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# Mediotrusive Occlusal Contacts: Best Evidence Consensus Statement

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## Abstract

**Purpose:** The impact of mediotrusive (MT) occlusal contacts has been a topic of controversy and confusion in both clinical practice and in the dental literature. The purpose of this Best Evidence Consensus Statement was to explore whether MT interferences are harmful in the natural or therapeutic occlusion directed by 4 focus questions relating to prevalence, jaw function, jaw dysfunction and biomechanical models.
**Materials and Methods:** An electronic search in October 2020 sought evidence in MEDLINE (Ovid) using (mediotrus* OR nonworking side OR nonworking contact OR balancing side OR interfer* side OR premature contact) in the multipurpose (.mp) search field; and in Google Scholar using permutations of the above. Supplementary articles were sourced from the associated reference lists. There was no language restriction. The search yield was reviewed in duplicate.
**Results:** The electronic search identified 420 articles. Following screening, 164 were selected for eligibility assessments. Of these, 47 were included in the current paper.
**Conclusions:** Non-standardized nomenclature and methodology is used to identify MT interferences in patient populations, with resultant prevalence varying from 0% to 77%, (median = 16%). MT interferences may alter the biomechanics of mandibular function. Together with the presence of repeated high loads resultant strain can manifest as pathophysiology of the temporomandibular joint and associated muscle structures. MT interferences should be avoided in any therapeutic occlusal scheme to minimize pulpal, periodontal, structural and mechanical complications or exacerbation of temporomandibular disorders (TMDs). Naturally occurring molar MT interferences should be eliminated only if signs and symptoms of TMDs are present. Literature supports there being a biomechanical basis which can explain how MT interferences may affect temporomandibular joint morphology and jaw function.

The impact of mediotrusive (MT) occlusal contacts in patients who are dentate, or in patients who have tooth-supported or implant-supported prostheses has been a topic of controversy and confusion in both clinical practice and in the dental literature. Indeed, there seems to be a disconnect between "clinical experience" and scientific evidence. A review in 2000[1] documented a century of controversy regarding the benefit or detriment of occlusal contacts on the MT side. Throughout the century the pendulum swung from advocacy for the presence of these contacts to distribute occlusal load over the greatest possible supporting area (balanced occlusion)[2] to being a potential for initiating pathology of the teeth, supporting tissues, muscles and temporomandibular joint.[3] Then towards the end of the century to serving in a protective role against pathology arising from overloading of the temporomandibular joint.[4]

Part of the confusion arising from the many studies relates to differences in terminology used, with these contacts having been variously described as relating to the MT, non-working, balancing or non-functioning side. Further, such terms are often not clearly described in the literature, notably when there is no distinction between MT contacts and MT occlusal interferences.

The 9th Edition of the Glossary of Prosthodontic Terms[5] describes MT/nonworking-side occlusal contact as—"contact on the teeth on the side opposite to the direction of laterotrusion of the mandible": but goes on to state—"an undesirable contact of opposing occlusal surfaces on the nonworking-side when it interferes with anterior guidance or group function on the working-side"; but further—"nonworking-side contacts are desirable with removable complete dentures when

establishing balanced articulation". The Glossary also defines an occlusal interference as—"any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts" or "any undesirable occlusal contact". Synonymous terms are "occlusal prematurity" and "deflective occlusal contact". There is also a definition of occlusal disharmony—"a phenomenon in which contacts of opposing occlusal surfaces are not in harmony with other tooth contacts and/or the anatomic and physiologic components of the craniomandibular complex". Functional occlusal harmony is defined as— "the occlusal relationship of opposing teeth in all functional ranges and movements that will provide the greatest masticatory efficiency without causing undue strain or trauma on the supporting tissues".

For the purposes of this discussion, the term **MT contacts** will be used when contacts on the MT or non-working side occur simultaneously with other contacts either anteriorly or posteriorly on the laterotrusive side. The term **MT interferences** will be used when a tooth contact on the mediotrusive side causes lack of contact elsewhere prior to a deflection or deviation of the mandible, or tooth movement occurs, in order to achieve anterior contacts or posterior contacts on the laterotrusive side during movement to that side. The distinction between these terms is important as it impacts on the biomechanical properties of mandibular movement.

The aim of this Best Evidence Consensus Statement was to explore MT interferences and whether they are harmful in the natural or therapeutic occlusion, directed by 4 focus questions relating to prevalence, jaw function, jaw dysfunction, biomechanical models.

## Search strategy

An electronic search in October 2020 sought evidence in MEDLINE (Ovid) using (mediotrus* OR nonworking side OR nonworking contact OR balancing side OR interfer* side OR premature contact) in the multipurpose (.mp) search field; and in Google Scholar using permutations of the above. Supplementary articles were sourced from the associated reference lists. There was no language restriction. The search yield was reviewed in duplicate.

The electronic search identified 420 articles. Following screening, 164 were selected for eligibility assessments. Of these, 47 were included in the current paper.

## Focus question 1: How prevalent are MT contacts and MT interferences?

### Search strategy

Articles which explored prevalence of tooth contacts on the MT side, in human participants, in restored or unrestored dentitions were eligible for inclusion. A sub-set of articles from the original search was assessed for eligibility for focus question 1 with 10 included.

### Qualitative review

A review which assessed 15 articles that each included diverse populations, reported the proportion of patients with MT side contacts ranged from 0% to 97% with a median value of 35% and the proportion with MT interferences ranged from 0% to 77% with a median value of 16%.[1] The reviewers noted that when cohorts were assessed for occlusal contacts on the MT side, it was unclear whether these contacts were simultaneous MT contacts or discluding MT interferences. Many of the prevalence studies enrolled children or young adults, so it is likely that the reported distribution will not provide an accurate estimation for older adult populations.[1]

Interpretation of the data has also been complicated by a lack of standardization between measurement methods.[1] Methods varied by the type of contact assessed (guided vs functional), the criteria determining contact classification (contact vs interference) and the recording medium (analogue vs digital) used.

Most studies have assessed intraoral markings from articulating paper of varied thicknesses to detect tooth contacts during guided lateral movements. Unfortunately, this method alone cannot differentiate between MT contacts or interferences. Further, methods across the studies varied by the operator who guided the excursive mandibular movement (the clinician or the patient), and the force used (slight, heavy, or unspecified). Few studies have attempted to differentiate between contacts and interferences. In one study, a lack of MT contact was determined with clearance of a 50-μm-thick polyester strip within the first few millimetres of the lateral excursion measured at the second molars. Jamming of the strip, but with contact still remaining on the laterotrusive side, was defined as a naturally occurring MT contact and jamming of the strip with lack of contact on the laterotrusive side was defined as a MT interference.[6] There was no attempt to measure the "slight" forces applied during the excursions, but the participants were asked to maintain the intensity and direction of jaw movement. The laterotrusive side was determined by observation of the preferred chewing side. There was no explanation as to why a 50-μm-thick polyester strip was used, when articulating papers of approximately 12 μm have been shown to be more precise than thicker ones in clinical settings.[7]

Functional dynamic occlusal contacts were recorded with the use of articulating paper and a digital occlusion analyzer (T-Scan™) in a study of 100 participants.[8] It was stated the advantage of the digital evaluation showed the actual velocity and amplitude of movement which was subsequently compared between symptomatic and asymptomatic participants. However, the reproducibility of the identified contacts within or between the two recording methods was not reported. The high cost of the digital system makes it impractical for routine clinical use.

Another dynamic measuring method (Bruxchecker™) used a 100 μm foil vacuum formed over the maxillary teeth during sleep.[9] The authors stated this method did not alter masticatory muscle activity during sleep and was therefore a more reliable method for detecting contacts during functional or parafunctional movements. MT contacts and MT interferences were defined by the area of the coating that had been removed. If the area was $\leqq 3.0$ mm$^2$ it was defined as a MT contact, if larger, than it was defined as a MT interference. However, this method remains a subjective assessment and is likely influenced by the opposing tooth cusp contour, force magnitude, and any wedging effect of the foil preventing maximum intercuspation.

### Discussion

Much of the controversy in the scientific literature, revolves around a confusion in terminology, a lack of standardized definitions, an inability to accurately identify MT interferences and a lack of consistent and accurate measurement techniques.

MT contacts can occur over an extended time through tooth movements or differential wear. However, due to tissue resilience, mandibular torque (bending),[10,11] fluid displacement in the capsular connective tissue[12] and differential capacity for tooth displacement,[13] identification of MT contacts can be deceptive. For example, no contact could be observed during lateral movements under light forces, MT contacts could be observed under heavier forces, and interferences could be observed under even heavier forces as might be applied in parafunctional movements. This disparity is similar to variation in tooth contacts that are observed in centric closure or the variation in mandibular "sideshift" measurements, both of which are also dependent on the force applied by the operator (participant or clinician) and TMJ stability. Such confounding factors clearly pose a challenge when standardizing and validating identification techniques. How is the level of force during the lateral movements controlled? Does marking with articulating paper indicate a MT contact or MT interference? Will the thickness of the articulating paper allow differentiation between a MT contact and MT interference? Is there concomitant observation of contact or lack of contact on the laterotrusive side?

From a clinical perspective, the resilience of different tissues involved and the variation in forces applied, make it impossible to adjust natural or artificial tooth surfaces to ensure simultaneous (balanced) contacts—even if they can be developed on an articulator. A decision then has to be made whether to attempt to introduce MT contacts or to eliminate them when working with a restored or altered therapeutic occlusal scheme.

### Evidence-based conclusion

It is unclear how common MT interferences are across patient populations. The reported prevalence of MT interferences is variable depending on the nomenclature used, classification criteria and measuring methods (measured prevalence 0-77%, median value16%). Unfortunately, the interchanging of the terms MT contacts and MT interferences is common. Under different functional and dysfunctional environments, all contacts on the MT side have the potential to become interferences.

## Focus question 2: Are experimental occlusal interferences associated with changes in jaw function?

### Search strategy

Articles which explored the impact of experimental mediotrusive interferences only; and those which explored the impact of intercuspal and laterotrusive interferences on jaw function in human participants were eligible for inclusion. A sub-set of articles from the original search were assessed for eligibility for focus question 2 with 8 included.

### Qualitative review

In an effort to explore causality, many studies have placed experimental MT interferences in asymptomatic participants to observe the impact on the onset of TMDs. In 1999 Clark et al[13] published a review summarizing experimental occlusal interference studies which had been published across a 68-year period. The review assessed 18 studies in which experimental occlusal interferences were used in human participants; 9 involved interferences in the inter-cuspal position, 8 on the MT side and 2 on the laterotrusive side. Participant numbers ranged from 3 to 27 and study duration ranged from same day to 30 days. It was found that; (1) occlusal interferences, which contacted only during laterotrusive jaw movements, were infrequently harmful to jaw function; (2) those contacts which interfered with maximum intercuspation may have a pathologic effect on pulpal and periodontal tissues, interrupt smooth jaw function and sometimes cause muscle pain and joint clicking; (3) those contacts which interfered during mediotrusive movements may have similar pathologic effects, but participants who had a good adaptive capacity established learned avoidance of these MT interferences when approaching maximum intercuspation, thereby minimising or eliminating adverse outcomes.[13] This avoidance behavior has been verified in later studies.

In a 2003 study of 30 young asymptomatic healthy participants, a unilateral intercuspal interference (200 μm) was placed alternatively on canines and posterior teeth of each participant and its effect on electromyographic recordings (EMGs) was analyzed with static clenching. The addition of the interference in either location resulted in a change from a symmetric to an asymmetric contraction pattern, at least in the short term,[14] with an inconsistent displacement of the mandible in a lateral direction in an effort to avoid the introduced interference.[15]

A 2014 dynamic study with 21 asymptomatic healthy participants compared changes in EMG activity when chewing jubes (Optosil Comfort, Heraeus Kulser) in dentitions before and after the placement of experimental MT interferences in the molar region.[16] When MT interferences were present, the natural chewing cycles were altered, and the masticatory performance measured by total muscle work significantly decreased during the 15 chewing cycles. This avoidance pattern may influence development of a preferred chewing side.[17]

In another study in 2005 involving 11 asymptomatic healthy young female participants, an intercuspal interference in the form of a gold foil bonded to the first molar on the preferred chewing side for 8 days resulted in an initial reduction of EMG activity (an avoidance pattern) during chewing tasks, but activity levels returned to pre-interference levels after a few days.[18] Any initial tooth discomfort and headache experience dissipated after a short period and an increase in occlusal contacts indicated an initial increase in tooth mobility and adaptive intrusion of the "interference" teeth. None of the participants developed any signs or symptoms of muscle related temporomandibular dysfunction or capsule-related temporomandibular joint derangement – jointly referred to as temporomandibular disorders (TMDs).[19] Although this study involved an experimental intercuspal rather than a MT interfer-

ence, it demonstrated that permanent changes in teeth due to wear or position, can effectively eliminate or avoid the interference. It is likely that the speed and capacity for such changes to occur impacts on the longevity of the mandibular movement avoidance patterns, and pulpal, periodontal and muscle-related symptoms (demonstrated in this study as headache).

Studies suggest that disruption to jaw function caused by MT interferences is relatively transitory and that adaptation and normal function occur in the long term. In a 2016 study of 30 healthy asymptomatic young adult participants divided into groups with and without naturally occurring MT contacts, there was no difference in EMG activity or asymmetric chewing indices between the groups.[20] In this study, a natural MT contact was defined as an occlusal contact, measured by a 50 μm polyester strip between cusps of the second molars on the MT side during a slightly forced lateral excursive jaw displacement guided by the participant, which did not interfere with the tooth contacts on the laterotrusive side (bilateral balance). Participants were instructed to maintain the intensity and direction of jaw movement during measurements, but the forces used were not measured. The laterotrusive side was determined by observation of the preferred chewing side. The method as described indicates that the authors have tested MT contacts (bilateral balance) rather than MT interferences.

### Discussion

Induced experimental interferences, whether they be intercuspal or eccentric, cause transitory changes in jaw function measured by changes in amplitude and velocity of muscular activity in EMGs. It has been shown that these activity levels soon return to normal values, although chewing patterns can be permanently altered. Induced interferences also result in transitory pathological changes in teeth and supporting tissues. Again, these mostly resolve as a result of the altered "avoiding" chewing patterns or increased physiological tooth mobility, tooth wear or altered tooth positions.

From a clinical perspective then, it could be argued that signs and symptoms caused by induced restorative or orthodontic interferences will resolve without further intervention. It is not uncommon for a patient to return following a restorative procedure and report that the restored tooth was sore for a few days but had since settled. Clinical examination may confirm there is evidence of "wear" of the contacting surfaces, but any subtle changes in tooth position which may also have occurred, are not easily detected. Clinical assessment is further complicated because it is not always possible to differentiate between a reversible pulpits secondary to transitory occlusal overload and reversible pulpitis secondary to direct pulp irritation from the procedure.

However, despite evidence that discomfort will resolve without intervention, if patients do present with discomfort following treatment, non-intervention is not practical. Patient adaptability is extremely variable and unpredictable. Most patients are unlikely to accept that their symptoms will resolve following a period of adaption, which may take days, weeks or months.

### Evidence-based conclusion

Experimental MT interferences in asymptomatic participants can cause changes in jaw function through avoidance movement patterns, at least in the short term, but rarely result in TMDs or ongoing pathological changes in the teeth or supporting tissues.

## Focus question 3: Is there a relationship between naturally occurring MT interferences and temporomandibular disorders (TMDs)?

### Search strategy

Articles which explored TMDs in human participants who presented with MT interferences in dentitions that were both unrestored and had not undergone orthodontic treatment were eligible for inclusion. A sub-set of articles from the original search were assessed for eligibility for focus question 3 with 10 included.

### Qualitative review

There is considerable controversy concerning the role of naturally occurring MT interferences in TMDs.

In participants with a history of TMDs, experimentally placed MT "interferences" did result in an increase in signs and symptoms.[21] In this 2002 study, 21 participants with a history of TMDs but with no history or signs of temporomandibular joint pathologies such as clicking, locking or crepitus were compared to 26 participants in the control group - healthy individuals with no history or signs of TMDs. The TMDs group had been successfully treated with a multi-faceted treatment regimen and had no subjective symptoms at the time of placement of the "interferences". Both groups were randomly divided and blinded into receiving active or placebo "interferences". Some participants entered the study with pre-existing mediotrusive interferences, which discluded the laterotrusive side. For those in the active group, experimental "interferences" were placed bilaterally on the first maxillary molars when the condyles were manipulated into centric relation, to create contacts during MT and contacts that interfered with centric occlusion (but not maximum intercuspation). It was found that those participants with pre-existing MT discluding "interferences" and a history of TMDs showed a significant exacerbation of their TMDs if in the active group when compared to the other participants. The authors concluded that the etiological role of occlusal interferences in participants with a history of TMDs may not have been correctly addressed in previous studies on experimental interferences. In this study, the authors have actually assessed MT contacts (bilateral balance), not MT interferences.

Similar results were found in a later study reported in 2013[8] comparing dynamic occlusion patterns in 50 healthy asymptomatic controls and in 50 participants that had at least one clinical sign of TMDs and also naturally occurring MT interferences. Functional dynamic occlusal contacts were recorded with the use of articulating paper and a digital occlusion analyzer (T-Scan™). Closure into centric occlusion was operator guided but it is not clear whether excursive movements

were participant or operator guided. Presence of MT interferences was found to have statistically significant correlations with TMDs ($p = 0.003$).

The correlation of occlusal factors for the prediction of disc displacement with reduction was studied in a stepwise multiple regression model in 2009.[22] Two groups were included-patients with disc displacement with reduction (DDWR, n = 165) and healthy participants (n = 145). Presence of MT interferences, together with two other occlusal variables, was significantly correlated with presence of DDWR (P = 0.002, OR 2.14 (1.33 to 3.45 95%CI), and retained in the final multivariate logistic regression analysis. Although the discrimination of the resultant model was good (all variables over 60%), it only explained the diagnosis of DDWR at 12.4% (R = 0.124), indicating that DDWRs are complex and multifactorial beyond the occlusal variables assessed.

A recent study in 2019[23] assessed occlusal factors in 150 TMDs patients divided into 5 groups – myogenous (n = 31, muscle pain present), disc displacement with reduction (n = 97, joint clicks generally present), disc displacement without reduction (n = 15, joint clicks absent; joint pain potentially present or resolved), degenerative temporomandibular joint arthroses (n = 5, joint crepitus potentially present; joint pain potentially present or resolved) and subluxation (n = 2); no participant was classified as having multiple diagnoses. Complicating review of the statistical assessments, participants were not specifically classified as having arthralgia (joint pain). The authors explored factors that were more prevalent in the various groups; and then recombined groups 2, 3 and 4 for additional analysis (n = 117) to explore factors when participants reported outcome measures of joint noises, joint pain or muscle pain. This means that when groups 2, 3 and 4 were combined, the outcome measures being explored were disparate. No significant differences in occlusal factors among the groups were found except for MT interferences which were significantly more prevalent in the disc displacement without reduction group (66.7%, $p = 0.02$; a group without joint noises). However, following group recombination, which then added two groups that had joint noises and two groups that may or may not have joint pain, the authors stated that, occlusal factors were now not positively related to joint pain or sounds, and hence MT interferences could not be considered a specific contributing factor for TMDs. Based on the information reported in the manuscript, this conclusion appears to be flawed as the combined group included participants that could not satisfy the inclusion criteria. Despite this statement, the authors did concede that when developing a functional occlusion, iatrogenic MT interferences should not be introduced in patients prone to TMDs because they might contribute to overloading of the joints and flare-up of the TMDs.

As previously stated, there is some advocacy that MT guidance may actually be protective of the temporomandibular joint on the ipsilateral side.[1] A study published in 1990 reported a significant correlation (r = 0.975) between the absence of MT guidance, increased temporomandibular joint sounds and participant age.[4] Relevantly, it is accepted in the literature that joint sounds have been associated with joint pathology.[24] In the study,[4] 430 participants (aged between 19 and 30) were divided into 4 groups (A,B,C,D) based on their preexisting occlusal contact pattern. Participants in Group D with "discluding guidance" (MT interferences) accounted for just 31 (3.6%) of the 860 laterotrusive excursions assessed, and were excluded from the correlation coefficient analysis. The authors clarify their definition of MT side protective contact to be contact on the first and/or second molars during lateral excursive jaw movements existing only when clenching force is exerted. These contacts, which were classified as protective, disappear when clenching is ceased so in functional excursive jaw movements there was no MT contact. Thus, the claim of a protective role was based on simultaneous MT contacts with those on the laterotrusive side only under heavy clenching and not discluding MT interferences.

The authors stated this protective role with specific MT contacts might help explain the apparent contradictory findings in several studies and also explain the psychosocial contribution of induced bruxing in the development of TMDs. Unfortunately, the authors specific definition of MT contacts is not clarified when this study has been cited in subsequent publications. As stated, the authors reported that in participants who had no balancing side contacts (Group C), the prevalence of joint noises was higher in older participants than younger participants, peaking at approximately 50% in 30-year-olds. However, graphs indicate the highest prevalence of joint sounds actually occurred in those participants aged 21 to 22 years (n = 79) with MT contacts (bilateral balance) under functional loads, (Group A, approximately 60%). This compared to those with MT contacts only with heavy clenching (Group B, approximately 17%) and those with no MT contacts even with heavy clenching (Group C, approximately 17%). Thus, the graphs indicate the disparity of prevalence in joint sounds between these groups and appear to contradict the reported results. Further reporting of statistical assessments and inclusion of raw data would have been of interest.

Moreover, the "protective theory" was challenged by Christensen and coworkers in 1996.[25] These authors studied dynamic tooth guidance—rather than static clenching, and temporomandibular joint sounds in 46 asymptomatic patients and 46 symptomatic patients with TMDs. They found there was a high probability (59%) that the presence of unilateral or bilateral MT guidance would be associated with temporomandibular joint sounds and associated joint pain resulting in participants seeking treatment. Further, there was a high probability (70%) that in the absence of unilateral or bilateral MT guidance, participants would not seek treatment. The authors stated there was no evidence that MT guidance protects the ipsilateral temporomandibular joint against the development of joint sounds. They concluded that occlusal, as well as psychosocial factors, were relevant in any assessment of the aetiology of TMDs. Contrary to the previous study, these conclusions were based on MT (discluding) interferences.

A systematic review in 2017[26] assessed the relationship between occlusal factors and TMDs. Only papers (n = 25) that explored occlusal factors and TMDs with single (n = 15) or multiple variable analyses (n = 10) and demonstrated internal validity of assessment of TMDs were included. Across almost 40 occlusion factors evaluated – only centric relation slide and MT interferences were identified in the majority ($\geq$50%) of single variable analyses and only MT interferences were

identified in the majority of multiple variable analyses as being associated with TMDs. However, the authors highlighted that such an association does not imply causality, stating that the findings may be the result, not cause, of the TMDs. However, there was no explanation of how a MT interference could be caused by TMD. Further, they claimed the review supported the absence of a disease-specific association with dental occlusion; did not support the role of dental occlusion in the pathophysiology of TMDs; and that clinicians "are encouraged to abandon the old gnathological paradigm in TMD practice" and consider psychosocial factors paramount.

Stone et al in 2017[27] in a synopses of this systematic review appraised that MT interferences were associated with TMDs in the majority of the 10 studies which utilized multiple variable analyses. However, they concurred there was little clinically relevant evidence presented in the review to support an occlusal cause for TMDs. They re-iterated that the dental community will need to move towards the acceptance of the bio-psychosocial model and abandon some of the older held beliefs about treating TMD. The authors did not provide any comment indicating they had considered that occlusal factors could be contributory to the bio-psychosocial model; rather implying that each model was disparate.

### Discussion

It is widely accepted that the etiology of TMDs is multifactorial with psychosocial factors being paramount. As noted by Marklund & Wänman,[1] the pendulum has swung and there is currently an almost complete exclusion of occlusal parameters having a role in the development of TMDs. However, there appears to be considerable publication bias and "group-think" in many of these more recent studies, arguably in an effort to confirm this paradigm shift. Many studies identify MT interferences at least as a factor involved, but then combined with the 40 or so other factors with no identified association, the overall resultant conclusion is that occlusal parameters do not significantly cause or contribute to pathologies.

Much of this controversy can again be attributed to confusion over the terms MT contacts and MT interferences. Where some studies are very specific in the description of the contacts, it is evident that they are not referring to MT (discluding) interferences as previously defined. Subsequent citations do not make the distinction between MT contacts and MT interferences.

Experimentally placed MT contacts did result in an exacerbation in symptoms in patients who had previously been successfully treated for TMDs. It could be reasonably deduced that there would have been an even greater increase in clinical signs of TMDs with placement of actual MT interferences.

There is one study that has stated MT contacts provide a protective role against TMDs. However, this study appeared to have observational data which was presented graphically that may contradict the reported conclusion, but these results were not synthesized in the paper. Further, the proposed protective nature is based on MT contacts (bilateral balance) under heavy clenching. These contacts are not present with light forces. As stated previously, from a clinical perspective, it is impossible to provide therapeutic occlusal contacts that are bilaterally balanced even if they could be demonstrated on an articulator. It is also not possible to vary the force on mounted models and equate this to heavy clenching. Moreover, even if these balancing contacts could then be replicated in the mouth, they would not remain static due to differential wear of natural and artificial materials and changes in tooth position, subsequently resulting in either a lack of contact or MT interferences. There is contrary evidence that MT contacts are not protective and are associated with exacerbation of TMDs in patients with a previous history of these pathologies.

Although the reported agreement across the literature is that MT interferences alone cannot be considered a specific causal factor for TMDs, it is conceded that when developing a functional or therapeutic occlusion, iatrogenic MT interferences should not be introduced in restored tooth contours, either because they may cause transient pain and discomfort in the adaptive patient or exacerbate TMDs in the susceptible non-adaptive patient. This would seem to be an acknowledgement of some correlation with MT interferences in the latter cohort.

Contrarily, in non-symptomatic naturally developed occlusal schemes, differential wear and changes in tooth position will commonly result in the development of working-side group function and even MT contacts (bilateral balance) or MT interferences. These small changes occur over an extended period of time and allow adaptation of the various occlusal components. There is little evidence to support that any resultant MT contacts should be eliminated in this non-symptomatic cohort. However, should they be eliminated in the non-adaptive patient cohort? Other than relying on a history of TMDs, how does the clinician predict who is the non-adaptive patient?

Certainly, the sentiment reported across the literature has swung. Occlusal adjustment which was previously considered a primary treatment modality, is currently frowned upon. It is even suggested that any form of occlusal adjustment as part of management of TMDs is contraindicated and may even be a cause for medico-legal action.[28] However, there are still relatively recent clinically oriented publications advocating their removal as part of management of these pathologies.[29] Does this represent lack of awareness of the current literature and adherence to the old-fashioned gnathological paradigm, as has been declared, or does it represent the amelioration of symptoms in patients experienced by many clinicians? Is this a disconnect between "clinical experience" and the scientific literature? Neither approach has convincing scientific evidence.

### Evidence-based conclusion

There is conflicting evidence that naturally occurring MT interferences are associated with TMDs and whether this is a cause or effect. However, there is agreement that MT interferences should not be introduced when developing a therapeutic occlusal form.

## Focus question 4: Is there a biomechanical basis for MT interferences to affect jaw function?

### Search strategy

Articles which explored mandibular movements and the temporomandibular joint complex in human participants were

eligible for inclusion. A sub-set of articles from the original search was assessed for eligibility for focus question 4, with 12 included.

## Qualitative review

Occlusal forces acting on a bolus generate reaction forces in the temporomandibular joints and these are influenced by the position of the occlusal force. In the absence of tooth contacts, these reaction forces will always be compressive on the mediotrusive side as the condyle is the fulcrum of a class I lever system.[30,31] However, they can vary from compressive, to neutral to tensile on the ipsilateral side as the occlusal force moves distally.[32] This was originally demonstrated in cinefluorographic observations in participants biting unilaterally and isometrically on a hard form (not specified).[33] The mandibular incisors moved up and the ipsilateral condyle lifted off the articular eminence in some participants, indicating tensile stress.

More sophisticated dynamic stereometry was developed to analyze the motion of the entire condyle in the fossa in three dimensions during jaw movements. It was used to analyze stress field translations with loading across the disc and condyle complex in ten healthy young adults with no signs of TMDs.[12,34] During mastication, the disc and capsule are concurrently maximally elongated (stressed) anterio-posteriorly during the power stroke on the mesiotrusive side, resulting in higher work-loads than on the laterotrusive side.[34] However, there is invariably also an added mediolateral component to these stress translations (movement across the disc), but these run transversally to the disc connective tissue fibers and the antero-posterior direction of disc movement resulting in shear stresses.[12,34] A pressure gradient develops in front of the lateral or mesial movement of the stress fields. The disc changes form elastically through fluid movement in the matrix and flattening of the connective tissue fibers, simulating a ploughing (crimping) effect. The energy of the loads is absorbed within the structures. The lateral area of the disc is more subject to these shear stress translations than the medial area.[12] Compressive stresses are resisted by the intra-capsular disc and tensile stresses controlling joint compactness and disc stability, are resisted by the capsular attachments preventing disc displacement.[35] Excessive accumulations of shear stresses can result in fatigue (plastic deformation) of the disc or ligaments. It was suggested[12] that these findings may explain why osteoarthritic lesions including disc perforations are more commonly observed on the lateral part of the joint as demonstrated by Hansson.[36]

An MT interference causing disclusion on the laterotrusive side, will become the point of occlusal force, thus changing the reaction forces at the condyles. The MT condyle becomes the ipsilateral condyle. The further distally the MT interferences are (e.g. between molars) the more likely these reaction forces will change from compressive to neutral to tensile stresses in the now ipsilateral condyle. Tensile strain resulting in plastic deformation of these ligaments through overload, is more prevalent in the lateral capsular attachments[37] and can lead to a lack of coordinated movement between disc and condyle manifesting in displacements, with associated clicking, or more debilitating forms of joint derangement.[35] Disc displacements are the most common form of intra-articular disorders accounting for over 40% of clinical diagnoses[38] and can occur in 33% of asymptomatic individuals.[39] Joint instability is also likely to stimulate adjacent compensatory muscle hyperactivity, which if prolonged can result in muscle fatigue and dysfunction.[40]

## Discussion

Occlusion is the dynamic interplay between the various components providing resistance to the application of forces. The velocity, amplitude and duration of the forces will influence whether adaptation or strain (pathology) ensues. Resistance against strain will be reduced by any compromise to the integrity of these components.[41] As in any physiological system, a "normal" state includes a degree of adaptability with variations in form and an absence of pathology.

Forces requiring resistance arise from functional and parafunctional activities. The actual forces involved are difficult to measure and are variable but parafunctional forces involving clenching and bruxism are much greater in amplitude and duration than functional forces.[42] The relatively regular pattern of sleep (nocturnal) bruxism, makes it easier to detect and facilitates adaptation of both the oral structures through tooth wear and positional changes, periodontal ligament thickening and increased periodontal bone density. It also facilitates muscle and ligament "training" with associated muscle hypertrophy, e.g., masseter hyperplasia, and joint stability, similar to any regular physiologic exercise regimen.

Awake (diurnal) clenching and bruxing have a high association with psychosocial factors such as stress.[43,44] The resultant irregular bursts of high intensity forces associated with transient and variable risk factors makes it difficult to detect in cross sectional or short term studies[45] and contrary to consistent nocturnal bruxism, this irregularity does not facilitate adaptation – "training" of the tissues. They are more susceptible to plastic deformation and associated pathology. This is analogous to the untrained athlete who is very susceptible to muscle fatigue and joint injury with a sudden burst of high intensity activity. It is likely that most people, with or without occlusal interferences, are stressed at irregular times and engage in high intensity parafunctional activity,

Therapeutic changes (prosthodontic, orthodontic, surgical) are relatively instantaneous and challenge the adaptive capacity of the occlusal components. The physiological adaptive capacity of all of these components can be exceeded.[46,47] Structures already compromised through disease or trauma are even more susceptible to new pathology or exacerbation of existing pathologies when subjected to functional and even more so parafunctional forces. However, given the weak predictive association of MT interferences alone and the high degree of irregularity of diurnal bruxism, there is no indication to eliminate naturally occurring MT interferences associated with teeth that are uncompromised, either structurally or periodontally, in the absence of any signs or symptoms of TMDs, even in the presence of bruxism.

Occlusal interferences transiently concentrate forces on individual teeth and in the case of MT interferences, involve high tensile lateral stress, so at least during therapeutic occlusal changes they should be avoided to minimize structural and me-

chanical failures, especially where the structural integrity of the teeth and supporting intra-oral tissues are already compromised through disease or trauma.

A rationale has also been presented that explains the biomechanical challenges in temporomandibular joint structures in the presence of MT interferences associated with molar teeth. In patients with TMDs (a reasonable surrogate marker for the non-adaptive patient), it is likely that MT interferences will further challenge the adaptive capacity and lead to an exacerbation of symptoms. Given the high incidence of bruxism; the difficulty in identifying the irregular bruxer; the periodicity of TMDs; the observed pathophysiology of teeth and other occlusal components; and the biomechanical rationale for modulating jaw function, the case for eliminating naturally occurring MT interferences associated with molars in the symptomatic patient is strengthened.

There is also the consideration of the biologic cost of carrying out any adjustment to eliminate MT interferences. Given the rationale previously discussed, any adjustments would be limited to the molar regions and confined to cusp inclines. This does not involve the traditional "occlusal equilibration" historically associated with the "gnathological paradigm". Thus, the protocols, although irreversible, are biologically conservative and cost effective relative to pharmacologic intervention, occlusal devices, or counselling sessions, aimed at reducing the parafunctional activity. This is especially pertinent given the limited scientifically validated long-term effectiveness of these alternatives.

There is no evidence that the absence of, or removal of MT interferences results in any pathology associated with intra- or extra-oral tissues.

Any treatment of TMDs arising from extrinsic or intrinsic trauma will require a multi-therapeutic approach. Elimination of specific MT interferences in the natural or therapeutically restored/altered dentition can be justified as part of any regimen.

### Evidence-based conclusion

MT interferences may result in tensile loads in the TMJ complex. Lateral movement of the condyle over the disc can make the disc and ligaments more susceptible to plastic deformation. These observations may explain the formation of disc displacements and the propensity for disc perforations to occur more commonly in the lateral part of the TMJ complex.

## Consensus conclusions

1. Differences in nomenclature, classification criteria and measuring methods impacted on reported prevalence of tooth contacts on the MT side. Despite reports that the proportion of patients in some populations experiencing MT contacts range from 0% to 97%, it remains unclear how common MT interferences are across patient populations.
2. Under different functional and dysfunctional environments, all contacts on the MT side have the potential to become interferences.
3. MT interferences may alter the biomechanics of mandibular function. In the presence of repeated high loads this can possibly lead to pathophysiology of the temporomandibular joint and associated muscle structures.
4. MT interferences should be avoided in any therapeutic occlusal scheme to minimize pulpal, periodontal, structural and mechanical complications or exacerbation of TMDs.
5. MT interferences associated with molars should be eliminated in naturally occurring occlusal schemes only in the presence of signs and symptoms of TMDs.
6. In asymptomatic patients, there is no indication to prophylactically eliminate naturally occurring MT interferences associated with uncompromised teeth, even in the presence of bruxism.
7. Literature supports there being a biomechanical basis which can explain how MT interferences may affect temporomandibular joint morphology and jaw function.

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