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RESEARCH

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Effect of occlusal interference on condylar position and trajectory of movement: a randomized crossover-controlled trial

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Abstract

Objective The occlusal interferences may alter the position of the condyles in the articular fossa and trigger abnormal mandibular movements, but the specific effects on condylar position and movement trajectory are currently unknown. The present study was designed as a randomized crossover-controlled trial to investigate the direct effects of distinguished types of occlusal interference on condylar position and movement trajectory.

Methods 14 volunteers with healthy dentition were recruited. Each of them underwent four occlusal interference conditions: mediotrusive occlusal interference (MOI), laterotrusive occlusal interference (LOI), dummy occlusal interference (DOI), and free of interference. The sequence of interferences was randomized. Mandibular movements were recorded and measured by using jaw motion analysis system, during which the condylar trajectory and functional parameters, including sagittal condylar inclination (SCI) and Bennett Angle (BA) were analyzed to assess the condylar motion status. Furthermore, a descriptive analysis of condylar positional trends was conducted to measure the relative three-dimensional position of the condyle.

Results Affected by MOI, the condylar axis turned towards the anterior and superior directions. BA values exhibited a significant increase on the interference side and a decrease on the other side, accompanied by a reduction in SCI on the interference side. LOI caused a larger mandibular deviation angle towards the interference side, resulting in a notable increase in BA. The differences were all statistically significant ($P<0.05$).

Conclusion Occlusal interferences can alter the condylar position and movement trajectory during the mandibular movement in laterotrusion and protrusion. Different occlusal interferences have different influences, manifested in the varying values of condylar guidance inclination.

Trial registration The study was registered at the Chinese Clinical Trial Registry on 01/05/2024 (Identification number: ChiCTR2400084150).

Keywords Temporomandibular disorders, Occlusal interference, Movement trajectory, Condylar position, Sagittal condylar guidance, Bennett angle

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Introduction

The association between occlusion and temporomandibular disorders (TMD) has been a focal point in research investigating the etiology of TMD [1]. While previous studies have not definitively established a causal relation between occlusion, occlusal factors, occlusal disharmonies and TMD, some research indicates that the presence of interference could potentially worsen the clinical manifestations in individuals with TMD [2]. Essentially, the existence of occlusal interference (OI) represents a specific risk to the health of the stomatognathic system.

TMD presents through various manifestations, such as masticatory muscle disorders, joint structural abnormalities affecting mandibular movement and condylar position, and orofacial pain [3].In the past, scholars have conducted lots of trials on animals which have shown that occlusal disturbances can trigger TMD by regulating specific facial factors controlling pain and inducing the expression of proteins associated with muscle damage, leading to pain and muscle injury in masticatory muscles [4, 5]. However, the conclusion cannot be applicable directly because of the differences between animals and humans. A limited number of interventional studies involving human subjects have found that OI can lead to abnormal electromyographic activity in the masticatory muscles [6]. Additionally, other studies have artificially induced occlusal abnormalities, resulting in changes in the position of the condyle within the glenoid fossa [7]. The latter findings provide more direct support for the link between occlusion and structural changes in the temporomandibular joint (TMJ). Unfortunately, however, the number of such studies remains relatively small.

By summarizing the research related to the correlation between occlusion and the TMJ, it was found that changes in jaw position may be correlated with the development of TMD [8]. OI can hinder the synchronous movement of the mandible, leading to non-functional contact and condylar position deviation [7–10]. A study by Choi BT et al. investigated differences in condylar motion performance between TMD patients and the general population [11]. The result revealed that, compared to the healthy population, TMD patients exhibited significantly larger motion paths and three-dimensional linear distances of the condyles on the working side during lateral motion than on the balanced side. Therefore, it is speculated that TMD may be induced when the state of jaw movement is altered.

Sagl B et al. [12] found that laterotrusive contact bruxing exhibits lower loading than mediotrusive guidance, which may help protect the TMJ. The interference generated between different tooth contacts may also differently affect the TMJ. Walton TR et al. [9] stated that mediotrusive occlusal interference (MOI) may impact the biomechanics of mandibular function. However, naturally occurring molar mediotrusive interferences should only be eliminated if signs and symptoms of TMDs are present. The consensus does not mention other types of occlusal interference. Until now, there is no literature on the specific effects of different types of occlusal disturbances on condylar position and motion pathways.

Early studies on condylar movements relied on basic mechanical tracers. Modern mandibular motion analysis system enables precise reproduction of mandibular movements based on effective transfer of occlusal relationships, including modules for precise recording of condylar movement trajectories, analysis of their positions in various jaw relations, and integration with computers to provide supplementary parameters on joint function at the same time. These features offer scientific help for oral research and clinical applications [13].

The purpose of this in vivo study was to investigate the impact of artificial laterotrusive occlusal interference (LOI) and MOI on subjects‘ condylar movement and to quantify the deviation of bilateral condyles under MOI condition. The null hypothesis was that differences would be found in condylar position and movement trajectory as a result of various occlusal interferences.

Materials and methods

Ethical statement

This was a randomized crossover controlled double-blind trial, which was approved by the Ethics Committee of Xuzhou Stomatological Hospital (No.2020-008) and registered in the Chinese Clinical Trial Registry (NO. ChiCTR2400084150).

Subjects

Fourteen subjects were recruited from among students in the School of Stomatology. Inclusion criteria: All of them had a full permanent dentition except for the third molars, no reverse articulation or open occlusal relationship, no habits of unilateral chewing, and no previous extensive restorative treatment or orthodontic treatment in the past 3 years. Exclusion criteria: Individuals who had ever exhibited any symptoms of temporomandibular dysfunction, as determined by reference to the International Criteria Society for the Study of Dentistry's criteria for DC/TMD or who were unable to complete the mandibular movement under the guidance of the doctor [14].

Sample size calculation

The sample size was calculated using Gpower software (v.14.8.1; Microsoft Partner, Ostend, W, Belgium). The parameters for within-factor repeated-measures analysis of variance (ANOVA) considered were 80% efficacy (Type II error, $\beta = 1-0.2 = 0.8$) and 95% significance level (Type I error, $\alpha=0.05$), number of groups = 1, number of measurements = 4 (no interference, MOI, LOI, and dummy occlusal interference), correlation between repeated measures = 0.5, and non-sphericity correction = 1. The effect size was considered to be 0.5, based on a pilot study involving three subjects and relevant literature references [15]. The calculations indicated that a sample of seven participants was required. With consideration of potential study withdrawals, confounding factors of gender and OI condition, we recruited 14 subjects (7 women and 7 men, mean age ± SD = 24.7 ± 3.3 yrs).

Study design

The experimental design adhered to the Consolidated Standards of Reporting Trials (CONSORT) statement (Fig. 1) [16]. Each subject underwent all four types of OI, which included: MOI, LOI, dummy occlusal interference (DOI), and a control condition free of interference. The sequence of interventions was determined randomly before the trial. A one-week rest period was implemented between each intervention to ensure adequate recovery and isolate the effects of each intervention.

Before the experiment began, all subjects were seated in an upright position and initially instructed to maintain their centric occlusion position. After the application of OI, they were directed to chew gum exclusively on their left side. This chewing process was repeated three times, with each session comprising 20 chewing cycles and separated by 5-minute intervals to minimize muscle fatigue accommodation. Following a 5-minute recess, the condylar trajectories of the subjects were then recorded. During each measuring session, subjects were instructed to execute three mandibular edge movements. Following this, the average values of their condylar path inclination were calculated. The computer program then processed these data, converting them into the values for condylar guidance inclination, encompassing the Sagittal condylar inclination (SCI) and Bennett angel (BA). In addition, the relative three-dimensional positions at the axiogram of the condyles were measured under MOI and free interference conditions.

Randomization and blinding

The subjects were randomly assigned to one of the four treatment sequences, which were determined by a computer-generated randomization plan prepared before the study. None of the subjects were aware of which OI condition was being applied. Group allocation and

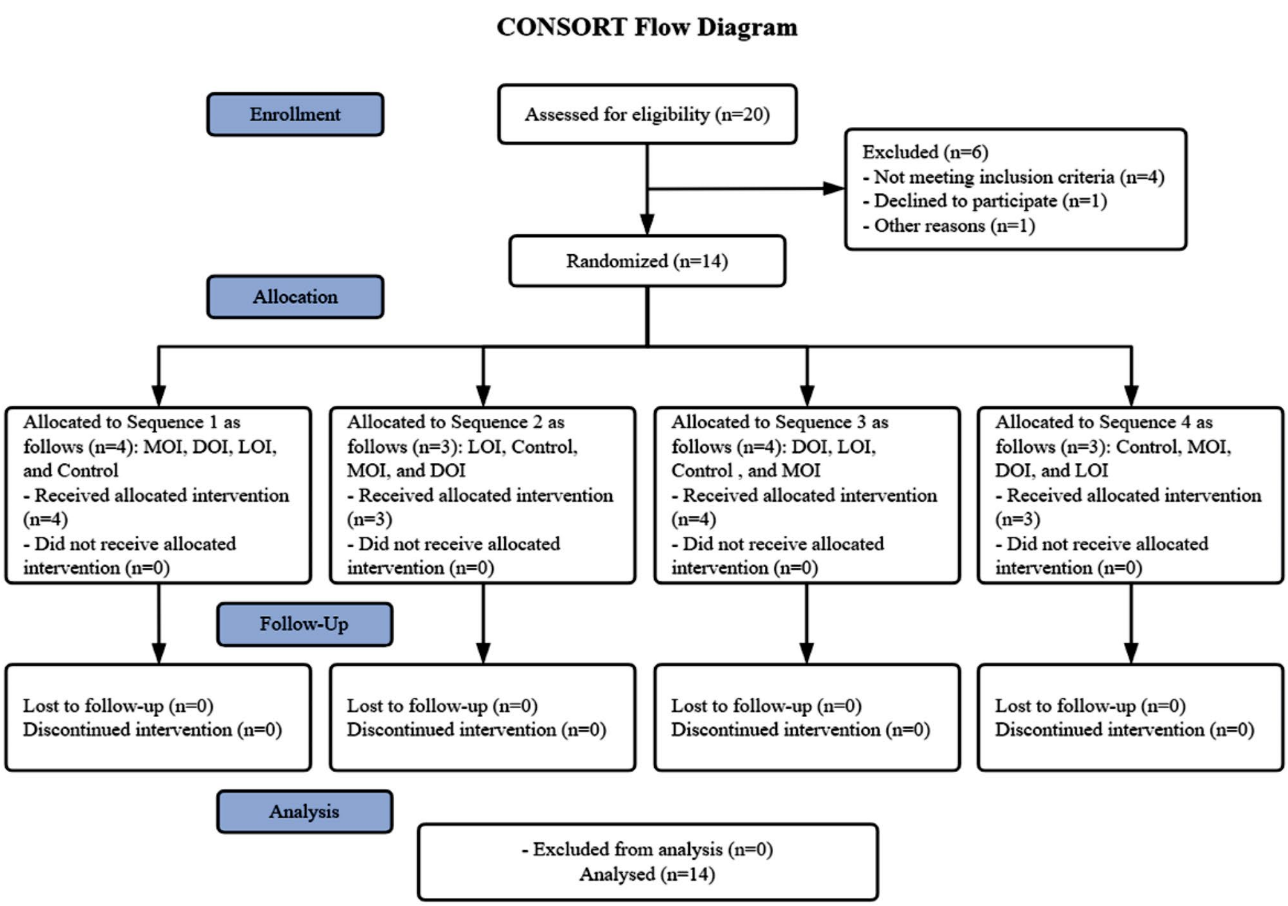

Fig. 1 Flow Chart depicting the Study Design

Fig. 2 Occlusal interferences were fabricated on the model in advance, then transferred and adhered into intraoral molars to obtain laterotrusive (**A**), mediotrusive (**B**) and dummy (**C**) interference, respectively

intervention distribution were managed by an investigator who was blinded to the data collection process. Additionally, a separate examiner, who was also blinded, was responsible for measuring and analyzing the samples both during and after the OI tests.

Occlusal interference

An impression model of the maxillary and mandibular full dentition of each subject was made, and then an ultra-hard plaster infusion was used as the experimental model. OIs were fabricated on the model and blue nano-particulate self-adhesive composite resin (light-curing resin blue glue, Xihu3iom, Hangzhou, China) was selected as the interference material. The construction and bonding of LOI on the tooth surface showed that it did not interfere with intercuspal contact but increased lateral tooth guidance by 10° and increased height by 0.5 mm while discluding all other teeth during right laterotrusion [9]. The LOI was contoured by adjusting and aligning the path of laterotrusion under both natural and overlay guidance on the articulator (Fig. 2A). It was then cemented onto the buccal cusps of left maxillary first molar to impede the sliding of the inner incline of the maxillary buccal cusps and the outer incline of the mandibular buccal cusps. MOI was cemented onto the buccal cusps of the left mandibular first molar to impede the sliding of the inner incline of the maxillary lingual cusps and the mandibular buccal cusps. Since no literature on the mean steepness of MOIs could be found, the same angles as for the laterotrusive simulations were used, just mirroring the lateral guidance angle (Fig. 2B). Moreover, DOI was made and cemented onto the buccal surface near the neck margin of the first mandibular molar (Fig. 2C).

Variables measuring

The mandibular motion was measured by Zebris jaw motion analysis system (Jaw Motion Analyser, JMA, Zebris Medical GmbH, Isny, Germany). It consists of a facial bow, an auxiliary metal fork, a mandible frame,

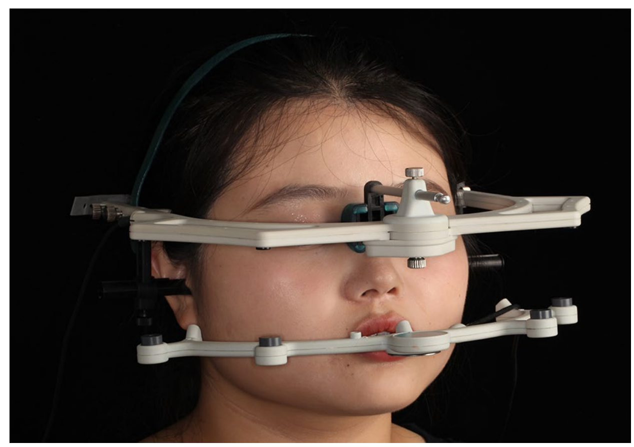

Fig. 3 Jaw motion analyzer, employing advanced ultrasonic sensing technology, precisely detects changes in the jaw's relative position. It accurately records jaw movement across six degrees of freedom by calculating the time taken for ultrasonic pulses to travel from the transmitters embedded in the mandibular frame to the receivers embedded in the face bow

and a mainframe. The device employs ultrasonic sensing technology to detect changes in the jaw's relative position, and it records jaw motion with six degrees of freedom (defined by sliding in three directions and rotating around three axes) by calculating the time it takes for ultrasonic pulses to travel from the transmitter to the receiver [13, 17].

During the measurement process, the subjects maintained an upright sitting position with their orbital-auricular plane aligned parallel to the horizontal plane (Fig. 3). They were then instructed to perform protrusive and transversal mandibular movements as smoothly as possible, ensuring that both the initial and final positions of the mandible were at maximal intercuspal position (MIP). To reduce random errors, each subject was asked to repeat the protrusive and transversal movements three times for each measurement. The WinJaw + software (version 1.4.10; Zebris Medical GmbH) was utilized to possess and output the values of SCI and BA, which were derived by calculating the average of the three measurements for each movement. Specifically, the BA represents the angle formed between the sagittal plane and the average path of the advancing condyle as viewed in the horizontal plane during lateral mandibular movements. The SCI is the angle formed between the horizontal plane and the average path of the progressive protrusion movement of the condyle as viewed in the sagittal plane [18].

In addition, the position of the condyle was recorded using WinJaw when the mandible was in its initial position of movement, known as the MIP. Since the LOI setting excludes interference with centric occlusion, a comparison between LOI and DOI versus no interference is meaningless. The current trial recorded the three-dimensional relative positions of all subjects' condyles under two interference conditions: MOI and free interference, which aimed to evaluate the influence of interference on condylar position by conducting a comparative analysis of the measurement outcomes.

Statistical analysis

Statistical analysis was performed using the IBM SPSS Statistics 22.0 program (IBM Company, Armonk, NY, USA). Normality of the quantitative variables was checked by the Shapiro−Wilk test and analysis of the equality of the variance was examined by Levene's test. Repeated-measures ANOVA and with post hoc Bonferroni tests were used to examine whether the values of variables varied under the different OIs. The data are presented as means with standard deviations. For every analysis, the level of statistical significance was determined at $P < 0.05$. Deviations in the three-dimensional coordinate system of bilateral condyle positions were obtained by the corresponding computer software. The results were presented as means with standard deviations and then were drawn to bubble charts to visualize their trends.

Results

The whole experimental process lasted for 3 months. Throughout the experiment, there were no reports of muscle tenderness or pain, and no irreversible effects were observed following the removal of the OI.

Descriptive Statistics of the bilateral SCI and BA values are shown in Table 1. After the introduction of MOI, the mean BA values on the left side exhibited a statistically significant increase, whereas those on the right side demonstrated a significant decrease when compared to the conditions under LOI, DOI, and free interference ($P < 0.001$). During mandibular lateral movement, the mean BA values on the right side significantly increased after the application of LOI, while there was no variation observed on the left side. Additionally, during mandibular movement in protrusion, the mean SCI values of bilateral condyles were all affected. However, the

Table 1 Descriptive statistics of the bilateral SCI and BA values, obtained from 14 subjects for each occlusal interference condition

Variables	Mean ± SD	F[a]	*P*-value	Post hoc[b]		
				MOI	LOI	DOI
L-SCI		60.336	<0.001			
Control	38.81 ± 3.45			***	n.s.	n.s.
MOI	30.89 ± 4.54				***	***
LOI	40.43 ± 3.90					n.s.
DOI	39.29 ± 3.68					
R-SCI		3.315	0.08			
Control	40.44 ± 4.33			n.s.	n.s.	n.s.
MOI	38.94 ± 5.90				n.s.	n.s.
LOI	40.15 ± 4.05					n.s.
DOI	41.03 ± 3.09					
L-BA		146.339	<0.001			
Control	11.99 ± 4.32			***	n.s.	n.s.
MOI	16.53 ± 3.32				***	***
LOI	12.60 ± 4.04					n.s.
DOI	12.04 ± 4.03					
R-BA		139.518	<0.001			
Control	11.63 ± 2.53			***	***	n.s.
MOI	7.51 ± 2.49				***	***
LOI	16.70 ± 3.33					***
DOI	11.30 ± 2.17					

[a] Degrees of freedom = [3, 39]

[b] Data were analyzed by a one-factor (occlusal interference) repeated-measurements ANOVA. Post hoc multiple comparisons were performed by the Bonferroni tests. Level of significance: *** = $P < 0.001$. n.s = Not significantly different

Abbreviations: L-SCI = left sagittal condylar inclination; R-SCI = right sagittal condylar inclination; L-BA = left Bennett angel; R-BA = right Bennett angel

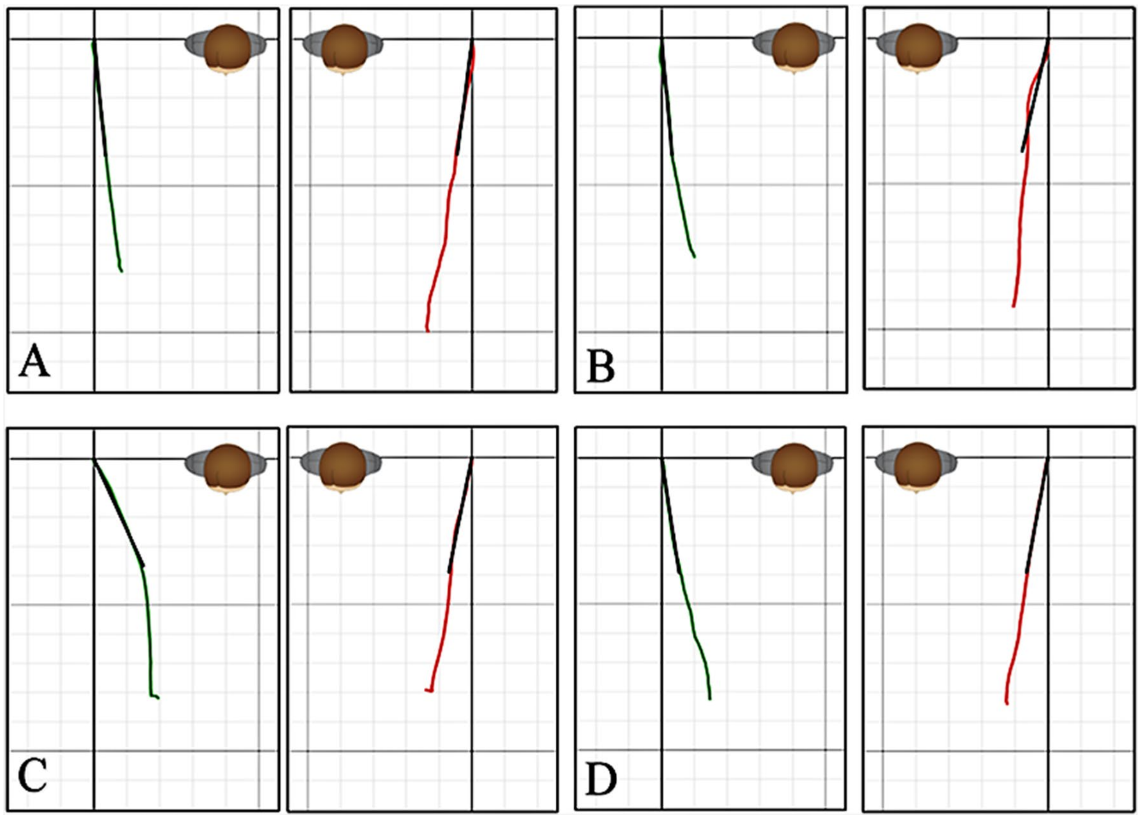

Fig. 4 Observed from the horizontal plane, the movement trajectories of bilateral condyles during mandibular lateral movement under four interference conditions as follows: free of interference (**A**), mediotrusive occlusal interference (**B**), laterotrusive occlusal interference (**C**); dummy occlusal interference (**D**)

Table 2 The average deviation values of bilateral condyle positions in a three-dimensional coordinate system under conditions of mediotrusive occlusal interference versus free interference(mm)

Coordinates						
	Left			**Right**		
Axis	X	Y	Z	X	Y	Z
Mean	0.00	0.17	0.15	0.01	0.12	0.18
SD	0.12	0.25	0.31	0.05	0.16	0.17

The X-axis represented the direction of the line connecting the right and left condylar points, the Y-axis denoted the vertical superoinferior direction, and the Z-axis indicated the sagittal anteroposterior direction. Abbreviations: SD = standard deviation

variation observed on the right side didn't exhibit statistical significance ($P>0.05$).

The movement trajectories of the condyles, as observed from the horizontal plane during mandibular lateral movement, are illustrated in Fig. 4. Under conditions of dummy interference and free interference, the condylar movements remained unaffected, exhibiting a swift and seamless trajectory with a suitable curvature. However, the trajectory curve of the condyles in the direction of the coronal axis experienced an obvious fluctuation towards the working side under MOI condition, suggesting excessive rotational movements for interference avoidance. Moreover, under the influence of LOI, the balancing-side condyle showed a greater rotation angle when moving towards the interference side. There was no significant variation in the width and length of the condylar paths, which may have been determined by the highly repetitive nature of the lateral border movements. The mandibular condyle movements recorded in this experiment were all fluid and smooth curves.

The differences in the three-dimensional positioning of the bilateral condyles along the X, Y, and Z axes during mandibular cusp elevation, between the free interference and MOI conditions, are summarized in Table 2, which were then graphically represented in Cartesian coordinates in Fig. 5. The presence of MOI caused the condylar axis to shift towards the anterior and superior direction.

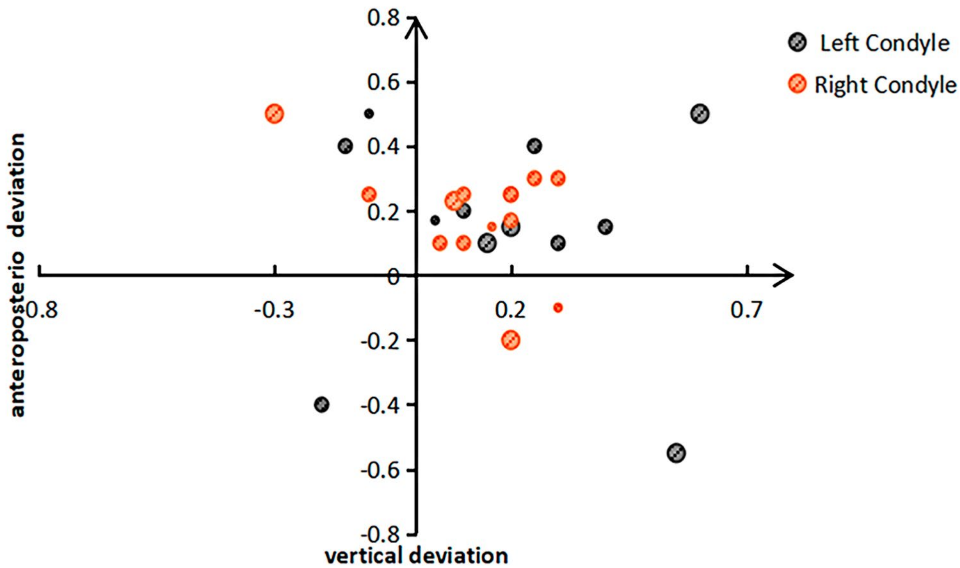

Fig. 5 Map of the bubble distribution of the condyle position. The horizontal-axis was the sagittal anteroposterior direction, the vertical axis was the vertical superoinferior direction, and the size of the bubbles was the direction of the line connecting the right and left condylar points

Discussion

In this study, four types of interference conditions were established: mediotrusion and laterotrusion, a dummy condition and a control condition (which involved no interference). By observing the changes in the trajectory of condylar movement during mandibular movement as well as deviations in their positions, the specific effects of different types of OIs on the condyles were explored. The null hypothesis that differences would be found in condylar position and movement trajectory under different OI conditions was accepted.

Jaw motion is a rapid, fluid, physiological movement with reproducibility that was regulated by TMJ in conjunction with occlusion. MIP serves as the beginning and ending posture of mandibular movements, playing a pivotal role in maintaining the healthy status of TMJ [19]. The current trial has revealed that MIP was altered due to the influence of OI, causing a deviation of the central pole of the condyle and subsequently abnormal movements of the mandible. Both the values of SCI and BA exhibited abnormal variations. BA is the angle formed between the movement path of the balancing-side condyle and the sagittal plane during mandibular lateral movement, while the SCI represents the angle formed between the movement path of the working-side condyle and the horizontal plane during mandibular protrusive movement [20, 21]. Upon observing the results of the current experiment, it could be found that under the MOI condition, the BA value on the left side increased, whereas the right side correspondingly decreased. The SCI value only showed changes on the side with interference, while the non-interference side, although increased, exhibited no statistically significant difference. Previous studies have revealed that OI can induce abnormal electromyographic activity in the masticatory muscles [6]. Mandibular movements that occurred at this time were therefore influenced by both the changes in tooth contact and the constraints imposed by masticatory muscles [22]. The fluctuation in the lateral movement trajectory indicated the condyle exhibited a clear avoidance behavior in response to interference.

Since the application of LOI had no impact on the MIP but only influenced the initial phase of movement, the results showed the BA value on the non-interference side significantly increased. By observing the movement trajectory of the condyle, we discovered that the rotation angle of the non-working side condyle in the sagittal plane significantly increased at this point. In a previous artificial interference experiment conducted by Huang et al., it was demonstrated that during the lateral movement, the rotation angle of the working-side condyle increased significantly in the sagittal plane as the displacement of the mid-incisor point augmented [9]. The mandibular condyle movements recorded in this experiment were all smooth curves, which may be attributed to the chewing practice sessions conducted before the measurements.

Most interference experiments have primarily focused on the impact of OI on muscle activity and chewing efficiency. A recent study revealed that unilateral posterior cross-bite is often associated with a mild bilateral maxillary constriction which causes OI in centric relation, provoking mandibular shift toward the cross-bite [23]. Compared to patients who did not receive early intervention, those who were treated with maxillary expansion not only experienced reestablishment of normal occlusion, improvement of mandibular function but also exhibited more harmonious and symmetric development of the palate. Giudice et al. conducted similar experiments employing another treatment protocol and discovered that proper occlusion facilitates the symmetrical development of the maxillary bone [24].

The variations in the value of condylar guidance inclination between MOI condition and LOI condition seem to be also associated with TMJ load. Tooth contact patterns affect the stress distribution on the condylar surface, and minor changes in the tooth surface may alter the TMJ load [25–27]. The masticatory forces of individuals with high-angle mandibular plane are closer to the TMJ compared to the low-angle individuals, and concurrently, there is a notable increase in the thickness of their condylar cortical bone [28]. An explanation for this may be that it is a direct outcome of the interplay and adaptive processes occurring between TMJ and masticatory activities. On the one hand, the load of masticatory muscle activities is delivered mainly to two specific anatomical regions: the teeth and their surrounding bone, and TMJ, which results in specific characteristics in the differentiation and development of the mandible [29]. On the other hand, patients with a high-angle mandibular plane have shown reduced occlusal forces during maximum bite and functional activities, resulting in a higher load being transmitted to the TMJ. The load on the condyle tends to be higher in patients with high-angle mandibular plane, whose TMJ is more significantly influenced by occlusal changes [30]. This heightened load subsequently elevates their risk for developing TMD.

Due to the inherent adaptability of the stomatognathic system to acute changes, not all risk factors necessarily result in the development of a TMD [31]. Research by K et al. discovered that after applying the interference and completing 60 chewing cycles, the smoothness of condylar movement and the spatial gap of the glenoid fossa began to recover [25]. Given the stability obtained by the condyle at this stage, the measurements of condylar guidance inclination and condylar positions exhibited consistent accuracy, making them more reliable and referential. However, it is noteworthy that the spatial position and movement pattern of the condyle did not fully revert to their initial state. Analysis of dispersion trend values indicated that the overall position of the bilateral condyles slightly shifted anteriorly and superiorly, albeit with minimal differences. Lim et al. reported that posterior positioning and clockwise rotation of the mandible along with TMJ disc displacement may occur when the discrepancy between centric occlusion and maximum intercuspation exceeds 2.0 mm [32, 33]. Therefore, it is reasonable to speculate that when occlusal changes were more significant or persist over an extended period, damage was often unavoidable, particularly for patients with weaker adaptive capacities or those already exhibiting TMD symptoms [34].

Although occlusion may act as a predisposing factor by altering joint biomechanics or as a perpetuating factor by exacerbating existing dysfunction, it is important to recognize that TMD is a multifactorial condition influenced by a complex interplay of factors [35–37]. Extensive research has demonstrated that psychological stress, muscle hyperactivity, abnormal joint loading, and genetic predisposition, among others, play significant roles in the development and progression of TMD. Therefore, occlusion should not be viewed in isolation but rather as one potential contributor within a broader etiological framework. In clinical practice, it is essential to actively identify and mitigate such risks, maintain a high level of vigilance, and implement effective measures to reduce these potential contributing factors.

The transversal and protrusive movement may be closely representative of some parafunctional movements and serve as the early opening phase of masticatory movements [9]. The main parameters used to quantify the path of condylar motion during lateral and protrusive movements of the mandible include sagittal condylar inclination, immediate mandibular lateral translation and transversal condylar inclination. JMA measured the values of balancing-side transversal condylar inclination, namely Bennett angle. It is generally considered that immediate mandibular lateral translation is the path of the condyle moving straight and medially during the initial phase of lateral movement. Due to the large individual differences and different standards, it was not included in the evaluation indexes [20]. The values of lateral condylar path inclination and protrusive condylar path inclination describe the angle between the motion path of condyle and the reference plane. JMA automatically measures and optimizes the whole condylar motion path to output the BA and SCI values of the certain Artex articulator system. A comparative study of using different methods to measure SCI and BA values has shown that JMA obtained better consistency and higher sensitivity of recordings. Moreover, it is simpler to perform, compared to, for example, the methods of measurement using dental wax and occlusal recording silicone rubber [38].

Limitations

- The inclusion criteria for the present study only required complete dentition and there were no specific requirements for jaw movement characteristics of individuals. Actually, differences in the degree of balancing-side contact during the lateral movement also affect the severity of interference with mandibular movements and condylar function values [39]. Furthermore, the impact of occlusal changes on the TMJ may vary among individuals with a different facial vertical skeletal pattern. The role played by the masticatory muscles or their vitality, as well as the bite force during maximum occlusion, in this context remains unknown [28].

- TMJ is one of the most complex joints in the human body, possessing the capability to adapt to acute changes within limitations. Due to medical ethical constraints and the protection principle for subjects, the current artificial study has only been able to observe immediate changes in condylar movement and position. These observations have not established a relationship between these changes and TMD, nor have they taken into account the role of time factors in this process. Throughout previous animal experiments, occlusal disturbances frequently result in the manifestation of TMD symptoms [4, 5, 40, 41].

Conclusion

In conclusion, the study findings confirm that occlusal interference induces changes in condylar position and trajectory, with different types of interference affecting the TMJ variably. LOI mainly influences the movement towards the interfering side while MOI influences the laterotrusive and protrusive movements of both condyles, leading to abnormal displacement and rotation of the condyles.

Abbreviations

TMD	Temporomandibular Disorders
OI	Occlusal Interference
TMJ	Temporomandibular joint
MOI	Mediotrusive Occlusal Interference
LOI	Laterotrusive Occlusal Interference
DOI	Dummy Occlusal Interference
JMA	Zebirs Mandibular Motion Recording Device
MIP	Maximal Intercuspal Position
SCI	Sagittal Condylar Inclination
BA	Bennett Angle

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Author contributions

M.W. and W.N. conceived the ideas. M.W., Y.X., and B.L. collected the data. Y.X. and M.W. analyzed the data. M.W. wrote the paper. W.N. reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Data availability

The complete data and materials described in the research article are freely available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the ethical committee of the Affiliated Stomatology Hospital of Xuzhou Medical University (Approval number: 2020-008). The study was in accordance with the Declaration of Helsinki. All participants provided written informed consent to participate in the study.

Consent for publication

The participants gave written informed consent for their clinical details and personal images to be published in this study.

Competing interests

The authors declare no competing interests.

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