Review Article

DIFFERENT PROSTHETIC COMPREHENSIVE METHODS OF INCREASING VERTICAL DIMENSION: A SYSTEMATIC REVIEW

Riyadh Ahmad Alzunaydi[1], Ghadah Bandar Alqahtani[2], Norah Ali Alqahtani[3], Mohammad Ibrahim AlSowail[2], Sarah Samer Aburaisi[4]*

[1] *College of Dental, Majmaah University, Zulfi, Riyadh, KSA. r0555122459@gmail.com*
[2] *College of Dental, Riyadh Elm University, Riyadh, KSA.*
[3] *College of Dental, King Khalid University, Riyadh, KSA.*
[4] *Department of Prosthodontics, Dental College, Riyadh Elm University, Riyadh, KSA.*

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ABSTRACT

Vertical dimension can be determined by different methods and the most common method used to evaluate VD is Freeway space. It was adverted by (Nyswonger ME. 1934). PROSPERO registration number CRD42020197154. In this systematic review guided by Prisma statement, the PICO formulation (population, intervention, comparison, and outcome) was allocated to adult patients who had undergone an increased vertical dimension. 3011 literature were searched and collected from various libraries on internet networks such as [Embase – PubMed – Cochrane Library – VHL – Clinical Trial- Web of Science - Google Scholar – SDL] by hand search. Keywords included (Bite raising, increase vertical dimension, Prosthetic rehabilitation, worn dentition, OVD, and minimally invasive treatment). After the quality assessment by using the Cochrane collaboration tool with the help of 24-item forms used by Heyashi *et al*., we ended with 8 studies eligible to be included. The OVD increase ranged from 0.5 mm to 6 mm. It increased depending on the patient's complaints and needs (aesthetically, functionality) and materials that were used in each study. There are two different ways to fabricate a new occlusion. The first way, by two stages, initiates with interim removable or fixed restoration for adjustment of the occlusion before the definitive restoration. While the other way by creating the new bite with the articulator arrangement then place the definitive restoration without provisional testing over a period of time. Two different methods were used to increase the vertical dimension by utilizing different materials and techniques.

Key words: Increase vertical dimension, OVD, Bite raising, Worn dentition.

Introduction

Vertical dimension (VD) is usually defined as the distance between two reference points to measure the VD at occlusion (VDO), as well as the rest vertical dimension (RVD) [1]. The measurement formula between VDO and RVD is called freeway space (FWS) [2]. In addition, the closest speaking space is another method that has been found by Silverman to determine OVD [3], which is about 1mm when the patient pronounces the letter S. The method that most of the clinician use is FWS, which has been adverted by Niswonger (1934) [4].

A decrease in VD can occur due to many etiologies most commonly mechanical or physiological wearing of the teeth that can lead to increased FWS, which may affect firstly the TMJ by aggravating a pain resulted from OVD loss as well as an aesthetic effect [5, 6]. In 1984, Turner classified the severity of dentition worn by quantifying the amount of VD loss and the available FWS. His classification has been widely used to diagnose and address deficient VD, which is divided into 3 categories: Category 1: extreme loss of teeth with OVD loss, Category 2: extreme loss of teeth without OVD loss and availability of space, Category 3: extreme loss of teeth without VD and No space available [7].

The most important reason for the increase in OVD is aesthetic, which pushes the patients to come to a dentist, for providing a proper relationship between opposing teeth and to allow space for the restoration to be seated [8]. The consequence of increasing vertical dimension is still unclear but there are many studies that have a claim on causing TMD. Some suggestions have said that increased vertical dimension causes severe pain in TMJ and others report transient effects, which are expected to adopt after 1-2 weeks, and the last group reports their studies with no effect. After all these studies, it depends on the patient's subjective response and the different range of millimeters the OVD has been increased [5, 6].

There are several methods used to increase VD. The First method was invented by Dahl with Co - Cr appliances that rest on the palatal surface of the maxillary arch. The concept behind this appliance is to intrude anterior and extrude posterior teeth, so it can provide space for restoration and improve the interocclusal space [9]. As Dahl *et al.*, 1975, suggested the successful range of increased vertical

dimension between 1.8 - 4.7mm. For instance, the new concept of Dahl is to restore the VD by replacing the removable with fixed appliances/restoration [10]. There are also different literature conducted with a different measurement for increasing vertical dimension, but most of the studies have resulted in ≤ 5mm [11]. Remiszewski *et al.*, 2017, mentioned when the OVD increased by 3mm, there was an insignificant facial height. Gough and Setchell intended to create interocclusal space with interim appliances. However, most of their cases were treated with cemented chrome-cobalt appliances that extend anteroposteriorly on the maxillary and mandibular dentition [12]. Next, Hemmings's case series advocated for different types of direct composite restorations (definitive restorations) to manage anterior tooth surface loss [13]. Afterward, Gow and Hemmings (2002) came to add indirect definitive appliances and restorations [14]. Later on, Redman *et al.* (2003) used both direct and indirect anterior restorations [15]. A retrospective study showed techniques for increasing VD for multiple statuses of oral and dental parts. Updated studies conduct the use of different materials to raise the VD in order to let the patient adapt with VD e.g. provisional restorations for different amounts as well as mockups [16].

These studies presented the increased VD by using two stages. The first stage was used to create a new bite with temporary restorations while the second stage used to replace the temporaries with definitive restorations. The patient's adaptation for the increased VD has shown various results based on different increased millimeters and we can conclude the safest range for adaption regarding the altered vertical dimension is up to 6 mm, whereas the adaption period is 1-2 weeks. For implant-supported prosthesis may need more time for adaptation between 2-3 months [17].

During this time, TMJ pain might occur with other consequences. To limit these complaints through commanding occlusal splint preferably metal splint over the acrylic one, which promotes lesser complain [11, 18]. Carlsson found the reason for complaints is due to the wear of occlusal splint rather than the increased OVD [19].

This review aimed to gather different methods that are utilized to increase the vertical dimension by prosthetic approach.

Materials and Methods

The design of the study was to address the reported methods and techniques, which treat patients attending dental clinics and hospitals complaining about the consequences that resulted from a decreased vertical dimension in terms of functional and biological aspects, or aesthetic due to worn dentition and loss of teeth. Therefore, all the presented studies aimed to increase the vertical dimension of occlusion by correcting and amplifying the reflection in aesthetic and functional-clinical performance. The studies involved were only randomized/nonrandomized clinical trials and cohort studies. The PICO formulation (population, intervention, comparison, and outcomes) allocated to address the adult patients who complained of the consequences of reduced vertical dimensions and attending dental clinics and hospitals where they're managed and underwent prosthodontic rehabilitation by means of the correction of vertical dimensions to facilitate the increased OVD, while the subjects who did not undergo with increased vertical dimension were excluded. On top of that, the outcomes shown in the studies showed an improvement in the functional and esthetic aspects acknowledging the complicated results, such as TMJ disorder.

Data collection

A thorough and updated comprehensive literature search was collected by 4 investigators from various libraries on internet networks such as [Embase – PubMed (MIDLINE) – Cochrane Library – VHL – Clinical Trial- Web of Science-Google Scholar – SDL] by hand search. The search strategy was conducted using a combination of keywords as follows: (Increase vertical dimension OR Bite raising OR Occlusion vertical dimension AND Prosthodontics), (Increase AND Vertical dimension AND Prosthodontics), (Increase AND OVD AND Worn dentition), (Prosthetic rehabilitation AND Minimally invasive treatment), and (OVD AND worn dentition AND prosthetic rehabilitation).

Data analysis

Accordingly, all results were downloaded to Endnote and duplicate studies were removed with the help of multiple steps of the Prisma flow diagram **(Figure 1)**. After that, 4 investigators screened and 4 evaluated the electronic database searches at the title and abstract levels. Then, the selected full-text articles were assessed and any disagreement between the investigators was solved by consensus with the most acceptable decision. Afterward, the collected studies were matched the inclusion criteria as follows: aimed to increase vertical dimension, performed on adult/nongrowing human including both genders, clinical trials, as well as retrospective and prospective trials, with medically fit sample, and written in English. Exclusion criteria were non-English language, published before 2000, non-human trials, case series, clinical reports, non-published studies, and studies with a high risk of bias.

Furtherly, the studies who failed to mention the quantitative values of the increased OVD and unable to follow the aim of our study were excluded. The total results were 3011 publications; 453 duplicate studies were excluded, (Initial records were screened by 4 investigators by revising the title and abstract levels). A total of 34 studies were included and 2524 were excluded. Full-text articles were reviewed and out of the 34 results, only 10 studies were eligible **(Table 1)**.

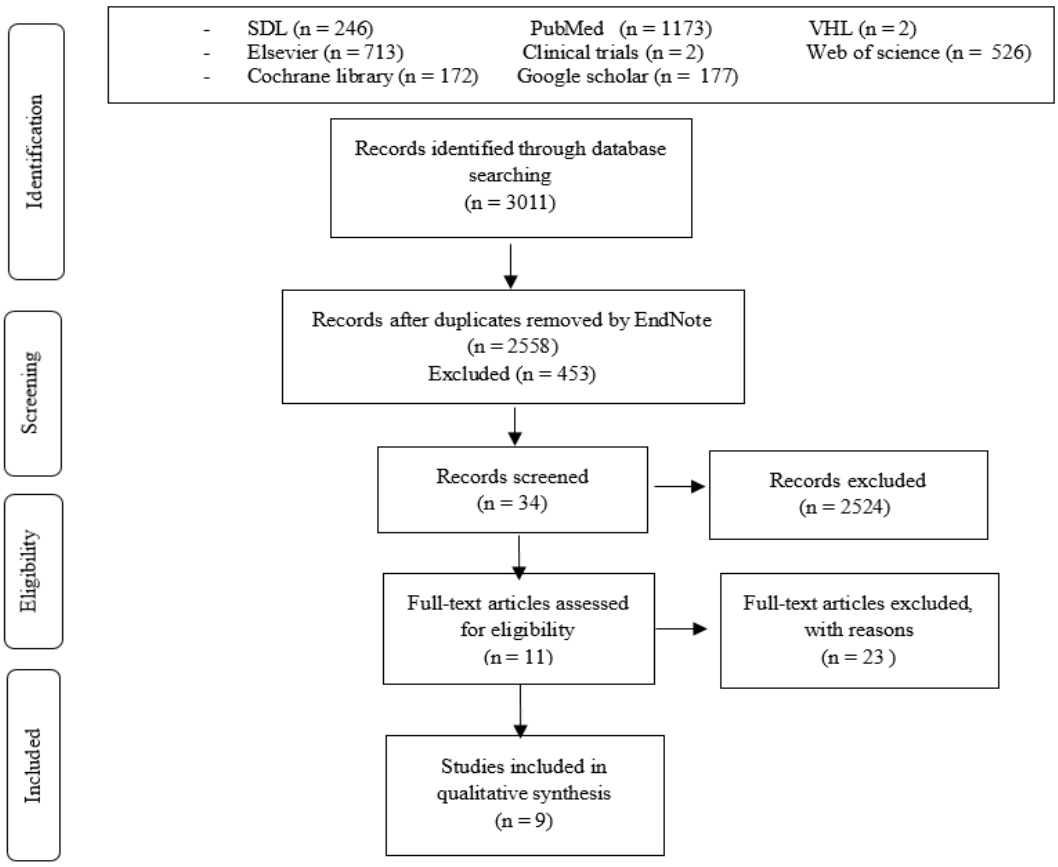

Figure 1. Prisma flow diagram of studies screening and selection

Table 1. for articles excluded with the reason

Name of article	Author	year	Reason for the exclusion
A 2-year follow-up of mandibular posture following an increase in occlusal vertical dimension beyond the clinical rest position with fixed restorations.	Ormianer *et al.*	1998	The study was conducted before 2000, which is one of the exclusion criteria.
Restoring the vertical dimension of mandibular incisors with bonded ceramic restorations.	Wylie *et al.*	2000	Laboratory studies were required to identify the limitations of the restorative technique.
The treatment of localized anterior tooth wear with indirect Artglass restorations at an increased occlusal vertical dimension. Results after two years	Gow *et al.*	2002	The author did not respond to the access.
The effect of increasing occlusal vertical dimension on face height	Gross *et al.*	2002	Their study evaluated lower facial height in 4 different VD (did not follow the aim of our study).
The Effect of Stepwise Increases in Vertical Dimension of Occlusion on Isometric Strength of Cervical Flexors and Deltoid Muscles in Nonsymptomatic Females	Abeer *et al.*	2002	Studying the isometric strength of the deltoids and cervical flexors and their correlation with increase OVD. The sample only females.
Influence of occlusal vertical dimension on the masticatory performance during chewing with maxillary splints	Olthoff *et al.*	2007	This study excluded because is done only on males without females.
Short-term effects of oral appliances with equal bite-raising distance but with varying protrusions on occlusal force, contact area and load center	Saito *et al.*	2008	The study was excluded because it was for oral appliances, which apply only to increase the OVD for hours to check if it affects the occlusal force, occlusal contact area, and occlusal load center.
The influence of the occlusal vertical dimension on masticatory muscle activities and hyoid bone position in complete denture wearers	Sierpinska *et al.*	2009	The author did not mention how much the OVD increased.

Survival analysis of composite Dahl restorations provided to manage localised anterior tooth wear (ten year follow-up)	Gulamali *et al.*	2011	They didn't specify how much OVD is re-established
An electromyographic study to assess the minimal time duration for using the splint to raise the vertical dimension in patients with generalized attrition of teeth	Nanda *et al.*	2011	The study focused on electromyographic, which had no relation with our aim
Prosthetic rehabilitation and treatment outcome of partially edentulous patients with severe tooth wear: 3-Years results	Katsoulis *et al.*	2011	They had not mentioned the success rate for increasing the OVD and no further information of increase vertical dimension
Effect of occlusal splint therapy on maximum bite force in individuals with moderate to severe attrition of teeth	Jain *et al.*	2012	Their study was about the bite force on restored OVD (did not follow the aim of our inclusion criteria).
Influence of vertical dimension of occlusion changes on the electroencephalograms of complete denture wearers	Matsuda *et al.*	2014	Effect of either + or - OVD influences on cephalogram (did not follow the aim of our inclusion criteria).
The relationship between facial morphology and the structure of the alveolar part of the mandible in edentulous complete denture wearers. A preliminary study	Kuć *et al.*	2015	Did not follow the aim of our inclusion criteria.
Changes in Lower Facial Height and Facial Esthetics with Incremental Increases in Occlusal Vertical Dimension in Dentate Subjects	Orenstein *et al.*	2015	This study was excluded because it focused on temporarily raising the OVD (only during measures and taking photo) to discuss if it affects facial esthetic.
Effect of placing intentionally high restorations: Randomized clinical trial	Gerasimidou *et al.*	2016	Single posterior restoration +05mm/500*µ*m that didn't affect OVD (to check teeth behavior and adaptation to intentionally supra-occlusion single restorations)
The survival of direct composite restorations in the management of severe tooth wear including attrition and erosion: A prospective 8-year study	Milosevic *et al.*	2016	Did not mention how much OVD increased.
Retrospective Study of the Survival and Patient Satisfaction with Composite Dahl Restorations in the Management of Localised Anterior Tooth Wear	Ayman *et al.*	2016	they did not mention the millimeter of OVD increase
Utility of Vaccum Pressed Silicon Sheet as a Bite Raising Appliance in the Management of TMJ Dysfunction Syndrome	Datarkar *et al.*	2016	They studied the way of treating TMJ compromise patients.
A retrospective audit of the outcome of composites used to restore worn teeth	Bartlet *et al.*	2017	no mention of an increase in the vertical dimension and other systematic outcomes
Using dental ceramics in treating patients with worn teeth. A randomized clinical trial	Isrctn *et al.*	2018	No response from the author
Impact of restorative treatment of tooth wear upon masticatory performance	Kalaykova *et al.*	2019	Did not specify how much OVD increased exactly.
Influence of occlusal vertical dimension on lip positions at smile in completely dentulous adults	Parmar *et al.*	2020	They have increased OVD temporarily by bite records during the photography sessions just to check the effect of lip position and smile, then afterwards were removed.

Data extraction

Data were collected from each study using excel review sheet form according to the age of participants, the number of involved groups, preoperative patients 'complaints and symptoms, single or 2-step treatment phase, type of materials used in the study, interval period of the observation and follow-up, quantity of increased OVD in mm, with or without an occlusal splint, success rate, survival rate, failure rate, type of failure, and postoperative symptoms if found.

Quality assessment

The quality assessment evaluation of the included papers was performed using Cochrane collaboration tools and the tool mentioned by Global Spine Journal to evaluate cohort studies (Definition of the levels of evidence (LoE) and overall strength of evidence (SoE) (2015) [20]. The assessment criteria were used in this review is done by evaluating the level of evidence based on the type of study design, follow up appointments, outcome expectation and finally the risk of bias. After the protocol assessment, we excluded 2 out of 11 due to their risk of bias.

Results and Discussion

The sample size of the studies ranged from 7 to 100 patients with the age ranged from 19 to 75 years. All studies were done on both genders except for one study, which did not mention this information. All patients were systemically healthy. The follow-up of the patients in the studies ranged from 3 months to 11 years **(Table 2)**.

Table 2. included studies

Author	Study design	Sample size	Groups	Age (years)	method	VD increased	Follow up
Loomans *et al.* [21]	Clinical trial	34	single	34±8	In this study, VD increased as one phase by getting the occlusion stop by fabricating anterior stop first	1.3±0.8 mm (0.5-2.1 mm)	39.7±9.9 months
Hamburger *et al.* [22]	Rss	18	single	45	One clinical phase was used while new VD was evaluated in the lab using an articulator	2-4mm	3.98 years
Luciano *et al.* [23]	Pss	8	single	57.9±7.2	The evaluation of new bite done on model cast then E-max Onlays were applied on the teeth	1.15mm	19-45 months
Hemmings *et al.* [13]	Clinical trial	16	Two groups	33.8	This study used 2 types of composite to increase the VD by restoring the palatal side of anterior teeth and that disclosed posterior teeth, then second phase by restoring the posterior teeth after 4.5 months.	Group A: 1.5mm. group B: 1.6mm	Till 3 months or occlusion established
Poyser *et al.* [24]	Pss	18	single	52	One phase was used to restore the VD using composite restoration in anterior and posterior teeth	0.5-5mm anterior	1,3,6 months then every 6 months
Sierpinska *et al.* [25]	Pss	50	single	49.5±9	Two phases were used to restore the VD. First provisional was used to confirm the new bite and then the final restoration with either FPD, RPD, or composite restoration	4.5±1.5mm	3months
Ormianer *et al.* [16]	Rss	16	Three groups	25-70	Three groups were divided based on prosthesis support either tooth or implant-supported or both. Starting with provisional with new VD after that restored the teeth with PFM	3-5mm	3-11 years
Oudkerk *et al.* [26]	Clinical trial	7	single	37.7±12.8	Single phase with the help of PICN CAD-CAM restoration after examine required VD	5.09±0.85mm	Till 2 years
Fabbri *et al.* [27]	Rss	100	Three groups	52.8	In this retrospective study, samples were divided into those supported by teeth, implants, or both. The VD was restored by beginning in mockups, temporary restorations, or removable appliances and after evaluation, in follow up visit, the final restorations were placed lithium disilicate	4.1±1.7mm	4.6±3.8 months

RSS: retrospective study PSS: prospective study VD: vertical dimension two phases treatment single phase treatment

Phases of the treatment, materials, and results

The studies were divided into two groups depending on the phases of treatment: 1) One-phase group: 6 studies that used composite or monolithic lithium disilicate overlays restoration and Polymer-Infiltrated Ceramic Network; 2) two-phase: 3 studies that used the provisional restorations as phase 1 and then permanent restorations (PFM crowns applied to restored heavily damaged teeth, composite applied to cover teeth with mild damage, RPD or metal-porcelain bridges for lost teeth) as phase 2, the study that used acrylic resin FPDs as phase 1 then PFM FPDs as phase 2, and the study that used mock-up, temporization, and removable partial or complete denture **(Table 2)**.

The OVD increased ranging from 0.5 mm to 6 mm **(Table 2)** depending on the patient's complaints and needs (aesthetically, functionality, or biologically) and materials used in each study. One study mentioned the use of splint with 4 patients because of tooth clenching after 3 months the symptoms ceased. Another study used splint but only with the cases that showed failure e.g. in wear and bruxism during the follow-up.

Survival, success, and failure rates

In terms of survival and success rate for the OVD increased, 5 studies mentioned the success rate and 5 studies mentioned the survival rate. Loomans *et al.* reported 94.8% success rate and 99.3% survival rate over 3.5 years; Luciano *et al.* reported 97.7% success and survival rates over 32 months; Hemmings *et al.* reported 89.4% success and survival rates, using Kaplan-Meier survival analysis; [26] reported 93.75% success rate and 100% survival rate; Hamburger *et al.* reported that 98% of 332 restorations was survived.

The rates and types of failures found in the studies differ from one study to the other. Loomans *et al.* mentioned that the annual failure rate at 3.5 years was 1.1% for anterior teeth, 1.9% for premolars, and 2.9% for molars; these failures were functional (chip and fracture) (n=43), biological caries (n=11), pain (n=2), aesthetic porosity (n=5), discoloration (n=2), and unknown (n=6). Hemmings *et al.* reported 33 failures in group A and 6 failures in group B; there were different reasons for these failures in group A including 18 fractures, 10 stains, and 5 lost; 24 of them were repaired and 9 were replaced. Also, in group B, there were 2 fractures, 2 stains, and 2 lost; 2 of them were repaired and 2 were replaced [3]. Poyser *et al.* mentioned that complete failures happened with 6% of the study restorations which means no composite remaining on the tooth surfaces. Partial failures determined in other restorations, 86% of restorations still maintained greater than 90% of the structure, while the other 14% still had about 50% to 90% of the restorations, reason of loss was determined as a result of wear rather than fractures and chipping [8]. Ormianer *et al.*'s study had 7.75% failures in group A, 3.9% in group B, and 3.7% in group C that failures varied between porcelain fractures, cement washouts, post-and-core failures, and extraction, Oudkerk *et al.* reported 0-3.1% failure rate caused by chipping and debonding. Luciano *et al.* mentioned that there was no failure in the study.

Postoperative symptoms

According to postoperative symptoms, which found with OVD increase in the included studies, there were complications noticed in some studies. In contrast, some studies reported no symptoms occurred. Hemmings *et al.* mentioned 3 patients with tooth wear in group A and 2 in group B. For the remained patients, there were no further teeth wear regarding study casts. Ormianer *et al.* had 2 patients in group B with TMD symptoms, which abated after 2 to 3 months and 4 patients in group C who were treated with an occlusal device, Fabbri *et al.* reported some prosthetic and self-functional compilation. 4 studies had no symptoms or complications after increase the OVD, and one study did not mention this information.

In this research, different highly qualified databases were used to extract scientific papers after the screening of the research collected by these different libraries. We ended with a minimal number of studies that underwent full-text evaluation. According to our inclusion criteria, the only studies that should be included were clinical trials and observational (pro & retrospective) studies to ensure a high level of evidence-based studies. The quality assessment procedure was done for the accepted studies after full-text reading. The most missing part in the included articles was the statistical part. 7 out of 11 research missed mentioning the power of the study [22, 24-26, 28, 29]. That helps identify the sufficiency of the sample size and the significance. The other missed part was the confidence interval [13, 22-26, 28, 29]. The last inquiry was during the quality assessment of the follow-up rate, which should be greater than the 80% recall rate.

As the aim of this systematic review to find different techniques to increase vertical dimension, this will provide evidence on different techniques and will guide the health care providers to use what they're confident with. Those current included studies had focused on restoring and increasing vertical dimension with different approaches but the majority of them used fixed prosthesis and restorations [13, 23]. The reason for preferring fixed prosthesis is that it does not need patient compliance and higher acceptance. Abdu (2012) suggested the safest amount for restoring vertical dimensions up to 5mm [30]. Whereas in our studies, it depended on patients' needs and requirements. There are 2 ways to increase vertical dimension either testing patient adaptation for a period by provisional restoration followed by definitive or as a one-step by checking and applying the definitive restoration simultaneously [22, 24, 25, 29]. The 2-step phase treatment requires more time and effort while the 1-step phase has the benefits of less time and effort demands; however, the patients' acceptance and adaptation should be first tested for better esthetic and functional improvement [21, 27].

Five out of 10 studies were managed with either direct or indirect composite adhesive restorations. 2 studies were treated with ceramic restorations as a 1-step phase, while 4 studies executed a 2-step phase of treatment. In 2 phases of treatment, we should check the occlusion at least for one month [31]. Regarding the included studies, when the clinician decides to use one phase, they usually distinguish the new vertical dimension either by mock-up or resin jig to evaluate esthetic demand or direct composite [22, 25, 26]. While, when the choice was 2-step procedure, the fix or removable interim restoration played an important role for new bite adaptation with the new vertical dimension, and then proceed for definitive restoration [25, 29, 30].

The occlusion scheme recommended for the cases who experience high occlusion forces is mutually protective occlusion, which usually results in teeth wearing. This concept will help to dis-occlude posterior teeth in the excursion movement of the mandible. This occlusion scheme is needed to decrease restorative and and phsiological problems. While the patient in maximum intercuspation the anterior teeth have light contact [32, 33].

Francesca Vailati (2008) demonstrated a three-step technique to restore the vertical dimension [34]. The first step is to construct the anterior mock-up for aesthetic purposes and occlusion plane assessment followed by the fabrication of a posterior mock-up for posterior support as the second step. Then, the creation of anterior guidance was done in the last third step. In adaption wise, this technique could be better than single- or two-step treatments. However, the longer the duration of the treatment the more effort it neccessiated [34]. Another case was reported using the PEEK framework as interim restoration to hold the new vertical dimension and to allow time for patients to adjust [35, 36]. Th (PEEK) polyether ether-ketone is a thermoplastic material, which was invented in 2007 by Kutz and Devine, is known to have biocompatible properties. Nevertheless, it was stated in a previous study that they used it as a removable framework to increase OVD [35, 36].

In our opinion, the preference of a 2-step over 1-step procedure is to examine the new bite of the same patient based on the biological, functional, and prosthetic outcomes. The limitation we faced in the review was the availability of studies in this field, insufficient high level of evidence studies which made the decision for choosing the proper technique debatable. On the other hand, the studies found in those databases were not highly qualified, which may increase the risk of bias and these were excluded to limit the effect on the conclusion of our review. Furthermore, the only studies that were collected according to the inclusion criteria were from 2000 and upwards, and this could leave valuable studies that existed before 2000. Due to the limited researches, we recommend insight on this topic to achieve a better conclusion and elevate the level of evidence based on the best methods used to increase the vertical dimension.

Conclusion

In conclusion, there are two different methods used to increase the vertical dimension by using different materials. The first method, where there are separate steps to increase the OVD before the final restoration. While the second method attempt to place the definitive restorations after the new bite is fabricated and tested extra orally. In the end, the success rate for increasing the vertical dimension either by one or two stages of treatment modalities was 96.2% regardless of the sample size [8].

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Ethics statement: This study was approved by the Institutional Review Board (IRB) of Riyadh Elm University (REU) and has been granted IRB number SRS/2020/25/197/200.

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