Safety of increasing vertical dimension of occlusion: A systematic review

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Objective: To review all the literature investigating the implications of increasing the vertical dimension of occlusion (VDO). **Method and Materials:** A comprehensive electronic search was conducted through PubMed with the aid of Boolean operators to combine the following key words: "occlusal vertical dimension," "increasing vertical dimension," "bite raising," "occlusal space," "resting vertical dimension," "rest position," "altered vertical dimension," "mandibular posture," "temporomandibular joint," and "masticatory muscles." The search was limited to peer-reviewed articles written in English and published through August 2011. Further, the literature search was endorsed by manual searching through peer-reviewed journals and reference lists of the selected articles. **Results:** A total of 902 studies were initially retrieved, but only 9 met the specified inclusion criteria for the review. From the selected studies, four variables were identified to be relevant to the topic of VDO increase: magnitude of VDO increase, method of increasing VDO, occlusion scheme, and the adaptation period. **Conclusion:** Considering the limitations of this review, it could be concluded that whenever indicated, permanent increase of the VDO is a safe and predictable procedure. Intervention with a fixed restoration is more predictable and results in a higher adaptation level. Negative signs and symptoms were identified, but they were self-limiting. Due to the lack of a well-designed study, further controlled and randomized studies are needed to confirm the outcome of this review. *(Quintessence Int 2012;43:369–380)*

Key words: muscle relaxation, occlusal splint, occlusal vertical dimension, occlusion, patient adaptation

Vertical dimension is defined as the distance between two selected anatomical or marked points.[1] For dentate individuals, the vertical dimension of occlusion (VDO) is largely determined by the occluding dentition.[1] Subsequently, loss of tooth substance will directly affect the VDO, leading to alteration in facial morphology, function, comfort, and esthetics.[2] Although the loss of VDO is clinically possible, the original VDO can be maintained by a dentoalveolar compensatory mechanism that involves the overeruption of worn teeth. This dynamic nature of the stomatognathic system is considered by several authors to be an adaptation mechanism of the masticatory system in response to progressive loss in tooth substance.[3–7] However, for generalized loss of crown height due to tooth wear, from the clinical perspective, it is advantageous to consider increasing the VDO since it will provide space for restorative material, enhance the esthetic tooth display, rectify anterior teeth relationship, allow for re-establishment of physiologic occlusion, and minimize the need for biologically invasive clinical procedures such as crown-lengthening surgery and elective endodontic treatment.[8–11]

Empirically, some authors[2,12,13] claimed that the VDO is a constant dimension through individual life. Subsequently, they expressed concerns and reservations regarding altering the VDO through dental rehabilitative treatment.[2,12,13] The expected consequences of increasing the VDO are hyperactivity of masticatory muscles, elevation of bite force, and temporomandibular disorders (TMDs). However, to date, there is no compelling evidence supporting the pathologic consequences of altering the VDO.

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The purpose of this study is to systematically review all the clinical studies that assessed the implications of increasing the VDO and to identify the factors associated with patient adaptation.

METHOD AND MATERIALS

A comprehensive electronic literature search was conducted through PubMed with the aid of Boolean operators. The outcomes of the following keywords were combined: "occlusal vertical dimension," "increasing vertical dimension," "bite raising," "occlusal space," "resting vertical dimension," "rest position," "altered vertical dimension," "mandibular posture," "temporomandibular joint," and "masticatory muscles." No publication year limit was applied. The purpose of the search was to obtain all the clinical studies that assessed the effect of increasing the vertical dimension of occlusion. The search included articles published through August 2011 that contained all or part of the key words in their headings. The electronic search was supplemented by manual searching through the following journals: *Journal of Oral Rehabilitation*, *Journal of Prosthetic Dentistry*, *Journal of Prosthodontics*, *International Journal of Prosthodontics*, *International Journal of Periodontics and Restorative Dentistry*, *Journal of Dentistry*, *Quintessence International*, and *Journal of Prosthodontic Research*. Further, the references of each selected article were reviewed for possible inclusion. Initially, the potential studies were selected on the basis of the relevance of the titles and abstracts. Subsequently, the full text of the article was reviewed and cross-matched against the predefined selection criteria. The inclusion criteria were as follows: human clinical studies on dentate and asymptomatic individuals, a minimum of five participants followed for at least 5 days, and the increase of VDO established by clinically relevant methods that might include full or partial arch coverage. The study was excluded if it was an animal study, a study on edentate or symptomatic individuals, or a case report.

RESULTS

Study search

After the electronic search, 902 articles were initially retrieved. The analysis of titles and abstracts excluded 838 articles, leaving only 64 articles eligible for inclusion. Following the application of the inclusion criteria, 26 articles were considered to be suitable for full-text analysis, which then revealed that only 6 articles were acceptable for inclusion.[14-19] Searching manually through the references of the selected articles, three additional articles were disclosed.[20–22] Two of the studies[16,18] were follow-ups of the same participants of previous experiments.[17,22] Since they provide information regarding the long-term effect of increasing the VDO, they were included. Therefore, a total of nine articles[14–22] were considered acceptable for this systematic review (Tables 1 to 4).

Description of studies

The selected studies show significant heterogeneity in relation to study design. Therefore, qualitative analysis of the studies was applied. One of the possible sources of this variation is the discrepancy in the inclusion of participants. The participants included healthy individuals,[14,15,21] in whom no treatment was indicated, as well as individuals with worn dentitions[16–18,20,22] or missing teeth,[19] in whom intervention was indicated. The difference between the studies is even more prominent in relation to the technique of patient adaptation assessment. The applied assessment techniques were:

- Evaluation of subjective patient symptoms such as headache, clenching, grinding, muscle and joint fatigue, soreness of teeth, cheek biting, and difficulties in chewing and speech[15–17,20–22]
- Masticatory muscles that are tender to palpation[15,17,18,21]
- Electromyography (EMG)[15]
- Objective speech and closest speaking space evaluation[14]
- Interocclusal space measurement[17,18]
- Radiographic measurement of the vertical dimension with the aid of tantalum implants inserted in the mandible and maxilla[16,22]

- Evaluation of mechanical and biologic complications associated with restored teeth or implants[19,20]

Studies classification

For the purpose of uniformity, the studies were classified into the two broad categories according to the prosthetic concept for increasing the VDO: removable (Tables 1 and 2) or fixed (Tables 3 and 4). From the identified studies, the fixed method comprised provisional restorations, composite resin buildups, onlays, and definitive fixed restorations. The removable method involved increasing the VDO by an occlusal splint or removable partial denture. Alternatively, in the experimental studies, the removable occlusal splint was temporarily cemented on one of the arches to ensure continuous splint wearing.

For each category, the increase in the VDO was accomplished either by fully or partially covering the arch. The partial arch coverage was further divided into anterior or posterior teeth coverage. Anterior teeth coverage was based on a treatment concept in which the partial increase of the VDO intended to orthodontically extrude the posterior teeth and intrude the anterior teeth, commonly known as the Dahl concept.[22]

In addition, the following variables were reported from each study: magnitude of the VDO increase, duration of follow-up after increasing the VDO, occlusion scheme, adaptation level, and adaptation period.

Wherever possible, the exact magnitude of the VDO increase was recorded from each study.

The duration of treatment follow-up after increasing the VDO was discretely classified into the following:

- Experimental duration: up to 1 week
- Short-term duration: up to 1 month
- Medium-term duration: from 1 month to 2 years
- Long-term duration: more than 2 years

The occlusion scheme was classified as follows:

- Static relationship: the maxillomandibular relationship after increasing the VDO
- Dynamic relationship: the form of guidance after increasing the VDO (In general, from the selected studies, the dynamic occlusal relationship can be mutually protected occlusion, group function occlusion, or bilaterally balanced occlusion. The adaptation level is defined as the proportion of the participants who adapted to the increase in the VDO. The adaptation period is the time required for the VDO increase–related symptoms to resolve.)

Study summary

A summary of all the studies included are provided in Tables 1 to 4. In general, the VDO increase range was from 2 to 5 mm. The studies clearly stated that the static occlusal relationship after increasing the VDO was according to centric relation. In relation to the dynamic occlusal relationship, three studies established bilaterally balanced occlusion,[14,15,21] four studies established mutually protected occlusion,[16–18,22] and one study established unilateral group function on premolars and molars.[19] One study did not clarify the dynamic occlusal relationship.[20] Regarding the duration of the studies, three studies were of experimental nature and followed the participants for up to 1 week.[14,15,21] One study was a short-term study that followed the participants for up to 1 month.[17] Two studies were classified as medium-term studies and followed the participants on average for less than 2 years.[20,22] The other studies were long-term studies and followed the participants for more than 2 years.[16,18,19]

Most of the studies agreed that patient adaptation can be obtained after increasing the VDO. Only one study reported no adaptation to VDO increase.[21] For the other studies, the adaptation level was 86% to 100% for the removable method and 100% for the fixed method. The adaptation period ranged from 2 days to 3 months.

Table 1 Summary of studies increasing the VDO by removable method and partial arch coverage

Study	Study details: Design	n	Duration	VDO increase (mm)	Occlusion: Static	Dynamic	Assessment method
Posterior teeth coverage							
Christensen[21]	P	20	7 d	4	CR	BBO	Subjective symptoms Muscle tenderness
Carlsson et al[15]	P	6	7 d	4	CR	BBO	Subjective symptoms Muscle tenderness Radiographic evaluation EMG
Anterior teeth coverage							
Dahl and Krogstad[22]	P	20	6 to 14 mo	1.8–4.7	CR	MPO	Radiographic evaluation of inserted tantalum implants Subjective symptoms
Gough and Setchell[20]	R	11	5.9 mo to 4.1 y	Variable	CR	NA	Subjective symptoms Patient compliance Biologic complications

NA, not available; P, prospective; R, retrospective; CR, centric relation; BBO, bilaterally balanced occlusion; MPO, mutually protected occlusion; EMG, electromyography.

Table 2 Summary of studies increasing the VDO by removable method and complete arch coverage

Study	Study details: Design	n	Duration	VDO increase (mm)	Occlusion: Static	Dynamic	Assessment method
Burnett and Clifford[14]	P	6	5 d	4	CR	BBO	CSS

NA, not available; P, prospective; CR, centric relation; BBO, bilaterally balanced occlusion; CSS, closest speaking space.

Table 3 Summary of studies increasing the VDO by fixed method and partial arch coverage

Study	Study details: Design	n	Duration	VDO increase (mm)	Occlusion: Static	Dynamic	Assessment method
Anterior teeth coverage							
Dahl and Krogstad[16]	P	20	67 mo to 5.5 y	1.8–4.7	CR	MPO	Radiographic evaluation of inserted tantalum implants
Gough and Setchell[20]	R	39	5.9 mo to 4.1 y	Variable	CR	NA	Subjective symptoms Patient compliance Biologic complications

NA, not available; P, prospective; R, retrospective; CR, centric relation; MPO, mutually protected occlusion.

	Main findings		
	Adaptation rate (%)	Adaptation period	Further comments
	0	No adaptation	Development of TMD signs and symptoms Development of clenching, grinding, soreness of teeth, cheek biting, speech difficulties, and chewing limitations Muscle and joint fatigue
	86	1–2 d	Development of clenching, speech difficulties, and discomfort No implication on muscle tenderness Reduction of EMG activities New interocclusal distance was established One participant could not adapt to the intervention
	100	2 wks	Development of speech difficulties and chewing limitations with lisping being the most prominent No symptoms of dysfunction or pain Teeth overeruption was more prominent than intrusion especially for younger participants The mean increase in VDO after the completion of the treatment was 1.9 mm
	91%	NA	One patient could not wear the appliance Minimal signs of functional discomfort Minimal pulpal and periodontal symptoms and vitality loss

	Main findings		
	Adaptation rate (%)	Adaptation period	Further comments
	NA	NA	Up to 1 mm reduction in CSS Significant reduction of CSS after increasing VDO

	Main findings		
	Adaptation rate (%)	Adaptation period	Further comments
	100	NA	Variable long-term individual response to adaptation Reduction of the increased VDO through the treatment period (1.73 mm after 6 mo and 1.52 mm after 67 mo)
	100	NA	Greater patient compliance with fixed appliance than removable appliance Minimal signs of function discomfort Minimal pulpal and periodontal symptoms and vitality loss

Table 4 Summary of studies increasing the VDO by fixed method and complete arch coverage

Study	Study details: Design	n	Duration	VDO increase (mm)	Occlusion: Static	Occlusion: Dynamic	Assessment method
Gross and Ormianer[17]	P	8	1 mo	3.5–4.5	CR	MPO	Subjective symptoms Muscle tenderness Interocclusal space measurements
Ormianer and Gross[18]	P: intervention	8	2 y	3.5–4.5	CR	MPO	Interocclusal space measurements EMG Muscle tenderness
	P: control group	8			MI	NA	
Ormianer and Palty[19]	R: tooth-supported FDP in both arches	10	3 y to 11 y	3–5	CR	GFO	Subjective symptoms
	R: tooth-supported FDP in one arch and implant-supported FDP in the other arch	10					Radiographic assessment of alveolar bone around teeth and implants
	R: implant-supported FDP in both arches	10					Complications assessment

NA, not available; P, prospective; R, retrospective; FDP, fixed dental prosthesis; CR, centric relation; MI, maximal intercuspation; MPO, mutually protected occlusion; GFO, group function occlusion; EMG, electromyography.

DISCUSSION

Although the included articles provide information regarding patient adaptation to increased VDO, they suffer from lack of randomization and control. In addition, the therapy was applied to a limited number of participants, and there is a lack of agreement in subjective and objective signs and symptoms assessments. Therefore, the results should be interpreted with caution.

In general, the outcomes of the studies reflect the adaptation of the masticatory system after increasing VDO in a time-dependent fashion. The emphasis of the discussion is placed on potential factors influencing the adaptation to the increase in the VDO, namely, the magnitude of VDO increase, adaptation period, method of increasing the VDO, and occlusion scheme.

Magnitude of VDO increase

Several authors mentioned the merit of increasing the VDO as a method to facilitate the restorative treatment and enhance dental esthetics.[10,11] These advantages are even more obvious for a dentition suffering from prominent tooth wear (Fig 1).[8,9] However, to date, there are no clear objective guidelines that determine the ideal increase of the VDO that can be physiologically accepted by the patient.[2,11] A commonly measured clinical variable is the freeway space (FWS), which is the difference in vertical dimension between when the mandible is at rest and when the mandible is in occlusion.[1] The rationale behind measuring the FWS is to determine how the VDO can be altered. An FWS of 2 mm has been suggested as the physiologic space, and therefore, an FWS of more than 2 mm indicates that the VDO can be safely increased.[2]

Main findings		
Adaptation rate (%)	Adaptation period	Further comments
100	2 wk	Initial development of muscle tenderness, clenching and speech difficulties Establishment of new interocclusal space after 1 mo
100	NA	No effect on EMG Consistent interocclusal space after 1 mo, 1 y, and 2 y No significant difference for the interocclusal space or EMG through the study
100	2–3 mo	Adaptation to new VDO Mean bone loss was 2.3 mm Few cases of porcelain fracture Adaptation to new VDO More bone loss around teeth than implants Mean bone loss was 2 mm Two patients reported grinding that resolved within 2 to 3 mo Adaptation to new VDO Mean bone loss was 2 mm No screw loosening or fracture Few cases of porcelain fracture Four patients reported grinding that resolved with occlusal device after 3 mo

Interestingly, several of the included studies in this systematic review reported patients' adaptation even after increasing the VDO beyond the FWS.[15,17–19] Therefore, this systematic review supports the observation of many authors that concluded the physiologic posture of the mandible occurs at a zone commonly referred to as the "comfort zone" rather than a specific constant location.[11,23,24]

Although the selected studies revealed that patients can adapt to an increase of VDO of up to 5 mm, it is impossible to determine the upper limit since there is a lack of evidence in relation to a greater increase in the VDO. Nevertheless, from the clinical perspective, it is difficult to recommend a greater increase in the VDO due to its significant impact on the horizontal relationship of the teeth.[8,10] As a consequence, greater clinical expertise is necessary to manage these cases. The emerging complexities are mainly related to loss of anterior guidance, excessive increase in the overjet, and loss of lip competence.[10] Such complexities are, however, advantageous in the case of severely worn dentition where a Class III incisal relationship or collapsed lower third of the face might be evident (Fig 2).[2,8]

Therefore, until clear guidelines are established in relation to the ideal magnitude of increasing the VDO, empirical clinical procedures should be employed and are largely variable between individual patients. It is also wise to consider increasing the VDO to the minimal level required to address patient functional and esthetic needs.

Adaptation period

In general, the short-, medium- and long-term studies reported resolution of signs

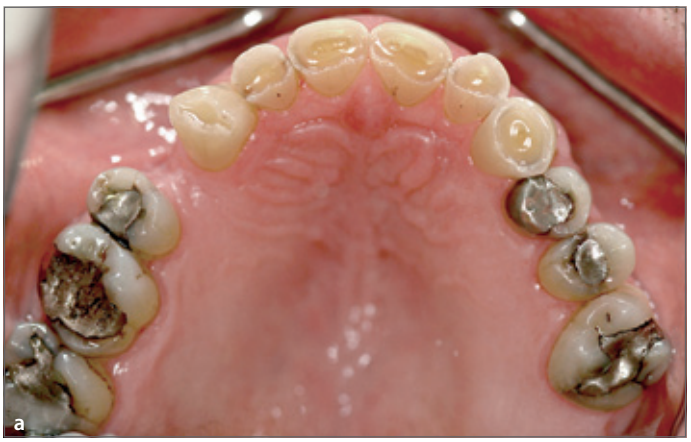
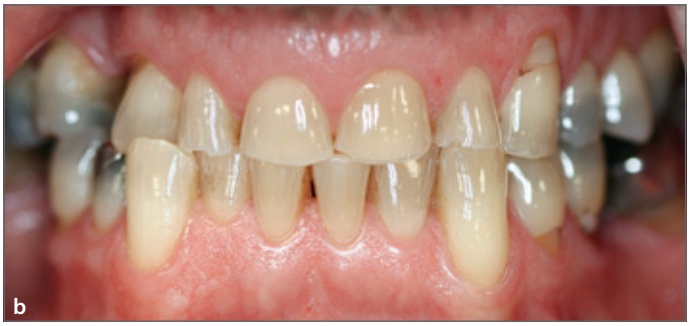
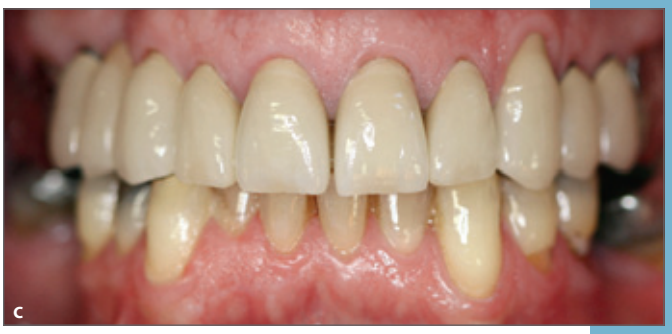


Fig 1a Occlusal view of a maxillary dentition illustrating prominent wear facets on the anterior teeth.

Fig 1b Frontal view of the dentition illustrating a Class III incisal relationship. The patient's main concern was the unesthetic appearance of the anterior teeth while smiling.

Fig 1c Frontal view of the definitive prostheses that involved a 3-mm increase of the VDO. Increasing the VDO allowed for significant esthetic improvement, correction of anterior tooth relationship, establishment of a natural overjet and overbite, and lengthening the anterior teeth.





and symptoms of maladaptation throughout the period of the studies. However, the experimental studies disclosed a lower level of adaptation.[14,15,21] This is anticipated from the short follow-up period (5 to 7 days) and the nature of studies, where the occlusal splint is temporarily cemented on the remaining teeth. Nonetheless, the outcome of the experimental studies indicated that the immediate acceptance of an increase in the VDO can be related to masticatory muscles lengthening and relaxing. This statement is supported by Carlsson et al, who found reduction of EMG activities after increasing the VDO.[15] After a period of 1 month, the short-term study[17] obtained a high adaptation level after increasing the VDO. The clinical significance of this observation is that permanent restoration can be predictably delivered after a period of 1 month. Likewise, the medium-term studies further proved the stability of increased VDO and the dentoalveolar maturation.[20,22] In addition, the long-term study that partially covered the anterior arch segment reported that occlusal stability was achieved as a result of orthodontic movement manifested as intrusion of the occluding segments of the arch and overeruption of the nonoccluding segments of the arch.[16] Although complete relapse of the altered VDO did not occur, a mean 0.4-mm reduction of the increased VDO was observed.[16] On the contrary, the long-term study that covered the entire arch found that the relapse of VDO to its original value was minimal.[18] This indicated that muscle relaxation and increase in muscle length were the primary adaptation mechanisms rather than alterations in dentoalveolar dimensions. This is even endorsed by the finding of Ormianer and Palty, who reported patient adaptation even when the implant support was utilized.[19] Therefore, it could be speculated that the VDO increase after partial coverage of the arch will lead to dentoalveolar alterations, while the complete coverage will immediately establish the occlusion with minimal alterations in the dentoalveolar complex. The clinical significance of this finding

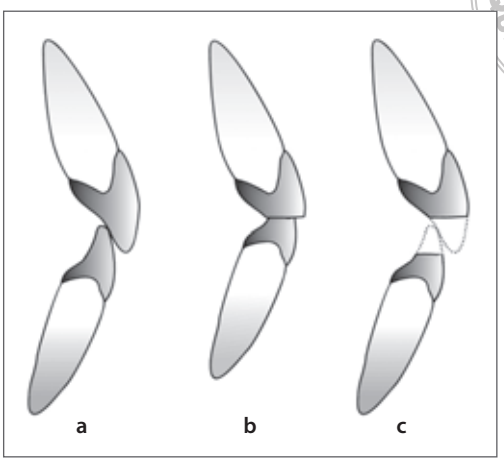


Fig 2 The impact of tooth wear on the anterior tooth relationship. *(a)* Natural relationship of anterior teeth with intact crowns. *(b)* Tooth wear resulting in the development of a Class III (edge-to-edge) incisal relationship. *(c)* Increasing the VDO allowed for restoring an adequate anterior tooth relationship.

is that complete coverage of the arch will manage the patient in a more predictable and time-controlled fashion.

Since the majority of the studies reported resolution of signs and symptoms within 1 to 2 weeks, it is wise to consider a probationary period of a few weeks before the placement of complex definitive restorations. Throughout this period, the patient can be thoroughly reviewed and the restoration adjusted accordingly.

Methods of increasing VDO

Since the studies[15,20,21,22] that increased the VDO by removable methods reported development of signs and symptoms, it could be speculated that the removable method suffered from a greater level of complications and limited patient compliance. After covering of the mandibular molars only, Christensen reported development of multiple complications that led him to the conclusion that increasing VDO can lead to joint and muscle derangement.[21] However, because the occlusal coverage was confined to only the mandibular molars, the intervention protocol in this study seems more similar to creating occlusal interferences than to increasing the VDO. This is in accordance with other investigations that found experimental introduction of occlusal interferences caused short-term clinical signs and symptoms.[25–27] Carlsson et al anticipated that the subjective signs and symptoms after increasing the VDO are associated with the discomfort from wearing the splint rather than a direct effect of the VDO increase.[15] Likewise, the phonetic difficulties reported by Burnett and Clifford could be due to covering the incisal surfaces of mandibular anterior teeth, which is significantly associated with phonetics.[14] Although the removable splint provided by Dahl and Krogstad achieved a high level of acceptance, lisping was the most commonly reported complaint, which can be the result of covering the palatal surfaces of the maxillary anterior teeth.[16,22] However, the complaints associated with their metal splint were limited in comparison with the previously mentioned studies that applied acrylic splints.[14,15,21] Due to the better fit and smoother finish, the metal splint contributes to greater comfort and adaptation and less interference with patient function.

After comparing fixed and removable methods for increasing the VDO, Gough and Setchell found that the fixed method was more predictable and comfortable for the patient.[20] Consequently, for the rehabilitation procedure in which the VDO increase is indicated, it is wise to reconsider the benefit of wearing the removable splint, since it does not provide a predictable indication for patient acceptance or adaptation. In general, the significant splint limitations are patient discomfort, interference with speech, and the lack of esthetic assessment. Nevertheless, the splint should still be considered when the patient presents with TMD signs and symptoms before embarking on definitive rehabilitation.[28,29]

In relation to the fixed method, all the studies reported consistent and predictable patient adaptation. Where the restorations are tooth-supported, the most commonly reported symptoms are the subjective grinding and clenching, which has the tendency to resolve within 1 to 2 weeks. For implant-supported prostheses, an extended adaptation period (2 to 3 months) was reported.[19] A possible explanation of this finding is that patients were initially edentulous and had considerable reduction in the occlusal force, even with conventional complete dentures.[30] However, several authors established that after the replacement of the conventional complete dentures by implant-supported prostheses, the occlusal force increased dramatically.[31,32] Subsequently, these patients might experience immediate improvement of the occlusal force that can manifest clinically as increased grinding and clenching. Another explanation of increased grinding and clenching is the lack of sensory input from the periodontal ligament that hinders rapid patient adaptation after increasing the VDO. Similar findings were observed by a few studies[33–35]; however, the clinical significance of this statement is doubtful. Therefore, when an implant-supported prosthesis is used to increase the VDO, it adds further variables that can influence patient adaptation. In the same study, the authors[19] reported more mechanical failure for implant-supported prostheses in comparison to tooth-supported prostheses, which supports the implication of the lack of sensory input from the periodontal ligament.

After comparing the fixed and removable methods of increasing the VDO, it seems the fixed method is more predictable. The main advantages of the fixed method are the reestablishment of original tooth morphology and the fixed nature of the restoration. As a result, minimal interference will be introduced to patient comfort and function. Subsequently, it is more feasible to assess patient function, esthetics, and phonetics.

Occlusion scheme

At the increased VDO, the included studies achieved a static occlusal relationship in the centric relation position that is in accordance with all the studies pertaining to occlusion reestablishment.[36–38] Centric relation establishment has been advocated since it is a reproducible position and is indicated for cases that require extensive occlusal rehabilitation as might occur after increasing the VDO.[36,39] Therefore, whenever increasing the VDO, it is wise to consider centric relation reestablishment, even if there is a lack of compelling evidence.

In relation to the dynamic occlusion relationship, mutually protected occlusion and group function occlusion were considered as acceptable elements of healthy occlusion.[36,37] In general, for the mutually protected occlusion and group function occlusion, studies revealed the possibility of safe application of such schemes.

Despite the limited evidence, bilaterally balanced occlusion was discouraged because of the possible risk of inducing parafunctional activities. This was supported by EMG studies that revealed increased muscle activities with the introduction of balanced contacts.[40,41] The included studies in this review that applied the bilaterally balanced occlusion reported greater incidence of subjective symptoms.[15,21] However, with the lack of a controlled group, it is difficult to state that the symptoms were associated with the occlusal scheme.

CONCLUSION

Within the limitations of this systematic review, the following can be concluded:

- Whenever indicated, permanent increase of VDO of up to 5 mm is a safe and predictable procedure without detrimental consequences. According to the included studies, the associated signs and symptoms were self-limiting with tendency to resolve within 2 weeks.
- Increasing VDO with a form of fixed restorations is preferable since it enhances patient function, acceptance, and adaptation and allows for esthetic evaluation. A removable splint provoked more signs and symptoms that appear to be associated with the appliance rather

than the actual VDO increase. The signs and symptoms are more prominent with acrylic splints than metal splints.

- Because of the limited number of available studies and the significant heterogeneity of the experimental design, well-controlled and robustly designed clinical studies are needed to validate the outcome of this review.

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