Review
Does altering the occlusal vertical dimension produce temporomandibular disorders? A literature review

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SUMMARY The purpose of this review was to present a comprehensive review of the scientific evidence available in the literature regarding the effect of altering the occlusal vertical dimension (OVD) on producing temporomandibular disorders. The authors conducted a PubMed search with the following search terms ‘temporomandibular disorders’, ‘occlusal vertical dimension’, ‘stomatognatic system’, ‘masticatory muscles’ and ‘skeletal muscle’. Bibliographies of all retrieved articles were consulted for additional publications. Hand-searched publications from 1938 were included. The literature review revealed a lack of well-designed studies. Traditional beliefs have been based on case reports and anecdotal opinions rather than on well-controlled clinical trials. The available evidence is weak and seems to indicate that the stomatognathic system has the ability to adapt rapidly to moderate changes in occlusal vertical dimension (OVD). Nevertheless, it should be taken into consideration that in some patients mild transient symptoms may occur, but they are most often self-limiting and without major consequence. In conclusion, there is no indication that permanent alteration in the OVD will produce long-lasting TMD symptoms. However, additional studies are needed.

KEYWORDS: vertical dimension, temporomandibular joint disorders, dental occlusion, stomatognathic system, masticatory muscles and prosthetic dentistry

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Introduction
Traditionally, it has been believed that changing the occlusal vertical dimension (OVD) is a precarious dental procedure causing problems such as muscle pain, temporomandibular joint pain, headaches, tooth grinding and clenching. In the first decades of the last century, some authors expressed their concerns about the ‘dangers’ of altering the OVD (1, 2). They hypothesised that changing the OVD caused physical suffering due to muscle strain (1). These authors believed that shortening of the lower third of facial (a decrease in the OVD) was a product of natural adaptation. Therefore, restoring this vertical dimension (e.g. edentulous patients) was an extreme dental treatment that went against the delicate balance of the stomatognathic system (1, 2).

Additionally, some decades later, several authors reported that creating an inadequate OVD by either increasing or decreasing it could create serious problems (3–5). They believed the OVD was a specific and fixed value that cannot be changed and that this value should be carefully and accurately calculated so that it will not be altered when treating patients.

Despite the fact that these conclusions were based solely on opinions and/or case reports, these beliefs have remained throughout the decades. It has since been believed that altering the OVD leads to the development of signs and symptoms of temporomandibular disorders (TMD). According to the Guidelines of the American Academy of Orofacial Pain,
temporomandibular disorders (TMD) are defined as ‘a collective term embracing a number of clinical problems involving the temporomandibular joint (TMJ), masticatory muscles or both’ (6).

More recently, attention has been drawn towards changing OVD (7). This article will review the literature regarding the effect of altering the OVD on producing TMD symptoms. The authors conducted a comprehensive search through PubMed from 1966 to 2013 with the following search MeSH (medical subject heading) terms ‘temporomandibular disorders’, ‘occlusal vertical dimension’, ‘stomatognatic system’, ‘masticatory muscles’ and ‘skeletal muscle’. Filters for English language were applied. A total of 380 were initially identified. After reading the abstracts, only 71 papers were selected. After full-text analysis, 6 papers were excluded as not having information related to this subject review. Bibliographies of all retrieved articles were consulted for additional publications, and 2 additional articles were disclosed. Hand-searched publications from 1938 were included. A total of 67 papers met the purpose of the study. These papers were reviewed, and both authors concluded that there were no randomised clinical trials available. The articles were often scientifically flawed because of design flaws, small study populations, lack of controls and others. Furthermore, most of the conclusions were based in case reports and opinions rather than in well-controlled clinical trials. This article will review the past and present views, and the authors will compare the clinical opinions on this topic and the outcomes reported in the available literature.

Available evidence will be presented to answer the following questions: Does increasing OVD lead to TMD?; Does decreasing OVD lead to TMD?; and Can the stomatognathic system adapt to changes in OVD?

Does increasing OVD lead to TMD?

One of the early studies that investigated OVD was written by Christensen in 1970 (8). He increased the OVD in 20 healthy dentate patients and 22 complete denture patients by placing overlays on the mandibular molars for a period of 3–7 days. He reported that subjects developed several symptoms after increasing the OVD, but these symptoms were of mild intensity and more frequent in the group of dentate subjects compared to complete denture patients. The symptoms were initiated as early as one hour after the overlays were inserted and lasted on average 30 h. Clenching and grinding of teeth appeared in the first 36 h after insertion in both groups and disappeared before the experiment had ended. He concluded that increasing the OVD resulted in an increased masticatory muscle and joint pain.

Although this was one of the first studies to evaluate symptoms associated with an increase of vertical dimension, there were some confounding factors that need to be considered. Certainly increasing the height of the molars altered the vertical dimension; however, with this increase in OVD there may have also been a loss of occlusal stability. Therefore, the symptomatology reported may have been the results of the occlusal instability and not the increase in OVD (9–12).

In a later study, Carlsson et al. (13) investigated the effect of increasing vertical dimension (3.9 mm) by means of posterior acrylic appliances which provided good occlusal stability in 6 healthy patients with no TMD signs or symptoms maintained for 7 days. The results demonstrated that subjects presented with moderate subjective symptoms, which decreased after 1–2 days. The main complaints were discomfort in wearing the splints, speech difficulties and cheek biting. The clinical examination performed did not demonstrate pain upon palpation any masticatory muscles or the TMJ structures. Thus, the authors concluded that increasing OVD did not seem to be a hazardous procedure when good occlusal stability was achieved.

In another study, Dahl et al. (14) evaluated the effect of increasing the vertical dimension (range: 1.8–4.7 mm) by placing a partial chrome-cobalt splint covering the maxillary anterior teeth for 6–14 months in 20 patients with severe tooth attrition. The use of a partial splint led to the intrusion of the anterior segment and extrusion of posterior teeth. Regarding the development of TMD signs and symptoms, the study reported that the splint caused short and transient discomfort, concluding that the increase of vertical dimension is well tolerated in most cases. This same sample was followed for a period of 5–5 years after anterior teeth were restored with crowns at the new vertical dimension, and no TMD symptoms were evident (15). This indicated that patients adapted to changes in their OVD in a relatively short period of time.
Another study was performed evaluating the effect of the abovementioned 'Dahl'-type appliances. The sample consisted of 45 patients who received different appliances for a mean of 5-9 months and were followed up to 4-43 years. They indicated that 94% of the sample reported no discomfort during splint treatment, 2% complained about mild muscular discomfort and 4% complained about moderate dysfunction, that subsided before the end of the treatment (16).

In a study by Gross et al. (17), OVD was increased by means of a complete arch acrylic fixed dentures (3-5-4.5 mm interincisally) in 8 healthy subjects with severe dental wear. The study reported initial speech difficulties and muscle discomfort that subsided after 1-2 weeks. The authors demonstrated that a new interocclusal rest space was re-established after increasing the OVD and this remained stable at the 2-year follow-up (18).

The same authors analysed the differences in increasing OVD in a range between 3 and 5 mm with fixed prosthesis on natural dentition and implant-supported restorations in 30 patients, followed for a period of 66 months. They reported that all the patients adapted to the new OVD. Only 6 patients in the implant-supported group developed tooth clenching or grinding that subsided after 2–3 months (19).

In another study, Tryde et al. (20) concluded that patients adapt to increases in OVD. They calculated that the 'comfortable zone' varied on average about 1-3 mm with the increased OVD.

Hellsing in 1987 studied the adaptability in edentulous patients when altering the OVD. He demonstrated that patients adapt very quickly to a new vertical dimension, creating a new interocclusal space of 3-3 mm (21).

It should be noted that the studies that investigated the relationship between increasing OVD and TMD symptoms were all conducted on relatively small changes in OVD, likely within the freeway space. Larger changes in OVD have not been well studied.

In summary, a review of the available literature regarding the effect of increasing OVD is limited. The scientific merit of the available studies is compromised by the lack of adequate sample size, control groups, randomisation and, in most of the cases, long-term follow-up. However, in spite of these shortcomings, the results of these studies do not suggest that increasing the OVD leads to the development, aggravation or perpetuation of TMD symptoms. On the contrary, the few published studies show a trend demonstrating that mild transient TMD symptoms may appear after moderate increases of OVD and these symptoms routinely resolve rather quickly. These findings suggest that the stomatognathic system has great ability to adapt to increases in OVD (22–25) without any major clinical consequences.

Does decreasing OVD lead to TMD?

Similar to increasing the OVD, there are conflicting reports in the literature regarding the effects of decreasing the OVD. Some authors have suggested that the stomatognathic system naturally adapts to decreases in OVD, for example in cases of tooth loss or severe dental attrition (1, 2). Conversely, other authors have suggested that a decrease in OVD can predispose the patient to TMD (3, 4). Nevertheless, there is no strong evidence in the literature supporting either of these statements.

It has been reported that severely worn dentitions resulting in a decrease in OVD are usually due to parafunctional habits or an abrasive diet (26). However, patients with significant tooth wear do not regularly present signs or symptoms of TMD (15).

Interestingly, Pullinger et al. (27) studied the correlation between the presence of severe dental attrition and TMD. They did not find any statistically significant correlation between the degree of dental attrition and TMD symptoms. Nevertheless, the same authors repeated the study in 2006 (28) and published that the presence of dental attrition could differentiate patients with masticatory muscle pain from controls and patients with intracapsular disorders. It is important to note that the cause of the masticatory muscle disorder was not determined to be associated with the loss of OVD. Perhaps a more logical association may be the increased use of the masticatory muscles in patients with severe dental attrition.

There is also controversy in the literature regarding the relationship between the loss of natural dentition and TMD (29). Pullinger and Seligman (12) published that TMD risk factors included the following: anterior open bite, cross-bite, overjet more than 6 mm, discrepancy between centric relation and intercuspal position more than 2 mm and loss of posterior teeth (9, 30). As abovementioned, the loss of posterior teeth often results in occlusal instability that is considered as a possible aggravating, perpetuating or predisposing
factor for TMD (31). However, it has been shown that even in shortened arches, good occlusal stability can be obtained (32). On occasion, the mandible may protrude to obtain major stability resulting in an overload of the anterior teeth (23) and possibly overloading the TMJ. However, this has not been demonstrated to routinely decrease OVD.

It has been suggested that an increase in signs and symptoms of TMD in elderly populations may be due to loss of the natural dentition and use of complete dentures (33). However, Schmitter (34) demonstrated that in the geriatric population (68–96 years old) symptoms of TMD actually decrease, whereas signs such as TMJ sounds increase in the elderly. An early assumption made by Tench in 1938 suggested a natural adaptability of the stomatognathic system with age (1).

It is interesting to note that when complete dentures are placed patients immediately adapt to a wide range of variation in OVD which is a different OVD from not having the dentures in place (4). This seems to once again demonstrate the adaptability of the masticatory system.

To summarise, a review of the available literature regarding the effect of decreasing OVD on producing TMD is very limited. There are no well-controlled studies, and most opinions are drawn from observations associated with loss of tooth structure. A decrease in OVD may occur with the loss of posterior teeth but, because other risk factors such as occlusal instability are involved, the relationship between decreased in OVD and TMD cannot be determined. It is logical to assume that a severely worn dentition results in a decrease in OVD. However, evidence does not suggest that there is increased presence of TMD symptoms in severely worn dentition. Perhaps this is further evidence of the favourable adaptability of the stomatognathic system.

How does the stomatognathic system adapt to changes in OVD?

The studies reviewed in the above sections lead to the conclusion that the stomatognathic system has the ability to adapt to changes in the OVD. Although in some studies, rapid changes in OVD in healthy individuals seem to lead to mild TMD symptoms, these symptoms seem to resolve relatively quickly. The following section will discuss how altering the OVD can impact on the different structures of the masticatory system including muscles and TMJs. The effect of altering OVD on the dentition (35) is not in the scope of this study.

Traditionally, it was suggested that increasing OVD led to muscle strain resulting in muscle hyperactivity, which predisposes to muscle pain (2, 3). Conversely, EMG studies have demonstrated the opposite. Manns et al. (36) demonstrated that the resting EMG activity of the masseter muscle was minimum at an intermediate range of mouth opening that varied between 10 and 16 mm of mouth opening depending on the muscle studied. Once the above-named range of mouth opening was reached, the EMG activity increased as maximum opening was obtained (37).

Thus, the so-called rest position is an active muscular position where masticatory muscles present a constant muscle activity positioning the jaw against the forces of gravity. Rugh et al. (38) demonstrated that there was a difference of 6 mm between this position and the minimal EMG, proposing the term of postural position of the jaw instead of rest position.

Additionally, Gross et al. (39) demonstrated that there was not a minimum EMG point during mouth opening. A mean plateau of EMG activity was found from maximal intercuspation to 20 mm of mouth opening, suggesting that masticatory muscles present a minimum EMG activity at a range of mouth opening and not at a specific fixed position. Using this same logic, regarding the EMG activity, interocclusal rest space could also be better described as that of a range instead of a fixed position (36, 40, 41).

In contrast, maximum bite force is achieved at the range of 15–20 mm of mouth opening and its minimum is found at maximum opening (36). It has been shown that bite force is decreased in patients with worn dentition but progressively increases 8–12 weeks after the daily use (8–10 h) of a stabilisation appliance. These same results are achieved in a control group (42).

Moreover, when muscles are relaxed, for example under hypnosis, 43–50% reduction of EMG activity was observed in masseter and temporalis muscles when the interocclusal space was increased from 2.2 to 8.9 mm (43).

It has been proposed that one possible mechanism of action of occlusal appliances is related to increasing the vertical dimension (31). In patients with TMD, the interocclusal appliance (IOA) adjusted at the OVD
corresponding to the minimum EMG activity was more effective in reducing symptomatology. Reduction in TMD symptoms was also faster for those patients wearing IOA at an increased OVD of 8-15 or 4-42 mm than an IOA increased at 1 mm (44, 45). Several studies have demonstrated that the EMG activity of masticatory muscles at postural position decreases when the IOA is used (46, 47).

It is noteworthy that there is no conclusive evidence regarding the association between pain and increased levels of EMG activity (48, 49). Therefore, the clinical relevance of increased EMG activity of the masticatory and cervical muscles remains unclear (49).

In animal models, several studies have demonstrated that plastic changes in muscle fibres occur following increases in OVD. In short-term studies, after 2 weeks of increased OVD, it was found that there was an increase in type II a fibres (slower phenotype) in the deep masseter muscle of open bite mice compared to the increase of type II b fibres (faster phenotype) of controls (50, 51). Conversely, another study demonstrated that no histochemical differences were found after 4 weeks in open bite rats (52).

These findings suggest that there is a great degree of adaptability in masticatory muscles following changes in OVD. Even though initial differences can be found in the phenotype of muscle fibres, they subsided after 4 weeks (53, 54).

Mechanistic finite element models have been recently developed to study the sarcomerogenesis response of adult skeletal muscles to passive overstretch (55, 56). It has been reported that the optimum length of the skeletal muscle regulates the number of sarcomeres. Thus, when the muscle is held at a shortened length, the number of sarcomere units decrease (57). This dynamic phenomenon is well described in the literature as muscle plasticity (58, 59) and has been studied in surgical limb lengthening and tendon transfer surgeries (60–66).

Similarly, after orthognathic surgery, differences in muscle size have been observed in long-term studies. It has been shown that muscles adapted to the new craniofacial morphology. After an initial increase in thickness was noted, at 4 years post-surgery the thickness was no longer noticeable (67).

Muscle size has also been studied by Kiliaridis et al. (68) in children with class II malocclusion treated with functional appliances for 9–17 months that resulted in an increase of vertical dimension of 5–2 mm. They demonstrated by means of ultrasonographic examination that increase of OVD lead to mild atrophy of the masseter muscle compared to controls.

Increasing OVD may also alter TMJ condylar position. Hellsing et al. (69) using radiographic examination demonstrated that at an interincisal mouth opening of 4–7 mm, there was not only pure rotation of the condyles but also a degree of translation. However, the direction of the movement was random. Thus, another possible mechanism of action of IOA would be a change in condylar position related to the increased OVD. Perhaps this may even reduce the load of the TMJ. Nitzan et al. 1994 (70) studied TMJ intra-articular pressure with different mouth openings as well as with and without an IOA. She demonstrated that during maximal mouth opening, the intra-articular pressure was negative, whereas during maximal voluntary clenching, the pressure was positive. Furthermore, when an IOA was placed and the patient was asked to clench, the intra-articular pressure was reduced in 81%. Given the anatomic realities of the TMJ being loaded at all times, these results are not likely valid and have not been reproduced.

It is interesting to note that Manns et al. (44) demonstrated that an increase in OVD in patients with muscle TMD reduced the painful symptoms. These findings suggest that a change in the working length of a painful muscle may actually reduce painful symptoms. This is certainly clinically verified when muscles that are tight and painful are passively stretched or lengthened. This, however, does not suggest that if this particular length is maintained, it will keep the patient muscle pain free indefinitely. This concept is not well appreciated in dentistry. In fact, when a patient reports a reduction in pain with an increased OVD, the dentist often assumes that this is the correct vertical dimension and if it were permanently established, the patient would be permanently free of pain. This concept is not evidence based but is still common in the practice of dentistry. In fact, muscles seem to be more pain free when they are allowed to change their length during normal function.

This section can be summarised by stating that the evidence does suggest that the stomatognathic system can adapt and does so routinely when OVD is altered, either naturally or by dental procedures. Adaptation may be the results of muscle or joint responses, or
both. Further studies are needed to more completely understand this process of adaptation.

**Conclusion**

This literature review revealed a lack of well-designed studies investigating the relationship between altering the OVD and producing TMD. Although some clinicians believe that changes in OVD are closely related to TMD symptoms, there is little evidence that this relationship exists. Traditional beliefs about this relationship have been based on case reports and anecdotal opinions rather than on well-controlled clinical trials. The evidence available to the date indicates that the stomatognathic system has the ability to adapt rapidly to moderate changes in OVD (<5 mm).

Nevertheless, it should be taken into consideration that in some patients, mild transient symptoms of TMD may occur, but they are most often self-limiting and without major consequence. On the other hand, in some instances, clinicians may increase the OVD with an oral splint as a treatment for TMD symptoms. This strategy usually produces symptomatic relief, and most patients’ muscles appear to adapt well to this approach. However, some clinicians have interpreted this outcome as an indication for permanently raising the vertical dimension, but that is not an appropriate conclusion. Instead, the IOA should gradually be removed after the symptoms get better.

As the available evidence is weak and does not allow any solid clinical recommendation, when there are therapeutic needs to increase the OVD (i.e. orthodontic needs, aesthetics and function) care should be taken to incorporate minimum changes and that orthopaedic stability is maintained during such change. Changes in OVD may be assisted by utilising an IOA or temporary crowns that can be fabricated at the increased OVD. The patient should be observed for an adequate period of time to assure a positive stomatognathic response. Permanent occlusal changes should only be attempted after the patient has demonstrated adaptability at the new vertical dimension.

In conclusion, much of the concepts regarding OVD and TMD are unfounded by scientific evidence. Additional studies are needed to more completely understand this relationship as well as important factors that may need to be considered when there are clinical needs to change a patient’s OVD.

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