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Systematic review

Efficacy of musculoskeletal manual approach in the treatment of temporomandibular joint disorder: A systematic review with meta-analysis

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ABSTRACT

Background: Temporomandibular joint disorder (TMD) requires a complex diagnostic and therapeutic approach, which usually involves a multidisciplinary management. Among these treatments, musculoskeletal manual techniques are used to improve health and healing.
Objectives: To assess the effectiveness of musculoskeletal manual approach in temporomandibular joint disorder patients.
Design: A systematic review with meta-analysis.
Methods: During August 2014 a systematic review of relevant databases (PubMed, The Cochrane Library, PEDro and ISI web of knowledge) was performed to identify controlled clinical trials without date restriction and restricted to the English language. Clinical outcomes were pain and range of motion focalized in temporomandibular joint. The mean difference (MD) or standard mean difference (SMD) with 95% confidence intervals (CIs) and overall effect size were calculated at every post treatment. The PEDro scale was used to demonstrate the quality of the included studies.
Results/findings: From the 308 articles identified by the search strategy, 8 articles met the inclusion criteria. The meta-analysis showed a significant difference ($p < 0.0001$) and large effect on active mouth opening (SMD, 0.83; 95% CI, 0.42 to 1.25) and on pain during active mouth opening (MD, 1.69; 95% CI, 1.09 to 2.30) in favor of musculoskeletal manual techniques when compared to other conservative treatments for TMD.
Conclusions: Musculoskeletal manual approaches are effective for treating TMD. In the short term, there is a larger effect regarding the latter when compared to other conservative treatments for TMD.

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1. Introduction

The temporomandibular joint (TMJ), located just anterior to the external auditory meatus, consists of upper temporalis bone and lower mandible, contains an intra-articular disk within the joint capsule, and its contractile tissue are the muscles of mastication. Collectively, anatomopathological dysfunctions of the TMJ have been defined as temporomandibular disorders (TMD) (Shaffer et al., 2014). The etiology of TMD is multidimensional, considering that neurobiological, biomechanical, neuromuscular and biopsychosocial factors may contribute to the disorder.

In the literature, treatments for TMD include patient education, home care programs, physical therapy, musculoskeletal manual approach, pharmacotherapy, nonsteroidal anti-inflammatory drugs (NSAIDs), local anesthetics, intracapsular injection of corticosteroids, muscle relaxants, antidepressants, occlusal appliance therapy, occlusal adjustment and surgical care (only indicated when non-surgical therapy has been ineffective) (Romero-Reyes and Uyanik, 2014). However, the multifactorial pathophysiology of TMJ related pain is far from being completely understood and effective management of pain has not been established yet (Lin, 2014). In addition to pain, which may be located on head, neck and face, symptoms of TMD may include limitations or deviations of mandibular movement and joint sounds with or without pain (i.e. clicks, crackles and/or tinnitus) (Kalamir et al., 2010).

Regarding conservative, non-medical and non-dental treatments, the musculoskeletal manual approaches (MMA) are noted for their impact on biological tissues involving biomechanical and neurophysiological effects (Bialosky et al., 2009, 2012). According to the Medical Subject Headings (MeSH) of the United States National Library of Medicine (NLM), Musculoskeletal Manual Approaches (MMA) are various manipulations of body tissues, muscles and bones by hands or equipment in order to improve health and circulation, relieve fatigue and promote healing. Currently, evidence suggests that MMA is effective in the treatment of musculoskeletal pain in a variety of movement disorders in spine, head and in upper and lower limbs (Licciardone et al., 2005; Chaibi et al., 2011; Slater et al., 2012; Coronado et al., 2012; Hurwitz, 2012; Brantingham et al., 2012).

The MMA for the management of TMD has also received attention from several studies. An advanced electronic search (without additional filters) in the NLM, using the key words "musculoskeletal manipulations" and "temporomandibular disorders", showed the existence of 151 articles related to the topics. Considering the evidence of this association, specifically investigated by systematic reviews, it is possible to find in an electronic search three articles: two of them (Medlicott and Harris, 2006; McNeely et al., 2006) were conducted to analyze the effectiveness of various physical therapy modalities in TMD and another one to analyze the effectiveness of manipulative and multimodal therapy (chiropractic, osteopathic, orthopedic, physical therapies) in TMD (Brantingham et al., 2013). In the review of McNeely et al. (2006) just one randomized clinical trial (RCT) provided evidence for the use of manual approach combined with active exercises to reduce pain and improve mouth opening. Medlicott and Harris (2006) recommended that active exercises and manual mobilizations or combinations of active exercises, manual therapy, postural correction, and relaxation techniques may be effective for TMD treatment. Considering the findings of these two systematic reviews that support essentially the combination of MMA with other physical therapy methods to produce favorable outcomes in TMD, the real effectiveness of different types of MMA in TMD remains unclear. However, the study of Brantingham et al. (2013), which included four RCTs on the effectiveness of MMA in TMD, reported fair levels of evidence (B) in the short term. Despite the fact that this study correctly investigated the impact of MMA on clinical improvement of TMD, no robust conclusions could be reached because of the absence of meta-analysis on this topic.

Thus, considering this context, the aim of this current systematic review and meta-analysis was to analyze the effectiveness of MMA in TMD patients and compare them to control treatments in randomized clinical trials (RCTs).

2. Materials and methods

This review was registered in PROSPERO, an international prospective register of systematic review (available at http://www.crd.york.ac.uk/PROSPERO/) under the number: CRD42015017585.

2.1. Search methods for identifying studies

Four databases (PubMed, The Cochrane Library, PEDro and ISI Web of Knowledge) were carefully examined, and the descriptors were obtained from the Medical Subject Headings (MeSH) of the NLM. The following key words in the English language were combined (by a minimum of two descriptors) for the search: Temporomandibular Joint Disorders, Temporomandibular Disorders, Temporomandibular Joint Disease, TMJ Disorders, TMJ Diseases, Musculoskeletal Manipulations, Manual Therapy, Manipulation Therapy, Manipulative Therapy. The literature review was performed in August 2014.

2.2. Selection criteria

Only RCTs in the English language were included in order to investigate the effect of different MMA techniques on the treatment of TMD, on individuals regardless of age and gender. What were considered as MMA techniques were any manipulations of body tissues, muscles and bones by hands to improve healing of the craniocervical mandibular system. The following exclusion criteria were considered: studies in which patients had a history of surgical intervention at the TMJ or interventions in which the MMA was used combined with other therapeutic resources with inadequate control comparisons (e.g. MMA and exercises vs splint therapy vs. control waiting list). The inclusion criteria were decided by consensus between the two reviewers.

2.3. Selection of studies

Two authors independently scanned titles and abstracts of the results identified by the search strategy. After that, a full text reading was done to the potentially eligible studies. Disagreements were resolved by consensus between two reviewers. The reference list of the selected articles was consulted to find possible additional studies. The duplicate items identified after searching the databases were removed.

2.4. Types of comparisons

Studies with active (e.g., home exercise, massage, usual care, sham treatment, splint therapy) and passive (e.g., no intervention, waiting list) interventions were included in this review. Therefore, the procedure of meta-analysis the MMA intervention was compared only with active control groups and not with untreated control groups.

2.5. Primary outcomes

The primary outcomes were pain and range of motion (ROM). The pain was measured by a number rating scale (NRS) for active and passive mouth opening. Studies have assessed active and passive ROM of mouth opening using the interincisal distance. For the meta-analysis, the outcome measures were closest to the last time point measurement, even if studies have used various time point measurements. So, the last post intervention measurement was chosen to the analysis.

2.6. Data extraction

The main characteristics of the studies were obtained through information about the study details (authors, year, country and aims of the study), subjects (sample size, gender, type of sample), interventional details (groups, duration, frequency and modality) and conclusion (outcome and author's conclusion). The data extraction was completed after the generation of a single shortlist of the papers included in the review.

2.7. Methodological quality assessment

The methodological quality of the identified RCTs was scored using the PEDro scale. The PEDro scale consists of 11 criteria (random allocation; concealed allocation; baseline comparability; blind subjects; blind therapists; blind assessor; adequate follow up; intention-to-treat-analysis; between groups comparisons; point estimates and variability), which receive either a "yes", or "no" rating. As criterium 1 is not used in the calculation, the maximum PEDro score is 10 points. Trials with a PEDro score ≥6 points were classified as of high-quality, while trials with a PEDro score <6 points were classified as low-quality. Two authors independently assessed the studies selected according to the Brazilian–Portuguese version of the PEDro scale (available at http://www.pedro.org.au).

2.8. Statistical analysis

The articles included in this review investigated the effectiveness of MMA for relieving pain and ROM in TMD by using continuous dependent variables. Therefore, when the results were properly described, the values were added into a database. In the case of inadequate information about the primary outcomes, the authors of the studies were contacted and additional information was requested. Standardized Mean Difference (SMD) and 95% of the Confidence Intervals (CI) were calculated for ROM and pooled together using a random effects model. Mean Difference (MD) and 95% of the Confidence Intervals (CI) were calculated for pain and pooled together using a random effects model. Assessment of clinical relevance was made using the recommendations of the Cochrane Back Review Group. Therefore, MD less than 0.1 and SMD less than 0.5 defined a small effect. A medium effect was defined as MD from 0.1 to 0.2 and SMD from 0.5 to 0.8. A large effect was considered for MD and SMD greater than 0.2 and 0.8, respectively (Furlan et al., 2009). The heterogeneity of the studies was assessed by the statistic I^2 and 95% CI. The Cochrane Collaboration provides the following interpretation of I^2: 0%–30%, might not be important; 30%–60%, may represent moderate heterogeneity; 50%–90% and 75%–100% may represent substantial and, considerable heterogeneity, respectively (Higgins et al., 2011). In order to examine for evidence of publication bias, visual inspection of Begg's funnel plots occurred. This process included the examination of scatter plots for pain and ROM against its SE. Complementarily, as formal check for publication bias, the Egger's were used. All statistical analysis were performed by using the Review Manager (RevMan® 5.3., Nordic Cochrane Center, http://ims.cochrane.org/revman) and Comprehensive Meta-analysis software (V2.0; Biostat., Englewood, New Jersey, USA, http://meta-analysis.com/index.php).

2.9. Dealing with missing data

Data required to enter into RevMan® for calculating the SMD and MD or pooled effect estimate for continuous outcomes were: (I) Mean change in variable x from baseline to follow up; (II) Standard deviation (SD) of the mean difference in variable x; (III) Number in each comparison group (n) at follow up. Unfortunately, sometimes these values have not been calculated in the source papers. So, a protocol was available for all the studies reviewed, retrieved data, tentative to contact authors for more information (when needed), calculated mean change (effect size), calculated de variance of mean change. In order to calculate the mean change in a variable from baseline to follow up, it was used: Mean difference = mean at follow up minus mean at baseline. The same process was used to calculate the mean difference in the experimental and control groups. Another data problem was the lack of SD difference measurement in the source papers. The authors who did not publish the SD difference were contacted in order to find out more information but this procedure was successful only in one study. Therefore, the variance of all articles was estimated considering the information available. For this purpose, the formula below was used to calculate the SD difference when the SD was presented for comparing groups at baseline and follow up.

Standard error (SE) difference = $\sqrt{[SD_1{}^2/n_1 + SD_2{}^2/n_2]}$; Where: SD_1 is the SD at baseline; n_1 is the n number at follow up; SD_2 is the SD at follow up; n_2 is the number at baseline.

To calculate the SD difference from the SE difference: SE = SD $\sqrt{n}$. So: SD difference = SE difference X $\sqrt{n}$.

3. Results

3.1. Included studies

The search strategy of the current review identified 308 studies. Reviewers judged fifty of them to be relevant. Out of these, 41 were excluded after reviewing their abstracts and/or full text based on the inclusion criteria and one was excluded for lack of statistical information. Finally, 8 RCTs were included in this systematic review (Fig. 1). All the included studies are presented in Table 1. The methodological quality from these studies is presented in Table 2. According to the PEDro scale, 5 studies presented a high quality level (≥6) and 3 showed low quality level (<6), with a global average of 6.

3.2. Subjects characteristics

Among the 8 studies included in this review, there were 375 individuals aged between 12 and 44.5 years old. The studies sample sizes (n) ranged between 26 and 122 individuals and size of comparison groups ranged from 13 to 41 individuals. All studies were performed with men and women allocated in the same comparison group.

3.3. Intervention and control characteristics

The duration of intervention ranged from one single session to 24 weeks (mean = 11.9 ± 8.7) at a frequency of 1–3 times per week (average = 1.6 ± 0.8). The number of MMA techniques varied from 1 to 5 (average 2.9 ± 1.2). The number of techniques/modalities from control groups ranged from 1 to 5 (average 2.5 ± 2.0). Only two studies had a control group without any intervention (Monaco et al., 2008; Oliveira-Campelo et al., 2010).

3.4. Effect of interventions

The meta-analysis showed significant results for (Shaffer et al., 2014) MMA to increase active ROM of mouth opening and

Fig. 1. Flowchart of study selection.

(Romero-Reyes and Uyanik, 2014) MMA to decrease pain during active mouth opening. On the other hand, analysis showed non-significant chances of (Shaffer et al., 2014) MMA to increase passive ROM of mouth opening ($p = 0.50$) (Ismail et al., 2007; Kalamir et al., 2010) and (Romero-Reyes and Uyanik, 2014) decrease resting pain ($p = 0.08$) (Kalamir et al., 2010; Tuncer et al., 2012). Significant results are presented in the forest plots (Figs. 2 and 3).

3.5. MMA versus control group on active ROM of mouth opening

Five studies with a total of 311 participants (Taylor et al., 1994; Ismail et al., 2007; Cuccia et al., 2009; von Piekartz and Ludtke, 2011; Tuncer et al., 2012) compare MMA with other interventions. There was a significant difference ($p < 0.0001$) and a large effect (SMD, 0.83; 95% CI, 0.42 to 1.25) in favor of MMA when compared to active control group on active ROM of mouth opening (all studies). Fig. 2 shows the forest plot comparison.

3.6. MMA versus control group on pain during active ROM of mouth opening

In this category, the pooled analysis included three studies (Cuccia et al., 2009; von Piekartz and Ludtke, 2011; Tuncer et al., 2012) and compared effects of MMA to others modalities and interventions. This results showed a significant difference ($p < 0.0001$) and large effect in favor of MMA when compared to active control group for pain outcome (MD, 1.69; 95% CI, 1.09 to 2.30). Fig. 3 shows the forest plot comparison.

3.7. Heterogeneity and publication bias

Two forest plots (Figs. 2 and 3) report the I^2 statistic due the heterogeneity of the data. There is low heterogeneity ($I^2 = 22\%$) for pain management and moderate heterogeneity ($I^2 = 40\%$) for the active mouth opening. Examination of Funnel plots (Figs. 4 and 5) demonstrated symmetry, suggesting that there was no significant publication bias. Results from Egger's test ($p = 0.72$ for ROM; $p = 0.82$ for pain) further confirmed no evidence of publication bias.

4. Discussion

The objective of the present systematic review was to establish the effectiveness of MMA in the treatment of TMD. To our knowledge, the meta-analysis procedure applied in this study is the first one to identify the real effects of MMA patients with TMD. The analysis showed that MMA increase active ROM of mouth opening and decrease pain during active mouth opening. For the analysis, the experimental group (MMA) was compared only with active controls groups. Therefore, MMA proved to be more effective than other conservative treatments of TMD.

The effects of MMA in patients with musculoskeletal pain for many years were explained within a biomechanical model (Bialosky et al., 2009). Biomechanical effects associated with MMA as motion have been quantified with joint biased MMA; however, the direct implication on clinical outcomes is questionable and only transient biomechanical effects are supported by researches that quantify motion (Bialosky et al., 2009). Although literature suggests inconsistencies regarding biomechanical effects, the results of the present study clearly showed that MMA are effective to significantly increase the active ROM of mouth opening when compared to other interventions. Regarding the techniques used in these studies, Taylor et al. (1994) demonstrated that MMA (mandibular distraction mobilization technique) is more effective than sham therapy (superficial massage) for one single session. Ismail et al. (2007) in a 12-week treatment showed the efficacy of MMA twice a week (mandibular passive traction and translation; myofascial release in jaw elevator muscle) when compared to splint therapy 24 h/day. Cuccia et al. (2009) demonstrated that 24-weeks (one session every 2 weeks) of MMA (myofascial release, muscle energy, thrust, balance membrane tension and cranial-sacral therapy) was effective when compared to oral appliance, stretching, TENS, hot or cold packs. In the study of von Piekartz and Ludtke (2011) 6 sessions (under 4–6 weeks) of MMA (accessory movements, tender-trigger point and muscle stretching) were more effective than manual therapy applied on cervical spine. Finally, Tuncer et al. (2012), in a 4-week treatment, showed the efficacy of MMA (tissue cervical and TMJ mobilization, TMJ stabilization; 3 times per week) when compared to home physical therapy (breathing exercises, relaxation techniques, posture correction, mandibular and resistance exercises).

On the other hand, the assumption that MMA is likely to increase ROM of mouth opening could not be stated for passive ROM, because analysis revealed non-significant effects in favor to MMA. In the study of Ismail et al. (2007) MMA (mandibular passive traction and translation; myofascial release in jaw elevator muscle) was not more effective than splint therapy 24 h/day for a 12-week treatment. Kalamir et al. (2010) demonstrated that MMA twice a week was not more effective than education plus self-care (one condylar cross pressure and two post-isometric relaxation exercises; twice a day; morning and night) for over 5 weeks (see the forest plot in the supplementary material). This mixed results could be attributed to the motor control regulation. To maintain the normal mandibular posture and movements, afferent information from muscle spindle is needed. In addition, brainstem interneurons have to work to assist in temporal, spatial and quantitative control aspects of jaw and muscles activity during normal orofacial behaviors. The cerebellum modifies the activity of fusimotor fibers innervating spindles and regulates the gain of the spindles in the jaw muscles (Turker, 2002). Considering the observations, it may be stated the close relationship of functional neurological integration

Table 1
Overview of included studies.

Author, year and country	Aim of the study	Sample size (n)	Age (years)	Gender	Groups	Duration (weeks)	Frequency	Intervention	Outcome measure	Author's conclusion
Taylor et al. (1994) Australia	Evaluate the effects of DMT on mandibular ROM and masseter muscle tone in patients with TMD.	MMA = 15 CG = 15	20–35 (only this single description)	Male Female	MMA = DMT CG = Sham	Single session	Single session	MM = DMT CG = Sham superficial massage.	EMG on masseter muscle, MMO and lateral glide	MMA was effective in increasing the mandibular ROM and in decreasing masseter muscle activity.
Ismail et al. (2007) Germany	Evaluate efficacy of PT in addition to ST on treatment in TMD.	MMA = 13 CG = 13	44.5 (14.1) 41 (16.5)	Male Female	MMA = ST plus PT CG = ST	12	MM = PT twice a week. CG = ST 24 hs/day.	MM = passive traction and translation movements, massage in jaw elevator muscle.	Active and passive MMO; VAS and MPMM	MMA gave a supplementary improvement of MPMM and in VAS
Monaco et al. (2008) Italy	Evaluate OMT on mandibular kinematics in TMD.	MMA = 14 CG = 14	12 (SD ND) 12 (SD ND)	Male Female	MMA = OMT CG = without intervention	MM = 8 CG = 24	ND	OMT = ND	MMO, MOV, MCV, OVA, CVA.	MMA showed a significant improvement in MMO and MOV when compared to CG.
Cuccia et al. (2009) Italy	Evaluate the effects of OMT in alleviating symptoms in TMD.	MMA = 25 CG = 25	40.6 (11.03) 38.4 (15.33)	Male Female	MMA = OMT CG = CCT	24	1 session every 2 weeks	MM = OMT (Myofascial release, muscle energy, thrust, balance membrane tension and cranial-sacral therapy. CCT = oral appliance, stretching and relaxing, TENS, hot or cold packs.	MMO, cervical ROM, VAS.	Reduction in pain and improved ROM were reported in both groups.
Oliveira Campelo et al. (2010) Portugal	Acute effects on PPT over trigger points in masseter and temporalis muscles and MO.	MMA1 = 41 MMA2 = 41 CG = 40	MM1 = 21 (Romero-Reyes and Uyanik, 2014) MM2 = 21 (Lin, 2014) CG = 20 (Romero-Reyes and Uyanik, 2014)	Male Female	MM1 = OMT MM2 = OMT CG = without intervention	Single session	Single session	MMA1 = OMT Atlanto-occipital thrust. MMA2 = OMT Suboccipital soft tissue CG = without intervention.	PPT and active MMO.	OMT produced immediate increase in PPTs over TrPs and increased in MMO.
Kalamir et al. (2010) Australia	Comparison of the effects of Intra-oral Myofascial Therapies (IMT) and IMT in addition to SCE and Control Group.	MMA1 = 10 MMA2 = 10 CG = 10	MM1 = 29.7 (8.3) MM2 = 37.3 (9.0) CG = 33 (7.4)	Male Female	MMA1 = IMT MMA2 = IMT plus SCE. CG Wainting list.	5	Twice/ week	MMA1 = IMT of temporalis, pterygoid, sphenopalatine ganglion. MMA2 = IMT plus SCE condylar pressure and post-isometric relaxation.	Pain at Resting, opening and clenching; MMO.	IMT alone or in addition of SCE can produce benefit in chronic TMD over the short – medium term
Von Piekartz and Ludtke (2011) Germany	Evaluate the effects of additional orofacial PT in comparison with the CG.	MMA = 22 CG = 21	MMA = 34.7 (7.1) CG = 36.1 (6.5)	Male Female	MMA = UC plus manual therapy on TMJ CG = UC	4 to 6	6 sessions	MMA = Accessory movements, tender-trigger point and muscle stretching. UC = manual therapy on cervical region	VAS; Mandibular deviation, MMO and PPT.	Treatment of temporomandibular region has beneficial effects with cervicogenic headaches, even in the long-term.
Tuncer et al. (2012) Turkey	Effectiveness of HPT alone with that of Manual Therapy in conjunction with HPT in TMD	MMA = 20 CG = 20	MMA = 37.0 (14.6) CG = 34.8 (12.4)	Male Female	MMA = manual therapy plus HPT CG = HPT	4	3 times/ week	MMA = Tissue, cervical and TMJ mobilization, TMJ stabilization. CG = Education and home exercises.	VAS and MMO free of pain.	MT with HPT was more effective than HPT alone for the treatment of TMD.

OMT = osteopathic manipulative treatment; MMA = musculoskeletal manipulation approaches; CG = control group; ND = Not described; SD = standard deviation; MMO = maximal mouth opening; MOV = maximal opening velocity; MCV = maximal closing velocity; OVA = Opening velocity average; CVA = closing velocity average; CCT = conventional conservative therapy; ROM = range of motion; VAS = visual analogic scale; PT = physical therapy; ST = splint therapy; MPMM = maximal protrusive mandibular movements; PPT = pressure pain thresholds; TrPs = trigger points; IMT Intra-oral myofascial therapy; SCE self-care and education; DMT = distraction mobilization technique; EMG = electromyography; UC = usual care; HPT = home physical therapy.

Table 2
PEDro scale scores of included studies.

PEDro scale	Kalamir et al. (2010)	Cuccia et al. (2009)	Von Piekartzl and Ludtke (2011)	Tuncer et al. (2012)	Oliveira-Campelo et al. (2010)	Monaco et al. (2008)	Taylor et al. (1994)	Ismail et al. (2007)
Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Concealed allocation	Yes	No	No	No	No	No	No	No
Baseline comparability	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Blinded subjects	Yes	No	No	No	No	No	Yes	No
Blind therapists	No	No	No	No	No	No	No	No
Blind assessor	Yes	Yes	Yes	Yes	Yes	No	No	No
Adequate follow up	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intention-to-treat-analysis	Yes	No	No	No	No	No	No	No
Between group comparisons	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Point estimates and variability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Score	9	6	6	6	6	5	5	5

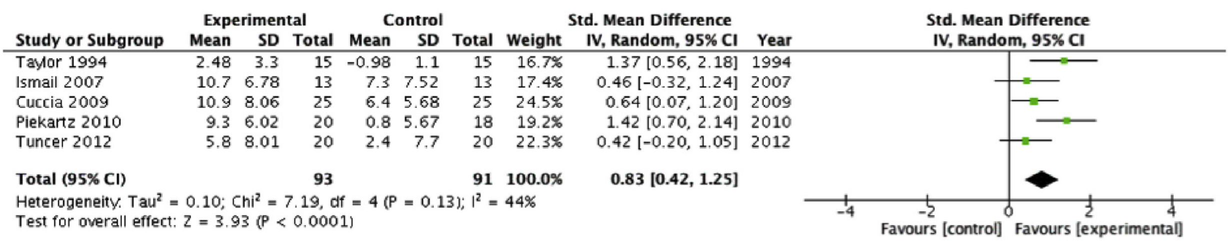

Fig. 2. MMA versus control group to increase active ROM of mouth opening.

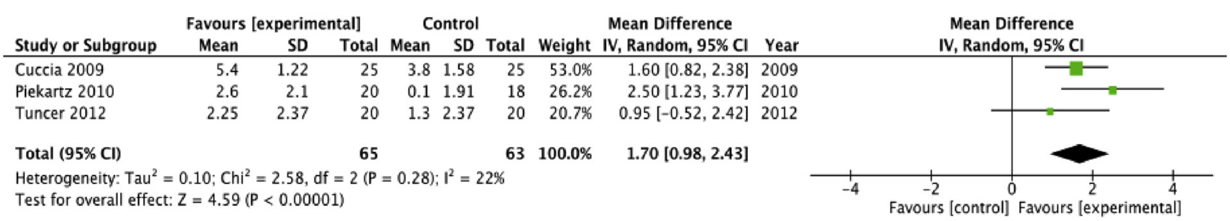

Fig. 3. MMA versus control group on pain during active ROM of mouth opening.

among temporomandibular and the craniocervical motor systems, brainstem, subcortical and cortical center during natural jaw activities (Eriksson et al., 2000; Yin et al., 2007).

Although the effects of MMA are classically explained within a biomechanical paradigm, current research points to the important role of neurophysiological processes. This proposed model takes into account the interaction between the central and peripheral nervous system, which controls the experience of pain and thus defines the potential mechanisms associated with pain relief MMA. According to the integrative review of Bialosky et al. (2009), the neurophysiological model suggests that hypoalgesia is caused by multiple mechanisms: action mediated by the periaqueductal gray; lessening of temporal summation; reduction of blood and serum level of cytokines and substance P levels; changes in muscle activity and motoneuron pool activity. In this context, thoracic manipulation (high velocity thrust), significant reduction in pain perception and in cerebral blood flow measured by blood oxygenation level-dependent response (area associated with the pain matrix) (Sparks et al., 2013). Moreover, significant relationship between reduced activation in the insular cortex and decreased subjective pain ratings were found. Finally, the systematic reviews of Coronado et al. (2012) and Voogt et al. (2015) reported a clear effect in favor to spinal manipulative therapy on pressure pain threshold (PPT), supporting a potential central nervous system mechanism. The results of the present analysis are partially in agreement with literature consensus regarding that hypoalgesia could be mediated by MMA. In our meta-analysis, MMA demonstrated to significantly decrease pain during active ROM of mouth opening (Cuccia et al., 2009; von Piekartz and Ludtke, 2011; Tuncer et al., 2012) but, on the other hand, non-significant alterations in resting pain (measured by PPT) were found (Kalamir et al., 2010; Tuncer et al., 2012). However, the latter should be interpreted with caution; although the meta-analysis revealed non-significant changes for this outcome, the two studies analyzed had considerable data of Mean Difference (MD) in favor to MMA. So, the non-significant could be attributed to the large variability of confidence intervals (see the forest plot and 95% CI in the supplementary material).

Our results and the evidence from the review studies of Brantingham et al. (2013), McNeely et al. (2006) and Medlicott and Harris (2006), all with a similar research question, could be complementary. These authors generally concluded that (Shaffer et al., 2014) there is a B-level of evidence that manual and manipulative therapy may be helpful in the short-term (≤3–6 months) treatment of TMD (and/or generally combined with multimodal therapy with exercise or rehabilitation in clinic, interdisciplinary clinics and/or at home) for decreasing pain and increasing oral opening

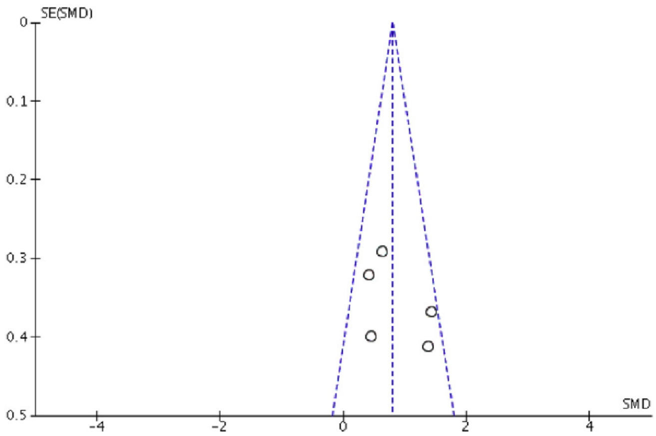

Fig. 4. Funnel plot for active ROM of mouth opening, with 95% CI.

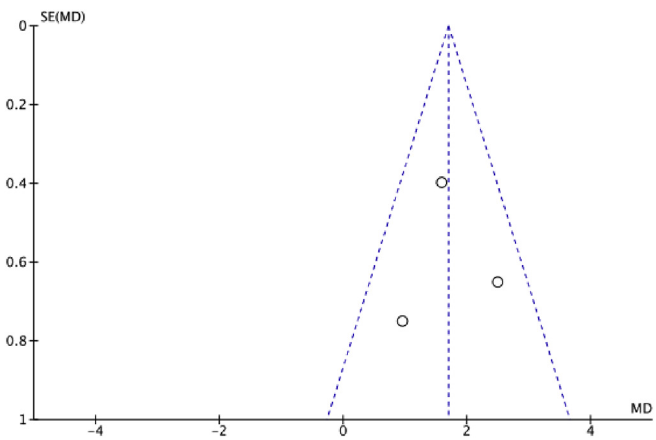

Fig. 5. Funnel plot for on pain during active ROM of mouth opening, with 95% CI.

(Romero-Reyes and Uyanik, 2014). Also, the goals of managing TMD are best achieved by using multidisciplinary approaches aimed to decrease pain and increase muscular coordination and strength. Concerning the present analysis, it is possible to state that MMA provides a significant short-term pain relief during active mouth opening and active ROM of mouth opening when compared to others interventions in TMD. Indeed, all these reviews could help professionals to make their clinical decision with more information available.

There are some limitations to our study. The therapeutic approaches for TMD vary largely according to different opinions based on its etiology. Considering this observation, it was not possible to draw conclusions about the most effective techniques to improve clinical outcomes (pain and ROM). The majority of studies had combined articular (e.g. mandibular distraction mobilization, mandibular translation mobilization, mandibular accessory movements, cervical mobilization, cranio-cervical thrust) and extra-articular (e.g. myofascial release in jaw elevator muscle, general myofascial release, muscle energy, balance membrane tension, cranial-sacral therapy, tender-trigger point, muscle stretching, soft tissue cervical and TMJ mobilization) techniques. In the same way, inclusion criteria of the included studies were considerably heterogeneous and conclusions could not be made to a specific diagnostic of TMD. Thus, the large variety of diagnosis compromises the external validity of our analysis. Tuncer et al. (2012) recruited subjects with diagnostic of anterior disc displacement with reduction according to category IIa of the RDC/TMD (myogenous TMD). Kalamir et al. (2010) treated patients with history of peri-auricular pain with or without joint sounds for at least 3 months. Taylor et al. (1994) selected patients who suffered symptoms including pain in the region of the TMJs and masticatory associated muscles, and limited mandibular movement for at least six months. Monaco et al. (2008) recruited patients with nonspecific TMD symptoms, limited mouth opening and history of trauma (delivery trauma, accident trauma). von Piekartz and Ludtke (2011) had a sample of patients diagnosed with cervicogenic headache according to the International Classification of Diagnostic Criteria of Headache and with the related symptoms: joint sounds, deviation during mouth opening, extraoral muscle pain at a minimum of two tender points in the masseter or temporalis muscles and pain during passive mouth opening. Ismail et al. (2007) selected patients with arthrogenic TMD with a limited (<38 mm) and painful jaw opening and also patients who suffered from acute symptoms (duration <6 months) of a TMD. Oliveira Campelo et al. (2010) recruited patients with diagnosis of latent trigger points (TrP) in the masseter muscle on either the left or right side, according to the related signs and symptoms: (Shaffer et al., 2014) the presence of a palpable taut band within a skeletal muscle, (Romero-Reyes and Uyanik, 2014) the presence of a hypersensitive area in the taut band, (Lin, 2014) a local twitch response provoked by the snapping palpation of the taut band, and (Kalamir et al., 2010) a reproduction of referred pain distant from the TrP in response to compression. Cuccia et al. (2009) reported only that diagnosed patients with TMD were selected.

According to the limitations, we believe that it is extremely necessary a comparative analysis of the effectiveness of articular and extra-articular techniques for intra and peri-articular conditions in future studies. More homogeneous comparisons might help the clinicians' perspective to decision making processes. We also believe that it is necessary the standardization of signs/symptoms in future studies. Based on the RDC/TMD classification, we may suggest that consideration of specific clinical features (i.e. intra-, peri- and or extra-articular disorders) for determining sub-groups should be recommended to enhance the effectiveness of treatment intervention and prognostic factors. Besides, despite the large disparity in the techniques definition, a standardization of techniques should also be taken into account. Moreover, characteristics and specificity of procedures (i.e. force distraction, mobilisation frequency, amplitude, duration) related to their physiological, mechanical or neurological effects should be emphazised, following clinical sub-groups. Finally, since only three studies conducted follow-up evaluations, we recommend that future studies perform a new battery of evaluation of patients after a segment without intervention.

5. Conclusion

Musculoskeletal manipulations approaches are effective for the treatment of temporomandibular joint disorders. In short term, there is a larger effect for musculoskeletal manual approaches manipulations compared to other conservative treatments for temporomandibular joint disorder.

Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.math.2015.06.009

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