

Clinical considerations for increasing occlusal vertical dimension: a review

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ABSTRACT

The purpose of this article is to discuss the clinical considerations related to increasing the occlusal vertical dimension (OVD) when restoring a patient's dentition. Thorough extraoral and intraoral evaluations are mandatory to assess the suitability of increasing OVD. In the literature, multiple techniques have been proposed to quantify OVD loss. However, the techniques lack consistency and reliability, which in turn affects the decision of whether to increase the OVD. Therefore, increasing OVD should be determined on the basis of the dental restorative needs and aesthetic demands. In general, a minimal increase in OVD should be applied, though a 5 mm maximum increase in OVD can be justified to provide adequate occlusal space for the restorative material and to improve anterior teeth aesthetics. The literature reflects the safety of increasing the OVD permanently, and although signs and symptoms may develop, these are usually of an interim nature. Whenever indicated, the increase in OVD should be achieved with fixed restorations rather than a removable appliance, due to the predictable patient adaptation. The exception to this is for patients with TMD, where increasing the OVD should still be achieved using removable appliances to control TMD-associated symptoms before considering any form of irreversible procedure.

Keywords: Occlusal vertical dimension, facial aesthetics, temporomandibular disorder, tooth wear, occlusion.

Abbreviations and acronyms: CLS = crown lengthening surgery; IORS = interocclusal rest space; OVD = occlusal vertical dimension; TMD = temporomandibular disorder; TMJ = temporomandibular joint.

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INTRODUCTION

The Glossary of Prosthodontic Terms defines the vertical dimension as the distance between two selected anatomic points.¹ The vertical dimension when the mandibular teeth are occluding with the maxillary teeth is defined as the occlusal vertical dimension (OVD). The OVD for dentate individuals is mainly determined by the remaining dentition, hence loss of tooth substance might influence the OVD. A loss of OVD can significantly affect patient function, comfort and aesthetics.²

Several authors have commented on the dynamic nature of the dentoalveolar complex and masticatory system.^{3–6} So, whilst the loss of OVD is a possible consequence of tooth wear, the original OVD can be preserved by a dentoalveolar compensatory mechanism involving the extrusion of worn teeth.^{3–6}

Increasing the OVD from the clinical perspective has been reported to facilitate the treatment of patients presenting with generalized and complex dental abnormalities such as generalized tooth wear and significant occlusal irregularities.^{7–9} However, there is still considerable debate in the literature about treatment modalities used to increase OVD. Some authors have assumed that the OVD is constant throughout an individual's life, and any alteration of the OVD will subsequently interfere with the physiology of the masticatory system and the patient's ability to adapt.^{10,11} The reported consequences of increasing the OVD are hyperactivity of the masticatory muscles, elevation in occlusal forces, bruxism and temporomandibular disorders (TMDs).^{2,10,11} On the contrary, other authors have reported that such symptoms are transitory.^{12–15}

Although evidence regarding the implications of increasing OVD is still lacking, the rehabilitative

procedures involving the increase in OVD should be approached with caution. The aim of this narrative review article is to discuss the clinical considerations related to increasing the OVD.

CLINICAL EVALUATION

In contemporary dentistry, emphasis should be placed on conservative management strategies.¹⁶ Since increasing the OVD by restorative means involves multiple teeth in at least one arch, it is regarded as an extensive, costly and time-consuming procedure. Prevention strategies and conservative measures should be the clinician's main priority. Conservative management for patients with reduced vertical tooth height includes dietary counselling, fluoride application, exclusion of dietary disorders, controlling parafunctional habits and management of gastro-oesophageal reflux disorder. As the prevention of tooth wear is not the purpose of this article, the readers are referred to other references on this topic.^{7,8,17,18} Nevertheless, it is important to state that increasing the OVD should only be considered where comprehensive prosthodontic rehabilitation is justified.

Comprehensive extraoral and intraoral assessments are mandatory before considering an increase in the OVD. This is important since increasing the OVD is normally part of a comprehensive rehabilitation rather than a single treatment modality. A thorough assessment process should reveal the merits of altering the OVD and allow the clinician to consider suitable treatment options. Given that the standard patient examination procedure is followed, the following extraoral and intraoral assessments should be considered for patients in need of an increase in OVD.

Extraoral considerations

The literature suggests several extraoral factors be considered prior to the clinical decision to increase the OVD. These include the magnitude of OVD loss, facial profile and aesthetics, and status of the TMJ.

Magnitude of OVD loss

Many authors recommend an evaluation of an actual versus apparent loss of OVD.^{2,19,20} One means of evaluation is the use of interocclusal rest space (IORS), i.e. the difference in vertical dimension between when the mandible is at rest and when the mandible is in occlusion.¹ For dentate individuals, the initial reference is the OVD of the existing dentition. Subsequently, the vertical dimension when the mandible is at rest can be evaluated clinically. The rationale behind measuring the IORS is to determine how much to increase the OVD. An IORS of 2 mm has been suggested as the physiolog-

ical space, and therefore an IORS of more than 2 mm indicates that the OVD can be safely increased.² However, the literature suggests that there are four limitations associated with positioning the mandible at rest: (1) for the same individual, different mandibular positions can be obtained at different examination periods. This has been attributed to the influence of muscle activity and fatigue.^{21,22} A suggestion has been made that the true rest position of the mandible, where all the muscles are relaxed, does not exist;²³ (2) loss of OVD is associated with a parallel loss of the vertical dimension when the mandible is at rest. This means the IORS is vulnerable to a similar loss in dimension to the OVD.^{24,25} Such a phenomenon would underestimate the IORS and, subsequently, the loss in OVD; (3) the mandibular rest position occurs at a zone rather than a specific level. This finding is supported by clinical studies that have confirmed the ability of the patient to adapt after increasing the OVD;^{12-15,26,27} and (4) there is substantial variation between clinicians in evaluating the resting position of the mandible. Clinically, an accurate determination of the vertical dimension is difficult when the landmarks are located on movable skin tissues,²⁸ and where the mean facial measurement could account for only half the skeletal movement.²⁹

Two questions would seem relevant for any given clinical situation: what is the most reliable technique for determining OVD loss? And what is the significance of any such loss? Unfortunately, both questions have not been answered in the literature. Table 1 presents the available clinical techniques to determine the loss of OVD. In general, many of the proposed techniques have been adapted from complete dentures fabrication procedures. Although all the stated techniques have been found to be useful, none have been assessed to be scientifically more accurate than another.³⁰ It has been suggested that in order to improve the accuracy of the recording procedure, more than one method should be used.¹⁹

The available clinical trials that increased the OVD beyond IORS (4–5 mm inter-incisally) did not reveal patient maladaptation or pathological reactions.^{12-15,26,27} On this basis, it could be stated that the determination of the OVD increase should not be based on IORS values.

Facial aesthetics

The determinants of facial aesthetics are the sagittal profile, facial tissues appearance, lip morphology and teeth display.³¹ Sagittal assessment of the face can reveal mandibular pseudo-prognathism which might be a sign of OVD loss and overclosure of the mandible. This observation has been confirmed clinically⁷ and anthropologically.³² On the basis of a cephalometric analysis of dry skulls, Fishman found that tooth wear resulted in a reduction of arch width and gonial angle that

Table 1. Described clinical techniques for assessment of OVD loss

Technique	Description	Advantages	Disadvantages
Pre-treatment record	<ul style="list-style-type: none"> – Visual assessment of old diagnostic models – Previous photograph 	<ul style="list-style-type: none"> – Approximates the loss of clinical crown height⁷⁸ – Formulates baseline record⁸ 	<ul style="list-style-type: none"> – Old models are rarely available before treatment⁷⁹
Incisors height measurement	<ul style="list-style-type: none"> – The distance between the gingival margins of the maxillary and mandibular anterior teeth when they are in occlusion. A distance of less than 18 mm indicates loss of OVD 	<ul style="list-style-type: none"> – Approximates the loss of clinical crown height – Applicable clinically – Aesthetically relevant – Measures the severity of tooth wear⁸⁰ 	<ul style="list-style-type: none"> – Poorly represents the actual loss of OVD⁵ – Affected by the original anterior tooth relationship
Phonetic evaluation	<ul style="list-style-type: none"> – S sound to measure the closest speaking space – F sound to locate the incisal edges of anterior maxillary teeth – M sound to locate the mandible in rest position 	<ul style="list-style-type: none"> – Reproducible⁸¹ – Applicable clinically – Indicates patient adaptation after loss of tooth tissues – Indicates incisal tooth relationship – Locates the incisal edges of maxillary anterior teeth in relation to lower lip⁷⁷ 	<ul style="list-style-type: none"> – Variable outcome for patients with Class II and III occlusions¹⁹ – Poorly represents the actual loss of OVD⁸² – More useful for complete dentures construction^{28,77}
Patient relaxation	<ul style="list-style-type: none"> – Mandible positioning at rest 	<ul style="list-style-type: none"> – Applicable clinically – Visualizes the facial appearance at rest⁸³ – Ensures the lips are meeting 	<ul style="list-style-type: none"> – Minor muscles tension will lead to inaccurate measurements^{28,84}
Assessment of facial appearance	<ul style="list-style-type: none"> – Evaluation of facial tissues and musculature at rest 	<ul style="list-style-type: none"> – Applicable clinically – Visualizes the facial appearance at rest⁸³ – Ensures the lips are meeting 	<ul style="list-style-type: none"> – Arbitrary evaluation of the facial aesthetics^{28,84}
Radiographic evaluation	<ul style="list-style-type: none"> – Cephalometric assessment of maxillomandibular relationship 	<ul style="list-style-type: none"> – Highly accurate and reproducible^{85,86} – Indicates incisal tooth relationship⁸⁷ 	<ul style="list-style-type: none"> – Controlled setting is mandatory – Additional equipment and radiation⁸⁵
Neuromuscular evaluation	<ul style="list-style-type: none"> – Recording EMG muscle activities where minimal muscle activity indicates the mandible is at rest position 	<ul style="list-style-type: none"> – Useful clinical and research tool for OVD evaluation^{88,89} – Accurate and reproducible^{90,91} 	<ul style="list-style-type: none"> – The devices are rarely available in the clinical setting – Great expertise is required – Rigorously controlled recording conditions are necessary⁸⁹

may contribute to the overall mandibular pseudo-prognathism.³³ Likewise, Varrela found that a worn dentition is associated with a reduced gonial angle and reduced face height.³⁴ Crothers anticipated mandibular pseudo-prognathism to develop from one or more of the following factors: loss of OVD and subsequent forward rotation of the mandible; dentofacial bone remodelling after tooth wear; an edge-to-edge anterior tooth relationship after loss of vertical tooth height; and anterior positioning of the mandible due to the loss of anterior tooth guidance.²⁴ The severity of mandibular pseudo-prognathism can be subjectively assessed by reviewing an old photograph of a patient's facial profile. Although increasing the OVD reduces the pseudo-prognathism of the mandible,²⁴ the significance of this effect is doubtful since increasing the OVD for dentate individuals is limited to 5 mm inter-incisally, which may not be sufficient to induce facial alterations.

From the frontal view, several facial implications can manifest after loss of OVD including altered facial contour, narrowed vermilion borders and an overclosed commissure.²⁴ These implications are exacerbated by increased mandibular pseudo-prognathism.²⁴ As long as the lip competence is not compromised, it is thought that

increasing the OVD might reverse the consequence of OVD loss and restore facial morphology.^{28,35} Mohindra and Bulman reported an improvement in facial aesthetics by the insertion of complete dentures constructed at an increased OVD.³⁶ However, Gross *et al.* reported that after experimental increase of the OVD by 2–6 mm for dentate individuals, there was an insignificant extraoral improvement of facial tissues appearance.³⁷ This finding can be attributed to the significant loss in OVD for edentulous individuals without compensation in comparison to dentate individuals. In addition to increasing OVD, the effect complete dentures have on facial aesthetics could be related to horizontal support of the facial tissues from the dentures.

The upper lip position in relation to the incisal edges of maxillary anterior teeth determines the teeth display while smiling and at rest.³¹ Insufficient display of the maxillary anterior teeth can be improved by lowering the occlusal surface of the maxillary teeth. Further, increasing the OVD allows the establishment of an incisal overjet that can augment the support of the maxillary lips. Subsequently, an overbite can be incorporated which can allow the maxillary incisal edge to be placed parallel to the lower lip, rendering a more

aesthetic appearance.³¹ On the contrary, excessive display of the gingival tissues will not be improved by increasing OVD. Rather, aesthetic crown lengthening surgery (CLS) should be considered.^{38,39}

It could be speculated that although the loss of OVD can lead to changes in sagittal profile and facial tissues appearance, there is no compelling evidence that increasing the OVD for dentate individuals by restorative means reverses these morphological changes. Therefore, it is important to emphasize that increasing OVD is not indicated to improve facial aesthetics. Nevertheless, teeth display might improve by lowering the maxillary occlusal plane after increasing OVD.

Temporomandibular joint status

The prevalence of temporomandibular joint disorders (TMDs) has been reported to be 7–10% within the population.^{40,41} Therefore, it is not uncommon to encounter patients with signs and symptoms of TMD seeking routine dental care. However, TMD has been found to primarily affect young and middle aged adults.^{40,42} Considering that this group of patients might not suffer from significant loss of OVD,⁴³ it could be speculated that the development of TMD is not associated with the loss of OVD. This assumption is supported by the clinical observation that attrition is not associated with an increased prevalence of TMD.⁴⁴

Through routine clinical assessment, it is critical to assess the status of the temporomandibular joint (TMJ) before intervention therapy. TMJ evaluation is comprised of assessment of joint and muscle pain, mandibular movement and associated sounds.^{7,8} Despite the lack of compelling evidence supporting a relationship between the OVD and TMD, TMJ evaluation will allow observation of the initial TMJ status of the patient. Even if increasing OVD may not exacerbate TMD signs and symptoms, patient adaptation might be masked by the pre-existing discomfort. Therefore, comprehensive restorative treatment involving an increase in OVD should be approached with caution for patients with TMD. Multiple authors have suggested stabilizing TMD patients and minimizing the signs and symptoms with a removable occlusal appliance before the commencement of irreversible prosthodontic treatment.^{7,45}

To date, there is more evidence to support conservative management of TMD such as with occlusal appliances, behavioural therapy, physiotherapy and jaw exercises than permanent occlusal alteration that has not yet been proven.^{46–48} Where there is a genuine need to increase OVD, it should be carried out using a conservative method such as with an occlusal appliance.^{46,47,49} Therefore, for patients with TMD, the occlusal appliance has a dual purpose: stabilizing the TMD and increasing OVD. The intended permanent

increase in the OVD can be incorporated into the occlusal appliance. On the basis of patient adaptation to the occlusal appliance, permanent restoration at the increased OVD can then be performed.^{45,50}

Intraoral considerations

Intraoral assessment involves examining the following parameters: remaining tooth structure and occlusion.

Remaining tooth structure

The prognosis of a dental restoration is directly determined by the amount of remaining tooth structure.⁵¹ For generalized loss of vertical tooth height, the clinician is faced with the dilemma of limited remaining tooth structure that is necessary for adequate retention and resistance of the restoration. The original tooth height determines the active preparation height, which can be defined as the vertical distance between the preparation margin and the occlusal-axial line angle. In order to avoid compromising the preparation height, increasing the OVD should be considered to provide adequate space to accommodate the restorative material. The merit behind this technique is more prominent in generalized loss of tooth height manifested from tooth wear. As a result of this approach, the teeth will be subjected to less pulpal trauma. In addition, by utilizing the available vertical height of the tooth, the indication for adjunctive crown lengthening surgery is minimized.

Given that tooth preparation taper for a crown is 10–20 degrees for a posterior tooth, according to Parker's *et al.* calculations, 3 mm is the minimal preparation height.⁵² Similar findings were confirmed by Maxwell *et al.* regarding anterior teeth and premolars.⁵³ Since only 46% of prepared molars exhibit an adequate resistance form,⁵⁴ according to Goodacre *et al.*,⁵¹ at least 4 mm is recommended as the minimal preparation height. If this height is not available, then auxiliary retention and resistance features should be incorporated. Therefore, with increasing OVD, it is possible to crown teeth with an original clinical crown height of 3 mm without adjunctive therapy. As a result, it appears that the final preparation height is a critical determinant of the need and the magnitude of the OVD increase.

When there is limited vertical tooth height, an alternative approach to increasing OVD is CLS.² However, the possible sequelae of CLS of multiple teeth in an arch are loss of a significant amount of soft and hard tissues, the effect on the emergence profile and the development of a black triangle. The exposure of root surfaces excludes the use of adhesive restorations, and necessitates restoring the crown lengthened teeth with full coverage restorations. In relation to aesthetics

of the anterior teeth, CLS is an excellent procedure to improve the contour of the gingival tissues and enhance the aesthetic display of the anterior teeth for patients with a high or average lip line when smiling.^{38,39} However for a low lip line, there will be minimal improvement of the aesthetic display unless the OVD is increased. Further, CLS by itself will not improve the relationship of the anterior teeth. One of the concerns associated with CLS is the increase in the crown-to-root ratio that might be attributed to increased teeth mobility and a compromised prognosis. However, there is no compelling evidence regarding the negative effect of an increased crown-to-root ratio.⁵⁵ A recent systematic review reported that a severely reduced but healthy periodontal support is not a compromising factor for the longevity of teeth utilized as abutments for fixed dental prostheses.⁵⁶

For a clinical crown height of less than 3 mm, CLS is the only means of providing for adequate preparation height by exposing more tooth structure. Nevertheless, for excessively short teeth, the rehabilitative treatment can be a combination of increasing OVD and CLS as an adjunctive treatment. The clinician should decide on the best compromise of the multiple treatment options to minimize the invasiveness of the overall treatment.

With the continuous development of adhesive technologies, it is possible to bond an onlay restoration to the remaining tooth structures, even if the remaining structure is less than 3 mm. The advantages of adhesive restorations are the conservative nature of the operative procedure in relation to the tooth and periodontal tissues, and less clinical time required for the application and completion of the treatment. However, significant care should be taken while bonding the restoration to dentine and the maximum amount of enamel should be used.⁵⁷ The available materials for bonding are metal, ceramic and composite resin.

Chana *et al.* reported a 89% survival rate of resin bonded metal veneers for a duration of 60 months.⁵⁸ Likewise, Jamous *et al.* found that 80% of resin bonded metal restorations survived after seven years.⁵⁹ In relation to ceramic onlays, Wagner *et al.* reported that the survival of ceramic onlays was 81% in seven years. In the same study, they found that the performance of ceramic onlays is comparable to metal onlays.⁶⁰ Similarly, Otto and Schneider found the survival rate for ceramic onlays to be 89% up to 17 years.⁶¹ As a simpler option, Hemmings *et al.* have shown favourable short- to medium-term performance of direct composite resin restorations when placed in a thickness of 2 mm or more.⁶² Poyser *et al.* reported a survival rate of 94% after two years for composite resin restorations placed at an increased OVD.⁶³ Composite resin restorations have the advantages of ease of repair or modification. However, they still suffer from wear,

margin staining, marginal fracture and surface roughness.⁶⁴ Therefore, it appears that increasing the OVD by direct composite resin restorations is a predictable medium-term option, while metal or ceramic onlays are more adequate as long-term options.

Occlusion

Clinically, unopposed teeth have been reported to be prone to overeruption, which can create occlusal interferences.⁶⁵ For some patients, increasing OVD facilitates occlusion reorganization and the achievement of an even occlusal plane.⁹ Subsequently, an invasive sacrifice of tooth structure can be avoided.

As a result of a worn anterior dentition, the mandible tends to be habitually located more anteriorly. By recording the difference in the horizontal mandibular position when the mandible is in centric relation and maximal intercuspation, a horizontal space can be obtained inter-incisally.⁶⁶ This space can be utilized to provide adequate room for restoration of the anterior teeth. The advantage of using this method is the feasibility of restoring worn anterior teeth without increasing the OVD.

Loss of posterior tooth support has been cited as probably the main cause for loss of OVD in dentate individuals.² The implications of losing the posterior teeth are the overloading of the remaining anterior teeth and increasing the potential to wear. A nine-year clinical trial comparing the occlusal stability of patients with complete dental arches and shortened dental arches revealed that patients of both groups exhibited a similar overbite and occlusal tooth wear.⁶⁷ More anterior teeth in the shortened dental arch group were in occlusion. Since the occlusion of the shortened dental arch group exhibited relative stability, the authors concluded that a new occlusal equilibrium was obtained.⁶⁷ On the contrary, one cross-sectional study confirmed that patients with an extremely diminished posterior tooth support (0 to 2 occluding units) tended to exhibit an anterior dentition with more prominent spacing, heavier occlusal contacts, occlusal wear, mobility and vertical overlap.⁶⁸ All of these findings can eventually lead to the loss of OVD. Therefore, for patients with extremely shortened dental arch, it is important to eliminate the potential cause of OVD loss by achieving a stable posterior occlusion before considering increasing the OVD.

Patients with a worn anterior dentition suffer from a loss of clinical crown height and the possibility of development of an edge-to-edge incisal relationship.^{6,7} As a result, the aesthetic appearance is affected and the anterior guidance is lost.⁶⁹ In addition to an aesthetic improvement, increasing the OVD rectifies the anterior tooth relationship, by re-establishing an overjet and overbite, and facilitating the establishment of anterior

tooth guidance.^{9,69} According to the modern theories of occlusion, anterior tooth guidance is desirable as it is believed to protect the posterior teeth in eccentric movements.⁷⁰⁻⁷²

Patients with a steep anterior tooth guidance can benefit significantly from increasing OVD as it will alleviate the broad area of anterior tooth contacts and provide shallower and less constrained angle of disclusion.^{9,69} Even though a steep anterior tooth guidance does not appear to be contributory to the development of pathological signs and symptoms, it still poses a daunting challenge for the restoration of anterior teeth.⁶⁹

Therefore, increasing the OVD facilitates reorganization of the occlusion by elimination of occlusal interferences, provision of adequate overjet and overbite, and alleviation of steep anterior tooth guidance.

FEASIBILITY OF INCREASING OVD

Increasing OVD has been considered by some authors to be a hazardous procedure that can violate a patient's dental physiology and adaptation.^{10,11} The basis of such claims is the thought that OVD occurs at a specific level that should be maintained through an individual's life.²

In the literature, multiple articles have challenged the hypothesis of the negative implications of increasing OVD beyond the IORS.^{12-15,26,27} In general, their outcomes reflect the safety, patient adaptation and predictability of increasing the OVD. This is true in relation to TMJ and masticatory muscle health. However, the available studies suffer from a lack of randomization and control group. In addition, significant variation exists in relation to the subjective methods to assess patient adaptation. All the available studies had a limited number of participants and it could be assumed that they are not representative of the whole population.

Carlsson *et al.* increased the OVD by 4 mm for six participants with removable appliances temporarily cemented on the occlusal surface of the mandibular posterior teeth and the canines. After seven days, despite all the participants reported subjective symptoms, five of them reported resolution of the symptoms within two days. One participant could not adapt to the intervention.¹⁵ However, the maladaptation could have been due to the appliance design and associated bulkiness rather than the increase in OVD. In two studies, Dahl and Krogstad increased the OVD for 20 participants up to 4.7 mm by using anterior removable splints. All symptoms resolved within two weeks, with lisping being the most common symptom.^{26,27} Likewise, Gross and Ormianer reported resolution of minor symptoms after two weeks of increasing the OVD up to 4.5 mm with fixed prostheses.¹⁴ The eight participants

were reviewed in a follow-up study that confirmed the long-term patient adaptation after increasing OVD.¹² More recently, in a retrospective study by Ormianer and Palty, the OVD was increased up to 5 mm for 30 patients requiring whole arch prostheses supported by teeth or implants.¹³ Despite all the patients adapted to the increase in OVD, a few patients with implant-supported prostheses suffered from prolonged grinding that resolved within 2-3 months after administering an occlusal splint.

In relation to the method of increasing OVD, the studies that increased OVD with fixed prostheses^{12,14} indicated less symptom severity than the studies that increased OVD with a removable appliance.^{15,26,27} This outcome could be attributed to the fixed prostheses having the advantages of being fixed in the mouth, mimicking natural tooth morphology, minimizing bulkiness with reduced interference with speech and improved overall comfort. In addition, the fixed nature of the prosthesis may enhance patient compliance and acceptance of the treatment. Therefore, whenever possible, the increase in OVD should be performed for TMD-free patients with fixed restorations rather than with a removable appliance. Removable appliances could be a source of patient maladaptation due to factors other than increased OVD.

In relation to the magnitude of increasing the OVD, an increase of up to 5 mm inter-incisally is a feasible alteration.^{12-15,26,27} Such outcomes support the assumption of other investigations that physiological OVD occurs at a range, commonly known as the comfort zone, rather than a specific constant level. Subsequently, it could be expected that the patient can adapt to an alteration in OVD as long as it is confined to this zone.

The possible adaptation mechanisms to an increased OVD could be masticatory muscle lengthening and relaxation, dentoalveolar maturation, or a combination of these two mechanisms. In a two-year study, after increasing OVD by covering the whole arch, Ormianer and Gross found that relapse of the OVD to its original value was minimal.¹² This finding supports the theory that muscle relaxation and changes in muscle length were the primary adaptation mechanisms,⁷³ rather than returning to the original OVD by dentoalveolar maturation. Further, this outcome is in accordance with the finding of Ormianer and Palty that reported patient adaptation even when implant-supported prostheses were utilized.¹³ On the contrary, after increasing OVD by covering the anterior teeth only, Dahl and Krogstad reported that occlusal stability was obtained orthodontically by intrusion of the occluding segments of the arch and extrusion of the non-occluding segments of the arch.²⁷ Therefore, it could be assumed that an OVD increase by partial arch coverage will lead to dentoalveolar alteration, while the complete arch coverage will lead to immediate establishment of an occlusion

with minimal alteration in the dentoalveolar complex. Although the clinical significance of this observation is doubtful, clearly complete arch coverage will establish the occlusion in a more controlled way.

Although a greater increase cannot be assumed to be hazardous, it should be stated that a greater increase in the OVD implies significant escalation in the rehabilitation complexity that might be difficult to justify. Since any restorative material can be applied on the occlusal surface in a space of 2 mm,^{51,62} a 4 mm interarch space will be adequate for comprehensive rehabilitation. Subsequently, an OVD increase greater than 5 mm inter-incisally is rarely indicated from the clinical perspective.

From the available studies, the negative consequences of increased OVD are of a minimal nature and most of the signs and symptoms resolve within two weeks. Therefore, it is wise to consider a probationary increase of the OVD, with a fixed provisional prosthesis or composite build-ups for a period of a few weeks before the provision of the definitive prostheses. For implant-supported prostheses, the only available study reported an extended period of grinding and clenching of up to three months. A possible explanation for this increased parafunctional activity is the lack of sensory feedback from the periodontal ligament that might hinder rapid patient adaptation after increasing OVD. Despite similar findings being obtained by other investigators,⁷⁴⁻⁷⁶ the clinical significance of the findings is still doubtful. In the same study, it was reported that more mechanical complications developed with implant-supported prostheses in comparison with tooth-supported prostheses, which support the effect of lack of sensory feedback from the periodontal ligament. Another explanation for the increased duration of symptoms with implant-supported prosthesis is that the treated patients were initially edentulous and experienced significant alveolar bone resorption and masticatory muscle atrophy. As a consequence, the OVD may be markedly reduced and the IORS will suffer from a parallel loss.^{25,77} In comparison with conventional complete dentures, implant-supported prostheses are capable of restoring the OVD to near original values. Therefore, these patients will be subjected to a greater adaptation burden.

CONCLUSIONS

Since the clinical techniques to assess OVD loss are of limited predictability and reliability, they cannot be used to estimate the magnitude of increasing OVD. Likewise, facial morphology cannot be used as a guide for increasing OVD. Instead, an increase in OVD should be determined on the basis of a need to accomplish satisfactory and aesthetically pleasing restorations. The factors that should be considered as

determinants for increasing the OVD are the remaining tooth structure, the space available for the restoration, occlusal variables and aesthetics. Minimizing the increase in OVD is useful to reduce the overall complexity of the prosthodontic treatment. Increasing OVD by more than 5 mm is rarely indicated. Furthermore, increasing OVD is a safe procedure, and any consequential signs and symptoms tend to be self-limiting. The use of a removable splint to increase OVD for TMD-free patients is not indicated as it might generate signs and symptoms related to splint wearing rather than OVD increase.

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