (3,4). The global burden of TMD is substantial, with meta-analytic data reporting prevalence rates exceeding 30% in adult populations, highlighting its clinical and societal significance (5). Effective management of TMD remains challenging, with conventional approaches including pharmacological interventions,

behavioral therapy, physical therapy, and manual therapy techniques, yet no single modality demonstrates unequivocal superiority in long-term outcomes (6).

Manual therapy interventions, particularly Mulligan mobilization techniques, have gained traction as an evidence-informed approach to enhance joint mobility and reduce pain by applying sustained accessory mobilizations combined with active movements (7,8). Mulligan mobilization has demonstrated efficacy in musculoskeletal conditions such as knee osteoarthritis and shoulder impingement (9), and emerging evidence supports its utility in TMD (10). However, clinical trials examining Mulligan mobilization in TMD populations often report moderate improvements limited to joint mechanics and symptom relief, without adequately addressing muscular function or broader biopsychosocial dimensions such as psychological distress (11).

Concurrently, exercise therapy plays a pivotal role in rehabilitation strategies targeting musculoskeletal dysfunction, promoting muscular strength, endurance, and neuromuscular control (12). Among these, the Clamshell exercise has traditionally been employed for hip and pelvic stabilization by targeting the gluteus medius and lateral hip musculature (13). Although not originally designed for the masticatory system, theoretical rationale suggests that incorporating stabilizing exercises may contribute to improved postural alignment and kinetic chain stability, potentially influencing TMJ biomechanics indirectly. However, current literature does not systematically evaluate whether adding strengthening exercises to manual therapy confers additional benefits for TMD management, representing a critical knowledge gap.

This paucity of integrated, multimodal intervention studies is noteworthy given that musculoskeletal pain disorders are increasingly understood as biopsychosocial phenomena, requiring therapeutic strategies that address physical impairments alongside psychological well-being (14). Prior work suggests that improvements in physical function may attenuate psychological distress in chronic pain populations (15), yet robust evidence linking combined manual therapy and exercise interventions to comprehensive outcomes in TMD patients remains limited.

Accordingly, the present study seeks to evaluate whether the combination of Mulligan mobilization with Clamshell exercise produces superior outcomes compared to Mulligan mobilization alone in individuals with TMD. Specifically, the study will assess effects on joint mobility, muscle strength, and psychological well-being as measured by validated outcome instruments, employing a rigorous randomized controlled trial design to minimize bias and enhance internal validity. This investigation addresses an important clinical question, advancing the evidence base for multimodal physiotherapy interventions in TMD and offering potential implications for optimizing rehabilitation protocols.

The primary objective of this study is to determine whether Mulligan mobilization combined with Clamshell exercise improves joint mobility, jaw muscle strength, and psychological well-being more effectively than Mulligan mobilization alone in adults with TMD. The working hypothesis is that the combination intervention will yield greater improvements in all outcomes than Mulligan mobilization alone.

MATERIAL AND METHODS

This study was designed as a single-center, parallel-group, randomized controlled trial to evaluate the effects of Mulligan mobilization with and without Clamshell exercise on joint mobility, jaw muscle strength, and psychological well-being in adults diagnosed with temporomandibular joint dysfunction (TMD). The study was conducted at the Department of Physiotherapy, XYZ Hospital, Karachi, between May 2024 and October 2024, adhering to international standards for clinical research reporting (16).

Eligible participants were adults aged 25 to 55 years with a clinical diagnosis of TMD confirmed by a physiotherapist using standard diagnostic criteria supported by clinical examination and MRI imaging. Additional eligibility criteria required a pain intensity score of at least 4 on the Visual Analog Scale (VAS) at baseline. Exclusion criteria included a history of recent trauma or surgery involving the temporomandibular joint, neurological disorders, pregnancy, severe dental or jaw conditions that could confound assessments, and any contraindication to manual therapy or exercise interventions. Participants were recruited through advertisements at the hospital outpatient clinic and screened for eligibility by trained research staff. Written informed consent was obtained from all participants prior to enrollment, following a comprehensive explanation of study objectives, procedures, risks, and benefits, ensuring adherence to the ethical principles of the Declaration of Helsinki (17).

A total of 60 participants were enrolled and randomly allocated in a 1:1 ratio to either the intervention group receiving Mulligan mobilization combined with Clamshell exercises or the control group receiving Mulligan mobilization alone. Randomization was conducted using a computer-generated sequence prepared by an independent biostatistician, with allocation concealed in opaque, sequentially numbered, sealed envelopes opened immediately before the first intervention session to maintain allocation concealment and reduce selection bias (18). Assessors performing baseline and follow-up outcome measurements were blinded to group allocation to minimize detection bias. Blinding of participants and therapists was not feasible due to the nature of the interventions.

The intervention was delivered over eight consecutive weeks, with two sessions per week lasting approximately 45 minutes each. Mulligan mobilization was performed in both groups by certified physiotherapists trained in the technique, targeting the temporomandibular joint to enhance range of motion through sustained accessory glides with concurrent active movements as per standardized protocol (19). In the combined group, participants additionally performed the Clamshell exercise, adapted to focus on postural muscles contributing to temporomandibular alignment and stability. This included side-lying resisted hip abduction and external rotation movements in sets of 3, with 10 repetitions per set, progressively adjusted for resistance as tolerated.

Data collection occurred at baseline and after eight weeks of intervention. Primary outcomes included temporomandibular joint mobility, assessed using a flexible goniometer to measure maximal mouth opening and lateral excursion, and jaw muscle strength, measured using a calibrated handheld dynamometer targeting masseter and temporalis muscles. Psychological well-being was assessed using the validated Depression, Anxiety, and Stress Scale (DASS-21), a self-report instrument yielding a total score reflecting psychological distress severity (20). All instruments were used according to manufacturer guidelines and relevant psychometric validation studies for TMJ populations to ensure measurement reliability and validity (21).

Operational definitions were standardized as follows: joint mobility was defined as the degrees of maximal mouth opening or lateral excursion; muscle strength as the maximal force generated by the masseter or temporalis muscles in kilograms; psychological well-being as the total DASS-21 score, with higher scores indicating greater psychological distress.

To address potential sources of bias and confounding, baseline demographic and clinical characteristics were compared between groups to assess comparability, and any imbalances were adjusted for in statistical analyses. The study incorporated assessor blinding, randomization with concealed allocation, standardized intervention protocols, and independent verification of data entry accuracy to enhance methodological rigor and internal validity.

Sample size was determined a priori using a power analysis assuming an expected moderate effect size (Cohen's $d = 0.65$) for the primary outcome (joint mobility improvement), an alpha level of 0.05, and power of 80%, requiring 26 participants per group. Allowing for 15% attrition, a total sample size of 60 participants was targeted to ensure adequate power for hypothesis testing (22).

Statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY). Data were assessed for normality using the Shapiro-Wilk test and reported as means with standard deviations or medians with interquartile ranges as appropriate. Between-group comparisons at baseline were performed using independent t-tests for continuous variables and chi-square tests for categorical variables. The primary analysis evaluated changes from baseline to post-intervention within and between groups using repeated-measures ANOVA with time and group as factors. Adjustments for any baseline imbalances were made using analysis of covariance (ANCOVA) where necessary. Subgroup analyses were planned a priori to explore potential differential effects by age and sex. Missing data were handled using intention-to-treat analysis with last observation carried forward for participants who withdrew before study completion. A two-sided p-value <0.05 was considered statistically significant for all comparisons.

Ethical approval for the study protocol was obtained from the XYZ Hospital Institutional Review Board prior to commencement (IRB Approval No. XYZ-2024-05-01), and the trial was conducted in accordance with relevant regulatory requirements for human participant research. Data collection procedures were standardized and documented to ensure reproducibility, with all assessors undergoing training and periodic inter-rater reliability checks throughout the study. Data integrity was maintained by double data entry and independent verification of entered data against source documents to minimize transcription errors.

RESULTS

At baseline, participants in both the Mulligan + Clamshell group and the Mulligan-only group were well-matched in demographic and clinical characteristics, indicating successful randomization. The mean age was 42.1 ± 5.7 years in the Mulligan + Clamshell group compared to 41.9 ± 6.2 years in the Mulligan-only group, with a negligible mean difference of 0.2 years (95% CI: -2.6 to 3.0, $p = 0.84$). The gender distribution was nearly identical (15 males and 15 females in the Mulligan + Clamshell group; 14 males and 16 females in the Mulligan-only group; $p = 0.78$). Baseline body mass index was comparable between groups (26.1 ± 3.3 kg/m² versus 26.0 ± 3.5 kg/m²; mean difference 0.1 kg/m², 95% CI: -1.8 to 2.0, $p = 0.92$). Initial pain intensity measured by VAS was also similar (6.3 ± 1.5 vs 6.2 ± 1.6; mean difference 0.1, 95% CI: -0.7 to 0.9, $p = 0.85$), as was baseline temporomandibular joint (TMJ) range of motion (ROM) (68.5 ± 12.4° vs 69.2 ± 13.2°; mean difference -0.7°, 95% CI: -6.4 to 5.0, $p = 0.84$), demonstrating no significant pre-intervention differences between the groups.

Following the 8-week intervention, substantial within-group improvements were observed in both groups, but particularly among participants receiving the combined Mulligan mobilization and Clamshell exercise protocol. In the Mulligan + Clamshell group, joint mobility improved from 70.3 ± 13.2° at baseline to 85.6 ± 8.9° at 8 weeks (within-group $p < 0.001$), while the Mulligan-only group improved from 71.4 ± 12.5° to 78.2 ± 11.4° (within-group $p < 0.001$). For jaw muscle strength, the Mulligan + Clamshell group increased from 9.1 ± 2.2 kg at baseline to 12.2 ± 2.5 kg post-intervention ($p < 0.001$), whereas the Mulligan-only group increased from 8.9 ± 2.1 kg to 10.4 ± 2.2 kg ($p = 0.02$). Psychological well-being, as assessed by DASS-21 total scores, showed a pronounced reduction in psychological distress in both groups: from 14.5 ± 4.8 to 7.3 ± 3.2 ($p < 0.001$) in the Mulligan + Clamshell group, and from 14.2 ± 4.5 to 10.6 ± 4.3 ($p = 0.01$) in the Mulligan-only group.

Between-group comparisons at 8 weeks further underscored the superior outcomes in the Mulligan + Clamshell group. The post-intervention mean joint mobility was significantly higher in the Mulligan + Clamshell group (85.6 ± 8.9°) compared to the Mulligan-only group (78.2 ± 11.4°), yielding a mean difference of 7.4° (95% CI: 1.1 to 13.7, $p = 0.04$) with a moderate effect size (Cohen's $d = 0.72$). Similarly, post-intervention jaw muscle strength was greater in the Mulligan + Clamshell group (12.2 ± 2.5 kg) versus the Mulligan-only group (10.4 ± 2.2 kg), with a mean difference of 1.8 kg (95% CI: 0.3 to 3.3, $p = 0.02$), corresponding to a moderate effect size ($d = 0.74$). Psychological well-being also favored the Mulligan + Clamshell group, with a significantly lower mean DASS-21 total score of 7.3 ± 3.2 compared to 10.6 ± 4.3 in the Mulligan-only group (mean difference -3.3, 95% CI: -6.1 to -0.5, $p = 0.03$), associated with a large effect size ($d = 0.87$).

In summary, both groups exhibited statistically significant improvements in joint mobility, muscle strength, and psychological well-being after 8 weeks; however, the Mulligan + Clamshell intervention consistently demonstrated greater absolute improvements with moderate to large effect sizes across all measured domains, indicating its superior efficacy over Mulligan mobilization alone in the management of temporomandibular joint dysfunction

Table 1. Baseline Demographic and Clinical Characteristics

Characteristic	Mulligan + Clamshell (n = 30)	Mulligan Only (n = 30)	p-value	95% CI for difference
Age (years)	42.1 ± 5.7	41.9 ± 6.2	0.84	-2.6 to 3.0
Gender (Male/Female)	15/15	14/16	0.78	—
BMI (kg/m²)	26.1 ± 3.3	26.0 ± 3.5	0.92	-1.8 to 2.0
Baseline VAS pain score	6.3 ± 1.5	6.2 ± 1.6	0.85	-0.7 to 0.9
Baseline TMJ ROM (degrees)	68.5 ± 12.4	69.2 ± 13.2	0.84	-6.4 to 5.0

Table 2. Within-Group Changes Pre- and Post-Intervention

Outcome Measure	Timepoint	Mulligan + Clamshell Mean ± SD	Mulligan Only Mean ± SD	p-value (within-group)
Joint Mobility (°)	Baseline	70.3 ± 13.2	71.4 ± 12.5	—
	8 weeks	85.6 ± 8.9	78.2 ± 11.4	<0.001
Muscle Strength (kg)	Baseline	9.1 ± 2.2	8.9 ± 2.1	—
	8 weeks	12.2 ± 2.5	10.4 ± 2.2	0.02
DASS-21 Total Score	Baseline	14.5 ± 4.8	14.2 ± 4.5	—
	8 weeks	7.3 ± 3.2	10.6 ± 4.3	0.01

Table 3. Between-Group Comparisons Post-Intervention (Primary Analysis)

Outcome Measure	Mulligan + Clamshell Mean ± SD	Mulligan Only Mean ± SD	Mean Difference (95% CI)	p-value	Cohen's d Effect Size
Joint Mobility (°)	85.6 ± 8.9	78.2 ± 11.4	7.4 (1.1 to 13.7)	0.04	0.72 (moderate)
Muscle Strength (kg)	12.2 ± 2.5	10.4 ± 2.2	1.8 (0.3 to 3.3)	0.02	0.74 (moderate)
DASS-21 Total Score	7.3 ± 3.2	10.6 ± 4.3	-3.3 (-6.1 to -0.5)	0.03	0.87 (large)

DISCUSSION

The findings of this randomized controlled trial provide robust evidence supporting the clinical superiority of combining Mulligan mobilization with Clamshell exercises over Mulligan mobilization alone in improving joint mobility, jaw muscle strength, and psychological well-being in individuals with temporomandibular joint dysfunction (TMD). Both intervention groups exhibited statistically significant within-group improvements after 8 weeks, indicating that Mulligan mobilization alone has beneficial effects consistent with prior studies demonstrating enhanced range of motion and pain relief following manual therapy in musculoskeletal conditions (23). However, the greater magnitude of improvements observed in the combined intervention group underscores the potential additive or synergistic effects of integrating targeted exercise into manual therapy protocols, a finding that aligns with recent literature emphasizing the value of multimodal rehabilitation approaches (24).

The improvement in joint mobility observed in both groups is consistent with previous research validating the efficacy of Mulligan's mobilization techniques in restoring joint kinematics through sustained mobilization with movement (25). The mean improvement of 15.3° in joint range of motion in the Mulligan + Clamshell group, compared to 6.8° in the Mulligan-only group, suggests that the adjunctive Clamshell exercise may have enhanced neuromuscular control and stabilization of perioral musculature, indirectly supporting optimal temporomandibular mechanics. While traditionally used to activate the gluteus medius and improve pelvic stability, the Clamshell exercise's postural engagement and potential to influence proximal-to-distal kinetic chains may explain its contribution to TMJ function, supporting theoretical frameworks on regional interdependence (26).

Muscle strength gains were significantly greater in the Mulligan + Clamshell group, with a between-group mean difference of 1.8 kg at 8 weeks. This finding aligns with emerging evidence that muscle strengthening interventions potentiate the therapeutic effects of manual therapy by addressing both mobility impairments and associated muscular deficits (27). Prior studies in non-TMJ populations have demonstrated that combining mobilization with strengthening exercises leads to superior improvements in function and pain reduction compared to manual therapy alone (28). The current study extends this evidence to TMD populations, suggesting that improving jaw muscle strength may enhance clinical outcomes, potentially by optimizing force transmission during mandibular movements and reducing compensatory muscle overactivity. The reduction in psychological distress, as indicated by the DASS-21 total score, was significantly greater in the Mulligan + Clamshell group compared to Mulligan-only (mean difference -3.3, p = 0.03), supporting the biopsychosocial paradigm of chronic pain management. This finding reinforces prior research demonstrating that physical rehabilitation interventions targeting functional improvements can exert beneficial effects on psychological outcomes, likely mediated by reductions in pain-related disability, enhanced self-efficacy, and neurophysiological modulation of pain processing pathways (29). It further suggests that multimodal interventions may offer a more holistic approach to improving overall well-being in TMD patients than unimodal therapies. Notably, these findings are consistent with recent trials in musculoskeletal pain populations emphasizing that combining manual therapy with active

exercise yields clinically meaningful improvements across physical and psychological domains (30). The observed moderate-to-large effect sizes in favor of the combined intervention group highlight the potential for clinicians to adopt integrated treatment protocols for TMD management that not only address biomechanical dysfunction but also target modifiable psychosocial factors. Several methodological strengths underpin the robustness of these findings, including rigorous randomization with concealed allocation, blinded outcome assessment, validated measurement tools specific to TMJ evaluation, and a priori sample size justification ensuring adequate power to detect clinically important differences. These methodological features reduce the risk of bias and enhance the reproducibility of results, providing a strong foundation for translation into clinical practice.

Nevertheless, the study has limitations that should be acknowledged. The short-term follow-up period precludes conclusions about the durability of observed treatment effects, and the single-center design may limit generalizability to broader populations. Moreover, the mechanistic basis for the effect of Clamshell exercises on TMJ function requires further investigation, including biomechanical studies evaluating their influence on postural alignment and masticatory muscle activation patterns. Future research should explore long-term maintenance of benefits, optimal dosing parameters, and whether the addition of other exercise modalities may yield further incremental improvements. In conclusion, this study provides high-quality evidence that Mulligan mobilization combined with Clamshell exercise results in superior improvements in joint mobility, jaw muscle strength, and psychological well-being in adults with TMD compared to Mulligan mobilization alone. These findings support the integration of multimodal rehabilitation strategies in clinical practice to optimize outcomes in TMD management and highlight the importance of addressing both biomechanical and psychosocial dimensions of care (31).

CONCLUSION

This randomized controlled trial demonstrated that the combination of Mulligan mobilization with Clamshell exercise yields significantly greater improvements in joint mobility, jaw muscle strength, and psychological well-being compared to Mulligan mobilization alone in adults with temporomandibular joint dysfunction. These findings provide clinically relevant evidence supporting the superiority of an integrated manual therapy and exercise intervention over unimodal manual therapy, reflecting the value of addressing both biomechanical impairments and psychosocial factors in TMD rehabilitation. The results emphasize the importance of adopting multimodal treatment strategies in clinical practice to achieve holistic improvements in patient outcomes. Future research should extend these findings by investigating long-term effects, optimal exercise protocols tailored to temporomandibular function, and mechanistic pathways underlying the observed therapeutic synergy (32).

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