Original Article

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Evaluation of maximum contact jaw position across three head postures using digital technology in TMD and Non-TMD patients

Rangsima Jareeburanaphapa[1], **Sunee Pongrojpaw**[2], Touch Itthikul[2], Somsak Mitrirattanakul[2]

[1] *Residency Training Program in Occlusion and Orofacial Pain, Department of Masticatory Science, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*
[2] *Department of Masticatory Science, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

Objectives: To investigate how head posture affects maximum contact jaw position (MCJP) in patients with temporomandibular disorder (TMD) and non-TMD conditions, and to compare the subjective perception of MCJP with the actual measurements under various head postures.

Materials and Methods: This case-control study included 68 participants comprising both TMD (n=34) and non-TMD (n=34) patients. The evaluation of head postures included three positions: supine, normal upright, and alert feeding positions. To record MCJP, we utilized the Three shape® TRIOS 3 WIRE Pengrip and TRIOS Cart S1A systems. The data were analyzed using the Ceramill® program to assess the variations in MCJP across the three head positions in vertical, anteroposterior, and mediolateral directions. Additionally, we obtained participants' perceptions regarding the differences in MCJP experienced during the three head positions.

Results: Patients with TMD and non-TMD did not exhibit significant differences in MCJP distance, except in the vertical direction, where the MCJP distance differences between the supine and alert feeding head positions were statistically significant (p=0.04). In both non-TMD and TMD patients, a significant relationship was found between their perceptions of head posture's influence on MCJP and the actual digitally measured MCJP differences across all head positions and directions (p<0.05 all positions).

Conclusions: MCJP differs in varied head positions, particularly in the vertical dimension between supine and alert feeding postures, and these measurable differences align with participants' perceptions in both TMD and non-TMD groups.

Keywords: digital occlusal analysis, head posture, maximum contact jaw position, perception, TMD

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Introduction

Occlusal contacts have a significant impact on various human functions, including chewing, swallowing, and speech. The term maximum contact jaw position (MCJP) refers to the position of the mandible when the teeth achieve their maximum intercuspal contacts. This differs from maximum occlusal contacts (MOC), which describes the specific tooth-to-tooth contact points when the mandible is in MCJP [1, 2] . MCJP is a crucial reference for dental treatments, as it represents the stable end position of the mandible during mastication and other functional activities.

During mastication, MCJP occurs slightly after the initial working side contact. The neuromuscular system regulates this position through proprioceptive input from the periodontal ligaments, which controls jaw movements [3].

Corresponding author: Sunee Pongrojpaw
Department of Masticatory Science, Faculty of Dentistry, Mahidol University,
No. 6, Yothi Road, Ratchathewi District, Bangkok 10400, Thailand
Tel: + 66 2200 7857-0 Email: sunee.pon@mahidol.ac.th
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The initial contact of teeth and mandibular movement are governed by the neuromuscular regulation of the masticatory muscles. Subsequently, the tooth inclines guide the jaw into the maximum intercuspal position [4, 5]. Any alterations in occlusal contacts can lead to occlusal instability and affect the activity of the masticatory muscles. Recent studies have suggested that occlusal abnormalities may be potential contributing factors to temporomandibular disorders (TMD) [6, 7].

Occlusal perception enables individuals to sense how their teeth interact during function. This perception depends on sensory input from various structures, including the teeth and periodontium. Sensorimotor neuroplasticity mechanisms influence how well a person adapts to changes in oral perception caused by dental treatments [8]. This adaptation process is particularly relevant for TMD patients, who may have altered proprioception and pain perception in the orofacial region [9, 10].

Head posture is determined by a complex equilibrium of tension among the craniocervical bones, myofascial structures, and dental occlusion. The upper cervical spine acts as an intermediary connecting the head and the trunk [11]. Neuroanatomical connections between the oral and cervical regions actively influence mandibular movement functions and cervical positioning. Studies have demonstrated a relationship between the activity of the sternocleidomastoid muscle and the jaw closing muscles involved in mastication and involuntary clenching [12-14]. Additionally, occlusal treatments have been found to alleviate pain in the region of the sternocleidomastoid muscle [15]. Since this muscle plays a role in controlling head position, it is possible to hypothesize that occlusion could influence head position, and conversely, that head position could affect occlusion.

The masticatory muscles are subject to multiple influences, such as cervical posture, gravitational force, control from higher centers, and reflexes. These factors collectively impact the resting position and direction of mandibular closure [16]. Alterations in head position can significantly influence the biomechanics of the temporomandibular joint (TMJ) and related structures [17, 18]. Recent evidence suggests that TMD patients often present with altered head and neck postures compared to non-TMD individuals [19, 20]. This relationship underscores the importance of considering head posture when evaluating and treating occlusal issues, particularly in TMD patients.

In clinical practice, dentists commonly utilize the supine and upright positions when performing various procedures, particularly restorative treatments. On the other hand, the active or alert feeding position (approximately 30° flexion) represents the natural position during daily activities, including mastication [21]. Changes in head posture are believed to affect dental occlusion [22]. The sliding cranium theory explains how changes in head posture can influence the occipito-atlantal joint, which can have effects on the maxilla and, consequently, on occlusion [17]. Although most studies suggest a relationship between head posture and occlusal contacts, the methodologies employed in previous research have been limited by technological constraints, often showing inconclusive relationships due to the subtle nature of the changes observed.

Traditional methods for evaluating occlusal contacts, such as articulating paper or wax registrations, lack the precision necessary to detect subtle changes in MCJP across different head positions. The advent of digital technology in dentistry has introduced new possibilities for occlusal analysis with greater accuracy.

Intraoral scanners (IOS) have been validated for their precision in recording occlusal relationships [23-26], making them suitable for studying the influence of head posture on MCJP.

Therefore, this research aims to investigate the impact of head posture on MCJP in both TMD and non-TMD patients using digital technology. Our primary objective is to determine whether MCJP differs across three head positions (supine, normal upright, and alert feeding) and whether these differences vary between TMD and non-TMD patients. Our secondary objective is to compare participants' subjective perception of MCJP differences with the actual measurements across different head postures.

Materials and Methods

Participants

This case-control study included a sample of 68 patients from the Faculty of Dentistry, Mahidol University. The sample size was determined through calculation based on the standardized effect size (expected effect size divided by the standard deviation of the outcome variable) regarding previous studies on head posture and occlusion [27]. The sample was selected using purposive sampling.

The participants were between 18 and 75 years of age and had a minimum of 24 teeth (excluding only anterior teeth or third molars [2, 28, 29]. Additionally, all participants had good communication skills to ensure accurate reporting of their perceptions. The participants were divided into two groups: Group A (34 individuals) comprised non-TMD patients without any signs or symptoms of TMD. Group B (34 individuals) consisted of TMD patients diagnosed according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) [30], based on their presenting signs and symptoms, including pain in the temporomandibular joint region, limited jaw movement, joint sounds, and/or muscle tenderness.

Exclusion criteria for both groups included limited mouth opening (less than 40mm), ongoing orthodontic treatment, and the presence of fixed or removable prostheses replacing posterior teeth [31, 32]. Patients with preexisting forward head posture were not specifically excluded; however, standardized head positions were ensured during measurements using a goniometer, as described in the postural evaluation section.

The examiner was not blinded to the group allocation as the TMD diagnosis was necessary for patient categorization. However, to minimize bias, the digital measurements were analyzed using standardized software algorithms without examiner intervention during the quantitative assessment phase.

Equipment

3 shape® TRIOS 3 WIRE Pengrip and TRIOS Cart S1A intraoral scanner systems were utilized to record intra-arch and inter-arch data. This equipment was chosen for its validated accuracy and precision in dental measurements [24, 25].

Postural Evaluation

The study assessed three head postures: supine position, normal upright position, and alert feeding position (30 degrees flexion). The patients were initially positioned in a supine position, lying on their back in a horizontal position with the dental chair parallel to the floor [1].

To ensure standardization, a goniometer was employed to measure the normal upright position and active feeding position. During the normal upright position assessment,

patients were seated on a dental chair with the backrest vertical and their heads unsupported. The goniometer was placed over the external auditory meatus, with the distal arm aligned to the base of the nares. The proximal arm of the goniometer was held perpendicular, with a measurement of 90 degrees [1, 33]. (Figure 1-A)

In the alert feeding head position, the goniometer was set at 30 degrees for the angle between the proximal and distal arm, creating a forward head flexion position that simulates the natural position during eating [1, 33]. (Figure 1-B)

Data Collection

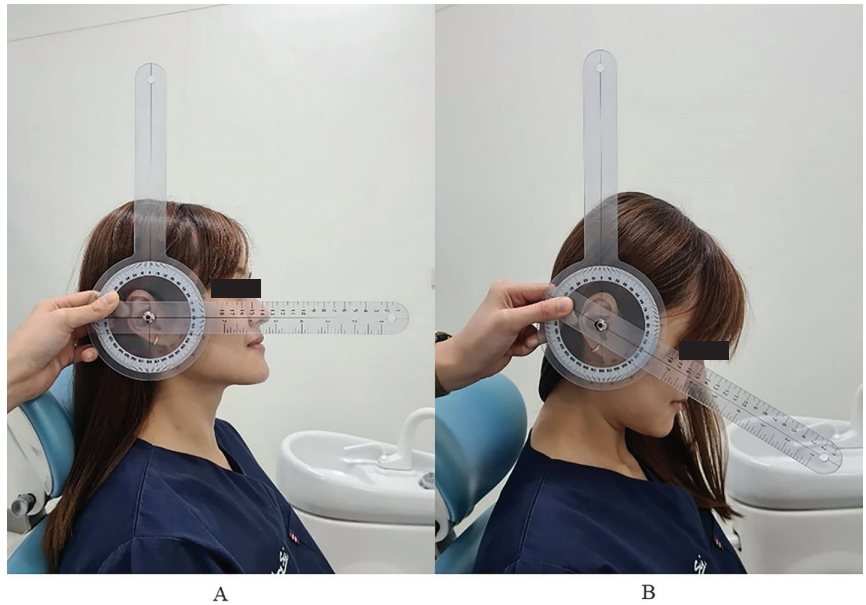
Patient Information

Patient information, including gender, age, and the patient's perception of the impact of head posture on MCJP, was gathered through a questionnaire. Occupation data were collected but not included in the final analysis, as this variable was not found to be relevant to the study objectives.

Occlusal Evaluation

The occlusal evaluation began with the patient in the supine position. Intra-arch scans of the maxillary and mandibular dentition were performed using the intraoral scanner. Before bite registration, patients were trained to close their mouths to achieve MCJP. This position was repeated several times to ensure consistency. The intra-arch and inter-arch data were merged using the artificial intelligence of the 3 shape® TRIOS system.

Subsequently, the patient was positioned in the normal upright and the alert feeding positions. Inter- arch recordings for the MCJP were then performed using a bite registration scan for each position. After completing all scans, patients were asked: "Do you feel the maximum occlusal contacts different between 3 head positions?" Their responses were recorded as “Yes” or “No.”



A B

Figure 1 A- Normal upright position (goniometer measured at 90 degrees)
B- Alert feeding position (goniometer 30 degrees by measuring the angle between the proximal and distal arms)

Data Analysis

The study analyzed data obtained from intraoral scanners using the Ceramill® program to investigate the influence of head postures on MCJP. The Ceramill® program evaluates alterations in the position of the mandibular arch by aligning the digital scans of the maxillary arch taken from two different head postures.

The measurements focused on changes in the direction and distance of MCJP, using the right and left mandibular canines and right and left mandibular first molars as reference teeth. The software measured the distance differences in the vertical (V), anteroposterior (AP), and mediolateral (ML) directions.

For consistency, a distance difference of ≥0.2mm was considered significant, based on the resolution capabilities of the scanner and previous studies on clinically significant occlusal discrepancies [34]. In cases where the alterations in each tooth did not match, the maximum distance difference was selected as the representative MCJP distance difference for each patient.

The head position comparisons included: Supine position versus upright position, supine position versus alert feeding position, and upright position versus alert feeding position (Figure 2).

Statistical Analysis

The demographic data and distance differences among different head positions were analyzed using independent sample t-tests and Chi-square tests. The agreement between the patient's perception and the actual presence of MCJP distance differences was assessed using the McNemar test.

A *p*-value of <0.05 was considered statistically significant. The data were evaluated using IBM SPSS Statistics, Version 26.0.

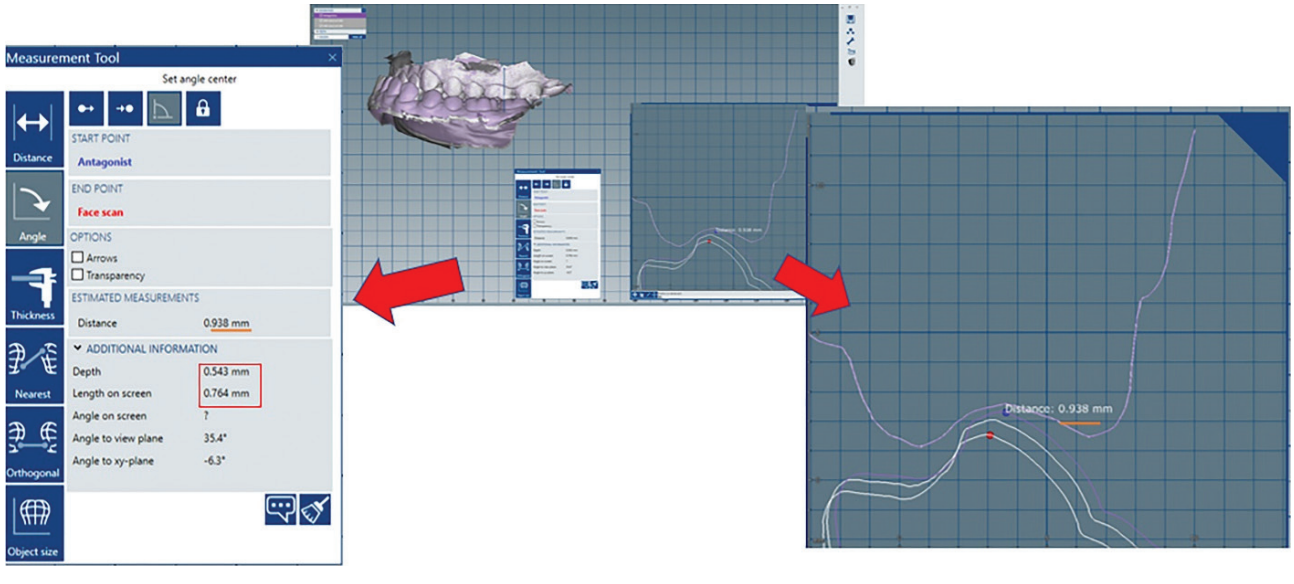


Figure 2 Ceramill® program works by superimposing the upper arch of 2 head postures bite registration scans to combine as one and check the alteration of mandibular arch position. Changes in direction and distance of the MCJP were measured

Ethical Consideration

The study obtained approval from the MU-DT/PY-IRB research ethics committee at Mahidol University's Faculty of Dentistry, with reference number MU-DT/PY-IRB 2020/075.2711. Prior to participation, all participants provided written informed consent. All methods were performed in accordance with the relevant guidelines and regulations.

Results

Demographic Data and MCJP Differences Between Groups

Regarding demographic data, there was a significantly higher number of younger patients in the non-TMD group (Table 1). The independent t-test comparing MCJP distance differences between non-TMD and TMD patients revealed a significant difference only in the vertical direction of the supine versus feeding head position (p=0.04).

Table 1 shows the comparison of MCJP distance differences between TMD and non-TMD groups across all measured directions and head position comparisons. The mean vertical MCJP distance difference between supine and feeding positions was 0.48 ± 0.54 mm in the non-TMD group and 0.26 ± 0.29 mm in the TMD group. The positive values indicate that the mandible is positioned more superiorly in the feeding position compared to the supine position in both groups, with a greater magnitude of change in the non-TMD group.

Table 1 Demographic profiles, MCJP distance differences and patient's perception of MCJP distance differences in non-TMD and TMD patients.

Variables	Non-TMD (n=34)	TMD (n=34)	*p*-value
Gender			
Female (n=52)	27 (79.4%)	25 (73.5%)	0.567
Male (n=16)	7 (20.6%)	9 (26.5%)	
Age			
Aged 18 to 45 (n=60)	33 (97.1%)	27 (79.4%)	0.024*
Aged 46 to75 (n=8)	1 (2.9%)	7 (20.6%)	
Job			
Working (n=17)	6 (17.6%)	11 (32.4%)	0.161
Studying (n=51)	28 (82.4%)	23 (67.6%)	
MCJP distance differences between different head positions (mm.) mean (SD)			
Antero-posterior direction			
Supine-Upright	0.3 (0.36)	0.21 (0.3)	0.29
Upright-Feeding	0.3 (0.41)	0.19 (0.31)	0.24
Supine-Feeding	0.4 (0.46)	0.24 (0.35)	0.12

Table 1 Demographic profiles, MCJP distance differences and patient's perception of MCJP distance differences in non-TMD and TMD patients. (continued)

Variables	Non-TMD (n=34)	TMD (n=34)	*p*-value
Medio-lateral direction			
Supine-Upright	0.37 (0.47)	0.27 (0.41)	0.34
Upright-Feeding	0.39 (0.45)	0.27 (0.37)	0.26
Supine-Feeding	0.46 (0.49)	0.33 (0.4)	0.26
Vertical direction			
Supine-Upright	0.38 (0.47)	0.24 (0.36)	0.18
Upright-Feeding	0.41 (0.55)	0.24 (0.25)	0.1
Supine-Feeding	0.48 (0.54)	0.26 (0.29)	0.04*
Patient's perception of MCJP distance differences			
no perceived differences	27 (79.4%)	28 (82.4%)	
perceived difference	7 (20.6%)	6 (17.6%)	

MCJP: maximum occlusal contact jaw position, non-TMD patients: patients who haven't any compliance with TMD, TMD: Temporomandibular disorder; TMD patients: patients who have compliance with TMD;
* significant at $p<0.05$

No significant differences were found between TMD and non-TMD groups in the anteroposterior or mediolateral directions, nor any direction when comparing supine versus upright or upright versus feeding positions.

Within-Group MCJP Differences Across Head Positions

When analyzing within-group differences across the three head positions using paired t-tests, significant differences ($p<0.05$) were found in the vertical direction for both TMD and non-TMD groups when comparing: supine versus upright positions, supine versus feeding positions, and upright versus feeding positions. The largest mean difference was observed between supine and feeding positions in both groups, with the mandible positioned more superiorly in the feeding position.

Patient Perception of MCJP Differences

Approximately 80% of both TMD and non-TMD patients perceived no difference in MCJP between different head postures, despite the measurable differences detected by the digital analysis.

In both non-TMD and TMD patients, a significant relationship was found between their perceptions of head posture's influence on MCJP and the actual digitally measured MCJP differences across all head positions and directions (Tables 2 and 3). This indicates that participants who perceived differences in MCJP across head positions could reliably detect actual differences, while those who reported no differences typically showed minimal changes in digital measurements.

Table 2 Agreement between patient's perception and presence of MCJP distance differences in non-TMD patients

	Anteroposterior direction (n=34)				Mediolateral direction (n=34)				Vertical direction (n=34)			
Head Position		No distance difference (n=13)	Distance difference (n=21)	p-value		No distance difference (n=12)	Distance difference (n=22)	*P*-value		No distance difference (n=9)	Distance difference (n=25)	*p*-value
Supine-Upright	no perceived distance differences (n=27)	11 (32.4%)	16 (47.1%)	0.001*	no perceived distance differences (n=27)	11 (32.4%)	16 (47.1%)	<0.001*	no perceived distance differences (n=27)	8 (23.5%)	19 (55.9%)	<0.001*
	perceived difference (n=7)	2 (5.9%)	5 (14.7%)		perceived difference (n=7)	1 (2.9%)	6 (17.6%)		perceived difference (n=7)	1 (2.9%)	6 (17.6%)	
		No distance difference (n=13)	Distance difference (n=21)	*p*-value		No distance difference (n=7)	Distance difference (n=27)	*P*-value		No distance difference (n=7)	Distance difference (n=27)	*p*-value
Upright-Feeding	no perceived distance differences (n=27)	10 (29.4%)	17 (50%)	0.003*	no perceived distance differences (n=27)	5 (14.7%)	22 (64.7%)	<0.001*	no perceived distance differences (n=27)	5 (14.7%)	22 (64.7%)	<0.001*
	perceived difference (n=7)	3 (8.8%)	4 (11.8%)		perceived difference (n=7)	2 (5.9%)	5 (14.7%)		perceived difference (n=7)	2 (5.9%)	5 (14.7%)	

Table 2 Agreement between patient's perception and presence of MCJP distance differences in non-TMD patients (continued)

		Anteroposterior direction (n=34)			Mediolateral direction (n=34)				Vertical direction (n=34)			
		No distance difference (n=8)	Distance difference (n=26)	*p*-value		No distance difference (n=5)	Distance difference (n=29)	*p*-value		No distance difference (n=4)	Distance difference (n=30)	*p*-value
Supine-Feeding	no perceived distance differences (n=27)	7 (20.6%)	20 (58.8%)	<0.001*	no perceived distance differences (n=27)	3 (8.8%)	24 (70.6%)	<0.001*	no perceived distance differences (n=27)	3 (8.8%)	24 (70.6%)	<0.001*
	perceived difference (n=7)	1 (2.9%)	6 (17.6%)		perceived difference (n=7)	2 (5.9%)	5 (14.7%)		perceived difference (n=7)	1 (2.9%)	6 (17.6%)	

MCJP: Maximum occlusal contact jaw position; Supine-Upright: comparison between supine head position and normal upright head position; Upright-Feeding: comparison between normal upright head position and alert feeding head position; Supine-Feeding: comparison between supine head position and alert feeding head position; McNemar test; Significant at p<0.05

Table 3 Agreement between patient's perception and present of MCJP distance differences in TMD patients (McNemar)

		Anteroposterior direction (n=34)			Mediolateral direction (n=34)				Vertical direction (n=34)			
		No distance difference (n=14)	Distance difference (n=20)	*p*-value		No distance difference (n=13)	Distance difference (n=21)	*p*-value		No distance difference (n=12)	Distance difference (n=22)	*p*-value
Supine-Upright	no perceived distance differences (n=28)	11 (32.4%)	17 (50%)	0.003*	no perceived distance differences (n=28)	10 (29.4%)	18 (52.9%)	0.001*	no perceived distance differences (n=28)	9 (26.5%)	19 (55.9%)	0.001*
	perceived difference (n=6)	3(8.8%)	3 (8.8%)		perceived difference (n=6)	3 (8.8%)	3 (8.8%)		perceived difference (n=6)	3 (8.8%)	3 (8.8%)	

Table 3 Agreement between patient's perception and present of MCJP distance differences in TMD patients (McNemar) (continued)

		Anteroposterior direction (n=34)			Mediolateral direction (n=34)				Vertical direction (n=34)			
		No distance difference (n=15)	Distance difference (n=19)	*p*-value		No distance difference (n=10)	Distance difference (n=24)	*p*-value		No distance difference (n=10)	Distance difference (n=24)	*p*-value
Upright-Feeding	no perceived distance differences (n=28)	12 (35.3%)	16(47.1%)	0.004*	no perceived distance differences (n=28)	8 (23.5%)	20 (58.8%)	<0.001*	no perceived distance differences (n=28)	8 (23.5%)	20 (58.8%)	<0.001*
	perceived difference (n=6)	3 (8.8%)	3(8.8%)		perceived difference (n=6)	2 (5.9%)	4 (11.8%)		perceived difference (n=6)	2 (5.9%)	4 (11.8%)	
		No distance difference (n=14)	Distance difference (n=20)	*p*-value		No distance difference (n=9)	Distance difference (n=25)	P-value		No distance difference (n=8)	Distance difference (n=26)	*p*-value
Supine-Feeding	no perceived distance differences (n=28)	11 (32.4%)	17 (50%)	0.003*	no perceived distance differences (n=28)	7 (20.6%)	21 (61.8%)	<0.001*	no perceived distance differences (n=28)	6 (17.6%)	22 (64.7%)	<0.001*
	perceived difference (n=6)	3 (8.8%)	3 (8.8%)		perceived difference (n=6)	2 (5.9%)	4 (11.8%)		perceived difference (n=6)	2 (5.9%)	4 (11.8%)	

Discussion

This study utilized digital technology to investigate the impact of head posture on maximum contact jaw position (MCJP) in TMD and non-TMD patients. The use of an intraoral scanner was chosen due to its reliability, accuracy, and user-friendly operation compared to the traditional method [23-26, 35]. To capture changes in both direction and distance of MCJP accurately, we measured four specific teeth (tooth numbers 33, 43, 36, and 46) as reference points. This approach was necessary because alterations in MCJP can occur in all directions, and these four teeth served as representative indicators for anteroposterior, vertical, and mediolateral positions.

Our study revealed significant MCJP distance differences in the vertical direction only, specifically between the supine and feeding head positions, with the non-TMD group showing a greater magnitude of change compared to the TMD group. This finding aligns with several previous studies. For instance, Kibana et al. demonstrated that altered head posture can impact mandible position [22]. Similarly, Haralur *et al.* utilized T-SCAN and observed significant changes in initial occlusal contact at all head postures [1].

The predominance of vertical changes over anteroposterior or mediolateral changes can be explained by several factors. First, the vertical dimension is more susceptible to gravitational forces when head position changes. Second, the morphology of the temporomandibular joint allows for greater freedom of movement in the vertical dimension compared to other directions. Third, the masticatory muscles, particularly the elevators (masseter, temporalis, and medial pterygoid), may adjust their activity more readily in response to head position changes to maintain functional occlusion [36, 37].

The finding that non-TMD patients showed greater vertical MCJP changes than TMD patients suggests that altered neuromuscular control may exist in the TMD population. This is consistent with recent research showing that TMD patients exhibit different muscle activation patterns and proprioceptive awareness compared to healthy individuals [38, 39]. The more stable MCJP muscle guarding and in the TMD group might reflect compensatory mechanisms to maintain functional occlusion despite potential joint or muscle dysfunction.

The relationship between head posture and MCJP can be explained by the complex equilibrium of tension among craniocervical bones, myofascial structures, and dental occlusion that collectively maintain head position [11]. Changes in cervical posture directly influence mandibular closure patterns and masticatory muscle activity, demonstrating a clear correlation between head position and mandibular posture. Tingey *et al.* established that mandibular movement patterns are regulated not only by rotational mechanics but also by head support and body positioning [40]. When head position changes, neurophysiological mechanisms activate vestibular, cervical, articular, and muscle receptors that regulate postural control. This activation modifies both general muscle tone and specifically affects masticatory muscle activity [41]. These interconnected systems explain why even subtle changes in head posture can produce measurable alterations in MCJP.

Previous research has primarily focused on anteroposterior and vertical dimensions of mandibular position changes. Mohl [33] hypothesized that forward head flexion produces a more anterior mandibular closing path, while posterior head positioning results in a more posterior closure pattern. Goldstein *et al.* [16] demonstrated that anterior head inclination from

the normal position decreases freeway space. Our study examined all three dimensions (vertical, anteroposterior, and mediolateral) but found significant differences only in the vertical direction. This finding can be attributed to the inclination of occlusal tooth morphology, where anteroposterior and mediolateral positional changes manifest primarily as vertical dimensional alterations due to the cusp-fossa relationships that guide mandibular closure.

Our study revealed a significant correlation between patients' subjective perception and objectively measured MCJP differences in both TMD and non-TMD groups. This finding indicates that patients can reliably sense alterations in their mandibular position across different head postures, regardless of their TMD status. The ability to perceive occlusal changes depends on the sensitivity of periodontal mechanoreceptors and the individual's attention to oral sensations [8]. Importantly, approximately 80% of participants reported no perceived differences despite measurable digital changes, suggesting that subtle MCJP alterations (in the range of 0.2-0.4mm) often occur below the threshold of conscious perception. However, when patients do perceive differences, these perceptions correlate strongly with actual measured changes [42]. This has significant implications for clinical practice, as patients may experience functional problems from MCJP changes that are not immediately apparent to them or easily detected through traditional clinical examination methods.

The study by Ransjo and Thilander [43] provides additional context, showing that patients with combined myogenic and articular TMD disorders demonstrate poorer mandibular position perception compared to those with purely myogenic conditions. This suggests that joint dysfunction may compromise proprioceptive feedback mechanisms. TMJ receptors contribute significantly to perceptual awareness of jaw position, movement patterns, and occlusal contact discrimination [44]. The proprioceptive function of the TMJ directly influences neuromuscular control of jaw movements [44]. Given these findings, future research should investigate whether different TMD subtypes (myogenous vs. arthrogenous) exhibit distinct MCJP response patterns to head position changes, which could inform targeted treatment approaches.

Clinical Implications

The finding that MCJP changes with head position, particularly in the vertical direction, carries significant clinical implications that challenge current dental practice protocols. Traditionally, dentists perform occlusal evaluations and adjustments with patients in the supine position for optimal access and visibility. However, patients function primarily in upright and alert feeding positions during daily activities such as chewing, swallowing, and speaking.

Our results demonstrate that occlusal relationships established in the supine position may not accurately represent functional occlusal contacts in upright positions. This discrepancy is particularly pronounced for non-TMD patients, who showed greater vertical MCJP changes between positions (0.34±0.15 mm vs. 0.27±0.12 mm in controls). The clinical significance becomes apparent when considering that changes of this magnitude can create premature contacts or occlusal interferences.

Recommended Clinical Protocol Modifications

1. Multi-Position Occlusal Evaluation: Clinicians should assess occlusal contacts in multiple head positions, particularly when performing extensive restorative work. This evaluation should include both supine and upright positions, with special attention to the alert feeding position (30° head flexion).

2. Digital Occlusal Analysis Integration: Traditional methods such as articulating paper may not detect the subtle MCJP changes identified in this study. Digital occlusal analysis systems offer superior precision for detecting these clinically relevant but small-magnitude changes that could impact patient comfort and function.

3. TMD Patient Considerations: Although TMD patients demonstrated lesser variability across head positions, they still require in MCJP careful multi-position occlusal evaluation. Occlusal adjustments should be verified in functional positions to ensure optimal treatment outcomes.

4. Post-Restoration Verification: Following restorative procedures, final occlusal adjustments should be confirmed in upright positions to ensure harmony with functional jaw positioning. This is especially critical for posterior restorations that significantly influence MCJP.

Limitations and Future Directions

Several important limitations should be considered when interpreting these results. First, the cross-sectional study design prevents establishment of causal relationships between head posture changes, MCJP alterations, and TMD development or progression. Longitudinal studies are needed to determine whether MCJP variations across head positions contribute to TMD onset, result from existing TMD pathology, or represent adaptive mechanisms.

Second, our TMD group was not subdivided by specific diagnostic categories according to the DC/TMD classification system. Future research should investigate whether myogenous, arthrogenous, or mixed TMD subtypes demonstrate distinctive MCJP response patterns to head position changes. Such differentiation could inform targeted treatment strategies and help predict which patients are most likely to benefit from multi-position occlusal evaluation.

Third, while our digital measurement approach provided high precision (0.2mm resolution threshold), the long-term clinical significance of these measured differences requires further validation. Future studies should correlate subtle MCJP changes with functional outcomes, symptom severity, treatment response, and patient-reported quality of life measures.

Fourth, our study examined static head positions rather than dynamic functional movements. Future research should explore MCJP changes during actual functional activities such as chewing, swallowing, and speaking to better understand the clinical relevance of head posture effects on occlusion.

Conclusion

This study demonstrates that MCJP differs significantly across head positions, particularly in the vertical dimension between supine and alert feeding postures. Non-TMD patients exhibited greater vertical MCJP changes compared to TMD individuals, suggesting compensatory mechanisms and altered neuromuscular control in TMD population. The strong correlation between patients' perceptions and objectively measured MCJP differences indicates that individuals can reliably detect clinically relevant occlusal changes across head positions.

These findings have important implications for clinical practice, highlighting the potential limitations of conducting occlusal evaluations and adjustments solely in the supine position. The integration of digital occlusal analysis technology enables precise detection of subtle MCJP changes that may be clinically significant but difficult to identify through traditional examination methods.

Our results support the recommendation for multi-position occlusal evaluation, particularly when performing extensive restorative procedures. This approach may improve treatment outcomes by ensuring occlusal harmony across the range of functional head positions encountered in daily activities. Future research should focus on establishing standardized protocols for clinical implementation and investigating the long-term therapeutic benefits of position-specific occlusal treatment approaches.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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