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Electromyographic Assessment of Muscle Activity in Different Malocclusions in Adults: A Systematic Review and Meta-Analysis

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Abstract

Aim

Malocclusion affects nearly half of the global population and is recognized by the World Health Organization as a major oral health concern. Orofacial muscles play a crucial role in occlusion and dentofacial development, and their dysfunction may contribute to the development or progression of malocclusion. Electromyography (EMG) provides a reliable method for assessing masticatory muscle activity. However, the current evidence regarding muscle activity patterns across different malocclusion classes remains inconsistent. This systematic review and meta-analysis aimed to evaluate the electromyographic activity of masticatory muscles in individuals with different classes of malocclusion.

Methods

This systematic review was conducted in accordance with the PRISMA 2020 guidelines and registered in PROSPERO (CRD42024595686). Comprehensive searches were performed in MEDLINE, Scopus, EMBASE, Web of Science, and Cochrane CENTRAL up to September 2025 without language or date restrictions. A total of 1,627 records were screened. Eligible studies included adult participants with sagittal malocclusions assessed using surface electromyography (sEMG). Studies involving pediatric populations, patients with systemic or craniofacial disorders, and interventional designs were excluded. Data extraction and risk-of-bias assessment using the NOS-XS tool were conducted independently by two reviewers. Random-effects meta-analyses were performed in R to compare masseter and temporalis muscle activity during maximum voluntary clenching, chewing, and rest. Heterogeneity and publication bias were assessed using Cochrane-recommended methods.

Results

Eighteen studies involving 724 participants met the inclusion criteria. The overall risk of bias ranged from low to moderate. Meta-analysis revealed no significant differences in muscle activity among malocclusion classes during chewing. During maximum voluntary clenching, individuals with Class III malocclusion exhibited significantly lower masseter and temporalis muscle activity compared with those with Class I malocclusion, although heterogeneity was substantial. At rest, temporalis muscle activity was significantly lower in Class II than in Class III malocclusion, while masseter activity showed no consistent differences between groups.

Conclusion

EMG evidence indicates that masticatory muscle activity may vary across different malocclusion classes. However, considerable heterogeneity among studies and the limited number of available investigations warrant cautious interpretation of these findings. Well-designed studies with larger sample sizes and standardized EMG protocols are needed to provide more definitive evidence.

Keywords: Electromyography, Malocclusion, Masticatory muscles, Angle's classification

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Background

Malocclusion ranks among the most common oral health disorders worldwide, affecting at least half of the global population. The World Health Organization identifies malocclusion as a major oral health concern, ranking it immediately after dental caries and periodontal disease. Among sagittal malocclusions, Class I exhibits the highest prevalence, followed in descending frequency by Class II Division 2, Class II Division 1, and Class III (1, 2).

Skeletal Class III malocclusion, arising from mandibular excess, maxillary retrusion, or both, typically presents with symptoms like a class III molar relationship, anterior crossbite, compensatory change in the angle of the incisors, and occasionally a unilateral or bilateral posterior crossbite (3-5). In contrast, Skeletal Class II malocclusion arises from the forward overgrowth of the upper jaw, deficiency of the lower jaw, or both, resulting in a distal position of mandibular teeth in relation to the maxillary teeth and increased overjet. In the case of skeletal Class I, there is a harmonious development of the maxilla and mandible, contributing to the correct relationship between them (5, 6).

Orofacial muscles play a pivotal role in dentition development and occlusion. Given their role, alterations in muscle morphology and activity may directly influence the development and severity of malocclusions (7-11). The muscles of mastication—including the masseter, temporalis, and internal and external pterygoids—are particularly influential in determining facial patterns (12). Clinical observations suggest that the position of these muscles and the force vectors generated during contraction can directly influence orthodontic treatment planning and retention, especially during periods of growth and dentoalveolar development (13, 14).

The relationship between malocclusion and muscle function has been investigated extensively, with particular attention to sagittal discrepancies. Importantly, altered jaw muscle strength is observed in individuals with both Class II and Class III malocclusions, which may vary according to severity (15-17). This highlights the importance of exploring correlations between muscle activity and craniofacial morphology, as such insights could support more rational treatment planning and relapse prevention (18, 19).

Various methods exist to evaluate the stomatognathic system (20), among which Electromyography (EMG) offers an accurate and consistent approach for assessing muscle function by recording electrical activity. EMG provides valuable information on muscle activity, intermuscular coordination, fatigue, and functional changes by capturing action potentials. Both intramuscular and surface EMG (sEMG) methods are available, with sEMG being widely favored in orthodontics due to its non-invasive nature and ability to record signals from multiple fibers simultaneously. As such, sEMG is a valuable tool for evaluating malocclusions and assessing both diagnostic procedures and treatment efficacy in orofacial deformities (21-24).

Despite numerous investigations, no consensus has been reached regarding consistent patterns of muscle activity across different skeletal classes, and findings remain controversial.(25-30) Given the clinical importance of this topic and the inconsistency of previous results—particularly in adult populations—we conducted a systematic review and meta-analysis to evaluate the electromyographic activity of masticatory muscles in individuals with different malocclusions.

Methods

Research Framework and Protocol

This study's protocol was prospectively recorded in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42024595686. The principles outlined in the PRISMA 2020 model were utilized to conduct this systematic review and Meta-Analysis (31).

Eligibility Criteria

Study selection was structured based on the PECO model, which involved identifying growing patients (Population), evaluating the effects of different sagittal malocclusions (Exposure) in comparison to normal occlusion (Comparison), and pointing out outcomes related to muscle activity measured by electromyography (Outcome). All relevant studies that aligned with the PECO model were included, irrespective of their publication date or language.

The inclusion criteria which were applied in study selection process are as follows:

- All related original studies on adults having Class I, II, or III malocclusion.
- Assessment of masticatory muscle activity using EMG.

The criteria for exclusion were outlined as follows:

- Unavailable studies or inappropriate research type (Reviews, case reports, case

series, animal studies, or unpublished data.)
- Studies evaluating treatment effects (e.g., surgery, fixed orthodontics, functional appliances).
- Research conducted on children or patients with systemic/craniofacial conditions (e.g., muscular dystrophy, temporomandibular dysfunction, cleft lip/palate, asymmetry).
- Studies limited to vertical dimensions, crossbite, or facial morphology without sagittal classification.

Information Sources and Search Strategy

Our literature search covers all relevant studies published in the following databases from their inception until September 2025: Scopus, MEDLINE, EMBASE, Web of Science, and Cochrane's CENTRAL, supplemented by reference list and hand screening. Search terms included combinations of: "Electromyography," "sEMG," "Malocclusion," and "Masticatory muscles". Full search strategies are reported in Table 1.

Study Selection

Two independent reviewers (KM, MO) conducted a literature search as comprehensive as possible without language or publication date limitations. The study titles and abstracts were independently reviewed. In cases of conflicting opinions, discussions were held, and a third expert (MD) provided the final decision when necessary. Duplicates and irrelevant records were excluded before full-text assessment against PECO-based criteria.

Table 1. Applied search strategy, and numbers of retrieved studies

Database of published studies, dissertations and conference proceedings	Search strategy used	Hits
MEDLINE searched via PubMed searched on July 22th, 2024, via www.ncbi.nlm.nih.gov/sites	masticatory muscle OR orbicularis oris OR temporalis OR masseter OR EMG OR sEMG OR electromyography AND ((malocclusion OR facial height OR long?face OR short?face OR open?bite OR deep?bite OR ("maxilla*" AND ("defic*" OR "excess" OR "protru*")) OR ("mandib*" AND ("defic*" OR "excess" OR "protru*"))))	693
Web of science Core Collection was searched via web of science on July 24, 2024, via apps.webofscience.com	ALL=(masticatory muscle OR orbicularis oris OR temporalis OR masseter OR EMG OR sEMG OR electromyography) AND ALL=(((malocclusion OR facial height OR long?face OR short?face OR open?bite OR deep?bite OR ("maxilla*" AND ("defic*" OR "excess" OR "protru*")) OR ("mandib*" AND ("defic*" OR "excess" OR "protru*")))))	293
EMBASE searched via Ovid on July 21, 2024, via http://ovidsp.dc2.ovid.com	#1 'masticatory muscle'/exp OR 'masticatory muscle' OR 'orbicuaris oris' OR 'temporalis' OR 'masseter' OR 'emg'/exp OR emg OR semg OR 'electromyography'/exp OR 'electromyography' #2 'malocclusion'/exp OR 'malocclusion' OR 'facial height'/exp OR 'facial height' OR (long AND ('face'/exp OR face)) OR (short AND ('face'/exp OR face)) OR (open AND ('bite'/exp OR bite)) OR (('maxilla'/exp OR 'maxilla' OR 'mandible'/exp OR 'mandible') AND ('deficiency'/exp OR 'deficiency' OR excess OR 'protrusion'/exp OR 'protrusion')) #3 #1 AND #2	457
Scopus searched via Scopus on July 20, 2024, via https://www.scopus.com	TITLE-ABS-KEY(masticatory muscle OR orbicularis oris OR temporalis OR masseter OR EMG OR sEMG OR electromyography) AND TITLE-ABS-KEY(((malocclusion OR facial height OR long?face OR short?face OR open?bite OR deep?bite OR ("maxilla*" AND ("defic*" OR "excess" OR "protru*")) OR ("mandib*" AND	108

	("defic*" OR "excess" OR "protru*")))))	
Cochrane Central Register of Controlled Trials searched via the Cochrane Library Searched on July 19, 2024, via www.thecochranelibrary.com	#1 masticatory muscle #2 electromyography #3 EMG #4 malocclusion #5 mandib* OR maxilla* #6 deficien* OR excess OR protru* #7 (#1 OR #2 OR #3) AND (#4 OR (#5 AND #6))	76
Total		1627

Data Collection Process and Data Items

A reviewer (KM) carried out data extraction from eligible studies, in collaborative discussion with the other reviewer (MO) when necessary. Some of the extracted data were as follows: author, year, study design, sample size, demographics, malocclusion type, study groups, symmetry index, and electrical activity of different muscles during maximum voluntary clench (MVC), chewing and rest.

Risk of Bias in Individual Studies and Certainty of Evidence

The NOS-xs tool was used to evaluate the potential biases within the included studies. The NOS-xs tool assesses bias in three distinct domains: "bias due to study sample selection, bias arising from assessment of exposure and outcome, and bias in selection of the confounding factors". According to the guidelines outlined in Carra et al (32), the studies were classified based on the mentioned criteria into three categories: low, moderate or high risk.

The GRADE framework was used to evaluate the reliability of the evidence, taking into account study design (randomized or non-randomized), potential bias, heterogeneity, relevance of measured outcomes, imprecision, and additional factors such as publication bias, large effect sizes, dose–response relationships, and possible confounding. Evidence was then categorized into four certainty levels: high, moderate, low, or very low.

Table 2: Summary of the included studies

Author-year-Study design	Sample size & gender	Subgroup sample size	Mean age(years)	Methods/ measurements	Outcome
K. Ramsundar/ 2023/ Prospective pilot observational	n=10 (6 male, 4 female)	Mild Class II: 5 Severe Class II: 5	22±2.5	Device: BioEMG III (BioResearch Associates, Inc.Milwaukee, WI, USA) with four-channel electrodes. Measurements: EMG activity of masseter and temporalis muscles was assessed at rest, during chewing, and clenching.	Overjet severity in Class II division 1 did not affect masseter/temporalis activity. Muscle symmetry was higher in >4mm overjet (not significant). No synergy differences between groups.
P. Kulchutisin/ 2023/ Cross-sectional/ Observational	n=20 (7 male, 13 female)	Cl I: 10 Cl III: 10	20.90 ± 3.19	Device: sEMG (BioEMG III; BioResearch Associates, Inc.,Milwaukee, Wisconsin, USA). Measurements: Muscle activity of masseter muscle and temporalis anterior, during maximum voluntary clenching and chewing in skeletal Class I and III patients.	Class III had weaker masseter /temporalis activity during MVC vs. Class I. Lower masseter/temporal activity in Class III during chewing (not significant). Higher symmetry during MVC vs. chewing; Class III had higher masseter but lower temporalis symmetry during chewing. Significant synergy difference during maximum voluntary clench (not chewing)

J. Gómez/ 2022/ Cross-sectional/ Observational (Spanish)	n=25(13 male,12 female)	Cl I: 7 Cl II type I:10 Cl III: 8	18 to 28	Device: sEMG VIII (ArtOficio, Chile). Measurements: EMG activity of masseter and temporalis muscles in patients with different occlusal relationships.	No significant EMG differences by sex or Angle classification during rest/swallowing.
R. Aggarwal/ 2022/ Cross-sectional/ Observational	n=39(16 male,23 female)	Angle's Cl I: 13 Angle's Cl II: 13 Angle's Cl III: 13	13 to 35	Device: Single-channel digital EMG unit (NeuroTrac Simplex, UK). Measurements: Activity of masseter, temporalis, and buccinator muscles at rest, chewing, and clenching in Angle's Class I, II, and III malocclusions.	Buccinator activity: Class I > II > III during chewing (significant). No differences at rest/clenching. No gender differences in muscle activity across tasks. Temporalis activity highest in Class I at rest/clenching.
N. Kawai/ 2022/ Cross-sectional/ Observational	n=57(19 male,38 female)	Normal occlusion: 12 Cl III malocclusion:45	22.7 ± 7.2	Device: K7 Evaluation System (Myotronics-Noromed, Inc., Kent, WA, USA). Measurements: Masticatory function differences in skeletal Class III malocclusion patients (camouflage vs. surgical candidates).	Class III had lower masseter activity vs. controls; ANB angle correlated with masseter activity. Temporalis trends similar but no significant differences among Class III subgroups.
S. E. Nishi/ 2017/ Cross-sectional/ Observational	n=28(13 male,15 female)	Angle's Cl I: 10 Angle's Cl II 9 Angle's Cl III 9	18 to 25	Device: ProComp Infiniti Encoder SA7500 (Canada). Measurements: sEMG of masseter and temporalis muscles in Angle's Class I and II malocclusions.	Right temporalis activity higher in males and varied by malocclusion. Class I had higher EMG activity vs. Class II/III. Left masseter chewing activity higher in males.
B. U. L. de Farias/ 2013/ Cross-sectional/ Observational	n=30 (gender not specified)	Angle Cl I: 10 Angle Cl III: 20	18 to 35	Device: Miotool 200/400 USB (4 channels, 2000 Hz sampling rate). Measurements: EMG of masseter, temporalis, and suprahyoid muscles in Class III dentofacial deformity patients during functional tests	Class III had lower masseter potential during isometric contraction vs. controls. Masseter asymmetry higher in Class III during isometric contraction.
G. Farronato/ 2012/ Prospective/ Observational/ Longitudinal	n=80(37 male,43 female)	skeletal Cl II: 40 skeletal Cl III: 40	32±4.1	Device: Freely electromyograph (Italy) and K6-I (Myotronics, USA). Measurements: Neuromuscular function in Class II and III patients pre- and post-treatment.	Pre-treatment masseter/temporalis activity higher in Class II vs. III (significant). Differences disappeared post-treatment.
B. Li/ 2011/	n=68(36 male,32	Normal occlusion: 36	24.2	Device: Eight-channel BioEMG II (BioResearch,	Mandibular Postural Position:

Cross-sectional/ Observational (Chinese)	female)	mandibular protrusion: 32		USA) with bipolar electrodes. Measurements: EMG of anterior temporalis (TA), masseter (MM), digastric (DA), and sternocleidomastoid (SCM) at postural position and mandibular movements in prognathic patients.	Elevated EMG activity in TA, DA, and SCM ($P < 0.01$ vs. controls). MM activity slightly lower (ns). Maximal Clenching: Reduced activity in TA and MM ($P < 0.01$ vs. controls). SCM and DA unchanged.
M. M. Amorim/ 2010/ Cross-sectional/ Observational	n=45(28 male,17 female)	Cl I: 25 Cl III: 20	23±4.2	Device: Myosystem I (12 channels, version 2.22 software; Brazil,USA). Measurements: EMG activity of anterior temporalis in skeletal Class I and III individuals.	EMG activity: No difference in temporal muscle activity between Class I (100.07 µV ± 0.023) and Class III (100.02 µV ± 3.08) ($P > 0.05$).
M. Albornoz/ 2009/ Cross-sectional/ Observational (Spanish)	n=19(7 male,12 female)	Normal occlusion: 8 skeletal Cl II div 1: 11	19±1.43	Device: Biopac fused cables (SS1L electrode SN 7094). Measurements: EMG activity of masseter (Ms) and anterior temporalis (Ta) muscles in subjects with Angle Class II malocclusion, Class I, and controls	Higher voltage amplitude in Angle Class II, division 1 vs. controls for masseter and anterior temporalis ($p<0.05$). Ms/Ta ratio was higher in control group than Class II div 1 patients.
V. F. Ferrario/ 2006/ Cross-sectional/ Observational (blinded)	n=62(27 male,35 female)	'complete' Angle Cl I: 26 'partial' Angle Cl I: 36	18 to 21	Device: Freely electromyograph (Myo-Tronics Inc., Seattle, WA, USA). Measurements: Neuromuscular equilibrium in jaw/neck muscles of "complete" vs. "partial" Angle Class I subjects.	Muscle Symmetry: High symmetry in masseter (82.8–86.6%), temporalis (86.6–87.9%), and sternocleidomastoid (80.7–86.0%) across groups. Temporalis symmetry significantly more variable in "partial" Angle Class I vs. "complete" Class I ($P = 0.013$) Standardized EMG Activity: No significant differences between "complete" and "partial" Class I ($P > 0.05$). No sex-based differences in muscle activity or symmetry.

B. K. Cha/ 2007/ Cross-sectional/ Observational	n=105(38 male,67 female)	Skeletal Cl I: 47 Skeletal Cl II: 33 Skeletal Cl III: 25	22.0 ± 6.7	Device: K6-I diagnostic system (Myotronics-Noromed, USA). Measurements: EMG of anterior temporal (T) and masseter (M) muscles in different facial skeletal types.	Resting Activity: Temporal Muscle (TMA): Significantly higher in Class III hyperdivergents vs. other groups ($P < 0.05$). Masseter Muscle (MMA): No significant differences among groups. Clenching Activity: No significant differences in TMA or MMA among groups. Cl III hyperdivergents showed a decreased T/M ratio during clenching vs. resting ($P < 0.05$), indicating lesser MMA increase in Class III hyperdivergent subjects. Class III Group: Positive correlation between resting TMA and SN-GoMe ($P < 0.05$); negative correlation between clenching TMA and ANB ($P < 0.05$).
R. P. Harper/ 1997/ Prospective/ observational	n=22(12 male,10 female)	Cl I occlusion: 10 Cl II malocclusion: 12	29.9	Device: PDP-11/34 computer system (USA). Measurements: Muscle recruitment patterns in mandibular retrognathism vs. orthognathic subjects.	Resting Position: Lateral pterygoid activity: Significantly higher variability in retrognathic patients vs. controls ($P < 0.05$). Maximum Clench: Masseter/Temporalis activity: Lower in retrognathic patients vs. controls ($P < 0.005$).
K. Hönicke/ 1995/ Cross-sectional/ Observational (German)	n=40 (gender not specified)	Cl I occlusion: 10 Class II :15 Class III: 15	22.3	Device: Myosystem 2000 (Neurodata). Measurements: EMG of orofacial muscles in Class I, II, and III malocclusions.	Class I: EMG activity concentrated in the lower third of masseter during occlusion/chewing Class II: Activity shifted to middle third Class III: Uniform activation across lower/middle/dorsal regions.
T. Deguchi/ 1995/ Cross-sectional/ Observational	n=40(0 male,40 female)	Normal occlusion: 20 Cl III malocclusion: 20	21.5	Device: Differential Lissajous EMG (Japan). Measurements: Bilateral anterior temporalis and masseter activity in normal occlusion vs. Class III malocclusion.	Normal Occlusion (Cl I): Higher EMG activity in working-side masseter and temporalis ($P < 0.01$). Cl III Malocclusion: Reduced EMG activity in working-side masseter and temporalis ($P < 0.01$). Cl III shows abnormal neuromuscular coordination ("chopping" pattern). EMG effectively

					differentiates malocclusion types based on muscle balance.
R. Miralles/ 1991/ Cross-sectional/ Observational	n=33(18 male,15 female)	skeletal Cl I: 13 skeletal Cl II: 11 skeletal Cl III: 9	22.9	Device: Grass 5e EMG (Grass Instrument Co., USA). Measurements: Elevator muscle activity at functional requirements in skeletal Class I, II, and III subjects.	Postural Activity: Class III subjects showed higher EMG activity in both masseter and anterior temporalis compared to Class I and Class II (P < 0.01). No significant difference between Class I and II (P > 0.05). Swallowing Activity: Masseter activity in Class III > Class I and Class II (P < 0.05). Anterior temporalis activity in Class III > Class II) (P < 0.05), but similar to Class I. Maximal Clenching: No significant differences among skeletal classes for either muscle (P > 0.05). Strong negative correlation between EMG activity and ANB angle Overjet correlated with reduced EMG activity
J. P. Moss/ 1974/ Cross-sectional/ Observational with a longitudinal component	n=20 (gender not specified)	normal occlusion: 20 postural Cl III malocclusion: 15 skeletal Cl III malocclusion: 15	>16	Device: EMG (unspecified). Measurements: EMG patterns in skeletal Class III malocclusion patients.	Normal Occlusion (Adults & Children): Habitual Bite: Balanced bilateral activity in masseter/temporalis Skeletal Class III: Elevated masseter activity in protruded contact (P < 0.01 vs. normal). Postural Class III: Muscle patterns intermediate between skeletal Class III and normal.

Outcome Measures and Data Synthesis

The primary outcomes were the surface electromyography (EMG) amplitudes (μV root-mean-square) of the masseter and anterior temporalis during (a) chewing, (b) maximum voluntary clench (MVC) and (c) rest.

Where authors reported separate recordings for right and left sides, the values were averaged to obtain one muscle-specific mean per participant. If different test foods were used for chewing, the hardest consistency was retained because it elicits the highest activity. Peak-to-peak values were converted to root-mean-square by dividing by $\sqrt{2}$. If only medians and inter-quartile ranges were given, means and standard deviations were estimated with the Wan equations (33).

All meta-analyses were conducted using a random-effects model, which accounts for both within-study and between-study variance, with the between-study variance (τ^2) estimated using the restricted maximum-likelihood (REML) method. Effect sizes for continuous outcomes were calculated as the Standardized Mean Difference (SMD), or Mean Difference (MD) where all studies reported results in the same units (e.g., μV root mean square for masseter activity during chewing). The results were presented using Forest plot.

To account for studies that compared multiple

arms with a shared group, we implemented a multi-arm pairwise meta-analysis approach. In this framework, each comparison between a group and the common control (e.g., Class I vs. Class II and Class I vs. Class III) was included in the analysis while properly adjusting for the correlation induced by the shared control group. This method ensures that the effect estimates are not artificially inflated due to double-counting of the control arm and provides accurate pooled estimates for each pairwise comparison, following the recommendations of the Cochrane (34).

Statistical heterogeneity was assessed using the Cochran's Q test (with $p<0.10$ considered statistically significant) and the I2 statistic. The I2 statistic quantifies the percentage of total variation across studies that is due to heterogeneity rather than chance, with thresholds interpreted as: 0% to 40%: might not be important; 30% to 60%: moderate heterogeneity; 50% to 90%: substantial heterogeneity; 75% to 100%: considerable heterogeneity. The $\tau 2$ statistic was also reported to quantify the between-study variance.

Publication bias was assessed by visual inspection of funnel plots and statistically evaluated using the Egger's regression asymmetry test ($p<0.05$ indicated significant small-study effects or publication bias). When the number of studies in a comparison was small, the results of Egger's test were interpreted with caution, as the test has limited power in such situations.

Additional Analyses:

A leave-one-out sensitivity analysis was performed to evaluate the influence of individual studies on the overall effect and on heterogeneity, allowing assessment of the robustness of the results.

All statistical procedures adhered to the methodological standards set forth in the Cochrane Handbook for Systematic Reviews of Interventions. Analyses were performed in R (version 4.4.3, R Foundation for Statistical Computing, Vienna, Austria) with the meta, package for meta-analysis.

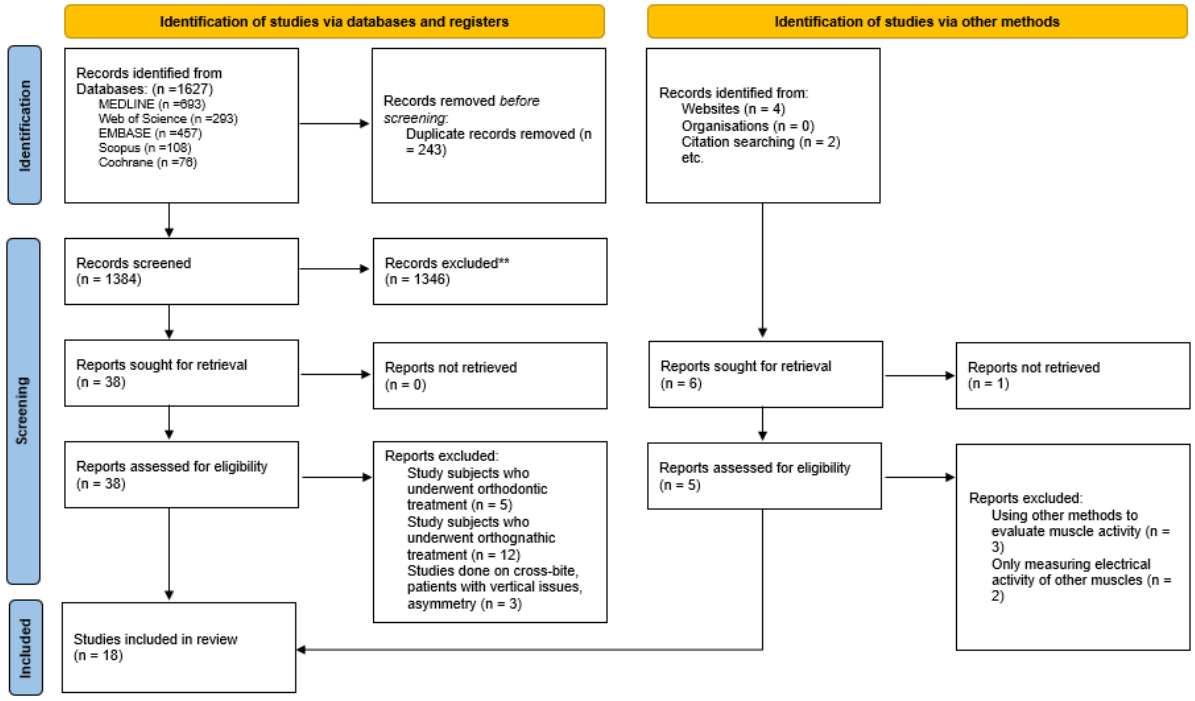
Results

Overview of study selection

Our search initially identified 1627 records. Following the removal of duplicate records, 1,384 studies were retained for title and abstract screening. Applying the PECO framework along with the predefined inclusion and exclusion criteria, 38 full-text articles were subsequently evaluated for eligibility. Of the excluded studies, 60 involved animal or in vitro research; 80 were reviews, congress proceedings, or book chapters; 335 were case reports or case series; 369 focused on children; 151 examined factors such as asymmetry, cross-bite, TMD, or other craniofacial anomalies; 62 employed non-EMG methods; and 289 were deemed irrelevant to the topic.

Eighteen studies ultimately met the criteria and were included in the quality assessment : Aggarwal et al.(26), Albornoz et al.(35), Amorim et al.(29), Cha et al.(36), Farias et al.(37), Deguchi et al.(38), Farronato et al.(39), Ferrario et al.(40), Gómez et al.(41), Harper et al.(42), Hönicke et al.(43), Kawai et al.(16), Kulchutisin et al.(44), Li et al.(28), Miralles et al.(45), Moss et al.(46), Nishi et al.(27), and Ramsundar et al.(15). All studies, with the exception of Deguchi et al., were included in the meta-analysis. The reason for exclusion was because Deguchi's bespoke analog differential lissajous EMG (DL-EMG) setup produced composite loop metrics (mean cumulative voltage, mean maximum peak voltage, rotation) that are not convertible to the RMS µV values generated by the digital multi-channel sEMG systems used in the other studies. Additionally, it reported only unilateral gum-chewing data, omitting the rest, MVC, and bilateral-chewing tasks needed for our comparative tables. The study selection process is illustrated in Diagram 1.

Diagram 1. PRISMA flow diagram for the search strategy.



Key Characteristics of the Selected Studies

Among the 18 observational studies, three were prospective (15, 39, 42), and the rest cross-sectional. Sample sizes ranged from 10 to 105 (age: 16–35 years), including 277 males and 376 females; although some studies did not specify the precise gender distribution (37, 43, 46). Seven studies compared Class I vs III, two compared Class I vs II, one compared Class II vs III, and six included all three classes. Some studies further subdivided samples (e.g., Ramsundar et al. by Class II severity; Ferrario et al. by complete vs partial Class I).

The majority of studies assessed masseter and temporalis activity during MVC, chewing, rest, or swallowing, with some extending to symmetry/synergy indices. Habitual, protrusive, or retrusive position were also considered by some of them. A few examined additional muscles (buccinator, digastric, sternocleidomastoid, lateral pterygoid and suprahyoid muscles). Assessments were performed using clinical examination, cephalometric radiography, and EMG. The main characteristics of the final studies included are shown in Table 2.

Table 3: Risk assessments for included studies based on NOS-x tool

Study	D1: Study sample selection		D2: Assessment of exposure and outcome		D3: Confounding factors		Overall Risk of Bias	
	Q1	Q2	Q3	Q4	Q5	Q6		
Albornoz 2009	0	0	2	2	2	1	7	Low
Amorim 2010	1	0	2	2	1	1	7	Low
Chaa 2007	1	0	2	2	1	1	7	Low
Deguchi 1995	0	0	2	2	1	1	6	Moderate
Farias 2013	1	0	2	2	1	1	7	Low
Farronato 2012	1	0	2	2	1	1	7	Low
Ferrario 2006	1	0	2	2	2	1	8	Low
Gomez 2022	0	0	1	2	1	1	5	Moderate
Harper 1997	0	0	2	2	1	1	6	Moderate
Honike 1995	0	0	2	2	1	1	6	Moderate
Kawai 2022	1	1	2	2	1	1	8	Low
Li 2011	1	0	2	2	1	1	7	Low
Miralles 1991	1	0	2	2	1	1	7	Low
Moss 1974	1	0	2	2	1	1	7	Low
Nishi 2017	1	0	1	2	1	1	6	Moderate
Kulchutisin 2023	1	0	2	2	1	1	7	Low
Ramsundar 2023	0	0	2	2	1	1	6	Moderate
Aggarwal 2022	1	0	1	2	1	1	6	Moderate

Table 4. Summary of GRADE assessment of the evidences.

Outcomes	Number of participants (studies)	Certainty of the evidence (GRADE)	Anticipated absolute effects
			Mean difference with control group (the first malocclusion) SMD (95% CI)
Masseter (chewing) Cl I vs Cl II	65 (3 non-randomized studies)	⊕⊕⊕◯ Moderate	0.68 (-5.54 to 6.89)
Masseter (chewing) Cl I vs Cl III	69 (3 non-randomized studies)	⊕⊕⊕◯ Moderate	0.26 (-0.63 to 1.15)
Masseter (chewing) Cl II vs Cl III	60 (2 non-randomized studies)	⊕◯◯◯ Very low[b]	-2.18 (-28.94 to 24.58)
Temporal (chewing) Cl I vs Cl II	46 (2 non-randomized studies)	⊕⊕⊕◯ Moderate	-0.18 (-2.74 to 2.38)
Temporal (chewing) Cl I vs Cl III	51 (2 non-randomized studies)	⊕⊕⊕◯ Moderate	0.13 (-5.75 to 6.01)

Table 4. Summary of GRADE assessment of the evidences.

Outcomes	Number of participants (studies)	Certainty of the evidence (GRADE)	Anticipated absolute effects
			Mean difference with control group (the first malocclusion) SMD (95% CI)
Temporal (chewing) Cl II vs Cl III	41 (1 non-randomized study)	⊕⊕⊕◯ Moderate[c]	-0.28 (-1.05 to 0.5)
Masseter (Maximum Voluntary Clench) Cl I vs Cl II	348 (7 non-randomized studies)	⊕⊕◯◯ Low[b]	1 (-0.77 to 2.77
Masseter (Maximum Voluntary Clench) Cl I vs Cl III	426 (10 non-randomized studies)	⊕⊕◯◯ Low[b]	1.44 (0.05 to 2.83)
Masseter (Maximum Voluntary Clench) Cl II vs Cl III	368 (6 non-randomized studies)	⊕⊕⊕◯ Moderate[a]	0.17 (-1.1 to 1.43)
Temporal (Maximum Voluntary Clench) Cl I vs Cl II	343 (6 non-randomized studies)	⊕⊕◯◯ Low[b]	0.42 (-2.36 to 3.21)
Temporal (Maximum Voluntary Clench) Cl I vs Cl III	436 (10 non-randomized studies)	⊕⊕◯◯ Low[b]	1.31 (0.32 to 2.3)
Temporal (Maximum Voluntary Clench) Cl II vs Cl III	353 (5 non-randomized studies)	⊕⊕⊕◯ Moderate[a]	-0.21 (-0.59 to 0.17)
Masseter (rest) Cl I vs Cl II	244 (6 non-randomized studies)	⊕⊕⊕◯ Moderate	0.19 (-0.41 to 0.8)
Masseter (rest) Cl I vs Cl III	266 (7 non-randomized studies)	⊕⊕⊕◯ Moderate[a]	0.48 (-0.15 to 1.12)
Masseter (rest) Cl II vs Cl III	200 (5 non-randomized studies)	⊕⊕⊕◯ Moderate[a]	0.5 (-0.3 to 1.29)
Temporal (rest) Cl I vs Cl II	244 (6 non-randomized studies)	⊕⊕◯◯ Low[b]	0.53 (-0.56 to 1.62)

Table 4. Summary of GRADE assessment of the evidences.

Outcomes	Number of participants (studies)	Certainty of the evidence (GRADE)	Anticipated absolute effects
			Mean difference with control group (the first malocclusion) SMD (95% CI)
Temporal (rest) Cl I vs Cl III	266 (7 non-randomized studies)	⨁⨁◯◯ Low[b]	-0.47 (-1.13 to 0.37)
Temporal (rest) Cl II vs Cl III	200 (5 non-randomized studies)	⨁⨁⨁◯ Moderate[b]	-1.29 (-2.58 to 0)

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
CI: confidence interval; SMD: standardized mean difference

GRADE Working Group grades of evidence
High certainty: we are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.
Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

Explanations
a. confirmed by the Leave-one-out analysis
b. Inconsistency due to heterogeneity
c. Only one study available — no meta-analysis conducted.

Risk of Bias within Studies

Bias assessment of the included studies was conducted using the NOS-XS tool. Table 3 summarizes the risk of bias across the eighteen studies, evaluated within three domains and six items. Overall, seven studies demonstrated a moderate risk of bias (15, 26, 27, 38, 41-43), while the remaining studies indicated a low risk.

In terms of study sample selection, the study by Kawai et al. received two points, while twelve studies (16, 26-29, 36, 37, 39, 40, 44-46) received one point. In contrast, the studies by Albornoz et al., Deguchi et al., Gomez et al., Harper et al., Hönicke et al., and Ramsundar et al. did not receive a score for “representativeness of the study sample” due to small sample sizes, lack of randomization in sample selection, or insufficient data reporting.

All studies applied gold-standard and reliable methods for measuring exposure and outcomes, and therefore received full scores for assessment of exposure and outcome, with the exception of Gomez et al., Nishi et al., and Aggarwal et al. These three studies relied solely on Angle’s molar classification or overjet without cephalometric evaluation.

The most important confounding variables identified were gender, age, weight, treatment history, the influence of vertical malocclusions, and normalization of electromyographic measurements. Only Albornoz et al. and Ferrario et al. considered these factors within their inclusion and exclusion criteria. The remaining studies lost a point in “adjustment for confounder(s)” because they did not account for all relevant confounding factors. Although several studies attempted to control for some confounders, none were able to fully eliminate their effects.

As a result, despite the valuable data and insights provided, some included studies carry a potential risk of bias in interpretation and reporting. Supplementary files entitled "Risk of Bias Assessment" comprise the detailed reasoning risk assessment for each of our studies based on NOS-x checklist.

Findings of certainty of evidence

Based on the GRADE framework, certainty of

evidence ranged from very low to moderate. Table 4 summarizes the GRADE assessment, illustrating areas where confidence in the results is stronger or weaker.

Results of Individual Studies

According to Ramsundar et al., overjet severity in Class II division 1 did not affect masseter/temporalis activity. Muscle symmetry was higher in subjects with >4 mm overjet, though this was not significant (15). The co-contraction (synergy) of the masseter and temporalis muscles did not differ between groups.

Kulchutisin et al. concluded that Class III patients exhibited weaker masseter/temporalis activity during maximum voluntary clenching (MVC) compared to Class I subjects, while masseter/temporalis activity during chewing was lower in Class III patients (not significant) (44). Class III cases showed higher masseter symmetry but lower temporalis symmetry during chewing.

Gómez et al. reported no significant EMG differences between the masseter and temporalis muscles by sex or Angle classification during rest and swallowing postures (41).

According to Aggarwal et al., buccinator muscle activity during chewing was significantly higher in Class I than Class II patients, and higher in Class II than Class III patients (26). No differences were observed at rest or during clenching. Additionally, no gender differences in muscle activity were found across tasks. Temporalis activity was highest in Class I patients at rest and during clenching.

Kawai et al. showed that Class III patients had lower masseter activity versus controls, and the ANB angle correlated with masseter activity (16). Temporalis activity showed similar trends, but no significant differences were found among Class III subgroups.

Nishi et al. demonstrated that right temporalis activity was higher in males and varied by malocclusion type (27). Class I patients had higher EMG activity than Class II/III patients. Left masseter chewing activity was higher in males.

According to de Farias et al., Class III malocclusion was associated with lower masseter potential during isometric contraction versus controls (37). Masseter asymmetry was higher in Class III malocclusion during isometric contraction.

Farronato et al. reported that pre-treatment masseter/temporalis activity was significantly higher in Class II than Class III patients, but these differences disappeared post-treatment (39).

Based on Li et al., in the mandibular postural position, EMG activity was elevated in the anterior temporalis, digastric, and sternocleidomastoid ($P < 0.01$ vs. controls) (28). Masseter muscle activity was slightly lower (not significant). During maximal clenching, reduced activity in the temporalis and masseter muscles ($P < 0.01$ vs. controls) was reported, while sternocleidomastoid and digastric activity remained unchanged.

Amorim et al. concluded that EMG activity showed no difference in temporal muscle activity between Class I (100.07 μV ± 0.023) and Class III patients (100.02 μV ± 3.08) ($P > 0.05$) (29).

According to Albornoz et al., higher voltage amplitude was observed in Angle Class II division 1 versus controls for the masseter and anterior temporalis ($P < 0.05$), while the masseter/temporalis ratio was higher in the control group than in Class II division 1 patients (35).

Ferrario et al. found high muscle symmetry in the masseter (82.8–86.6%), temporalis (86.6–87.9%), and sternocleidomastoid (80.7–86.0%) across groups (40). Temporalis symmetry was significantly more variable in "partial" Angle Class I versus "complete" Class I patients ($P = 0.013$). Evaluation of standardized EMG activity revealed no significant differences between "complete" and "partial" Class I cases ($P > 0.05$). No sex-based differences in muscle activity or symmetry were observed.

Cha et al. reported that resting activity of the temporal muscle was significantly higher in Class III hyperdivergent patients versus other groups ($P < 0.05$) (36). Masseter muscle activity showed no significant differences among groups. Clenching activity had no significant differences in anterior temporal muscle or masseter muscle among groups. Class III hyperdivergent patients showed a decreased temporal/masseter ratio during clenching versus resting ($P < 0.05$), indicating a lesser increase in masseter muscle activity in Class III hyperdivergent subjects. The Class III group showed a positive correlation between resting temporal muscle activity and SN-GoMe angle ($P < 0.05$) and a negative correlation between clenching temporal muscle activity and ANB angle ($P < 0.05$).

According to Harper et al., in the resting position, lateral pterygoid activity showed significantly higher variability in retrognathic patients versus controls ($P < 0.05$) (42). During maximum clenching, masseter/temporalis activity was lower in retrognathic patients versus controls ($P < 0.005$).

Hönicke et al. reported that in Class I patients, EMG activity was concentrated in the lower third of the masseter during occlusion/chewing; in Class II patients, activity shifted to the middle third; and in Class III patients, uniform activation was observed across the lower, middle, and dorsal regions (43).

According to Deguchi et al., normal occlusion (Class I) cases showed higher EMG activity in the working-side masseter and temporalis (P < 0.01) (38). Class III malocclusion patients had reduced EMG activity in the working-side masseter and temporalis (P < 0.01) and showed abnormal neuromuscular coordination. EMG effectively differentiates malocclusion types based on muscle balance.

Miralles et al. demonstrated that in the postural position, Class III subjects showed higher EMG activity in both the masseter and anterior temporalis compared to Class I and Class II subjects (P < 0.01) (45).). No significant difference was found between Class I and Class II cases (P > 0.05). During swallowing, masseter activity in Class III patients was greater than in Class I and Class II patients (P < 0.05). Anterior temporalis activity in Class III patients was greater than in Class II patients (P < 0.05) but similar to that in Class I subjects. During maximal clenching, no significant differences among skeletal classes were observed for either muscle (P > 0.05). A strong negative correlation was found between EMG activity and ANB angle; overjet correlated with reduced EMG activity.

Moss et al. concluded that in normal occlusion subjects (adults and children), during habitual bite, there was balanced bilateral activity in the masseter and temporalis (46). In skeletal Class III patients, elevated masseter activity was observed during protruded contact (P < 0.01 vs. normal). Postural Class III cases showed muscle patterns intermediate between those of skeletal Class III and normal occlusion subjects.

Synthesis of results

Masseter muscle activity during Chewing:

Four studies (n = 97; Class I = 37, Class II = 28, Class III = 32) contributed to this outcome, two of which contained all three groups (23, 24). Versus Class I, Class II showed a non-significant decrease of 0.09 µV RMS (95 % CI −3.44 to 6.63), while Class III also showed a non-significant decrease of 0.26 µV RMS (95 % CI −0.63 to 1.15). Class III showed a non-significant increase of -2.18 µV RMS (95 % CI −28.94 to 24.58) over Class II (Figure 1).

For Class I versus II comparison, moderate-to-substantial heterogeneity was observed among studies, with an I^2 of 69.0%, a Tau^2 of 1.32, and a statistically significant Cochran's Q test (p = 0.04), suggesting variability in effect sizes beyond chance.

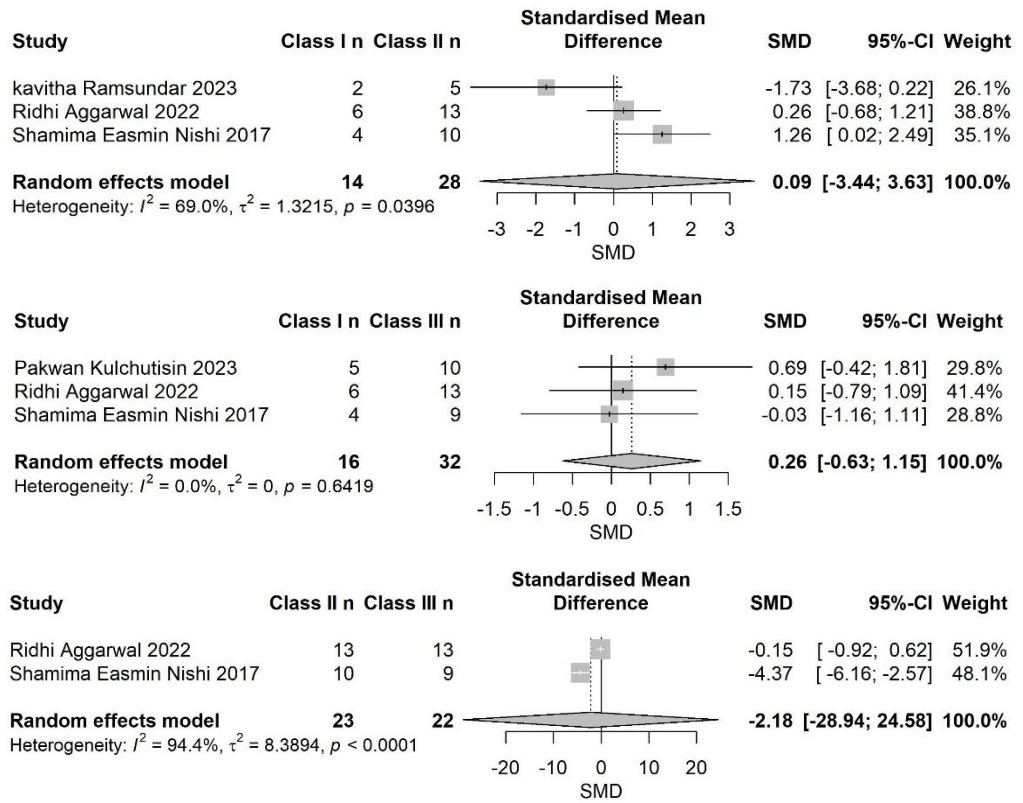


Figure 1: Forest plots of comparing different classes in terms of Masseter activity during Chewing.

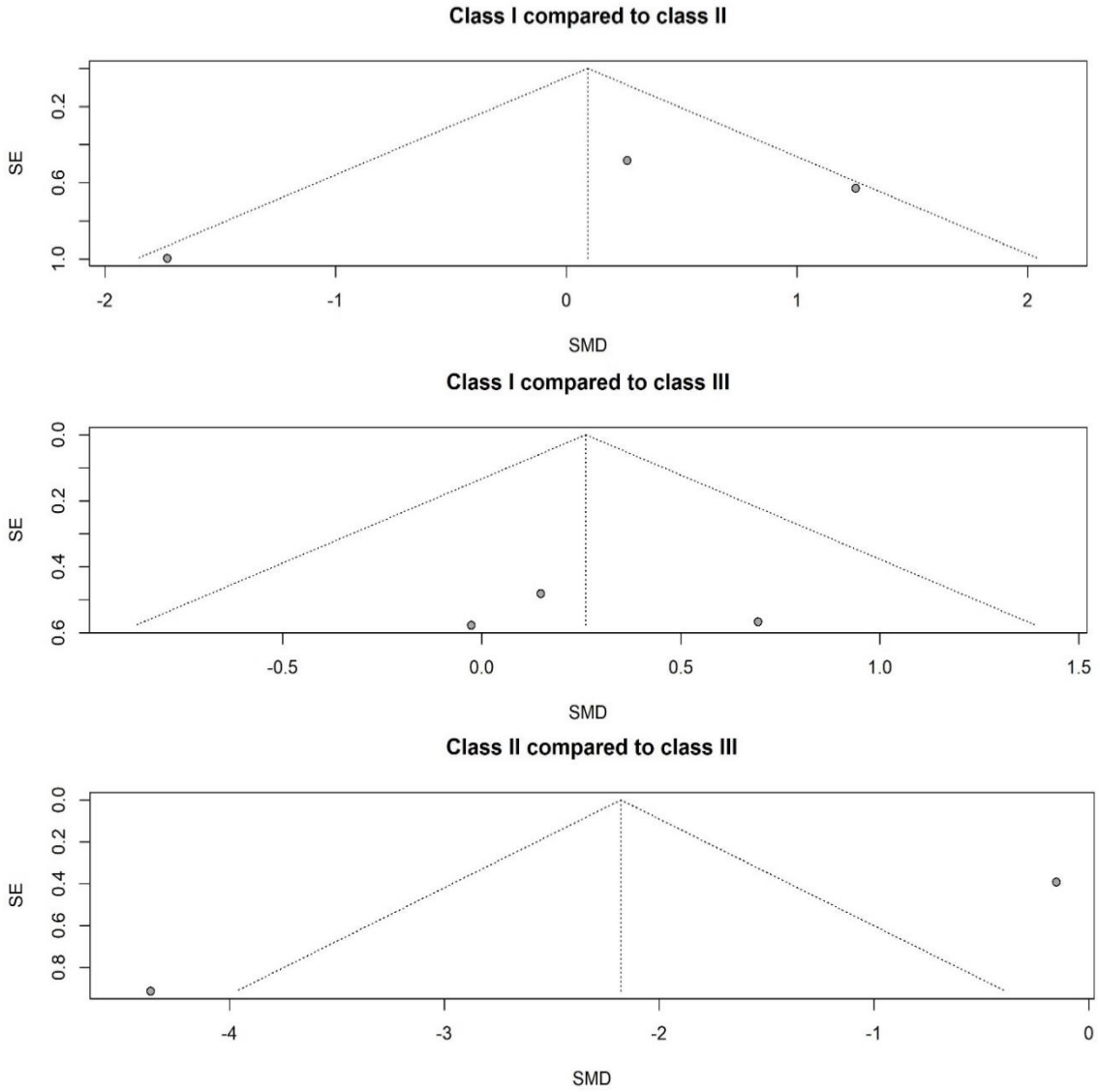


Figure 2. Funnel plots of comparing Class I, II and III in terms of Masseter muscle activity during Chewing.

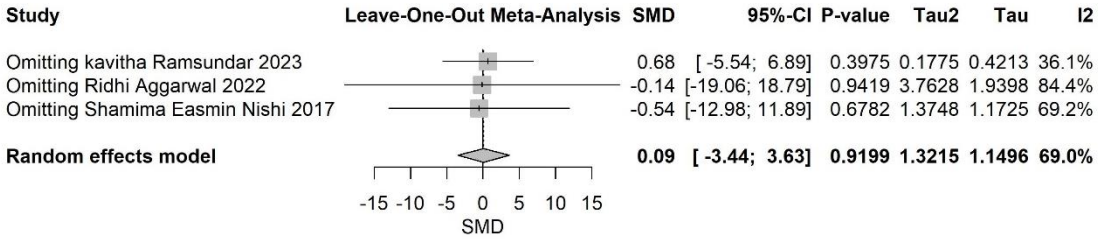


Figure 3. Sensitivity analysis of comparing Class I, II in terms of Masseter muscle activity during Chewing.

For Class I versus III comparison, no heterogeneity was observed among studies, with an I^2 of 0.0%, a Tau^2 of 0.0, and a statistically non-significant Cochran's Q test ($p = 0.64$), indicating that the variation in effect sizes is likely due to chance.

For the Class II versus Class III comparison, substantial heterogeneity was observed among studies, with an I^2 of 94.4%, a Tau^2 of 8.39, and a highly significant Cochran's Q test ($p < 0.001$), indicating considerable variability in effect sizes beyond chance.

Temporal muscle activity during Chewing:

Three studies (n = 69; Class I = 28, Class II = 18,

Class III = 23) reported temporalis activity while chewing.

Class II showed a small, non-significant increase relative to Class I (SMD = SMD = −0.18, 95% CI −2.74 to 2.38) (Figure 5). No heterogeneity was detected across studies, with an I^2 of 0.0%, $\tau^2 = 0$, and a non-significant Cochran's Q test (p = 0.62), suggesting that variation in effect sizes is consistent with chance.

Class III was associated with a small and insignificant reduction compared to Class I (SMD = 0.13, 95% CI −5.75 to 6.01) (Figure 5). Moderate heterogeneity was present, with an I^2 of 36.3%, τ^2 = 0.16, and a non-significant Q test (p = 0.21), indicating some between-study variability, though not statistically significant.

For the comparison between Class II and Class III, only one study (Aggarwal et al., 2022) provided relevant data. In this study, temporalis muscle activity in Class II subjects (M = 47.62, SD = 13.029) was lower than in Class III subjects (M = 53.31, SD = 24.941); however, the difference did not reach statistical significance (p = 0.571).

Masseter muscle activity during Maximum Voluntary Clenching:

The effect of various malocclusions in altering masseter muscle activity during MVC was assessed in a meta-analysis of 13 studies with 571 participants, out of which 203 were Cl I, 145 were Cl II and 223 were Cl III.

For the Class I versus Class II comparison, the pooled analysis suggested a non-significant increase in effect size for Class I group (SMD = 1.00, 95% CI −0.77 to 2.77) (Figure 6). However, substantial heterogeneity was detected, with an I^2 of 85.2%, τ^2 = 3.00, and a highly significant Cochran's Q test (p < 0.001), indicating considerable variability in effect sizes beyond chance.

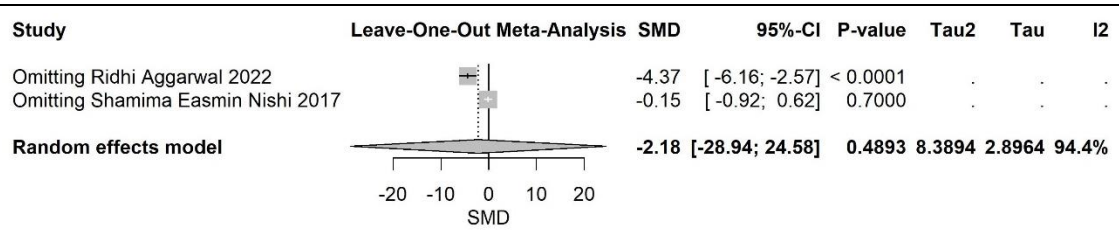


Figure 4. Sensitivity analysis of comparing Class II and III in terms of Masseter muscle activity during Chewing.

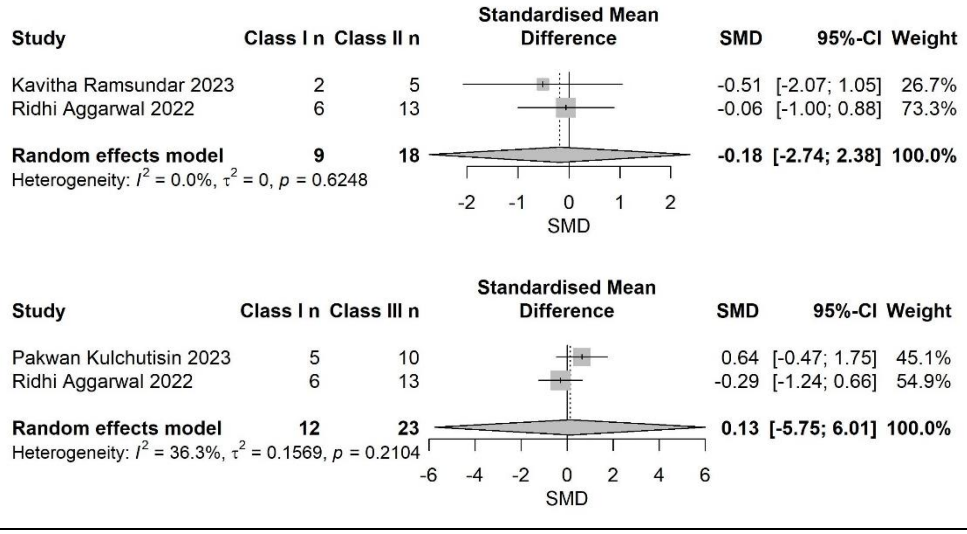


Figure 5: Forest plots of comparing different classes in terms of Temporal activity during Chewing.

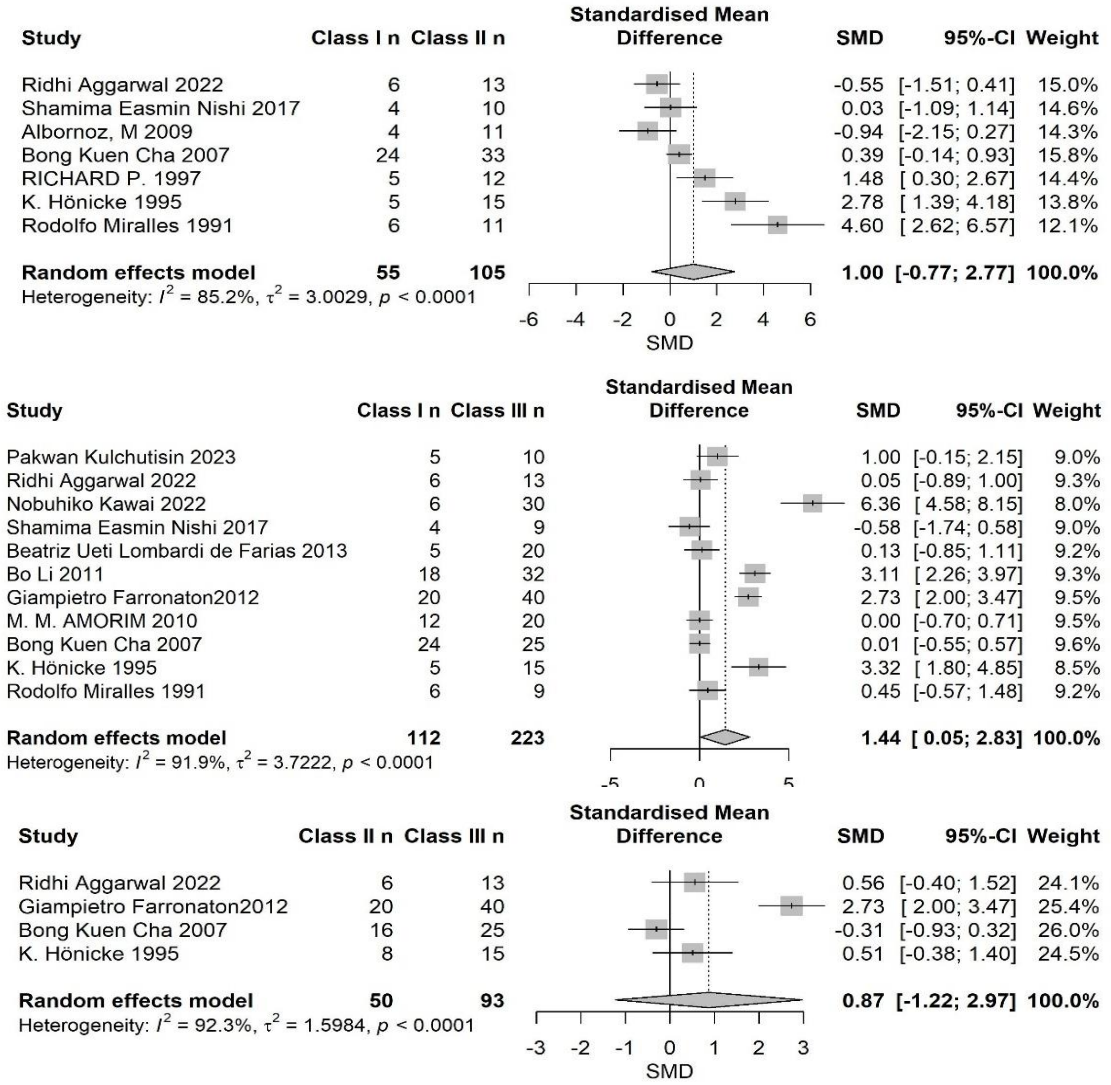
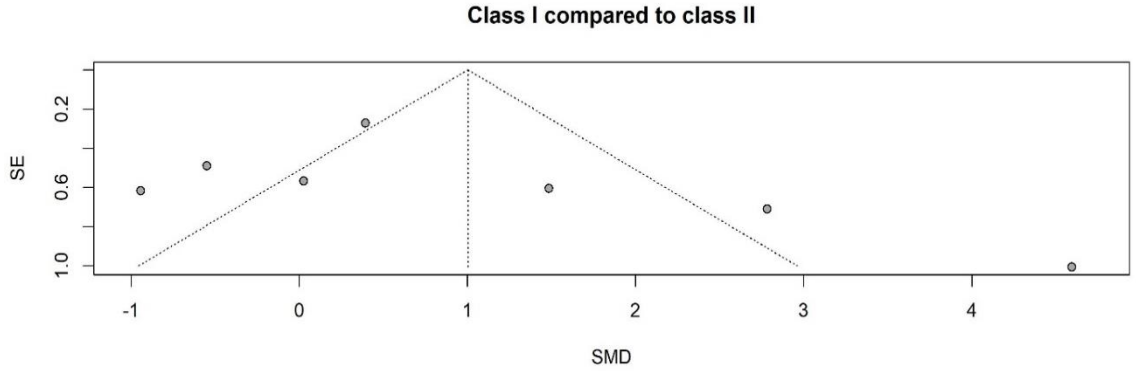


Figure 6: Forest plot of comparing different classes in terms of Masseter activity during Maximum Voluntary Clenching.



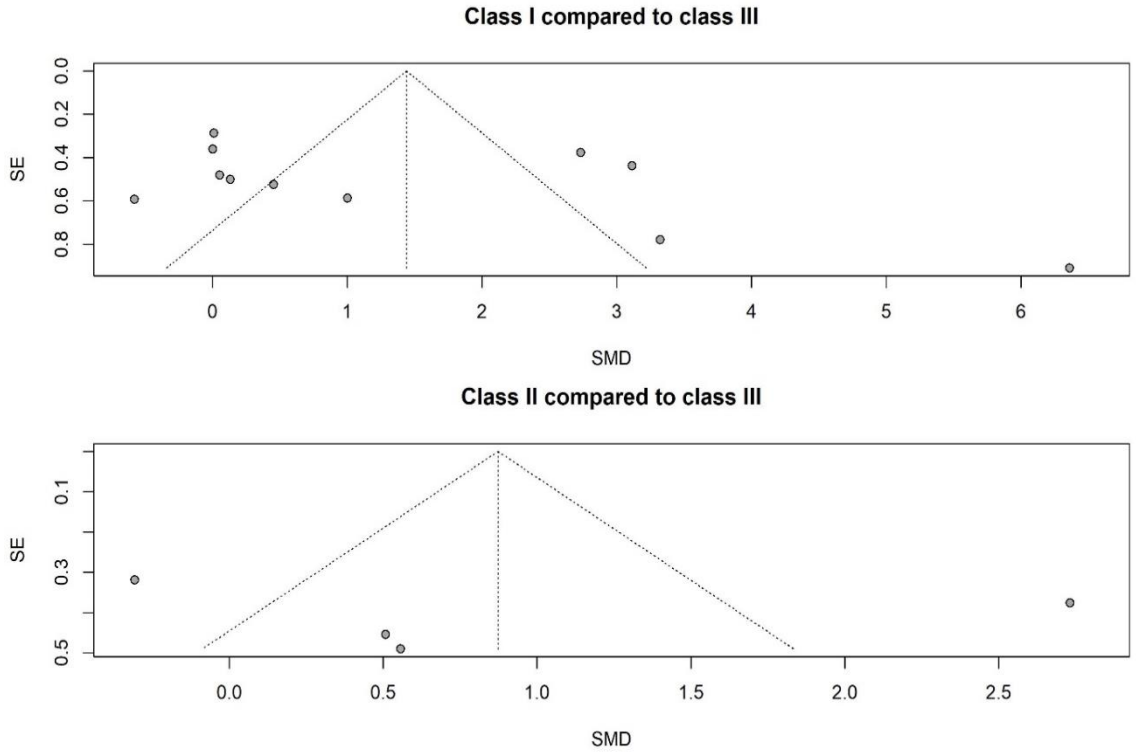


Figure 7. Funnel plots of comparing Class I, II and III in terms of Masseter muscle activity during Maximum Voluntary Clenching.

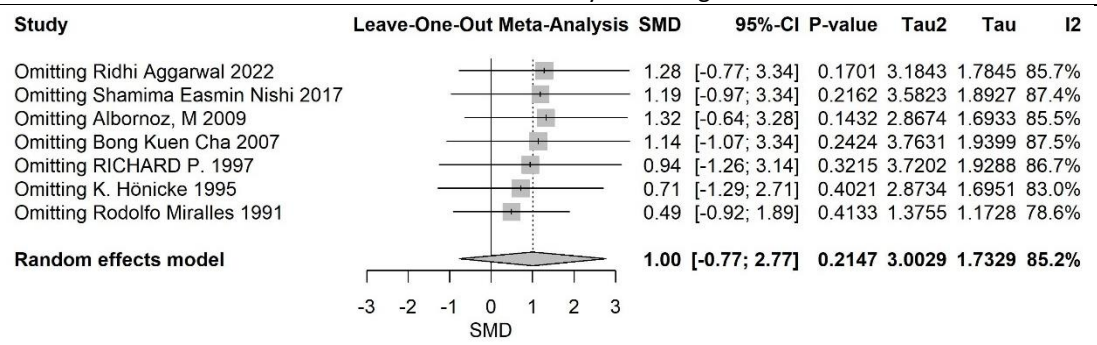


Figure 8. Sensitivity analysis of comparing Class I, II in terms of Masseter muscle activity during Maximum Voluntary Clenching.

Class III showed a greater reduction relative to class I, which was statistically significant (SMD = 1.44, 95% CI 0.05 to 2.83, p = 0.017) (Figure 6). Heterogeneity was very high, with an I^2 of 91.9%, τ^2 = 3.72, and a significant Q test (p < 0.001), suggesting that study results varied widely.

For the Class II versus Class III comparison, a non-significant increase was observed (SMD = 0.87, 95% CI −1.22 to 2.97) (Figure 6). Heterogeneity was again very high, with an I^2 of 92.3%, τ^2 = 1.60, and a significant Q test (p < 0.001), reflecting marked inconsistency across studies.

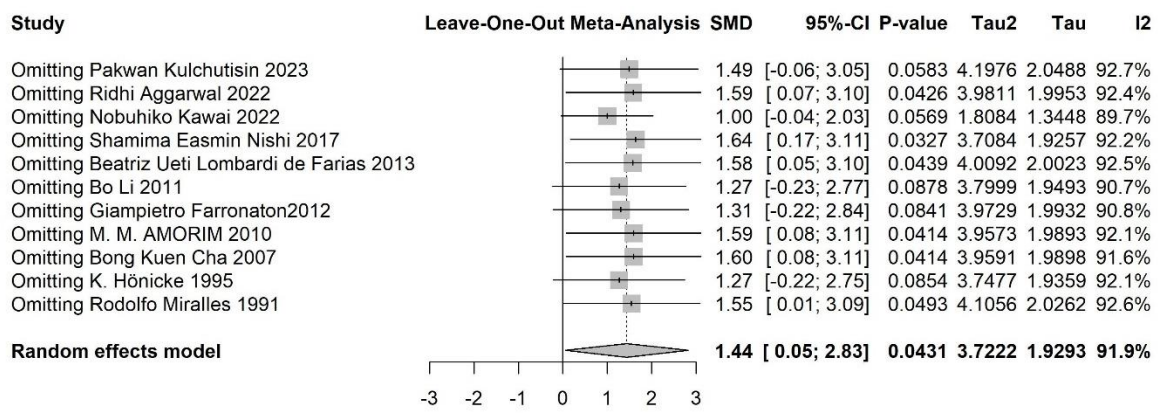


Figure 9. Sensitivity analysis of comparing Class I, III in terms of Masseter muscle activity during Maximum Voluntary Clenching.

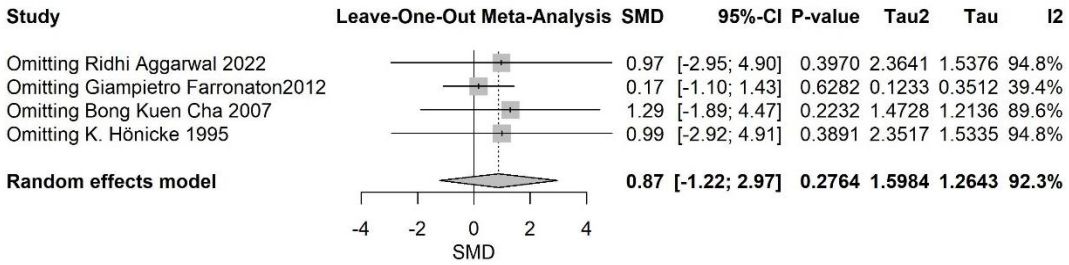


Figure 10. Sensitivity analysis of comparing Class II, III in terms of Masseter muscle activity during Maximum Voluntary Clenching.

Temporal muscle activity during Maximum Voluntary Clenching:

In an effort to evaluate the effect of malocclusion on temporal activity during MVC, A meta-analysis was performed on 13 studies that included a total of 566 patients. Of these patients, 213 were Cl I, 130 were Cl II and 223 were Cl III. A total of six studies examined the differences between Class I and Class II (23, 24, 28, 29, 35, 38), nine focused on the distinctions between Class I and Class III (14, 24-26, 29, 30, 37-39), and five compared Class II with Class III (23, 24, 29, 32, 38).

For the Class I versus Class II comparison, the pooled effect suggested a non-significant increase (SMD = 0.42, 95% CI −2.36 to 3.21) (Figure 11). However, heterogeneity was substantial, with an I^2 of 86.0%, $\tau^2 = 5.89$, and a highly significant Q test ($p < 0.001$), indicating that variability across studies was well beyond chance.

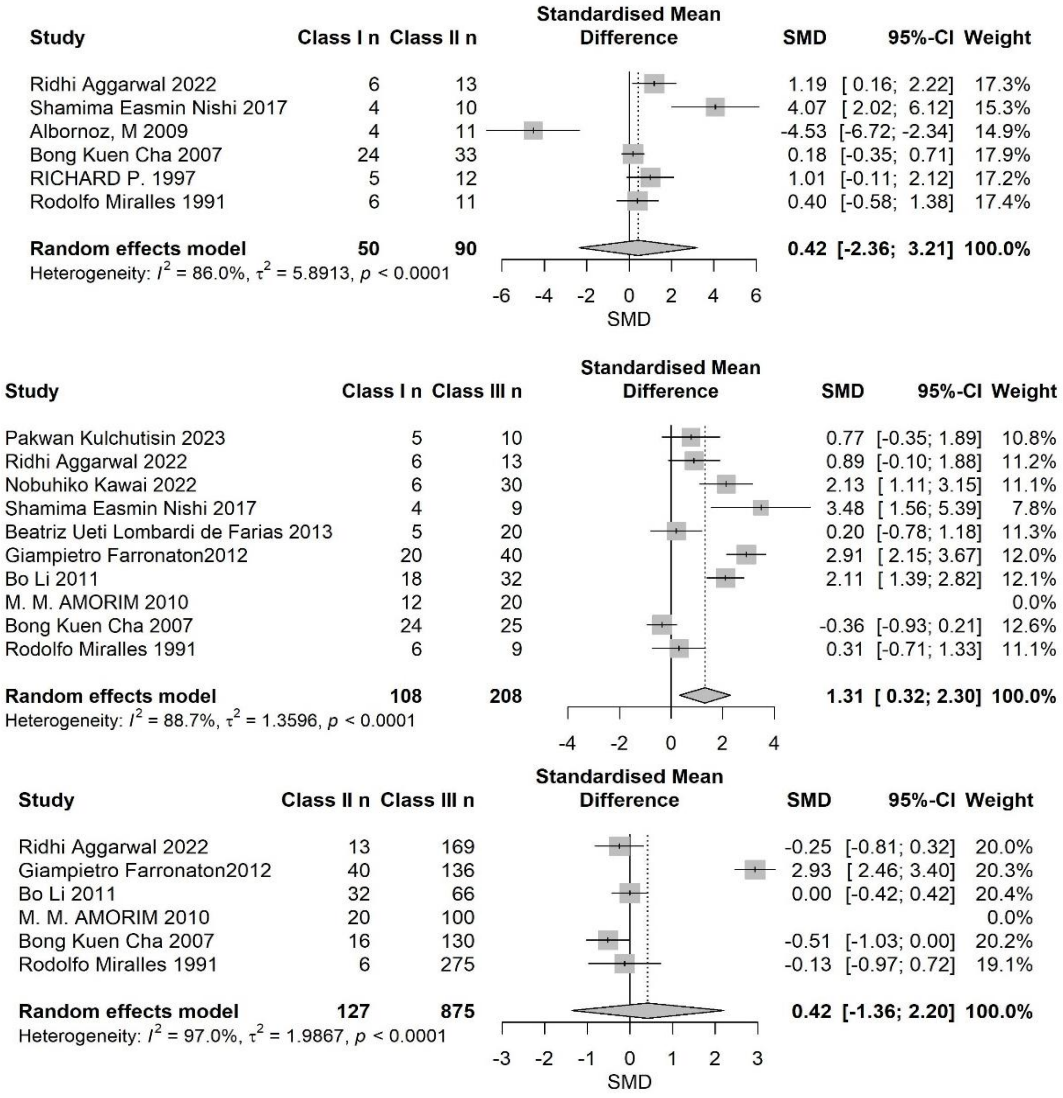
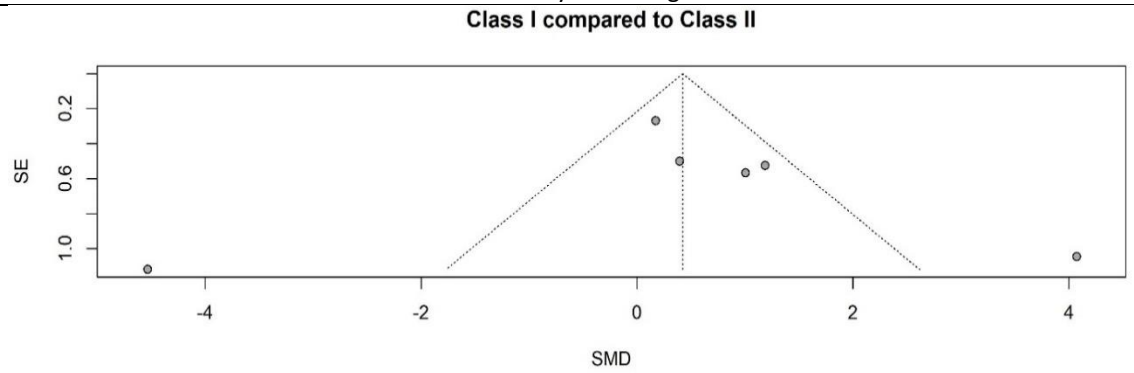


Figure 11: Forest plot of comparing different classes in terms of Temporal activity during Maximum Voluntary Clenching.



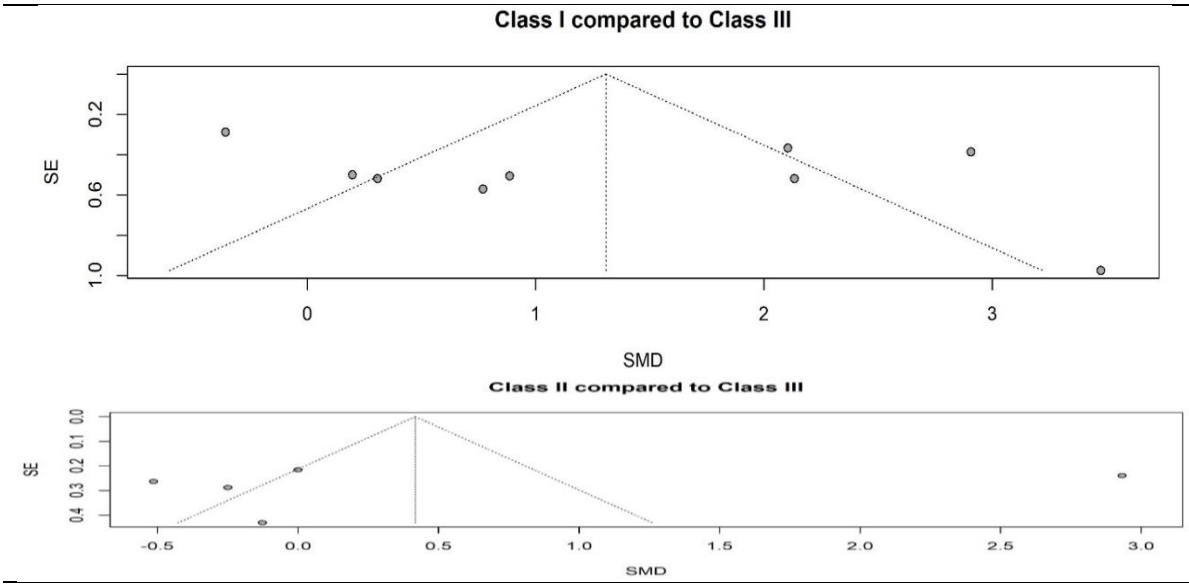


Figure 12. Funnel plot of comparing Class I, II and III in terms of Temporal muscle activity during Maximum Voluntary Clenching.

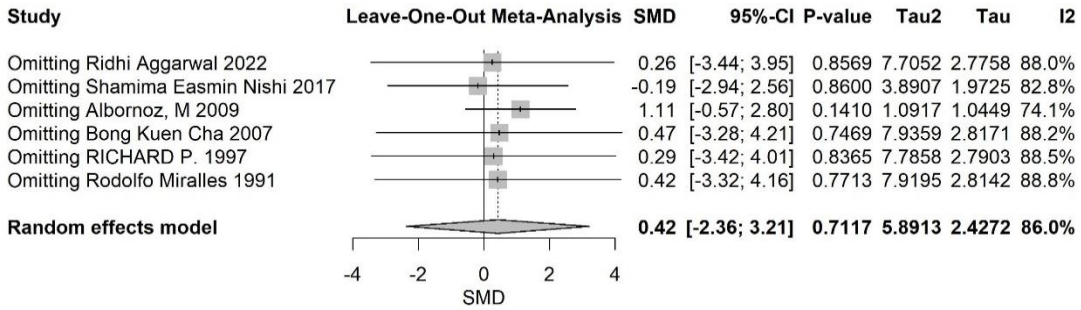


Figure 13. Sensitivity analysis of comparing Class I, II in terms of Temporal muscle activity during Maximum Voluntary Clenching.

Class I versus Class III showed a significant increase in muscular activity (SMD = 1.31, 95% CI 0.32 to 2.99, p = 0.02) (Figure 11). Heterogeneity was very high (I^2 = 88.7%, τ^2 = 1.36, Q p < 0.001), reflecting marked inconsistency between study results.

For the Class II versus Class III comparison, a non-significant pooled increase was found (SMD = 0.42, 95% CI −1.36 to 2.19, p = 0.55) (Figure 11). Heterogeneity was extreme, with an I^2 of 97.0%, τ^2 = 1.99, and a highly significant Q test (p < 0.001).

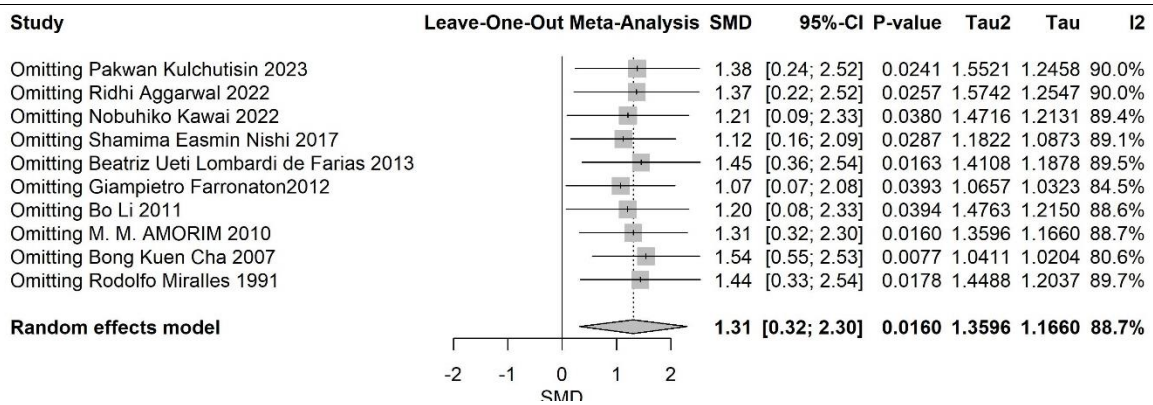


Figure 14. Sensitivity analysis of comparing Class I, III in terms of Temporal muscle activity during Maximum Voluntary Clenching.

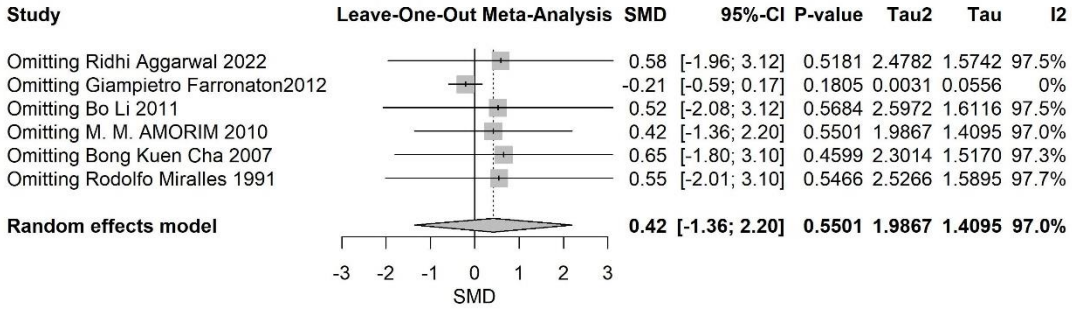


Figure 15. Sensitivity analysis of comparing Class II, III in terms of Temporal muscle activity during Maximum Voluntary Clenching.

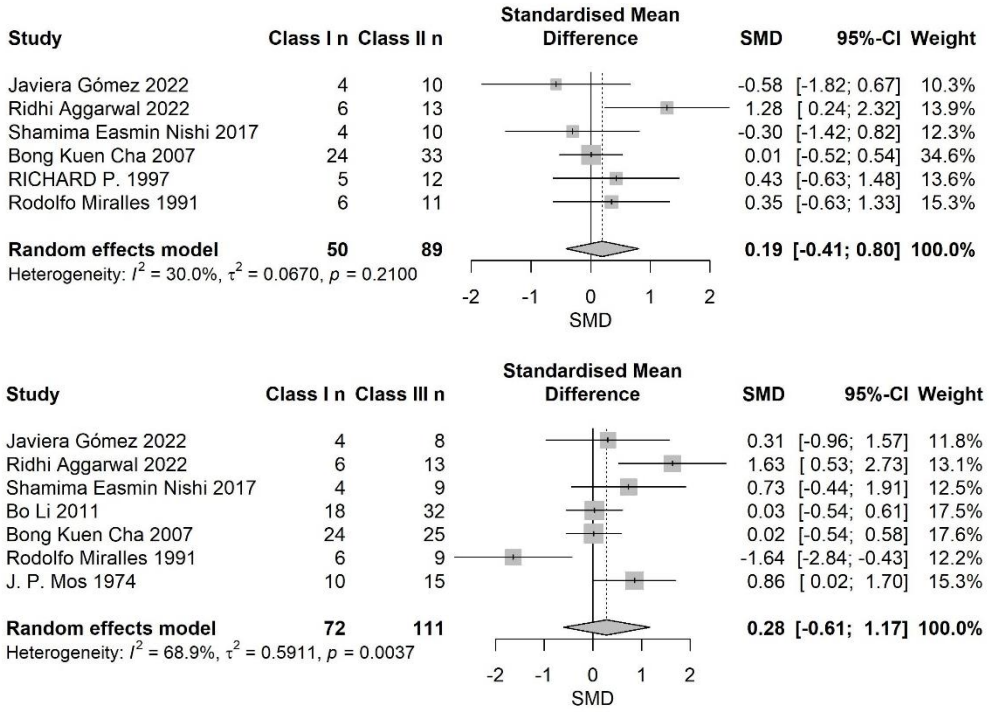
Taken together, both Class II and Class III demonstrated lower temporalis muscle activity at maximum voluntary clench compared to Class I; However, only Class I versus III comparison was statistically significant.

Masseter muscle activity during rest:

Eight studies comparing muscle activity at rest were enrolled in the meta-analysis, from which two focused on Class I vs Class III differences (28, 46), and one study investigated Class I vs Class II disparities (42). Others provided data about all three Classes. A total number of 355 patients were studied (155 Cl I, 89 Cl II, 111 Cl III).

For the Class I versus Class II comparison, the pooled effect size indicated a small and non-significant increase (SMD = 0.19, 95% CI −0.41 to 0.81, p = 0.45) (Figure 16). Heterogeneity was low to moderate, with an I^2 of 30.0%, $\tau^2 = 0.07$, and a non-significant Q test (p = 0.21), suggesting that variability across studies was largely due to chance.

For the Class I versus Class III comparison, the pooled analysis suggested a non-significant increase (SMD = 0.28, 95% CI −0.61 to 1.68, p = 0.47) (Figure 16). However, heterogeneity was substantial, with an I^2 of 68.9%, $\tau^2 = 0.59$, and a significant Q test (p = 0.004), indicating considerable variability in study findings.



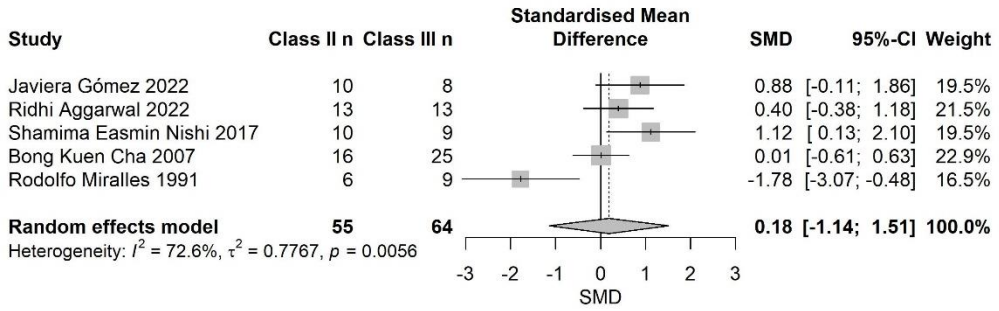


Figure 16: Forest plot of comparing different classes in terms of Masseter activity during rest.

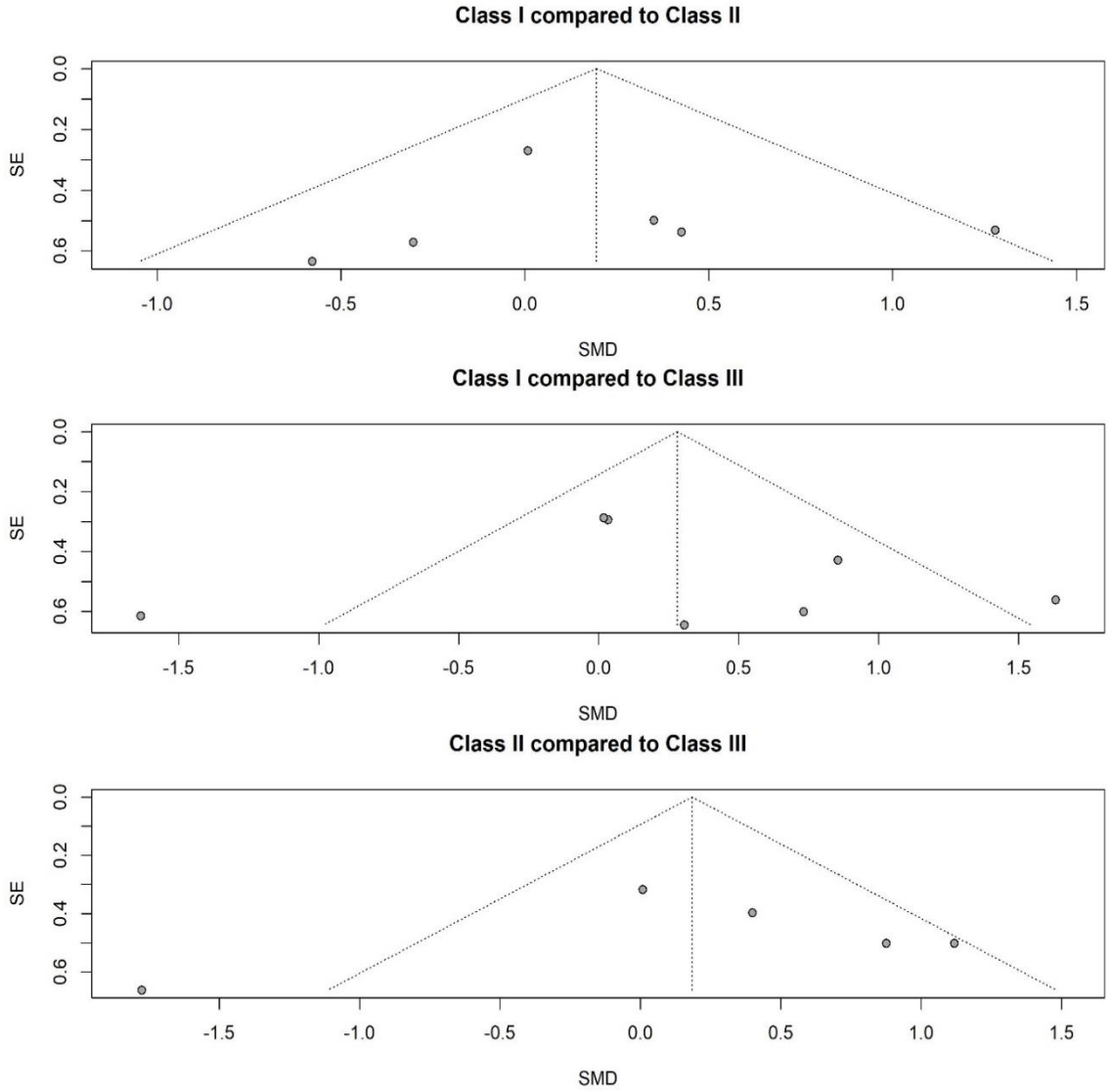


Figure 17. Funnel plot of comparing Class I, II and III in terms of Masseter muscle activity during rest.

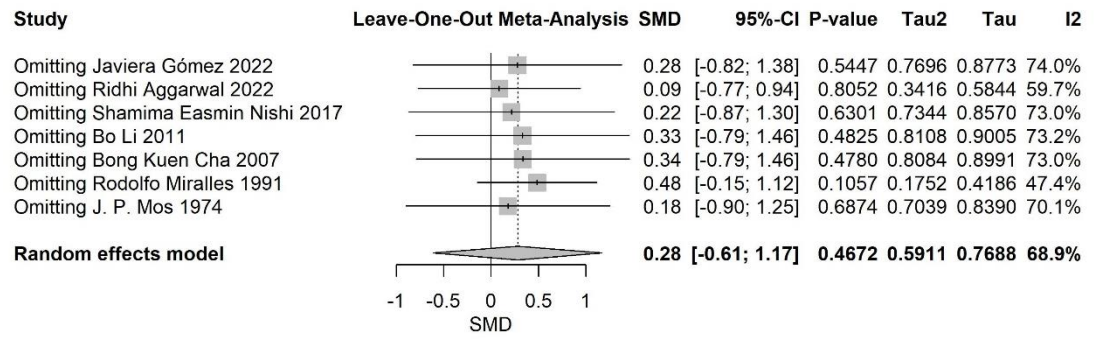


Figure 18. Sensitivity analysis of comparing Class I, III in terms of Masseter muscle activity during rest.

For the Class II versus Class III comparison, the pooled effect size also suggested a non-significant increase (SMD = 0.18, 95% CI −1.14 to 1.51, p = 0.72) (Figure 16). Heterogeneity was high, with an I^2 of 72.6%, τ^2 = 0.78, and a significant Q test (p = 0.006), indicating that between-study differences contributed substantially to the variation in effect estimates.

Based on results, generally Class II patients exhibited higher range of muscle activity compared to Class III and both were lower than Class I patients, although none of the comparisons showed statistically significant differences. The presence of moderate to high heterogeneity in the Class I vs III and Class II vs III comparisons suggests caution in interpreting the pooled findings.

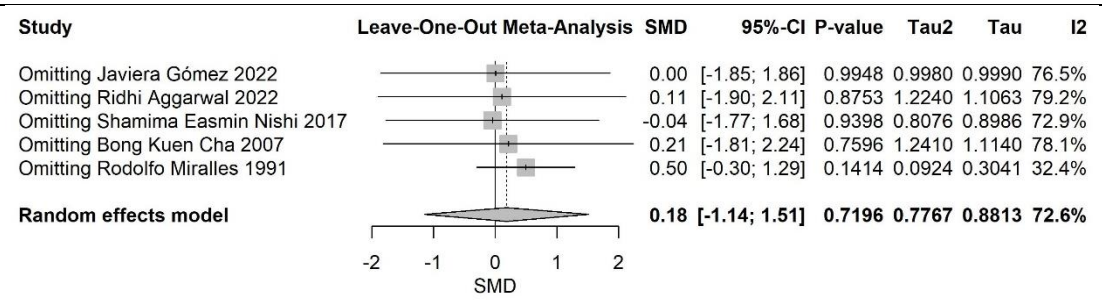
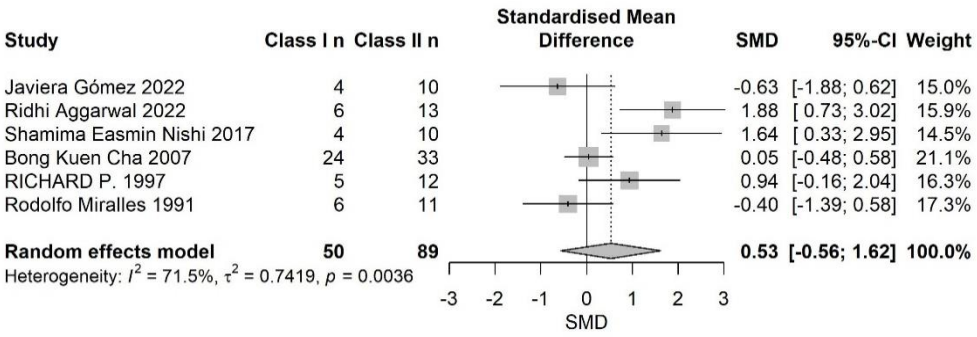


Figure 19. Sensitivity analysis of comparing Class II, III in terms of Masseter muscle activity during rest.

Temporal muscle activity during rest:

In a similar way, a meta-analysis was done on eight studies correlating differences in temporal muscle EMG during rest. All studies examined the differences among the three classes except for Li et al and Moss et al.'s study. 155 Class I, 89 Class II and 111 Class III patients were enrolled.

For the Class I versus Class II comparison, the pooled estimate suggested a small, non-significant increase in effect size (SMD = 0.53, 95% CI −0.56 to 1.62, p = 0.26) (Figure 20). However, heterogeneity was substantial (I^2 = 71.5%, τ^2 = 0.74, Q = 17.53, p = 0.0036), indicating considerable variability between studies.



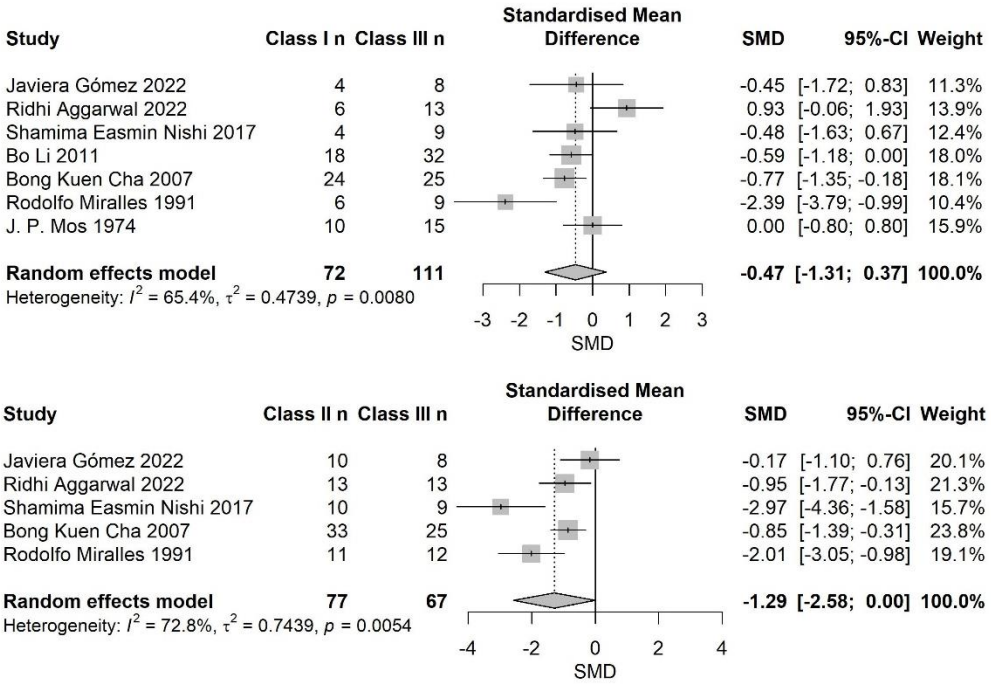
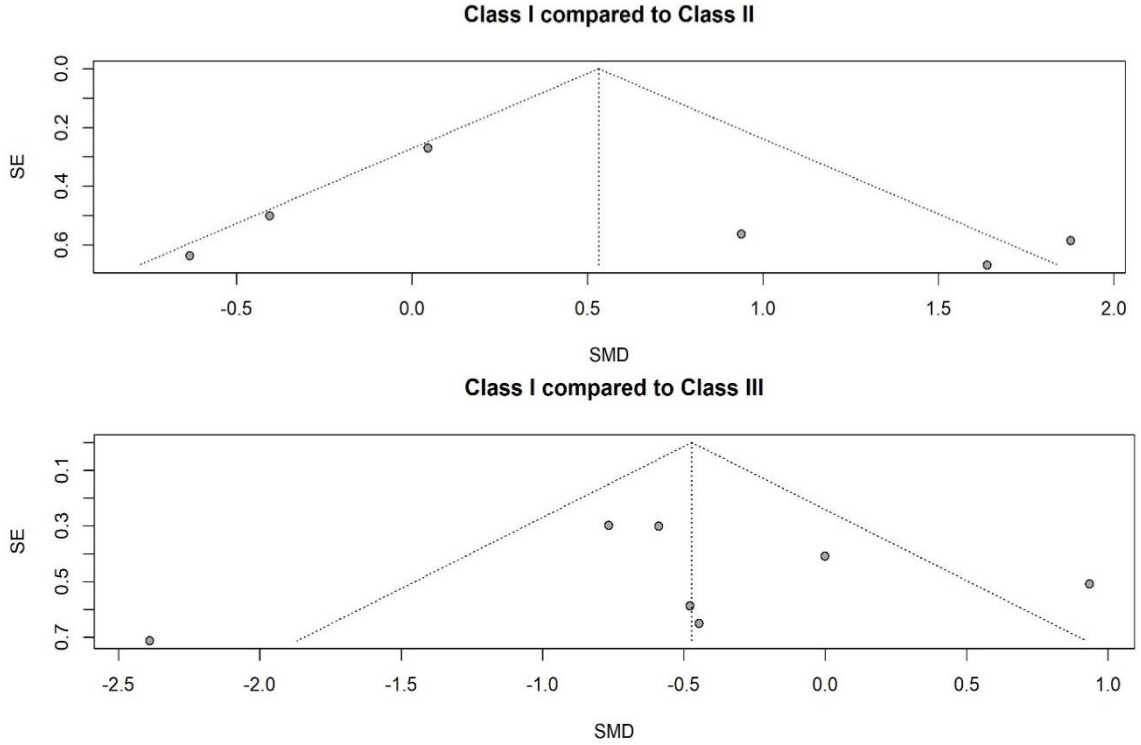


Figure 20: Forest plot of comparing different classes in terms of Temporal activity during rest.



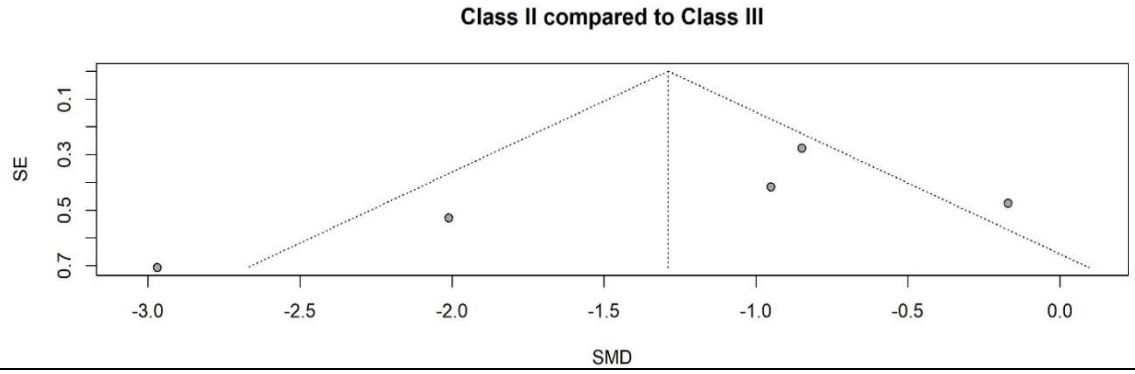


Figure 21. Funnel plot of comparing Class I, II and III in terms of Temporal muscle activity during rest.

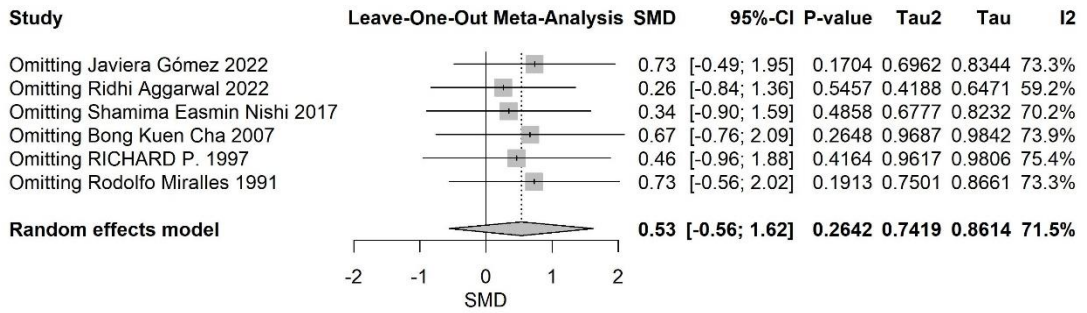


Figure 22. Sensitivity analysis of comparing Class I, II in terms of Temporal muscle activity during rest.

For the Class I versus Class III comparison, the pooled result indicated a non-significant decrease in effect size (SMD = −0.47, 95% CI −1.31 to 0.37, p = 0.22) (Figure 20). Moderate-to-high heterogeneity was observed (I^2 = 65.4%, τ^2 = 0.47, Q = 17.36, p = 0.008), reflecting inconsistency across studies.

For the Class II versus Class III comparison, the pooled analysis demonstrated a statistically significant decrease in effect size (SMD = −1.29, 95% CI −2.58 to 0.000, p = 0.05) (Figure 20). Heterogeneity was again high (I^2 = 72.8%, τ^2 = 0.74, Q = 14.69, p = 0.0054), suggesting substantial between-study differences.

Overall, while two of the three comparisons (Class I vs II and Class I vs III) yielded non-significant pooled effects, the Class II vs III contrast demonstrated a significant negative effect size, albeit with high heterogeneity.

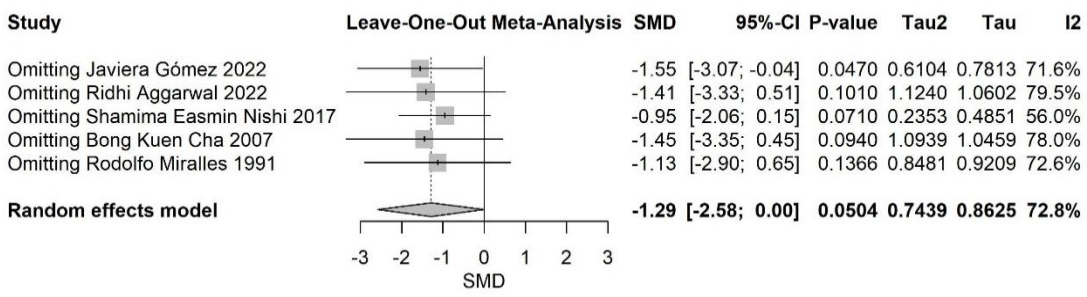


Figure 23. Sensitivity analysis of comparing Class II, III in terms of Temporal muscle activity during rest.

Risk of bias across studies

Masseter muscle activity during Chewing:

For the Class I versus II comparison, publication bias was assessed using a funnel plot (Figure 2) and further evaluated with Egger's test (p = 0.58). The results showed no strong evidence of small-study effects or publication bias.

In the Class I versus III comparison, the same approach—funnel plot (Figure 2) supported by Egger's test (p = 0.85)—similarly indicated no

strong evidence of such bias.

For the Class II versus Class III comparison, Egger's test could not be reliably performed due to the limited number of included studies. Although there is substantial variation across studies, these findings suggest that caution is warranted when interpreting the pooled effect.

Temporal muscle activity during Chewing:

For the Class I versus II comparison, the very limited number of included studies prevented reliable interpretation of Egger's test for publication bias.

Similarly, for the Class I versus III comparison, the small study precluded a robust evaluation of publication bias using Egger's test.

Regarding the Class II versus Class III comparison, only one study contributed data; as a result, heterogeneity could not be assessed, and publication bias analyses were not applicable. This outcome is therefore presented narratively rather than through meta-analysis.

Masseter muscle activity during Maximum Voluntary Clenching:

For the Class I versus II comparison, funnel plot inspection revealed no evidence of small-study effects or publication bias, supported by Egger's test ($p = 0.28$; Figure 7).

In the Class I versus III comparison, Egger's test similarly did not suggest strong evidence of publication bias ($p = 0.19$; Figure 7).

Regarding the Class II versus III comparison, Egger's test indicated no strong evidence of publication bias ($p = 0.82$); however, the reliability of this test is limited due to the small number of included studies (Figure 7).

Temporal muscle activity during Maximum Voluntary Clenching:

For the Class I versus II comparison, Egger's test ($p = 0.91$) showed no evidence of small-study effects or publication bias (Figure 12).

In the Class I versus III comparison, Egger's test ($p = 0.38$) similarly revealed no strong indication of publication bias (Figure 12).

For the Class II versus III comparison, Egger's test again provided no evidence of publication bias ($p = 0.70$); however, the small number of included studies limits the reliability of this finding (Figure 12).

Masseter muscle activity during rest:

For the Class I versus II comparison, Egger's test ($p = 0.78$) showed no evidence of publication bias (Figure 17).

In the Class I versus III comparison, Egger's test similarly did not reveal evidence of small-study effects or publication bias ($p = 0.73$; Figure 17).

Regarding the Class II versus III comparison, Egger's test indicated no publication bias ($p = 0.75$); however, the limited number of studies restricts the reliability of this finding (Figure 17).

Temporal muscle activity during rest:

Across all analyses, Egger's tests did not suggest evidence of publication bias, though the limited number of included studies reduces the power of these tests.

For the Class I versus II comparison, the Egger's regression test showed no evidence of small-study effects ($t = 0.98$, $df = 4$, $p = 0.38$; Figure 21).

In the Class I versus III comparison, Egger's test similarly indicated no publication bias ($t = -0.06$, $df = 5$, $p = 0.96$; Figure 21).

For the Class II versus III comparison, Egger's test revealed no significant evidence of small-study bias ($t = -1.38$, $df = 3$, $p = 0.26$; Figure 21).

Additional Analysis

The results of the sensitivity analysis—conducted to assess the influence of individual studies on the overall effect and heterogeneity—are presented in Figures 3, 4, 8, 9, 10, 13, 14, 15, 18, 19, 22, and 23.

Masseter muscle activity during Chewing:

For the Class I versus II comparison, moderate heterogeneity prompted a leave-one-out meta-analysis to evaluate the impact of each study (Figure 3). Leave-one-out analysis indicated that the overall conclusion remained unchanged regardless of which study was removed. However, heterogeneity decreased most notably when the study by Ramsundar et al. (15) was omitted ($I^2 = 36\%$), suggesting this study contributed most to variability.

For the Class II versus Class III comparison, only two studies measured this variable; therefore, sensitivity analysis could not lead to a meta-analysis (Figure 4).

Masseter muscle activity during Maximum Voluntary Clenching:

For the Class I versus Class II comparison, leave-one-out analysis confirmed that the overall result remained unchanged, although heterogeneity decreased slightly (to 78.6% when omitting Miralles 1991). However, I^2 consistently remained high (>75%), indicating that heterogeneity cannot be attributed to a single study but is likely due to broader methodological or clinical differences across studies (Figure 8).

In the Class I versus III comparison, the overall pooled effect was statistically significant; however, the leave-one-out analysis revealed sensitivity to the omission of certain studies, with the association becoming non-significant in some cases. Importantly, heterogeneity remained persistently very high ($I^2 \approx 90\%$) regardless of which study was excluded, suggesting that the variability is systematic rather than driven by individual studies. Consequently, studies cannot be simply excluded based on heterogeneity alone, and the significant pooled effect should be interpreted with caution (Figure 9).

For the Class II versus Class III comparison, leave-one-out analysis revealed that heterogeneity markedly decreased ($I^2 = 39\%$) when omitting Farronato et al. (39), suggesting this study was the primary driver of between-study variability. However, the pooled effect remained non-significant in all cases (Figure 10).

Temporal muscle activity during Maximum Voluntary Clenching:

For the Class I versus Class II comparison, leave-one-out sensitivity analysis showed that omitting Albornoz et al. (35) reduced heterogeneity most ($I^2 = 74\%$), while exclusion of other studies did not meaningfully change results. However, the pooled effect remained non-significant in all scenarios (Figure 13).

In the Class I versus III comparison, the overall effect remained significant regardless of which study was omitted, demonstrating robustness. The largest decrease in heterogeneity occurred after removing Bong Kuen Cha et al. (36) ($I^2 = 80.6\%$), followed by exclusion of Giampietro Farronato et al. ($I^2 = 84.5\%$) (Figure 14).

For the Class II versus Class III comparison, leave-one-out analysis revealed that heterogeneity was largely driven by Giampietro Farronato et al.; excluding this study reduced I^2 to 0%, although the pooled effect remained non-significant. Exclusion of other studies had minimal impact on heterogeneity or the overall result (Figure 15).

Masseter muscle activity during rest:

For the Class I versus Class III comparison, leave-one-out sensitivity analysis indicated that heterogeneity decreased most when omitting Rodolfo Miralles et al. (45) ($I^2 = 47.4\%$), suggesting this study contributed most to between-study variability. The pooled effect remained non-significant regardless of which study was excluded (Figure 18).

In the Class II versus III comparison, a similar pattern emerged: the greatest reduction in heterogeneity occurred after removing Rodolfo Miralles et al. ($I^2 = 32.4\%$), suggesting this study substantially contributed to between-study variability. Again, the pooled effect stayed non-significant in all cases (Figure 19).

Temporal muscle activity during rest:

For the Class I versus Class II comparison, leave-one-out sensitivity analysis indicated that heterogeneity decreased most when omitting Ridhi Aggarwal et al. (26) ($I^2 = 59.2\%$), suggesting this study contributed somewhat to between-study variability. The pooled effect remained non-significant in all cases (Figure 22).

For the Class II versus Class III comparison, leave-one-out analysis showed that omitting Javiera Gómez et al. (41) resulted in a statistically significant effect (SMD = −1.55, 95% CI −3.07 to −0.04, $p = 0.047$), whereas exclusion of other studies rendered the effect non-significant. This suggests that the overall result is somewhat sensitive to the inclusion of individual studies (Figure 23).

Discussion

This systematic review and Meta-Analysis consolidates current evidence on the association between malocclusion and masticatory muscle electromyographic (EMG) activity in adults. A total of eighteen studies were analyzed, each evaluating alterations in EMG activity of orofacial muscles across different sagittal malocclusion classifications. According to the NOS-xs assessment and GRADE framework, the overall quality of evidence ranged from very low to moderate, with most studies demonstrating either a low (16, 28, 29, 35-37, 39, 40, 44-46) or moderate (15, 26, 27, 38, 41-43) risk of bias. Across the included studies, variations in muscle electrical activity were observed depending on both the muscle examined and the functional task performed. The most commonly assessed activities were rest, clenching, chewing, and swallowing. Among the investigated muscles, the masseter and anterior temporalis were most frequently studied, while several investigations also examined additional muscles such as the buccinator, lateral pterygoid, sternocleidomastoid, and anterior digastric.

We performed several separate meta-analyses examining masseter and temporalis activity during rest, functional chewing, and maximum voluntary clenching (MVC); to clarify how sagittal skeletal patterns influence EMG activity. Pooling was undertaken despite notable heterogeneity in

certain outcomes because the populations, exposures, and outcome measures were conceptually comparable. To enhance robustness, leave-one-out analyses were conducted for outcomes showing substantial heterogeneity. Importantly, the only consistent statistically significant findings—reduced masseter and temporalis activity in Class III relative to Class I during MVC, and reduced temporalis activity in Class II versus III at rest—should be interpreted cautiously given the small number of studies, and residual heterogeneity.

Many factors may account for the overall heterogeneity. One important determinant is the severity of malocclusion. Some EMG studies included individuals with severe skeletal discrepancies who were candidates for orthognathic surgery, while others enrolled patients with much milder conditions. Although we selected studies with generally comparable sample groups, differences in case severity may still have influenced the results. Furthermore, since the studies were conducted in various settings, they used different EMG devices and measurement protocols, which could not be fully standardized across investigations. A few of the included studies also considered vertical facial classification in addition to sagittal relationships—such as Cha et al., who subdivided patients into hypo- and hyperdivergent groups—whereas others did not take this factor into account. This variation in study design may explain why certain studies contributed more strongly to heterogeneity.

According to the sensitivity analyses, Farronato et al. (2012) exerted a major influence on several pooled outcomes. Their inclusion of adult surgical patients with severe skeletal discrepancies likely created a clinical profile that was not directly comparable to nonsurgical orthodontic samples. Moreover, they employed two different EMG devices (Freely and K6-I) with distinct acquisition protocols, unlike most other studies that used a single standardized system—factors that likely contributed to the observed heterogeneity.

During chewing, pooled results were inconsistent, suggesting that adaptive neuromuscular mechanisms may obscure true associations. Even so, the trend pointed to the strongest masseter bursts in Class I subjects. Under MVC for both muscles, Class I produced the highest EMG amplitudes, Class II occupied an intermediate position, and Class III showed the lowest readings. Some studies suggest that this reduction in Classes II and III may reflect the altered orientations and leverage of their masticatory muscle attachments. In Class I individuals, the orientation of the masseter and temporalis muscles aligns more vertically with the mandibular closing trajectory, maximizing their mechanical efficiency during clenching. Conversely, the altered skeletal relationships in Class II (retrognathic mandible) and Class III (prognathic mandible) shift the origin and insertion angles of these muscles, reducing their leverage and effective force transmission. Cone-beam CT studies have demonstrated that masseter orientation in Class III subjects becomes more oblique (~82°), diminishing its vertical force vector, while Class II shows a more acute angulation (~67°), both deviating from the optimal near-vertical alignment seen in Class I (47, 48). Additionally, cranial base morphology and mandibular plane angles further modulate muscle efficiency by affecting jaw posture and occlusal contact patterns (49).

From a neuromuscular perspective, differences in muscle recruitment and coordination may also contribute. Class I subjects tend to show more synchronized and efficient masseter–temporalis co-activation, whereas Class II and III malocclusions are associated with less coordinated firing patterns, possibly due to skeletal discrepancy-induced adaptations in motor control (50). These discrepancies may trigger protective neuromuscular inhibition, especially in the presence of unstable or limited occlusal contacts, as often observed in Class II (e.g., excessive overjet) and Class III (e.g., edge-to-edge bites). Periodontal proprioception and temporomandibular joint discomfort can further dampen muscle activation through central feedback inhibition. However, our included studies did not find any significant asymmetry differences among skeletal classes, suggesting that while absolute EMG activity is modulated by sagittal discrepancies, the side-to-side coordination remains largely unaffected.

Finally, the number and quality of occlusal contacts play a crucial role in modulating EMG output. Class I occlusion typically provides broad, bilateral molar contact during intercuspation, enabling balanced force distribution and maximal elevator muscle engagement. In contrast, malocclusions often result in fewer functional contacts, especially posteriorly, which reduces bite force capacity and thus muscle activation levels. Empirical studies confirm that both bite force and EMG amplitudes correlate positively with the extent of occlusal contact area (51, 52). Furthermore, compensatory skeletal and dental shifts in Class II and III—such as proclined incisors or molar crossbites—can limit occlusal stability and direct clenching forces away from ideal vectors. Collectively, these findings explain why EMG

activity during MVC is highest in Class I and progressively reduced in Class II and III individuals.

As for the differences during rest, the temporalis behaved differently across classes: activity dropped significantly in Class II compared with Class III. Masseter activity, by contrast, did not reach statistical significance across groups, although the numerical ordering (Class I > Class II > Class III) echoed the MVC pattern. A potential explanation for this might be that at rest, the temporalis muscle's baseline tone appears sensitive to mandibular posture: in Class II the retruded mandible shortens the temporalis fibers, reducing their passive tension and EMG activity, whereas in Class III the prognathic mandible lengthens those fibers, increasing resting stretch and hence activity relative to Class I. The masseter, being more robustly anchored and less affected by small postural shifts, shows no statistically significant resting differences, though it follows the same numerical trend.

Several studies have suggested that, beyond the anterior–posterior skeletal relationship, vertical dimensions also influence masticatory muscle activity. One such investigation by Cha et al. classified individuals according to ANB and SN-GoMe values. They demonstrated that vertical dimension can significantly affect muscle function. Specifically, they found that a greater tendency toward Class III malocclusion, combined with increased vertical facial dimensions (hyperdivergent pattern), was associated with higher temporalis muscle activity at rest. In contrast, temporalis activity during clenching increased only with a greater tendency toward Class III malocclusion and showed no association with vertical dimension. No significant relationship was observed between masseter muscle activity and skeletal classification (36). Nonetheless, other studies have indicated a notable negative correlation between superficial masseter and vertical measurements, including facial height, anterior to posterior facial ratio, and the mandibular and occlusal plan inclination (53-55).

The disparities between male and female muscle strength continue to be a contentious topic of discussion. Certain investigations remarked a significant correlation between gender and muscle activity. Generally, the variations in muscle strength between men and women are believed to be influenced by the type of muscle contraction and the muscle's length. In adults, these differences are typically more pronounced in the upper body compared to the lower parts and are stronger during concentric contractions compared to eccentric ones. Some research indicates that men tend to demonstrate greater strength, while other studies have reported conflicting findings regarding orofacial muscles (56-59).

In our review, some researchers had investigated this issue. Regarding that only three of the included studies stratified participants by sex, a separate analysis of male versus female muscle activity was not feasible. Gómez and his team studied the EMG activity of the masseter and temporal muscles at various oral openings in a group of adults. They assessed the influence of sex and Angle classification while participants were at rest and during swallowing. The findings revealed no notable differences concerning sex in any of the jaw classifications (41). Similarly in Aggarwal et al.'s study, no significant gender-wise differences was found when comparing masseter, temporalis and buccinator muscle activity at rest, during chewing, and during clenching (26). In the same way, Ferrario et al. found no significant sex-related differences in any of the measured muscular activity indices, including masseter, temporalis, and sternocleidomastoid symmetry, or normalized muscle activity levels (40).

In contrast to the above findings, Shamima Easmin Nishi et al. (2017) conducted a study that examined sex-related differences in masseter and temporalis muscle activity across rest, post-rest, chewing, and clenching states. The results demonstrated that the right temporalis muscle exhibited significantly greater activity in men compared to women during clenching. Although the right masseter muscle showed no statistically significant difference between sexes, its mean activity was higher in women. Conversely, the left masseter muscle was more active in men during chewing, while the left temporalis muscle showed no significant sex-related differences during rest, clenching, or post-rest phases (27). Given these findings, it is essential to explore gender-based muscle activity further to gain a more nuanced understanding that could impact training, rehabilitation, and therapeutic strategies.

Some studies suggest that malocclusion may also affect other muscles. This relationship has been investigated by several researchers; However, these parameters were not included in our meta-analysis because the available data were insufficient for quantitative synthesis. The number of studies evaluating medial pterygoid muscle activity was very limited, and none met our criteria; likely due to the difficult and painful procedures required for EMG recording. This procedure requires the insertion of a needle at the same anatomical site used for administering an inferior alveolar nerve block. After each insertion, the

needle must be taken out, while the wires remain within the muscle. Many individuals may find this procedure difficult to tolerate (60).

A study on buccinator muscle activity found maximum activity in class I malocclusion during chewing, compared to class II and III. However, there were no significant differences in buccinator muscle activity at rest or during clenching (26). Another research on sternocleidomastoid and anterior digastric showed that in retrusion and protrusion positions of mandible, at rest and during clenching, the electromyographic activities of sternocleidomastoid in Class III patients were higher than the Class I group. Whereas anterior digastric showed lower activity during MVC, protrusion and retrusion positions in Class III patients but higher values at rest (28). Also lateral pterygoid muscle activity was found to be lower at maximum clench position in Class II group relative to normal occlusion both before and after mandibular advancement (42). These findings imply that malocclusion could influence other muscles activities as well, but Additional research is required to comprehensively elucidate how malocclusion affects these muscles.

In case of muscle symmetry, almost none of our included studies found significant effect of malocclusion on the harmony of muscle contraction. Ramsundar and colleagues, in their study on skeletal Class II division 1 patients with varying overjets, compared the symmetry and synergy of masseter and temporalis muscles. The muscle symmetry was found to be greater in individuals with severe Cl II malocclusion, though the difference was not statistically significant. The same result was concluded for synergy; However, the synergy of masseter and temporalis tended to decrease with increasing severity of malocclusion. Also they found that more severe Class II cases were associated with a poorer intensity and balance between the temporalis and masseter muscles while chewing (15).

In the study by Kulchutisin et al., the surface electromyographic activity of the masseter and temporalis muscles was evaluated during both chewing and maximum voluntary clenching (MVC). Muscle contractions were more symmetrical during maximal voluntary contraction (MVC) than during chewing in both Class I and Class III groups. Additionally, skeletal Class III patients demonstrated greater masseter symmetry but reduced temporal symmetry compared to skeletal Class I; however, the difference was not statistically significant. The synergy of masseter and temporal was significantly lower in skeletal Class III patients during MVC but not during chewing, suggesting a decrease in muscle coordination in Class III malocclusion (44).Farias et al. observed significantly greater asymmetric muscle activity in Class III patients during isometric contractions, contrasting with earlier studies (37). Furthermore, In the study by Ferrario et al. focusing on dental malocclusion, a bilateral and symmetric Angle Class I relationship demonstrated a greater tendency for homogeneous muscle activity compared to 'partial' Angle Class I relationships which may indicate a possible effect of occlusion on symmetric muscle contraction (40).

Some studies reported not only a more asymmetric muscle activity associated with malocclusion, but also a positive effect of orthodontic treatment on its recovery (25, 61).It is crucial to consider the variety within malocclusion classifications, as the severity and specific characteristics of the malocclusion likely play a significant role in influencing muscle activity. Further investigation with larger sample sizes should explore the potential adaptive mechanisms of masticatory muscles symmetry in response to malocclusion and consider the influence of factors such as age, gender, and individual chewing habits.

The assessments presented so far have important clinical applications in the diagnosis, treatment planning, and follow-up of patients. Orofacial muscles are essential for the proper development of dentition and the establishment of normal occlusion, as well as maintaining long-term occlusal stability. An imbalance in these muscles may jeopardize the long-term stability of outcomes obtained through orthodontic treatment; thus, paying attention to the muscle condition of patients before treatment seems to be necessary (14, 62). Studying the electromyographic activity of the muscles in the face and jaw can be valuable in routine clinical settings, particularly when specific skeletal malocclusions are evident before, during, and after orthodontic treatment. Surface electromyography is an effective tool for assessing this activity. However. It is contingent to various factors like skeletal structure, age, gender, and technical aspects, including the type of hardware and software employed, the way electrodes placed and signal processing procedures (63-65).

The studies included in our review, used this technique to measure muscle activity variation in different malocclusions. Numerous studies have shown that electromyography is a valuable, noninvasive, and painless method for monitoring changes in masticatory muscle strength before, during, and after orthodontic treatment. The data obtained from electromyography is essential for diagnosing, treatment planning, and monitoring

patients who are undergoing orthodontic procedures or using myofunctional appliances. It can also help determine the optimal times for wearing orthodontic appliances by comparing muscle activity at different times of the day. This technique can measure maximum voluntary clenching, assess muscle symmetry, and analyze the synergistic activity of the masseter and temporalis muscles. Additionally, with the use of surface electromyography, It is possible to compare muscle activity on the laterotrusive or chewing side with that on the opposite (mediotrusive) side, enabling the identification of right–left asymmetries during chewing and maximum voluntary contraction (21-23, 64, 66).

An interesting topic to explore is whether orthopedic and orthodontic treatments are effective in correcting variations in muscle activity. If they are, understanding the connection between malocclusion and muscle strength could significantly influence treatment decisions tailored to each individual's specific condition. Akturk et al. conducted a study on a group of Class III patients who exhibited significantly lower masseter muscle activity compared to a Class I control group before surgery. After the surgery, the Class III patients showed notable improvement and increased muscle activity, although it did not reach the levels of the control group three months postoperatively (67). Similar results were reported by Muftuoglu et al. in an electromyographic and sonographic evaluation of Class III individuals (68). The study by Trawitzki et al. reported that both masseter and temporalis muscle activity showed an immediate significant increase following surgical correction; though, these values remained lower than those observed in the control group (69). However, same authors in their next study, explained that in long term the electromyographic measurements of the masticatory muscles, particularly the masseter, became almost the same of normal individuals (70).

Some studies reported an initial reduction in muscle activity following orthognathic surgery and subsequent orthodontic treatment in Class III individuals, temporarily worsening muscle function; however, this decline was later followed by a gradual increase and long-term improvement in musculature activity (61, 71). Giannini et al. conducted an evaluation of patients at various stages throughout their orthodontic treatment, including before and after surgery. They found that electromyographic values declined during pre-surgical orthodontic treatment but improved post-surgery and significantly increased after the removal of orthodontic appliances. This study demonstrates that functional recovery through surgical and orthodontic correction is effective (72). In another study, the researchers compared Class II and Class III patients and found that at the beginning of treatment, Patients with Class II deep bite malocclusion exhibited higher muscular activity. By the end, these differences had diminished and were similar for both groups (25).

According to Priyadarsini et al., A significant association has been observed between vertical maxillary excess and reduced muscular strength. Corrective surgery improves occlusion, leading to more effective tooth contacts and greater muscle strength, collectively enhancing overall muscular function (73).According to all of these evidences, electromyographic activity is essential not only for diagnosing malocclusions but also for monitoring the effects of orthopedic and surgical interventions over time. As demonstrated, while initial muscle activity may decline or remain suboptimal post-treatment, long-term observations reveal a trend toward normalization and improvement in muscle function. Due to a recent systematic review, orthodontic treatment can promote greater symmetry in masticatory muscles and lead to potential enhancement of the neuromuscular control during chewing. However, further studies are necessary to validate these observations (64).

Limitations

The main strength of this review lies in its comprehensive search strategy and the inclusion of multiple analyses addressing different aspects of the topic, which enhances the credibility of our findings. Nevertheless, a number of constraints should be taken into account. A considerable proportion of the included studies were rated as having a moderate risk of bias according to the NOS-xs tool. The overall certainty of the evidence ranged from very low to moderate. Variability across studies was evident in terms of sample size, methods used to classify malocclusion, and the severity of malocclusion under investigation. These inconsistencies may have influenced the observed outcomes. For instance, skeletal and dental malocclusions can affect muscle activity differently, yet some studies did not clearly distinguish between these categories, which could have introduced further heterogeneity into the analyses. Future research should consider these issues and record more detailed data, including gender differences and vertical facial patterns. These clarifications will enhance our understanding of the topic and enable us to draw more confident conclusions.

Conclusion

This systematic review and meta-analysis suggests that malocclusion may be associated with differences in masticatory muscle activity; however, the available evidence remains limited and heterogeneous. Some findings indicate that individuals with skeletal Class III malocclusion may show lower masseter and temporalis activity during maximum voluntary clenching compared with those with Class I relationships. Temporalis activity at rest may also be lower in Class II than in Class III individuals. In contrast, no consistent differences were observed during chewing or in muscle symmetry indices among malocclusion classes.

Given the methodological variability, relatively small sample sizes, and heterogeneity across studies, these findings should be interpreted cautiously. Current evidence does not allow definitive conclusions regarding the relationship between malocclusion and masticatory muscle function. Further well-designed studies with larger samples and standardized electromyographic protocols are needed to clarify these associations and their potential clinical relevance.

Acknowledgment

None

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request

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