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Increasing Vertical Dimension and Occlusal Adjustment in the Management of Tooth Wear using Fixed, Minimal-Invasive Direct and Indirect Restorations: A Systematic Review and Meta-Analysis

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Abstract:

Purpose: To assess the increasing vertical dimension in worn dentition using fixed, minimal invasive, direct and indirect restorations through a systematic Review

Materials and Methods:

Literature search was conducted using electronic MEDLINE/ Cochrane databases, relevant references, citations and hand search was conducted. Academic Colleges were contacted to identify relevant studies and full texts. Inclusion Criteria were Randomized clinical trials, human cohort and case series reporting increasing vertical dimension and restoring worn dentition in adults suffering from tooth wear using fixed, minimal invasive and adhesive techniques.
The search period spanned from 2000 up to January 2023. Of the 550 articles identified, 111 went throw full text screening for eligibility and 12 studies were included in our study.

Failure, follow-up period for all the studies were assessed. Attrition , Bruxism, increase of vertical dimension rates and mean time of failure were calculated using random effect models.

Results: Tooth wear was reported equally in anterior and posterior region, and restorations were done in direct and indirect manners, mostly with pre-evaluation of the needed increase of vertical dimension. The mean of increased vertical dimension was 2.3 mm. The mean observation time of the restorations was 41.3 months with a minimum observation period of 12 months and a maximum of 84 months. Failure rate of all the included studies was 9.9% (95% CI: 91.00 % to 95.80%) high heterogeneity was detected in Failure rate with I2 of (93.85). Time to fail was calculated to be 37.5 months for 2458 cases (95% CI:32.32 to 91.13%). A fixed effect model was performed to calculate the event of increasing vertical dimension , the event rate was 81.72% (95% CI: 0.00 to 88.10%).

Conclusion: the performance of direct and indirect restorations is satisfactory, and the failure rate is low, which leads us to conclude that these non-invasive restorations are a reliable and cost-effective middle-term treatment method to restore vertical dimension in moderate to severe worn dentition.

Conflict of interest: None

Zusammenfassung:

Bisshebung und okklusale Adjustierung bei der Behandlung des Abrasionsgebisses durch festsitzende, minimal-invasive direkte und indirekte Versorgung-
ein systematische Review und Meta-Analysis

Ziel: Ziel ist es, die Langlebigkeit und komplikationsraten der Bisshebung und okklusale Adjustierung bei der Behandlung des Abrasionsgebisses durch festsitzende, minimal-invasive direkte und indirekte Versorgung, im Sinne einer Metaanalyse zu analysieren.

Material und Methoden: Es wurde eine intensive Literatursuche in den elektronischen Datenbanken MEDLINE/Cochrane sowie in relevanten Referenzen, Zitationen und manueller Suche mit der Schlüsselwörte “Tooth Wear /therapy“ durchgeführt. Einschlusskriterien waren randomisierte klinische Studien, Kohortenstudien und Fallserien an erwachsenen Patienten mit Abrasionsgebissen, bei denen mit festen, minimalinvasiven und adhäsiven Techniken eine Erhöhung der vertikalen Dimension und die Restauration des abgenutzten Gebisses erfolgte. Der Suchzeitraum erstreckte sich von Anfang 2000 bis Januar 2023. Von den identifizierten 550 Artikeln wurden 111 als Volltext erfasst; nach vollständiger Textprüfung erfüllten 12 Studien die Einschlusskriterien und wurden in die Analyse einbezogen.

Die Überlebensraten sowie die Nachbeobachtungszeit wurden für alle Studien bewertet. Abrasion, Bruxismus, Raten des vertikalen Dimensionenanstiegs und Versagenszeit wurden mithilfe von Random Effect Models bewertet.

Ergebnisse: Zahnabrieb wurde sowohl im anterioren als auch im posterioren Bereich beobachtet, und Versorgungen wurden sowohl direkt als auch indirekt durchgeführt, meistens mit vorheriger Evaluierung des benötigten vertikalen Dimensionsanstiegs. Die durchschnittliche, vertikale Erhöhung betrug 2.3 mm. Die durchschnittliche Nachbeobachtungszeit war 41.3 Monate, mit einer Mindestbeobachtungszeit von 12 Monaten und einer Höchstbeobachtungszeit von 84 Monaten. Die Versagensrate lag bei allen eingeschlossenen Studien bei 9.9% (95%-CI: 91.00% bis 95.80%). Es wurde eine hohe Heterogenität in der Versagensrate mit I2 von 93.85% festgestellt. Die Versagenszeit betrug 37.5 Monaten in 2458 Fälle (95%-CI: 32.32 bis 91.13%) .

Mittels Fixed-Effect-Model wurde den Einstieg in der vertikalen Dimension berechnet. Die Rate betrug 81.72% (95%-CI: 0.00 bis 88.10%).

Schlussfolgerung: Direkte und indirekte Versorgungen sind zufriedenstellend, die Versagensraten sind gering. Somit können die minimalinvasiven Versorgungen als zuverlässige und kostengünstige, Behandlungsmethoden zur Wiederherstellung der vertikalen Dimension bei mäßigem bis starkem Abrasionsgebiss angesehen werden.

Die guten klinischen Ergebnisse lassen den Einsatz von direkten und indirekten Versorgungen, empfehlenswert erscheinen.

Interessenkonflikte: Keine

Introduction:

Tooth wear is a physiological phenomenon that, when becoming severe or pathological, can lead to impaired dental attractiveness, pain, and reduced quality of life or may compromise the prognosis of healthy oral functioning of the dentition. Preferably, the management of tooth wear is focused on prevention, counseling and monitoring . When tooth wear has led to functional or aesthetical problems a restorative treatment plan should be discussed with the patient, which is based on the approach of minimally invasive interventions. [22]

Several techniques have been described to rehabilitate a worn dentition using direct composite restorations, indirect restorations of composite resin, lithium disilicate, polymer infiltrated ceramic network (PICN) , and combined techniques. However, the available clinical evidence for any restorative approach of the worn dentition is still limited, and a systematic review was not conclusive on which materials and techniques are preferred. [22]

In cases of generalized severe tooth wear, minimally invasive rehabilitation of the dentition involves restoring all teeth in an increased vertical dimension of occlusion (VDO), is a challenging procedure for the dentist. When composites are applied directly, advanced operator skills are required to build up all teeth, while for indirect procedures the treatment might be less technically demanding, as restorations are designed and produced extra-orally. [11]

There are Limited number of available clinical studies, most of them are extended case reports, retrospective studies, or uncontrolled trials.

According to a systematic review on longevity of dental materials/techniques to restore teeth with severe wear, direct composite has been studied most frequently, and modern adhesives and hybrid composites show acceptable results with AFRs varying from 0.4% to 6.9% .[46]

Another systematic review showed that the total intervention rate of direct composite restorations placed in patients with tooth wear was ranging between 0.8–17.9% , showing a large variation between studies, which makes it difficult to make solid conclusions. It underlines the multifactorial factors involved in these high-risk patients.[35]

So far, only one randomized controlled trial has been published, comparing microfilled direct and microfilled indirect composite restorations in 16 patients with tooth wear receiving a total of 32 restorations. [8]

After up to 3 years, this study showed poor success for both direct (50%) and indirect restorations (50%). Also, in the control group consisting of patients without tooth wear, restorations showed relatively poor performance at (80% success, which is markedly lower than other studies on large composite restorations, where failure rates of approximately up to 3% were found.[53,65] This indicates that the results of the randomized clinical trial should be interpreted with caution.

Two clinical studies on the success of indirect restorations showed very satisfactory success of 100% for lithium disilicate partial crowns using a moderately invasive concept in 7 patients [20], and 93% for indirect CAD/CAM composite restorations placed in a non-invasive concept in 7 patients. [54]

A more invasive treatment with full zirconia crowns in anterior teeth also showed a satisfying performance although no failure rate was reported. Both the technical advantage for the operator and the success of indirect restorations in these studies suggest a place for indirect restorations in the rehabilitation of severe tooth wear. [29]

Aim of the study

To assess the increasing vertical dimension in worn dentition using fixed, minimal invasive, direct and indirect restorations through A systematic Review

Review of literature

Worn dentition

The severely worn dentition often poses a challenge to the restorative clinician. Diagnosis and treatment planning involve multidisciplinary and in-depth evaluation of etiological, esthetic, occlusal, functional and preventive factors. Modern dentistry has made tremendous progress in areas of decay prevention, treatment of periodontitis and preservation of the natural dentition. Patients in general are more than ever informed and equipped to preserve their natural teeth and oral health. However, the prevalence of tooth wear from multi-factorial causes appears to be increasing in the dentate population. At the same time, global life expectancy has increased significantly. Hence, the profession is seeing an older population group presenting with severely worn teeth from normal day-to-day function seeking to maintain oral health quality of life. [38]

Definition

Worn dentition, also called tooth wear or erosion, is characterized by a pathological loss of tooth structure that occurs for reasons other than normal tooth decay. [59]

Signs and Symptoms of Worn Dentition

Worn dentition is primarily marked by the loss of tooth enamel. As a result, patients often experience: [3]

- yellowed tooth appearance (due to exposed dentin)
- shortened or otherwise misshaped teeth

Worn dentition, however, is not a purely cosmetic concern. Patients with extremely worn teeth also experience: [3]

- extreme tooth sensitivity and pain
- fractured teeth
- tooth weakness
- bone loss

- changes in their bite
- tooth loss
- receding gums
- diminished tooth function

Causes of Worn Dentition

Four factors can contribute to a person's teeth wearing down more quickly than normal. These include:

Attrition

Wear and tear caused by tooth-to-tooth contact is called attrition. The progressive loss of tooth structure due to attrition is usually associated with bruxism or sleep bruxism. The type of grinding or clenching associated with bruxism can be related to temporomandibular joint disorders, sleep apnea, stress, genetics, and more. [76]

Abrasion

Worn dentition caused by foreign objects is called abrasion. This can occur due to brushing too hard or chewing on ice or other hard objects. [22]

Erosion

The loss of tooth structure due to chemical factors is called erosion. Tooth erosion can occur as a result of acid gastric reflux disorders, consuming highly acidic foods and drinks, or even due to vomiting. [41]

Bruxsism

Bruxism is a pathological activity of the stomatognathic system that involves tooth grinding and clenching during parafunctional jaw movements.[42]

Most patients with pathologically worn dentition suffer from a combination of the above-mentioned factors. [41]

Tooth Wear Assessment:

At the time of its publication, the TWES Module Quantification used two ordinal grading scales for screening. A 5-point ordinal scale for occlusal/incisal surfaces is used; in the adapted TWES 2.0 this grading remains the same (**Table 1).** [75]

TABLE 1. Tooth Wear Screening, grading scales of the TWES 2.0

Five-point ordinal scale for occlusal and incisal grading
Grade 0 = no (visible) wear Grade 1 = visible wear within the enamel Grade 2 = visible wear with dentin exposure and loss of clinical crown height ≤ 1/3 Grade 3 = loss of clinical crown height > 1/3 but < 2/3 Grade 4 = loss of clinical crown height ≥ 2/3
Five-point ordinal scale for non-occlusal and non-incisal (= oral and vestibular) grading :
Grade 0 = No (visible) wear Grade 1 = Wear within the enamel Grade 2 = Wear with dentin exposure (less than 50% of the area) Grade 3 = Wear with dentin exposure (50% or more of the area) Grade 4 = Wear with dentin exposure (complete-tooth loss of enamel or pulp exposure)
Tooth Wear Screening, Grading Document

sextant 1	sextant 2	sextant 3
occlusal	occlusal	occlusal
	sextant 2	
	palatinal	
sextant 6	sextant 5	sextant 4
occlusal	occlusal	occlusal

For the assessment of non-occlusal/non-incisal (or oral/vestibular) tooth wear, a 3-point ordinal scale is used (Grade 0 = No (visible) wear; Grade 1 = Wear confined to the enamel; Grade 2 = Wear with exposed dentin). During Tooth Wear Screening in the TWES, grading is limited to the palatal surfaces of the second sextant, while the more detailed follow-up examination inspected all oral and vestibular surfaces. However, users experienced that this screening grading cannot adequately represent oral and vestibular findings of advanced loss of dental hard tissues. Therefore, in the TWES 2.0, a 5-point ordinal scale is incorporated for the assessment of the palatal surfaces during screening, based on comparison of existing grading scales (see Table 1). [75]

The evaluation of tooth wear in the original TWES was limited to natural teeth, as it was for all other existing indices as well. However, tooth wear can also affect direct and indirect restorative materials. Since the prevalence of tooth wear was increasing during the last decade, also more often, already restored dentitions will be present in the daily clinical practice. Tooth wear in connection with restorations allows conclusions to be drawn about the etiology of tooth wear, because chemical tooth wear affects the dental hard tissues more severely than restorative materials. For teeth with restorations, the amount of substance lost is judged in comparison to the adjacent teeth or to unrestored teeth. [75]

Therefore, to assess the relevant wear on restorative materials and since no existing grading scale was detected in the literature, a 5-point ordinal scale was suggested by some authors. By means of a Delphi process, all members of the working group commented until consensus was achieved) .The resulting scale is as follows: Grade 0 = No (visible) wear; Grade 1 = Wear within the ceramic/resin composite material (“at enamel level”); Grade 2 = Wear within the ceramic/resin composite material (“at dentin level”); Grade 3 = Wear with metal/hard dental tissue exposure; Grade 4 = Wear with

complete destruction of the ceramic/resin composite material. This new scale must and will be tested extensively before implementation can occur. In the meantime, the two above-mentioned scales can be used. [75]

Classification of tooth wear

As mentioned in the first version of the TWES, the occlusal/incisal and non-occlusal/non-incisal (oral/vestibular) wear levels are leading to the following severity classification: [11]

- Grade 0 = No wear
- Grade 1 = Mild tooth wear
- Grade 2 = Moderate tooth wear
- Grade 3 = Severe tooth wear
- Grade 4 = Extreme tooth wear

Tooth wear screening

The first step of the diagnostic process remains the Tooth Wear Screening. The goal of this examination is to identify patients with increased levels of tooth wear. Patients with prominent findings can or will undergo a more detailed examination, as the basis for possible treatment decisions. The screening is designed in such a way that it can be carried out quickly. [9]

No additional instruments are required for Tooth Wear Screening except for a mouth mirror and a documentation form. The highest grade for each sextant is entered in this documentation form, supplemented by an additional grade for the palatal surfaces of the maxillary anterior teeth (sextant 2). The five-point ordinal scales mentioned in **Table 1** are used to record the highest gradings. The individual grades obtained from the Tooth Wear Screening are interpreted as standalone values; no summation is performed. The results of the Tooth Wear Screening are documented in the form provided for that purpose, in which the individual grades are entered (see **Table 1).** [9]

The indication for a more detailed Tooth Wear Status depends on the highest individual grades, according to the following rules:

- Grade 0 in all sextants and the anterior palatal sextant
  - → No tooth wear → No action required
- Grade 1 in any or all sextants and/or the anterior palatal sextant
  - → Mild tooth wear → No action required
- Grade 2 in any or all sextants and/or the anterior palatal sextant
  - → Moderate tooth wear → Detailed Tooth Wear Status *can* be performed
- Grade 3 or 4 in any or all sextant

→Severe or extreme tooth wear → Detailed Tooth Wear Status *should* be performed, if the patient and/or the dentist have reason to assume that the tooth wear might be pathological. In contrast to the TWES 1.0, additional information regarding medical and dental history taking, and assessment of individual morphological characteristics (TWES Module Qualification), should be reserved for the extended diagnostics. This deliberately keeps the screening straightforward and limits the time and effort. [9]

Tooth wear status

In accordance with the stepwise concept, a more detailed and therefore more complex examination is carried out at the second diagnostic stage. It is indicated in the following situations: [19]

1. Optional when the Tooth Wear Screening has indicated moderate tooth wear (TWES 1.0), obligatory when severe or extreme tooth wear are revealed
2. To assess tooth wear progression in detail, in order to evaluate preventive measurements (TWES 1.0)
3. When a detailed treatment plan is required (TWES 1.0)
4. A brief visual inspection reveals severe/extreme tooth wear (TWES 2.0)
5. Oral history taking/questionnaires indicating pathological tooth wear (TWES 2.0)

In case of situations 4 and 5, the Tooth Wear Status can be obtained directly (step one, the Tooth Wear Screening, can be skipped).In the first version of the TWES (TWES

1.0), this examination was mentioned the "finer-grained module" and included a much more detailed survey of all teeth and all surfaces. In the extended Tooth Wear Status are incorporated: 1. a detailed grading; 2. an adapted qualification to reveal etiological factors; and 3. recording of pathological symptoms. [19]

Methods for assessing and monitoring tooth wear

Colour measurement

Assessment of the colour change when enamel is lost. [6]

Quantitative light-induced fluorescence (QLF)

This uses auto-fluorescence of teeth, which occurs when a high-intensity blue light is shown on the teeth causing them to emit green light and an image of this is captured on a computer, as a potential means to identify progressive erosive surface loss. There are no studies or applications as of yet. [60]

Optical coherence tomography (OCT)

This method measures the intensity of back-scattered light on the tooth tissue surface, similar to ultrasound but using light in place of sound waves. OCT is favoured for accurate measurements of tooth erosion changes in *in vitro* studies due to its high degree of accuracy, and has also been used *in vivo* for caries progression studies, but is difficult to apply clinically. [48]

Optical reflectometer

One study has recently developed a pen-sized device using the principle of specular reflection intensity to measure the degree of light that is reflected and scattered, and can detect early erosive changes. [12]

Three-dimensional digital superimposition

It is possible to scan study casts and superimpose the digital models of the canines using a reference point. This is a potentially costly method to create models then a 3D scanned image and then analyse them and although the use of a CAD-CAM, laser was able to detect changes. It was the least sensitive method and not capable of detecting progression. [43]

Stereoimagery (photogrammetry)

This process uses software to locate multiple common 3D reference points on two or more 2D images and uses a complex mathematical relationship to build a digital surface model; however, unfortunately, it requires the teeth to be coated or for special study cast material to be used. [56]

Laser profilometer

This method uses a non-contacting laser to scan the outline of the teeth, or dental study casts to record the profile of the teeth. Sequential scanning over time can detect changes in the profile . [57]

Photographs

Clinical photographs can be a useful method for assessing changes over a period of time. Usually, an anterior view, left and right posterior views, and both upper and lower occlusal views are recorded. Photographs may be useful for detecting macro changes over time, but are unlikely to show early or slight changes in short periods of time. It is also limited by its 2D nature of a 3D scenario and dentists may underestimate or misdiagnose the extent of tooth wear. [62]

Tooth wear indices

At present, these are often the most favoured method for assessing tooth wear, other than study models, as they require no specialist or expensive equipment, nor is there a laboratory fee associated with them. There are a number of indices available, the most commonly used of which are examined below, all of which aim to quantify or qualify

the amount of tooth tissue lost. With indices that qualify the amount of tooth tissue rather than measure and quantify, the results can be subjective when the examiner has not been properly trained or calibrated to use the scale. Those that quantify tooth wear are often more easily applied using models or in laboratory research than in clinical scenarios where qualitative methods can be more practical. Further complications arise as there is no standardisation of terms across countries when referring to tooth wear, particularly regarding the use of the term 'erosion'. Indices in use are: [52]

- Anterior Clinical Erosive (ACE) classification: this index, devised by Vailati and Belser, focuses on the upper anterior teeth and aims not only to grade the severity but also to offer restorative decision input. This index is often used in epidemiology and, while it gives a very accurate way of monitoring tooth wear in the long term, it can be complicated to use clinically
- Smith and Knight tooth wear index (TWI): the TWI was designed to take account of all etiologies of tooth wear, as opposed to other indices of its time that were specific to a single cause. The main issue with this index is that it focuses on the anterior upper teeth
- Basic Erosive Wear Examination (BEWE): its main aims are to be simple to use and to demonstrate that tooth wear has been assessed by the clinician, not necessarily to monitor the progression of tooth wear. The index scores the worst affected tooth in the sextant and the total score for the mouth can be used to guide restorative managementThe name of the index is deceptive as it suggests that it only records tooth wear with an erosive aetiology, but it is actually intended to include all forms of tooth wear (using the term 'erosion' to mean 'surface loss' and not specifically limited to 'acid erosion'). Similar is the Dental Wear Index (DWI), which describes multifactorial wear and has similar grading criteria to BEWE, but does not group scores into sextants.

Silicone indices

These can be made on the teeth or models and then sectioned according to the area of the wear. It is relatively cost-effective, but requires the use of models, is time-consuming and only provides a 2D assessment. [52]

Digital impression scanner

Digital impression scanners can be used to record tooth wear. The rise in the use of intraoral scanners, some of which are now capable of taking serial intraoral impression scans and overlaying them to highlight changes in the dentition, has enabled instant analysis and creation of colour-coded areas of change [77]

Treatment Options for Worn Dentition

The recommended treatments for worn dentition depend on the extent of damage and include: [28]

- night guards
- bonding
- veneers
- crowns
- implants

Although tooth wear is considered to be age dependent, an increasing number of both adult and young patients are experiencing tooth wear, usually erosive in nature. It can present in a variety of forms and severity. Prevention of further tooth wear should form the basis of care, but in severe cases interventive restorative treatment may be necessary to protect vulnerable tooth surfaces and re-establish satisfactory appearance and function. Indications for interventive restorative treatment are: [28]

- Unacceptable appearance of the teeth
- Loss of normal function
- Progressive tooth wear resulting in pulp necrosis and/or difficulty in teeth restoration

The restorative treatment options possible with today's materials and techniques include: [79]

- Conventional fixed restorations
- Removable onlay/overlay prostheses
- Minimal preparation adhesive restoration

Overview (see Table 2)

Table 2 Restorative techniques for managing the worn dentition (11)

	Indication	**Application**	**Contrain dication**	**Advantages**	**Disadvantages**
Conventional fixed restorations	Worn and broken teeth	Fixed restoration of dentition requiring reorganisation of dental occlusion	Parafunctional clenching and grinding	Versatility with regard to appearance and occlusal form Can be used as provisional crown	Invasive procedure High cost and skill demands
Removable onlay/overlay prostheses	Moderate/severe tooth wear Missing strategic teeth	For patients with more severe forms of tooth wear	Parafunctional clenching and grinding	Simple Non-invasive Cost-effective Maintenance of alveolar bone and support Improved sensory feedback Masticatory performance Reduced psychological trauma of tooth extraction	Space demands are usually greatest The abutment teeth are at an increased risk of primary dental disease Risk of root surface caries
	Cervical tooth wear	Aesthetics sensitivity	Parafunctional	Minimal tooth preparation	Micro-leakage Marginal

	Indication		Application	Contrain dication	Advantages	Disadvantages
Minimal preparation adhesive restorations			Prevention of further tooth wear	clenching and grinding	Better aesthetics	Discoloration of the restoration Restoration longevity
	Anterior tooth wear	Palatal tooth wear	To offer some resistance to further palatal tooth wear which will reduce the risk of significant enamel fractures			
		Incisal/palatal tooth wear	Worn upper anterior teeth			
		Labial/incisal/palatal tooth wear	For patients with particularly compromised dentitions			
	Posterior and generalized tooth wear		Full mouth reconstruction of the dentition			

Materials/instruments

Conventional fixed restorations: [73]

- Porcelain-fused-to-metal (PFM) crowns
- All-metal crowns
- All-ceramic crowns

Removable onlay/overlay prostheses : [15]

- Acrylic resin
- Composite resin
- Cobalt–chromium framework
- Gold alloy framework

Minimal preparation adhesive restorations: [71]

- Composite resin
- Glass ionomer cements
- Resin modified glass ionomer cements
- Resin-bonded palatal metal alloy veneers (heat-treated gold alloys or nickel–chromium alloys)
- Modified porcelain laminate veneer
- Indirect densified composite resins

Procedure

Conventional fixed restorations

Conventional crown restorations, being an invasive procedure, require adequate interocclusal space which is usually lost as a result of compensatory eruption of opposing teeth during the process of tooth wear. Conventional restorative techniques to overcome the reduced crown height and lack of interocclusal space are: [69]

- Opposing tooth reduction.
- Elective endodontic treatment and post retention.
- Occlusal adjustment (retruded arc of mandibular closure).
- Periodontal surgical crown lengthening (Fig. 1).

Fig. 1

Periodontal surgical crown lengthening on worn upper anterior teeth prior to the construction of conventional crown restorations. **a** Before surgery. **b** Immediately after surgery

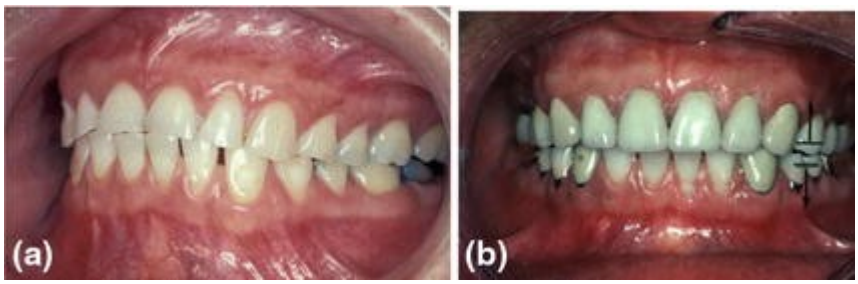
Localized orthodontic tooth movement **(conventional fixed appliance or 'Dahl' appliance) (Fig. 2)**

Fig. 2

a Localized anterior tooth wear. **b** 'Dahl appliance' cemented in place. **c** Interincisal space recreated following the removal of the 'Dahl appliance' prior to anterior restorations

Overall increase in occlusal vertical dimension (Fig. 3).

Fig. 3

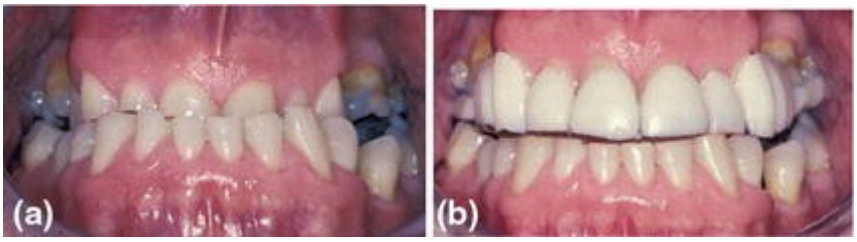


Generalized tooth wear restored with conventional crown restorations in the anterior and posterior segments at an overall increase in occlusal vertical dimension. **a** Before restoration. **b** After restoration

Removable onlay/overlay prosthesis

It is recommended to construct a provisional acrylic resin removable prosthesis so that the shape, position, occlusal relationship of the prosthetic teeth and soft tissues as well as the patient's tolerance of a removable prosthesis can be assessed (Fig. 4)[36]

Fig. 4



Moderate/severe tooth wear with an unfavourable occlusal relationship initially restored with a provisional onlay/overlay removable prosthesis to assess appearance and function. **a** Before restoration. **b** After restoration with removable prosthesis

The available space determines whether or not an anterior labial flange can be used or alternatively gingival fitting and/or butt-fitting tooth facings. The space demands are usually greatest in the anterior region both in the vertical and labiolingual dimensions (Fig.5) [5]

Fig. 5

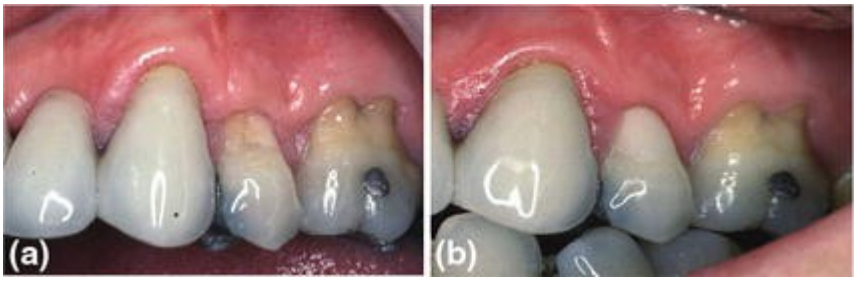
a Full labial flange. **b** Gingival fitting anterior tooth facings

Minimal preparation adhesive restorations

Cervical tooth wear

Depending on the type of the lesion, different materials can be used (Fig.6) [10]

Fig. 6

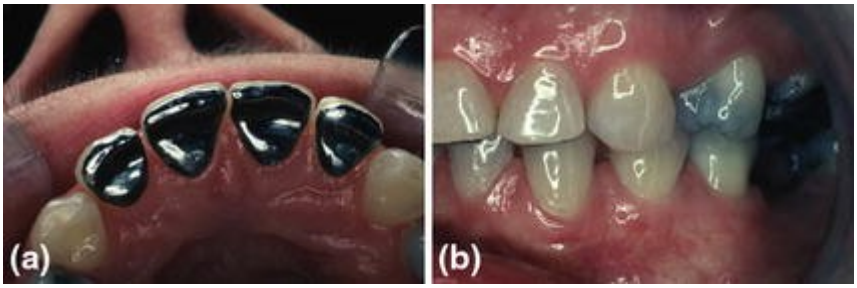


Restoration of a cervical abrasion/erosion lesion using a layered glass ionomer and direct composite resin technique. **a** Before restoration. **b** After restoration

Anterior tooth wear

Palatal tooth wear To manage this form of tooth wear resin-bonded palatal metal alloy veneers can be considered. The incisal and palatal peripheral enamel margins are smoothened and laboratory fabrication of the metal alloy veneers is either done directly on a refractory working cast or by a wax/resin 'lift-off' technique. Interocclusal space is usually created to accommodate the thickness of the restoring material. When there is excessive tooth wear in the cervical region rubber dam isolation is used and occasionally gingival retraction cord. Cementation is done using luting cements that are usually resin-based and used in combination with the manufacturer's dentin bonding agent where appropriate (Fig. 7) [39]

Fig. 7



Nickel–chromium alloy resin-bonded palatal veneers used to restore localized palatal tooth wear for maxillary incisor teeth. **a** Palatal view of veneers. **b** Labial view demonstrating re-establishment of posterior occlusal contacts

Incisal/palatal tooth wear

The incisal portion of the tooth can be built with direct acid-etch retained composite resin and then a resin-bonded metal alloy palatal veneer can be constructed to cover both the palatal tooth tissue and composite resin by which the appearance of lost incisal and labial tooth tissue can be improved. The incisal and palatal tooth surfaces can be restored conservatively with direct acid-etch retained composite resin at an increase in occlusal vertical dimension to accommodate the thickness of the restorative material. Diagnostic wax-up is done on stone casts of planned restorations. Then rubber dam

isolation of teeth is done prior to adhesive restorations. Silicone putty index and interproximal tape are used to aid restoration (Fig. 8) [11]

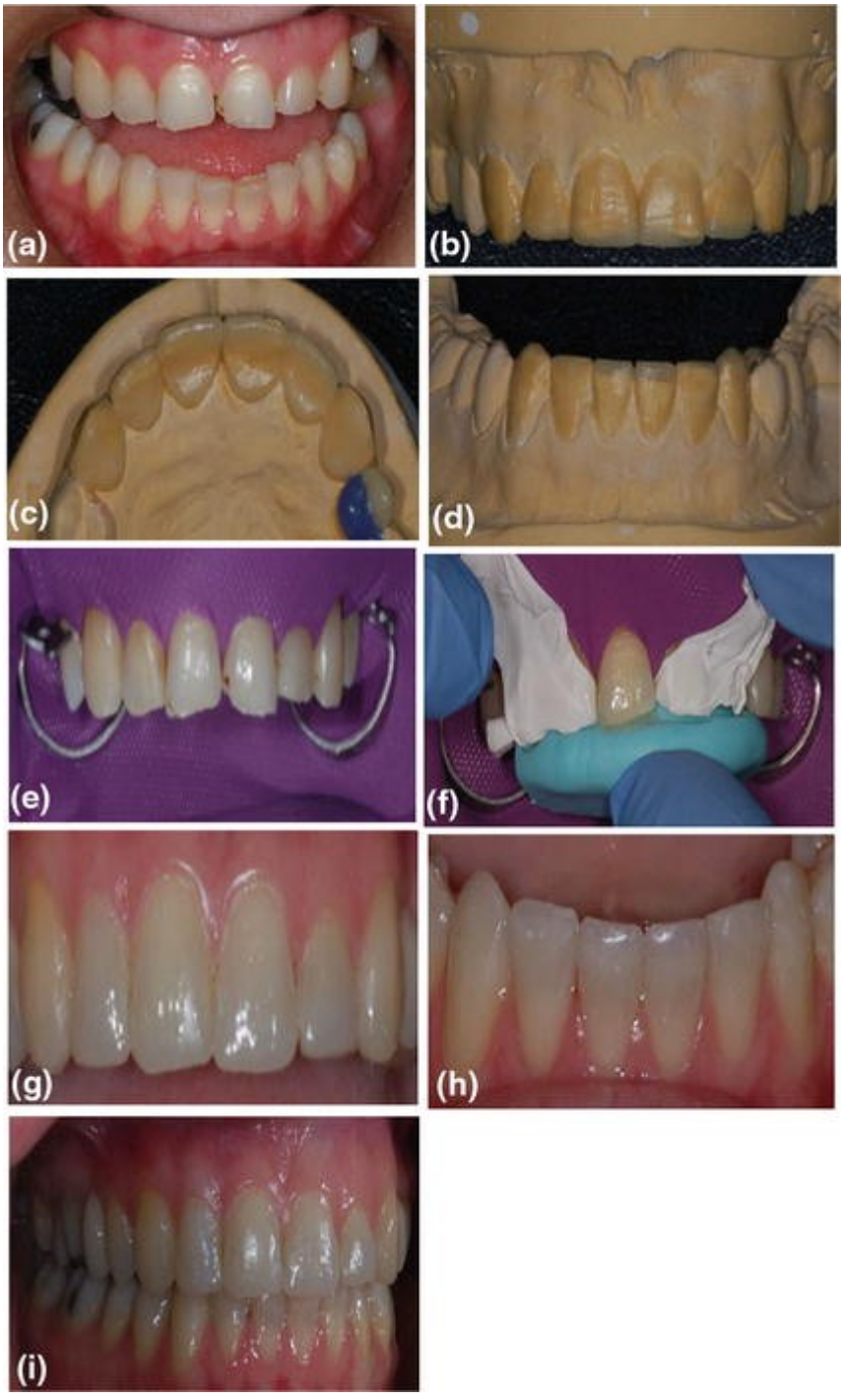


Fig. 8

a–**i** Restoration of worn upper and lower anterior teeth with direct composite resin restorations. **a** Before restoration. **b**–**d** Diagnostic wax-up on stone casts of planned restorations. **e** Rubber dam isolation of teeth prior to adhesive restorations. **f** Use of

silicone putty index and interproximal tape to aid restoration. **g** Post restoration upper anterior teeth. **h** Post restoration lower anterior teeth. **i** Restorations 6 months following placement demonstrating re-establishment of posterior occlusal contacts

A number of clinicians use modified porcelain laminate veneer restorations for the incisal and palatal worn tissue.Indirect densified composite resins are the alternatives to using direct composite resins, with the potential advantages of improved physical properties and better control regarding occlusal and interproximal contouring. [23]

Labial/incisal/palatal tooth wear

All tooth surfaces can be restored with direct composite resin at an increased occlusal vertical dimension in an attempt to initially recreate lost interocclusal space. After that a decision can be taken either to continue with ongoing maintenance of the composite resin restorations or alternatively to consider proceeding to conventional crowns conforming to the newly established occlusion (Fig. 9) [37]

Fig. 9

Direct acid-etch retained composite resin restorations used to restore extensively worn maxillary anterior teeth at an increase in occlusal vertical dimension. **a** Before restoration. **b** After restoration

In some cases with minimal tooth structure, localized crown lengthening surgery can be advantageous which will help to capture all remaining tooth enamel. If for any reason surgical crown lengthening is not available, then indirect splinted composite resin restorations can be considered to aid retention and durability (Fig. 10) [50]

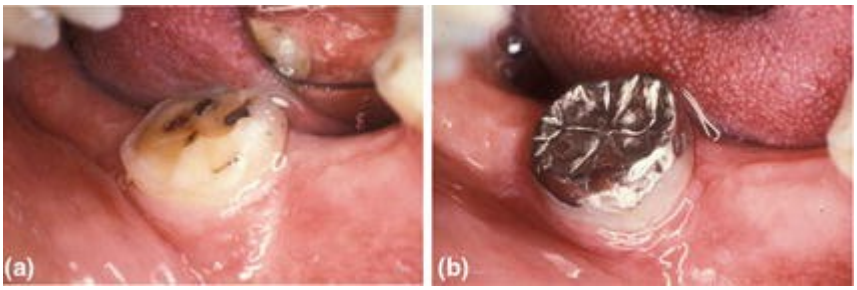
Fig. 10

Direct acid-etch retained composite resin restorations used to restore severely worn lower anterior teeth following periodontal surgical crown lengthening to expose available tooth structure. **a** Before surgery. **b** After periodontal surgical crown lengthening. **c** Immediately following placement of restorations

Posterior and generalized tooth wear

Resin-bonded heat-treated gold alloy restoration can be used in cases where aesthetics is not paramount (Fig. 11) [19]

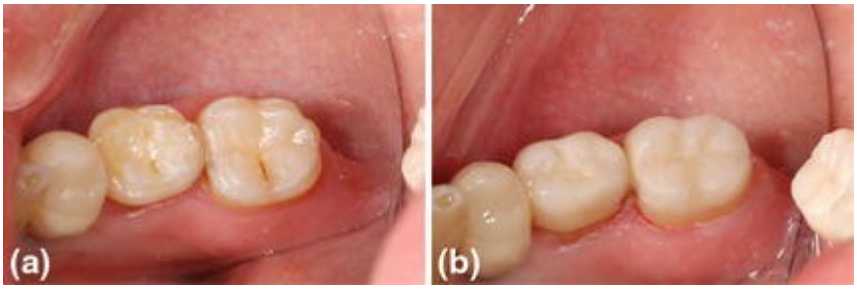
Fig. 11



Minimal preparation resin-bonded gold alloy onlay used to restore worn posterior tooth. **a** Before restoration. **b** After restoration

If aesthetics is a primary concern then a resin-bonded ceramic or indirect composite resin onlay can be considered.In situations where retention and resistance form for conventional crowns are particularly compromised these techniques are helpful (Fig. 12) [13]

Fig. 12



Minimal preparation resin-bonded indirect composite resin onlay restorations used to restore worn posterior teeth. **a** Before restoration. **b** After restoration

In cases of generalized tooth wear, where a full mouth reconstruction of the dentition is indicated, the use of adhesive onlay restorations in the posterior quadrants can be considered in certain circumstances. If space is at a premium, the selection of a gold alloy instead of porcelain will be advantageous. In some cases, a full mouth reconstruction of the worn dentition using resin-bonded ceramic or indirect composite resin restorations is possible. [14]

Complications

Conventional fixed restorations: [51]

- Pulp necrosis
- Tooth fracture
- Loss of cementation
- Marginal caries
- Postoperative sensitivity
- Interproximal spacing
- Placement of crown margins on root surfaces

Removable onlay/overlay prostheses: [78]

- Maintenance demands – material wear and fracture being common
- Difficulty in adapting both functionally and psychologically

Minimal preparation adhesive restorations

Unpredictable longer-term durability, particularly of the posterior onlay restorations; characteristically small fracture lines can appear in time which may eventually result in a catastrophic failure [67] .

Temporization

Procedures involving complete resin bonding of the temporary restoration to the underlying tooth tissue may compromise the subsequent adhesive bond for the final restoration [27]. The risk of damage to the tooth preparation during the removal of the interim resin lute should also be considered [51] .

On the other hand, using a less adhesive material or technique can result in the early loss of any temporary restorations, with the possible consequences of unplanned tooth movement. [63]

Therefore, choosing the right temporary luting cement is critical to the final cementation process .

In try-in stage checking the occlusal relationship can be a challenge also due to the relative lack of retention of the restorations before cementation.[63]

MATERIAL AND METHODS

Search strategies

This systematic review is conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. [55]
The search included Fixed, minimal invasive direct , indirect restoration, worn teeth.
At the beginning of this review, a study protocol was thoroughly documented based on International prospective register of systematic reviews (PROSPERO Protocol) by the National Institute for Health Research (NIHR). **Supplementary details (1).**
To identify studies for this review, the population, intervention, comparison, outcome, and study design (PICOS) question was used to guide construction of the search strategy: P = adults of any age who suffer of tooth wear; I = fixed minimal invasive restorations ; C = direct and indirect restorations O = Increase of vertical dimension and restore worn dentition; S = randomized controlled trials (RCTs) and cohort studies and case series.

Search methodology

A literature search of the Medline and Cochrane databases (from articles published from 2000, to January 31, 2023) was performed to identify studies for inclusion.
The Medical Subject Heading (MeSH) “Tooth Wear” linked to the MeSH subheading “therapy” was used (“Tooth Wear/therapy” [MeSH]). The Cochrane database search was designed as a permutation of the Medline search strategy by manually selecting the studies. To ensure a highly sensitive search strategy, only the MeSH term “Tooth Wear/therapy” [MeSH] was used. This MeSH term also covers tooth abrasion, tooth attrition, and tooth erosion.
The results of the search were extended by hand searching. Hand searching was performed by reference lists of included studies to identify additional studies (citation mining) and expert recommendations. The performed searches are shown in **(Figure 13).**
We made an effort to contact corresponding authors for more information when data were missing.

Identification of articles and data extraction

We divided the selection and data extraction procedure into 3 phases and placed no restrictions on the search to maintain more specific methodological characteristics. In the first phase, studies were selected based on the titles and abstracts and all the remaining abstracts were screened to decide whether the study was consistent with the inclusion criteria as described in the next paragraph. In the second phase, full articles were evaluated using the same inclusion criteria. In the third phase, articles that were Published only as abstract or not published in English, Does not report adequate clinical outcomes , cannot be included in quantitative analysis were excluded.
The Data were extracted, including first author, publication year, type of design, patients 'age, gender, , restorations number, , complaints, restorative materials and procedures, outcomes, and success and failure rate.

Inclusion criteria

We collected the studies on the basis of the following eligibility inclusion criteria:
All adult patients of any age, ethnicity and gender with tooth wear and loss of vertical dimension who were treated with Fixed, minimal invasive direct and indirect restoration, in order to increase of vertical dimension and restore worn dentition.
The procedure and the steps should be thoroughly documented.
The included studies can be:
case series with >=2 participants, cohort studies (prospective and retrospective), randomized and non-randomized studies to treatment groups.
we restricted the language in the articles to English only.

Quality assessment of included studies:

The methodological quality of the studies was evaluated, to assess each of the included articles more accurately.
We used the Cochrane Collaboration's tool for assessing risk of bias [32] in the review. The reviewer assessed and scored the random sequence generation (selection bias), allocation concealment (selection bias), masking of participants and personnel (performance bias), masking of outcome assessment (detection bias), incomplete outcome data (attrition bias), and selective reporting (reporting bias). We judged each study to have a low risk of bias, a high risk of bias, or an unclear risk of bias.

We did Cochrane Collaboration Assessment to evaluate mean differences for visual analog scale (VAS) scores. **(Figure 14, A&B)**
Additionally, Risk of bias for prospective studies included in this study were evaluated with **ROBINS-I tool (Table 4)** and for case report, case series and retrospective studies **The Newcastle-Ottawa Scale (NOS) tool** was performed in order to assess the quality of non-randomized included studies**.(Table 5-7)**

Data synthesis and analysis

We performed meta- analyses on restoring and increasing vertical dimension in worn dentition.

Data were fed to the computer and analyzed using MedCalc software package version 20.100. The Cochran's Q test (Total variance for heterogeneity) was used for heterogeneity test (a P value of 0.05 or less indicated statistical significance), and the I2 statistic as a measure of inconsistency across studies (observed variance for heterogeneity). If the I2 value was 30% or less, we used a fixed-effects model; if the I2 value was over 31% we used a random-effects model.

Quantitative data are reported as Mean and SE standard error while Qualitative Data are reported as total Number and number of event.

We identified statistical heterogeneity by eyeballing (that is, visually inspecting forest plots).

RESULTS

Study Characteristics:

On the basis of our search criteria at the end of January 2023, we identified 550 related titles after our initial screening. The abstracts were then obtained from 111 appropriate titles and assessed for inclusion according the broad inclusion criteria. After reading the titles and abstracts, we excluded 75 articles for not being relevant to our search or not meeting our inclusion criteria.. After conducting a full-text review of the remaining 36 articles, we excluded 24 articles for not being published in English, not reporting robust clinical outcomes, cannot be included in quantitative analysis, for having both fixed and removable or more invasive treatments such as implants and prothesis. Finally, a total of 12 studies remained for data extraction and were included in pool analysis (Figure 13). The (Tables 8-12) depicts the characteristics and methodologies of these studies.

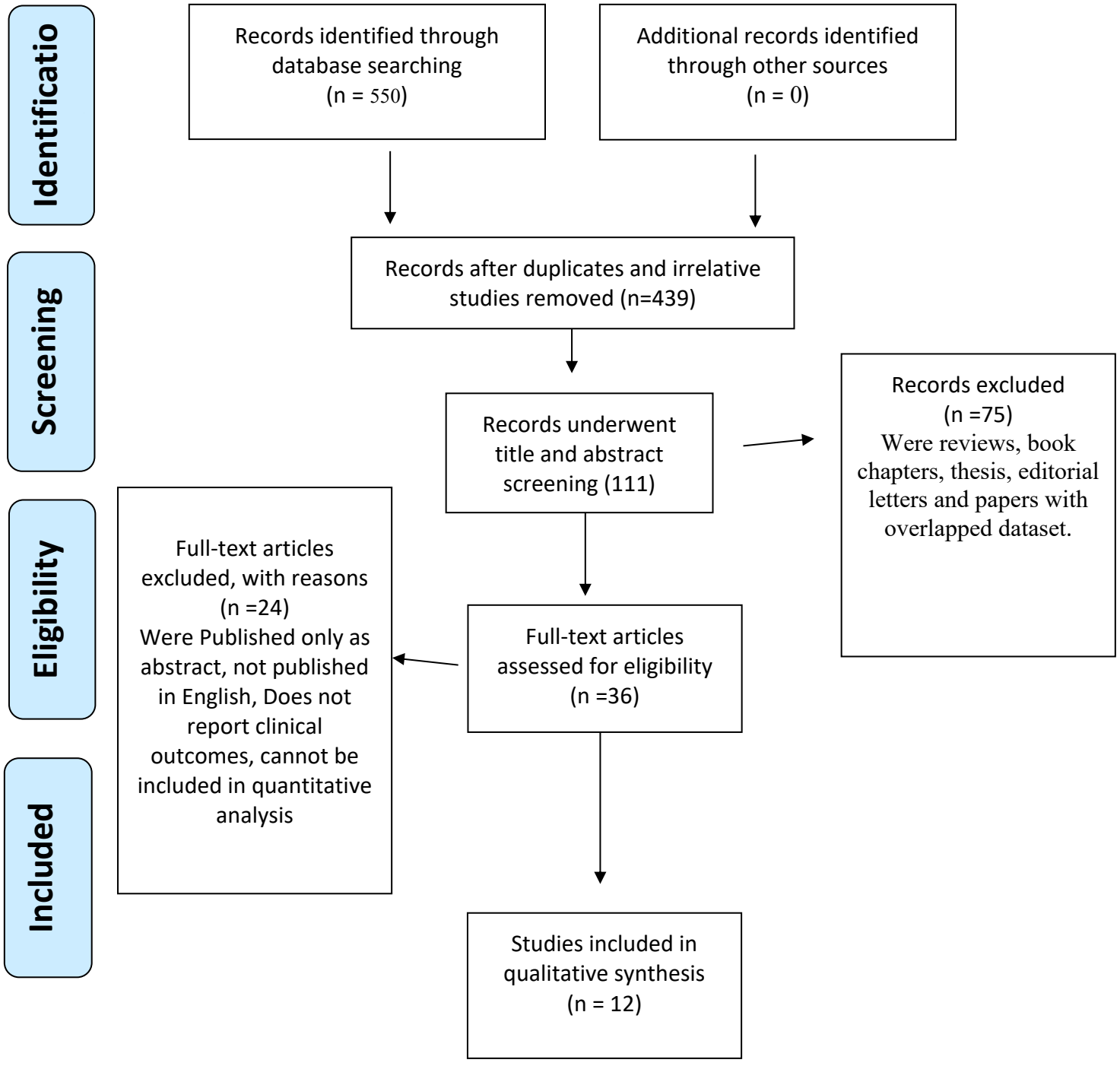
Data extraction included the participants' characteristics of Type and date of study, sex, age, complaints, number of restoration, restorative materials, site and procedures, follow-up, failure and success rate)

We could not include all 12 of the articles in 1 meta-analysis owing to inconsistent measurement methods and insufficient data. However, many study investigators had similar outcomes (that is, increase in OVD, mean of OVD, Attrition, Bruxism). Therefore, we divided the studies into subgroups and investigated the Meta-analysis using fixed and random effect test and forest plot.

Failure rate and follow-up period was reported in all the included studies, and therefore we included all the studies in Meta-analysis, analyzing these two data.

Because of the distinct rating systems used and the various measurement For **failure** rate, that was discussed in details in some studies, we read each study thoroughly and only the restorations that were lost or replaced during the follow-up period was considered as failure, all the other restorations that stayed in situ with minimal fracture or discoloration were considered as survivals.

Figure 13 :PRISMA flow diagram showing process of studies selection

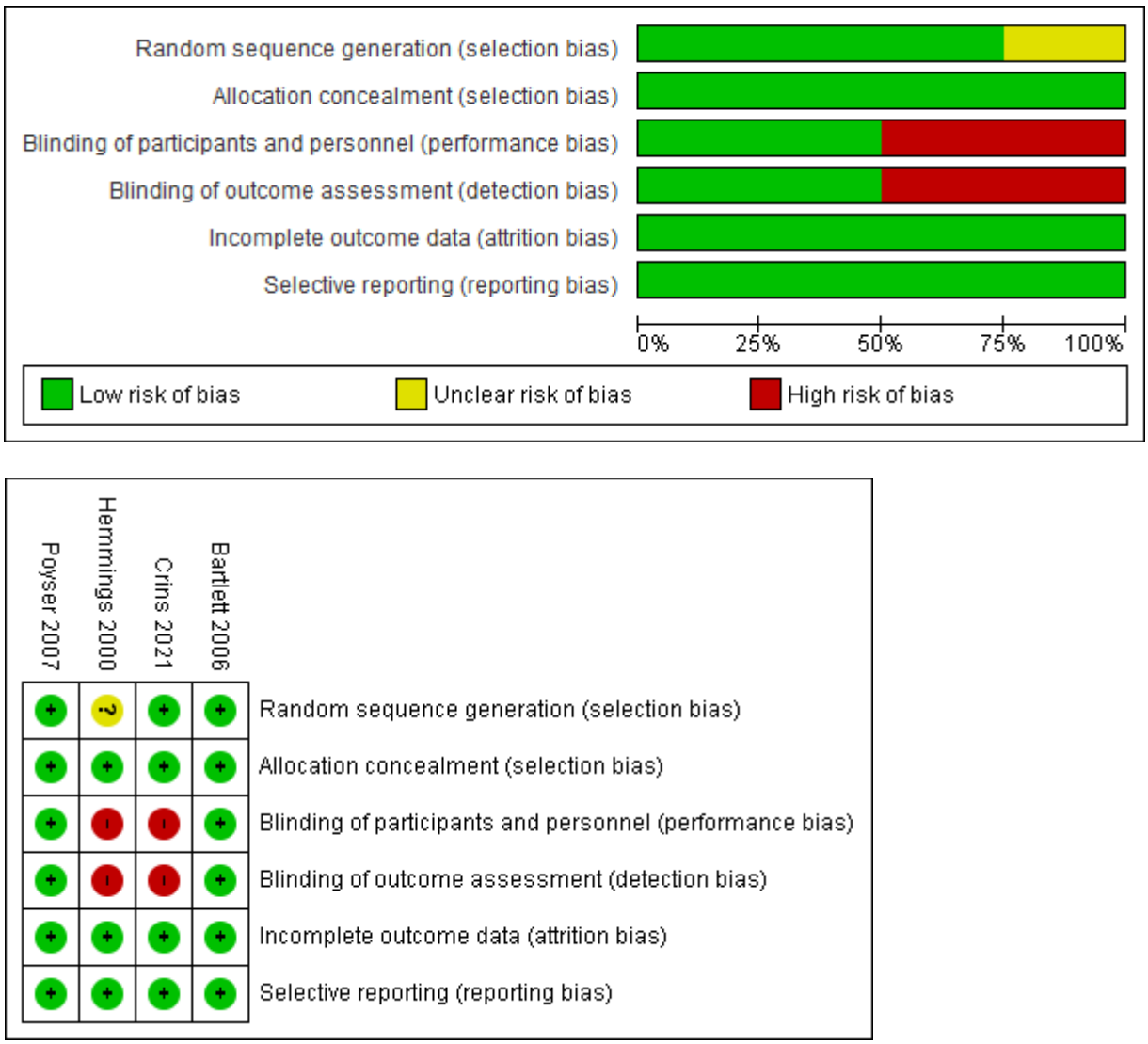


Risk of bias

Risk of Bias assessment using Cochrane Collaboration's tool for assessing Randomized clinical studies:

The Cochrane Collaboration´s tool for assessing risk of bias [32] showed that only 2 studies had high risk of bias because of blinding of participants (that is, performance bias) and blinding of outcomes (that is, detection bias) [18- 31] and 1 study that used Random sequence generation had an unclear risk of bias (that is, selection bias) [31],all of the studies had incomplete outcome data, but this represented a low risk of bias (that is, attrition bias) [8, 18, 31, 58].

Risk of bias assessment of the included Randomized Clinical Trials:



(Figure 14) Results of the Cochrane Collaboration's tool for assessing risk of bias in answer to the following items: 1, Random sequence generation (selection bias); 2, Allocation concealment (selection bias); 3, Blinding of participants and personnel (performance bias); 4, Blinding of outcome assessment (detection bias); 5, Incomplete outcome data (attrition bias); 6, Selective reporting (reporting bias)
A. Risk-of-bias graph: review of authors' judgments of each risk-of-bias item presented as percentages across all included RCT studies. **B.** Risk-of-bias summary: review of authors' judgments of each risk-of-bias item for each RCT included study:
Green: Low risk of bias. Yellow: Unclear risk of bias. Red: High risk of bias.

Table 3 *Risk of bias according to the ROB 2 tool for the included RCT studies*

	Hemmings et al., 2000	Bartlett et al., 2006	Poyser et al., 2007	Crins et al., 2021
Random sequance generation (selection bias)	Unclear	Low	Low	Low
allocation concealment (selection bias)	Low	Low	Low	Low
Blinding of participants and personnel (performance bias)	High	Low	Low	High
Blinding of outcome assessment (detection bias)	High	Low	Low	High
Incomplete outcome data (attrition bias)	Low	Low	Low	Low
selective outcome reporting (reporting bias)	Low	Low	Low	Low
Overall bias	High	Low	Low	High

Risk of bias assessment of the included studies Using ROBINS-I and The Newcastle-Ottawa Scale (NOS):

Risk of bias **according to the ROBINS-I tool for the included prospective studies and by The Newcastle-Ottawa Scale (NOS) tool for assessing the** quality **of non-randomized included studies**

Table 4 *Risk of bias according to the ROBINS-I tool for the included prospective studies (44,47)*

	Milosevic et al., 2016	Mehta et al., 2021
Confounding	Serious	Serious
Selection of participants into the study	Low	Low
Classification of interventions	Low	Low
Deviations from intended interventions	Low	Low
Missing data	Low	Low
Measurement of outcomes	Low	Low
Selection of the reported result	Low	Low
Overall bias	Serious	Serious

Table 5 *Risk of bias according to the NOS tool for the included case-series studies*

	Attin et al., 2011	**Vailati et al., 2013**
Was the study question or objective clearly stated?	Yes	Yes
Was the study population clearly and fully described, including a case definition?	Yes	Yes
Were the cases consecutive?	No	Yes
Were the subjects comparable?	Yes	Yes
Was the intervention clearly described?	Yes	Yes
Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes
Was the length of follow- up adequate?	Yes	Yes
Were the statistical methods well- described?	Yes	Yes
Were the results well- described	Yes	Yes
Quality (Total Quality Score	88.8%	100%
Risk of Bias	Low	Low

Table 6 *Risk of bias according to the NOS tool for the included case-report studies*

	Tew et al., 2022 case1	Tew et al., 2022 case 2
Were the patient's demographic characteristics clearly described?	Yes	Yes
Was the patient's history clearly described and presented as a timeline?		Yes
Was the current clinical condition of the patient on presentation clearly described?	Yes	
Were diagnostic tests or assessment methods and the results clearly described?	Yes	Yes
Was the intervention(s) or treatment procedure(s) clearly described?	Yes	Yes
Was the intervention(s) or treatment procedure(s) clearly described?	Yes	Yes
Were adverse events (harms) or unanticipated events identified and described?	Yes	Yes
Does the case report provide takeaway lessons?	Yes	Yes
Quality (Total Quality Score)	87.5%	87.5%
Risk of Bias	Low	Low

Table 7 *Risk of bias according to the NOS tool for the included retrospective cohort studies*

		Hamburger et al., 2011
Selection	Representativeness of the exposed cohort	*
	Selection of the non-exposed cohort	
	Ascertainment of exposure	*
	Demonstration that the outcome of interest was not present at the start of the study	*
Comparability	Comparability of cohorts on the basis of the design or analysis	
Outcome	Assessment of outcome	*
	Was follow-up long enough for outcomes to occur	*
	Adequacy of follow-up of cohorts	*
Overall score		

Description of studies

12 studies were included 3 were prospective studies [21,44,47] , 1 retrospective studies[26], 5 RCT [4,8,18,31,58], and 3 case series [7,69,72] as shown in (**Table 8)**

Table 8. Description of studies

Author	type of study
Tew MI et al.,2022	case seriees
Crins L.A.M.J et al.,2021	RCT
Mehta SB et al.,2021	prospective
Milosevic A et al.,2016	Prospective
Vailati et al. 2013	Case series (12)
Al-Khayatt et al.,2013	RCT
Attin et al. 2012	Case series
Hamburger et al.,2011	retrospective
Poyser NJ et al.,2007	RCT
Bartlett et al. 2006	RCT
Gow and Hemmings 2002	Prospective
Hemmings KW et al.,2000	RCT

Patient's characteristics

354 cases were included with mean age was 43.9 years, main complaint was sensitivity in the mandibular right teeth difficulty in chewing and teeth deteriorating functionally as well as esthetically as shown in **(Table 9)**

Restoration of worn dentition: The investigators of all of the studies assessed teeth wear and loss of vertical dimension: the investigators of 2 studies [69,72] reported complaints before treatments beginning.

Table 9. Patient's characteristics

author	number	age	m\f	complaints
Tew MI et al.,2022	2	54	1\1	sensitivity in the mandibular right teeth difficulty in chewing
Crins L.A.M.J et al.,2021	41	36.6	36\5	
Mehta SB et al.,2021	34	35.3		
Milosevic A et al.,2016	164	51.35	138\26	
Vailati et al. 2013	12	39.4	7\5	teeth deteriorating functionally and esthetically
Al-Khayatt et al.,2013	15	58		
Attin et al. 2012	6	35	5\1	
Hamburger et al.,2011	18	44.8	16\2	
Poyser NJ et al.,2007	18	52	14\4	
Bartlett et al. 2006	16	43		
Gow and Hemmings 2002	12			
Hemmings KW et al.,2000	16	33.8		

Protocol of Placing restorations intraorally:

Many of the included studies reported detailed protocol in placing the restorations and increasing the vertical dimension intraorally. **(Table 10)**

Vailati et al [72] followed a unified technique for all the patients included in her study, known as the **Three step technique**:

An increase in vertical dimension of occlusion (VDO) was arbitrarily decided on the casts articulated in **maximum intercuspation position (MIP)**, and transferred to the mouth by means of posterior provisional composite restorations (step 2 of the 3-step technique). Due to the presence of these posterior restorations, an anterior open bite was created.

Following an equal protocol, **after 1 month** of functioning without anterior guidance, six palatal composite restorations were placed and the anterior contacts reestablished (step 3 of the 3-step technique). According to the given interocclusal space, it was decided for each individual patient whether direct or indirect restorations were best suited. When the distance to the antagonistic teeth was more than 1 mm, an indirect approach was preferred.

Using this protocol, Vailati et al reported a high mean of favorable clinical outcomes with a high mean of VAS score of 94%. And a functional survival rate of 100%.

Mehta et al [44] followed **Direct Shaping by Occlusion technique (DSO)** protocol:

For this technique, matrix bands and wedges are inserted without interference with antagonists in the desired occlusion. The final increment of soft-composite resin is shaped by letting the patient occlude on the uncured composite. It offers a possibility to restore teeth with direct composite in occlusion, especially in clinically complicated cases like replacing existing crowns or rehabilitations in increased vertical dimension. Planning was carried out using the pre-treatment mounted study casts. The new VDO was based on an estimation of the interocclusal space necessary to permit the restoration of the anatomical forms of the teeth that were to be treated using direct resin composite. This information was transferred from the mounted gypsum casts to the patient's oral cavity, using **two bilateral polyvinyl silicone bite stops** (Star VPS, Danville Material, USA). These were fabricated at the premolar areas. The stops were to serve as supports during the restorative phase to enable the direct resin composite restorations to be placed at the new VDO. The overall aim was to attain an acceptable aesthetic outcome and a fully supported occlusion (with even centric stops in the

MIP), with the ideal of a canine-guided occlusal scheme and shared anterior occlusal contacts during mandibular protrusion.
To help plan the aesthetic prescription, an intra-oral mock-up was performed applying established concepts in smile design, the so called "lip-generated smile design". [49]
Mehta reported a mean failure rate of 2.6% after 5.5 years of follow-up.[42]

Barlett et al made a diagnostic wax up of the proposed vertical dimension was, and a **silicone matrix** was made to guide placement of the resin composite on the anterior teeth when necessary, Barlett study had failure rate of 50% from restorations used to re-establish loss of vertical dimension in worn dentition.[8]

Hamburger et al reported that before the restorative treatment was started, the increase of the vertical dimension was determined from the casts mounted in an articulator (Denar) to a level that allowed building up teeth to anatomical proportions. The new vertical dimension was copied from the cast using **acrylic or silicon stops placed in the molar area** while building up anterior teeth.
Hamburger had failure rate of 6.9%, and high mean of VAS patients 'satisfaction of (9/10) [26]

Crins et al estimated the increased Vertical Dimension of Occlusion
(VDO) from the models that were mounted in an articulator. The possibility to lengthen upper and lower anterior teeth was also established. It was assessed clinically by an intraoral mock-up on the maxilla from canine to canine. **Direct Composite Restorations (DRC**) and **Indirect Composite Restorations (ICR) o**n molars and anterior teeth.
Crins reported low AFR of 0.5–0.7% for anterior direct restorations and much higher AFR of 8.5–15% for indirect posterior composite restorations.[18]

Tew et al followed **Dahl´s concept** in his two cases and reported the usage of **fixed Dahl appliances** made from direct composite resin or metal onlays for 3 months. By following this procedure:
Study casts were mounted on a semi-adjustable articulator, a centric relation, diagnostic wax-up, increased occlusal vertical dimension of 1.5 mm. The incremental composite

build-up was achieved by using a **stable and rigid polyvinylsiloxane matrix guide** (3MTM Express XT Putty Vinyl Polysiloxane Impression Materials) derived from the lingual aspect of the diagnostic wax-up.

occlusal contact re-establishment was achieved in the second and third month after metal onlays and composite build-up retrospectively.

Tew et al reported to have no failure in restorations build up. [69]

Attin et al produced and mounted full-arch cast models on a semi-adjustable articulator. A diagnostic wax-up of all teeth was then made in a balanced occlusion, providing the intended vertical bite reconstruction

To enable accurate transfer of the waxed-up occlusion from the articulator into the patient's mouth, **wax-up-based templates** were fabricated.

After restorative treatment, all patients received acrylic splints (night guards) to protect the restorations, this could be the reason for the low AFR 2.5% after a minimum follow-up of 5.2 years. [7]

Hemming et al Occlusion was arranged to provide **even contacts in the RCP** on the restored teeth. This was commonly on the 6 maxillary anterior teeth. Canine guidance was established in lateral excursions where possible.

Posterior disclusion was measured from a wax record taken postoperatively between the first molar teeth.

Postoperative follow-up was at 1 week, 1 month, and then every 3 months until the posterior occlusion had reestablished, within the mean of (4.6 months).

Hemming reported good patient satisfaction with a success rate of 89.4%. [31]

Milosevic et al performed **Dahl´s concept**. Treatment planning involved mounted study casts on a Denar Mark II semi-adjustable articulator in **centric occlusion,** and a determination of whether or not an increase in occlusal vertical dimension (OVD) was needed. Any increase in OVD was measured on the pin. Most anterior composite build-ups were placed with the aid of a **stent constructed from a diagnostic wax-up** at an increased OVD as "Dahl" type restorations.

Milosevic reported AFR of 7% in mean follow-up of 33.8 months. [47]

Poyser et al performed **Dahl´s concept** as well.

All of the mandibular teeth were restored at the same visit. If the opposing dentition required restoration, then this was provided at a subsequent appointment, usually 4 weeks later. Canine guidance was established in lateral excursion, if possible.
Posterior occlusal contacts was re-established by 13 months.
Poyser reported high patient satisfaction and failure rate of 6% during 2.5 years of follow-up. [58]

Al Khayatt et al did a follow-up of Poyser Randomized clinical trial after 7 years, and reported 85% survival rate. [4]

Treatment characteristics:

Different restorative materials was used like metal onlays [69] , anterior Feldspathic Veneers [72] , palatal Veneers and Tabletops [18] , direct Resin Composite restorations Anterior and Posterior ((using: Clearfil AP-X, Spectrum®, Hybrid resin composite, fine Hybrid resin composite Herculite XRV composite, Durafill composite, Ceromer and microfilled composite) [4,7,21,26,31,44,47, 58,72] .
As regard to site 3 investigators reported the wear to be in the Anterior site [21,47,72] and 3 investigators reported the wear to be in the Posterior site [7,8,69] and 2 investigators reported the wear to be in the Anterior and Posterior site [18,26].
All the investigators reported the **restorative procedure** whether it was direct or indirect restoration [4,7,8,18,21,26,31,44,47,58,69,72] . Restorative procedures used mainly was direct in 8 studies [4,7,26,31,44,47,58,69] and in indirect in 1 study [21]; 3 studies used both direct and indirect. [8,18,72].

Placement techniques for intraorally Composite build up;
5 studies investigators reported using different techniques in order to help placing the Composite build-up intraorally in the most accurate ways, after measuring the required increasing in vertical dimension on mounted casted on

semi adjustable articulator and doing wax up, then transferring this increase intraorally[7,8,26,47,69,72]

Two investigator reported increasing the vertical dimension with direct shaping by occlusion technique (DSO) [18,44]

In other 2 studies that established Dahl's concept [31,58] on the anterior teeth, the procedure was done directly intraorally with direct composite , Canine guidance was established when possible, the posterior disclusion was es re-established in (4.6,13) months respectively.

Mean follow-up for restorations in months after delivering was **41.3 months,** this was reported by the investigators in all the 12 studies[4,7,8,18,21,26,31,44,47,58,69,72] **as shown in Table 10**

Table 10. Treatment characteristics

Author	**Restorative materials**	**site**	**Restorative procedures**	**aided placement techniques for intraorally Composite build up**	**Follow-up\mn**
Tew MI et al.,2022	Direct resin composite and metal onlays	Posterior (Dahl´s concept)	Direct	stable and rigid polyvinylsiloxane matrix guide from diagnostic wax up	12
Crins L.A.M.J et al.,2021	palatal veneers ,tabletops resin composite	maxillary anterior teeth,first molar	direct , indirect	Mock up and DSO Technique	40
Mehta SB et al.,2021	resin composite restorations (Clearfil AP-X		Direct	Direct shaping protocol DSO	66
Milosevic A et al.,2016	Spectrum1 (DentsplyDeTrey).	Anterior (Dahl´s concept)	Direct	stent constructed from a diagnostic wax-up	33.8
Vailati et al. 2013	Direct and indirect Composite and feldspathic veneers	anterior teeth	Anterior with palatal direct composite and buccal porcelain veneer and Posterior with direct or indirect	Posterior provisional composite restoration for one month	50

			restorations to increase the vertical dimension		
Al-Khayatt et al.,2013 2013*	Hybrid resin composite	lower anterior teeth	Direct		84
Attin et al. 2012	Fine hybrid composite	Posterior	Direct	wax-up-based template aided placement technique	67
Hamburger et al.,2011	Hybrid resin composite	Anterior and posterior	Direct	wax-up-based acrylic or silicon stops placed in the molar area while building up anterior teeth	47.7
Poyser NJ et al.,2007	Herculite XRV composite	Anterior then posterior (Dahl´s concept)	Direct	Direct composite restoration, without wax up	30
Bartlett et al. 2006	microfilled composite	Posterior	direct , indirect	silicone matrix was made to guide placement of the resin composite on the anterior teeth	12
Gow and Hemmings 2002	palatal veneer restorations with ceromer	Anterior (Dahl's concept)	indirect		24
Hemmings KW et al.,2000	Durafill composite .Herculite XRV composite	Anterior	Direct	Direct composite restoration, without wax up	30

Outcome

Investigators of 2 studies [47,58] reported Attrition in 68 cases, Increase in OVD (n) was reported in 3 studies [47,58,69] among 151 cases, Bruxism was reported in 3 studies [26,47,58] among 155 cases, mean VDO increase in (mm) was 2.3 extracted from 7 Studies [7,8,18,26,47,58,69] , continued tooth wear stated in 1studies [31] in 5 cases as shown in **Table 11**

Table 11. Outcome

Author	Attrition	Increase in OVD (n)	Bruxism	VDO inc (mm)	continued tooth wear
Tew MI et al.,2022		2		1.5	
Crins L.A.M.J et al.,2021				2.5	
Mehta SB et al.,2021					
Milosevic A et al.,2016	66	135	136		
Vailati et al. 2013			4		
Al-Khayatt et al.,2013 2013*					
Attin et al. 2012				2.5	
Hamburger et al.,2011			15	3	
Poyser NJ et al.,2007	2	14		2.75	
Bartlett et al. 2006				2.5	
Gow and Hemmings 2002					
Hemmings KW et al.,2000				1.6	5

Outcome measures

A total number of restorations was 3767 , failure was in 206\3767 , 0 failure was reported in 3 studies [7,69,72] , the highest rate failure was in [8] with 50% of failure, in this Randomized Clinical Trial the investigator concluded that direct and indirect resin composites for restoring worn posterior teeth are contraindicated , this was

followed by Randomized clinical trials [18] with a failure rate of 15.1% in indirect posterior composite restorations , whereas a maximum of 5.4% failure rate was recorded in the same study for direct restorations. Third RCT [4] with a failure of 15% this can be due to the long follow-up period that the investigator had over 84 months. The highest failure rates were recorded in Randomized Clinical Trials, this can be due to the fact that RCT studies gives always the most accurate results and is higher evidenced based than other methodologies such as cohort studies and case series. Failure rate was 9.94% in all included studies with a minimum of 0% and a maximum of 50%, the wide variation between the failure rate in included studies.

Mean time to reported failure was 37.5 months and success was in 3350\3767 as shown in **Table 12**

Table 12. Outcome measures

Author	number of restoration	failure	Time to failure\mn	Failure percentage	Functional Survival \n
Tew MI et al.,2022	4	0		0%	2
Crins L.A.M.J et al.,2021	408	62		15.1%	346
Mehta SB et al.,2021	1269		62.4	2.2%≤2.9%	1219
Milosevic A et al.,2016	1010	71	33.8	7%	939
Vailati et al. 2013	204	0		0%	204
Al-Khayatt et al.,2013	85	13		15%	72
Attin et al. 2012	75	0		2.5%	75
Hamburger et al.,2011	332	23		6.9%	309
Poyser NJ et al.,2007	169	10		6%	
Bartlett et al. 2006	32	16		50%	16
Gow and Hemmings 2002	75	10	24	13.3%	65
Hemmings KW et al.,2000	104	11	30.1	10.5%	93

Al Khayatt AFR:

Al Khayatt et al [4] did a follow-up of 7 years on the patients included in Poyser et al. [58]

However, this study was restricted to worn mandibular anterior dentition only.

A total of 145 direct composite restorations were placed on the worn anterior dentition by Poyser et al [58] only 85 direct composite restorations placed on the anterior mandibular dentition were included for this further analysis. [4]

However, Al Khayyat et al. set high successful criteria for the restorations, and all these criteria should be fulfilled at 7-years follow-up in order for the restoration to be a success:

1- Survived (not been lost, replaced or repaired) at 7 years
2- 50% or more of the restorative material was remaining regardless of wear or fracture
3- No or mild restoration staining.
4- No surface roughness
5- No marginal discoloration.
6- A clinically acceptable shade match
7- A clinically acceptable marginal adaptation

Of the 85 restorations included for analysis, 43 restorations (51%) were successful. [4]

In the same study survival' of a restoration was defined as any restoration that had not been lost, replaced or repaired in the preceding 7 years.

Seventy-two of the 85 restorations (85%) had survived at the 7-year follow-up.

As mentioned earlier, we included the functional survival rate in our study.

Meta-analysis

The main causes of teeth wear such as attrition and bruxism, were analyzed in this study.

Additionally, the increase in vertical dimension was very important to be assessed.

Not all the studies documented these details, and therefore, **subgroups** were formed concerning each one.

In addition, the failure rate and follow-up period were documented in **all** studies and could be analyzed in our Meta-analysis with a random effect model and explained in forest plot figures.

Many other problems were mentioned in some studies **individually,** such as main complaints, time to final restorations cementation, and patients' satisfaction, but it was impossible to include all the information mentioned in the study mainly due to lack of data and standardized criteria.

Attrition

2 studies mentioned attrition showed significant heterogeneity between studies with event rate 27% with 68 events of attrition among 182 cases evaluated **(Table 13).** Significance level: The significance level is stated as 0.008*, I2 (inconsistency): The I2 value of 85.52%, and (95% CI: 41.59 to 96.41), these values suggest that significant heterogeneity in the results across studies is attributed not by chance alone but by genuine differences in treatment effects, this could be caused by the differences in study design (RCT and prospective)

Table (13): Meta-analysis for Attrition

Study	Total number	Event	Event rate (%) (Proportion)	95% CI of rate (%)
Milosevic A et al.,2016	164	66	40.244	32.673 to 48.174
Poyser NJ et al.,2007	18	2	11.111	1.375 to 34.712
Total (random effects)			27.05	5.518 to 57.116
Test for heterogeneity				
Q			6.9039	
DF			1	
Significance level			0.0086*	
I^2 (inconsistency)			85.52%	
95% CI for I^2			41.59 to 96.41	

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

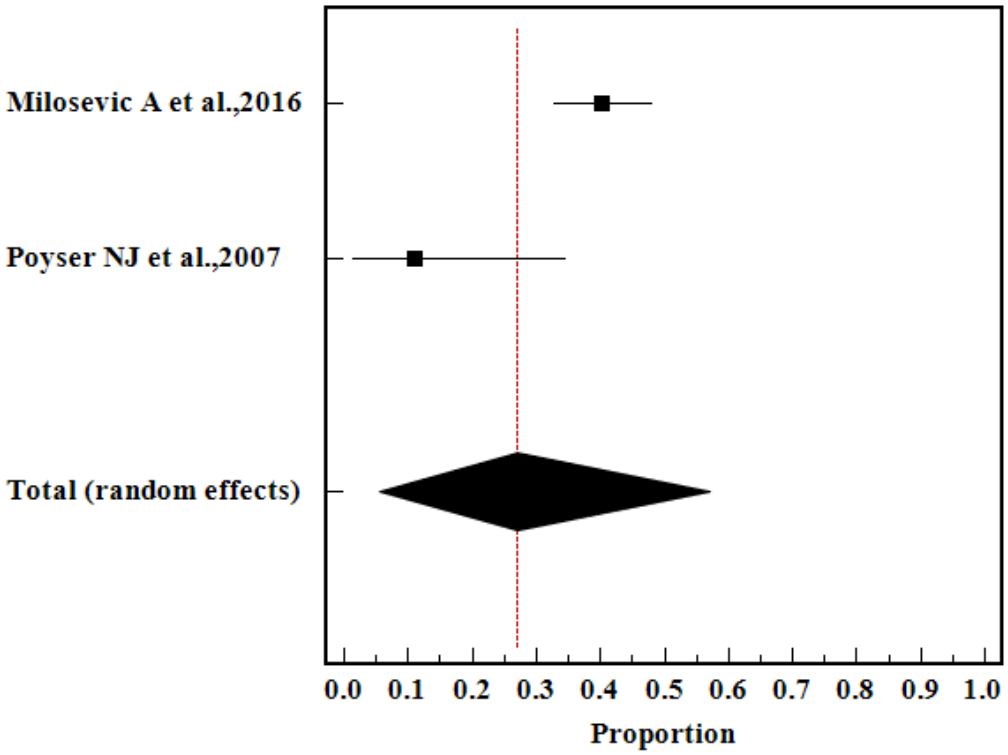


Figure (15): Forest plot for Attrition

Bruxism

3 studies mentioned bruxism, the event rate was dominant and reported in majority of cases 69.817% (in 155 cases out of 194 case) (95% CI: 53.18 to 94.75%), the high event rate is predictable as one of the most important causes for teeth wear is bruxism. Significance level: The significance level is stated as 0.0017*, I2 (inconsistency): The I2 value of 84.32%, these values suggest significant heterogeneity between the studies. (**Table 14)**

Table (14): Meta-analysis for Bruxism

Study	Total number	Event	Event rate (%) (Proportion)	95% CI of rate (%)
Milosevic A et al.,2016	164	136	82.927	76.279 to 88.345
Vailati et al.,2013	12	4	33.333	9.925 to 65.112
Hamburger et al.,2011	18	15	83.333	58.582 to 96.421
Total (random effects)			69.817	43.081 to 90.783
Test for heterogeneity				
Q	12.7587			
DF	2			
Significance level	0.0017*			
I^2 (inconsistency)	84.32%			
95% CI for I^2	53.18 to 94.75			

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

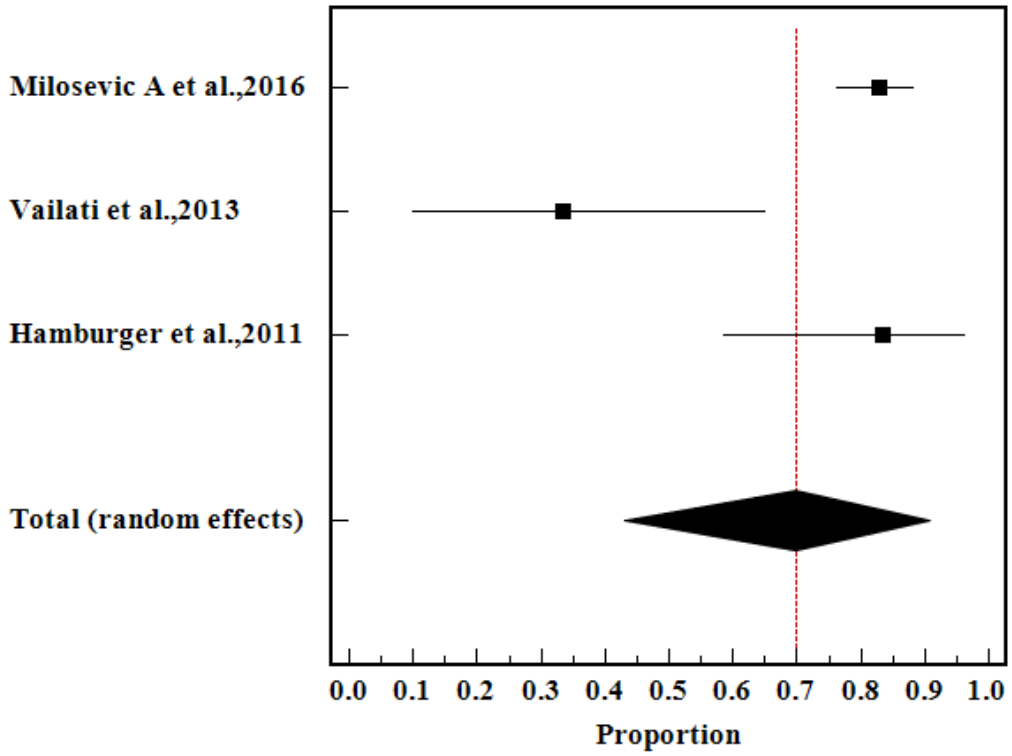


Figure (16): Forest plot for Bruxism

Increase in OVD

3 studies mentioned **Increase in OVD** the Meta-analysis reported I2 value of (0.00%) this suggests that there is no significant inconsistency or heterogeneity among the studies, also the Q Test for heterogeneity was 0.5636 this value suggests that the observed variability among the studies is small.

The insignificant heterogeneity is due to the similarity of the approach in all studies, the 3 studies had the same patient characteristics (patients with wear dentition, same intervention protocol (increase in vertical dimension)

The event rate was 81.725% (95% CI: 0.00 to 88.10) for 3 studies (153 incidence out of 186 total case) **Figure (17):**

Table (15): Meta-analysis for Increase in OVD (n)

Study	Total number	Event	Event rate (%) (Proportion)	95% CI of rate (%)
Tew MI et al.,2022	4	4	100	15.811 to 100.000
Milosevic A et al.,2016	164	135	82.317	75.602 to 87.826
Poyser NJ et al.,2007	18	14	77.778	52.363 to 93.591
Total (fixed effects)			81.725	75.428 to 86.987

Test for heterogeneity	
Q	0.5636
DF	2
Significance level	0.7544
I^2 (inconsistency)	0.00%
95% CI for I^2	0.00 to 88.10

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

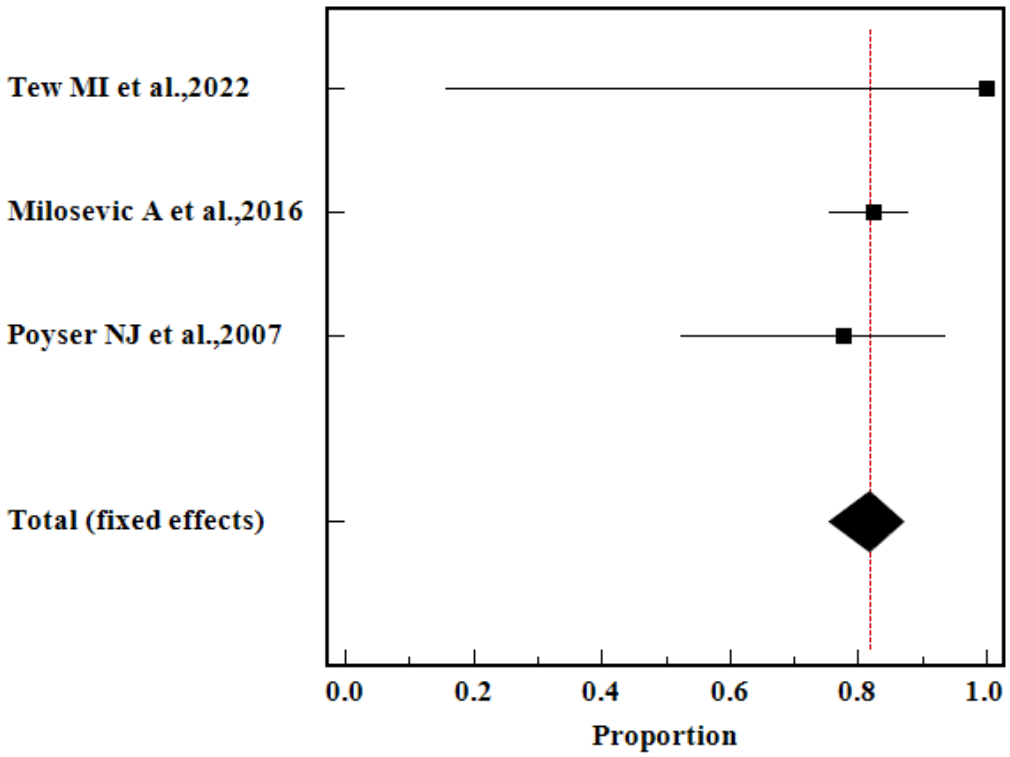


Figure (17): Forest plot for Increase in OVD (n)

VDO increase in (mm)

7 studies mentioned **mean VDO inc (mm)**, the I2 value between the 7 studies was 0% and the significance level is stated as p=0.9648. These values indicates that the observed heterogeneity is not statistically significant. In other words, the variation among the estimated increase in vertical dimension s is likely due to indication rather than genuine differences in treatment effects. (95%CL: 0.00% to 0.00%) suggests that the true value of I2 is likely to be exactly zero.

Table (16): Meta-analysis for VDO inc (mm)

Study	Total number	Estimate	Standard Error	95% CI
Tew MI et al.,2022	4	1.5	0.9	-0.264 to 3.264
Crins L.A.M.J et al.,2021	41	2.5	0.8	0.932 to 4.068
Attin et al. 2012	6	2.5	1.7	-0.832 to 5.832
Hamburger et al.,2011	18	3	1.7	-0.332 to 6.332
Poyser NJ et al.,2007	18	2.75	1.5	-0.190 to 5.690
Bartlett et al. 2006	16	2.5	1.1	0.344 to 4.656
Hemmings KW et al.,2000	16	1.6	1.3	-0.948 to 4.148
Total (random effects)				1.376 to 3.070
Test for heterogeneity				
Q	1.4172			
DF	6			
Significance level	P = 0.9648			
I^2 (inconsistency)	0.00%			
95% CI for I^2	0.00 to 0.00			

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

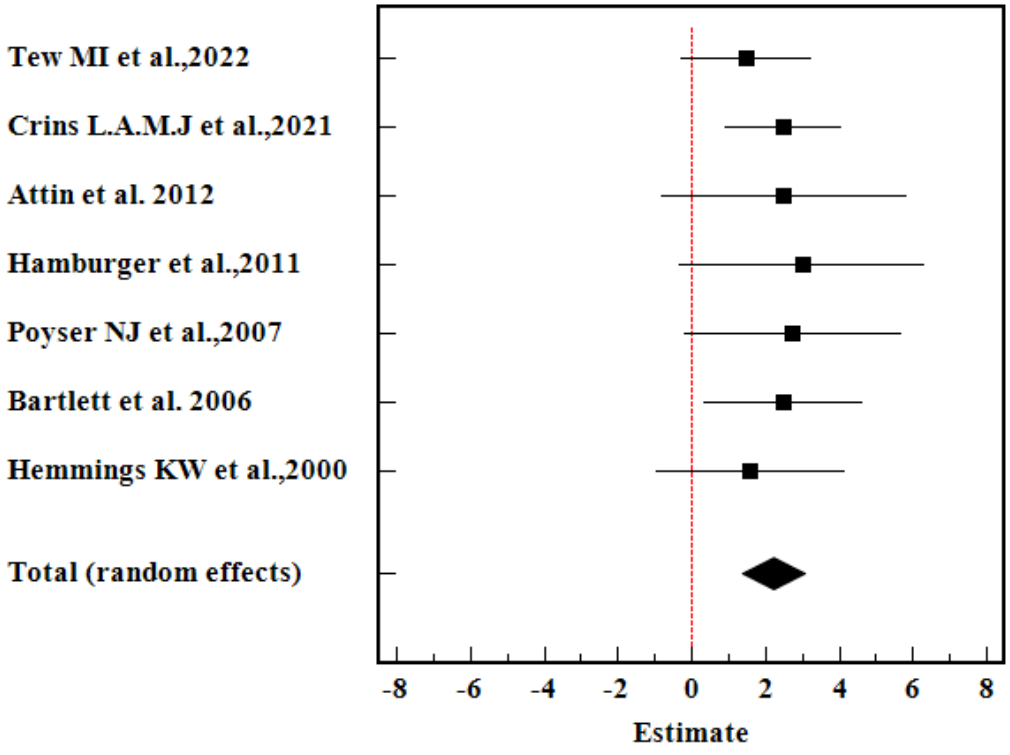


Figure (18): Forest plot for VDO inc (mm)

Time to Follow-up:

The mean of observation period in all the 12 included studies was **41.3 months** with a minimum of 12 months and maximum of 84 months. The heterogeneity was significant among the included studies, P < 0.0001 , I^2 (inconsistency) 90.82% (95% CI: 85.89 to 94.02%). (Table 17, Figutre19)

Table (17): Meta-analysis for follow-up\mn

Study	Total number	Estimate	Standard Error	95% CI
Tew MI et al.,2022	4	12	5.6	1.024 to 22.976
Crins L.A.M.J et al.,2021	41	40	3.8	32.552 to 47.448
Mehta SB et al.,2021	34	66	7.6	51.104 to 80.896
Milosevic A et al.,2016	164	33.8	4.5	24.980 to 42.620
Vailati et al. 2013	12	50	6.9	36.476 to 63.524
Al-Khayatt et al.,2013	15	84	7.8	68.712 to 99.288
Attin et al. 2012	6	67	6.8	53.672 to 80.328
Hamburger et al.,2011	18	47.7	5.8	36.332 to 59.068
Poyser NJ et al.,2007	18	30	4.9	20.396 to 39.604
Bartlett et al. 2006	16	12	5.9	0.436 to 23.564
Gow and Hemmings 2002	12	24	10.8	2.832 to 45.168
Hemmings et al.,2000	16	30	7.9	14.516 to 45.484
Total (random effects)				29.987 to 52.377
Test for heterogeneity				
Q			119.7635	
DF			11	
Significance level			P < 0.0001	
I^2 (inconsistency)			90.82%	
95% CI for I^2			85.89 to 94.02	

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

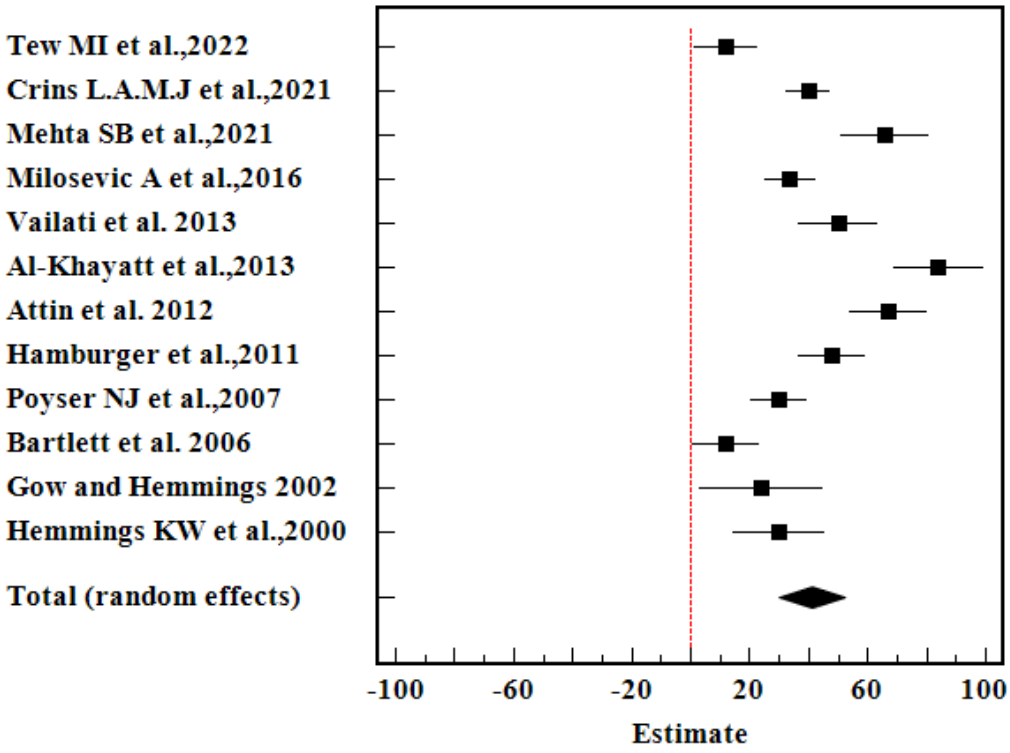


Figure (19): Meta-analysis for follow-up\mn

Time to failure\mn

4 studies mentioned **mean Time to failure\mn** shows the mean of failure to be reported **37.5 month** for 2458 cases.

the results of this meta-analysis indicate that there is significant heterogeneity among the studies included, I2 value was reported to be (75.50%), (95% CI:32.32% to 91.13%) (Table 18, Figure 20)

Table (18): Meta-analysis for Time to failure\mn

Study	Total number	Estimate	Standard Error	95% CI	Random Weight (%)
Mehta SB et al.,2021	1269	62.4	8.9	44.95 to 79.84	26.1
Milosevic A et al.,2016	1010	33.8	12.5	9.300 to 58.300	21.38
Gow and Hemmings 2002	75	24	6.8	10.67 to 37.32	28.82
Hemmings KW et al.,2000	104	30.1	10.7	9.128 to 51.072	23.7
Total (fixed effects)				27.34 to 44.98	100
Total (random effects)				18.86 to 56.26	100
Test for heterogeneity					
Q	12.2467				
DF	3				
Significance level	0.0066*				
I^2 (inconsistency)	75.50%				

95% CI for I^2	32.32 to 91.13

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit)

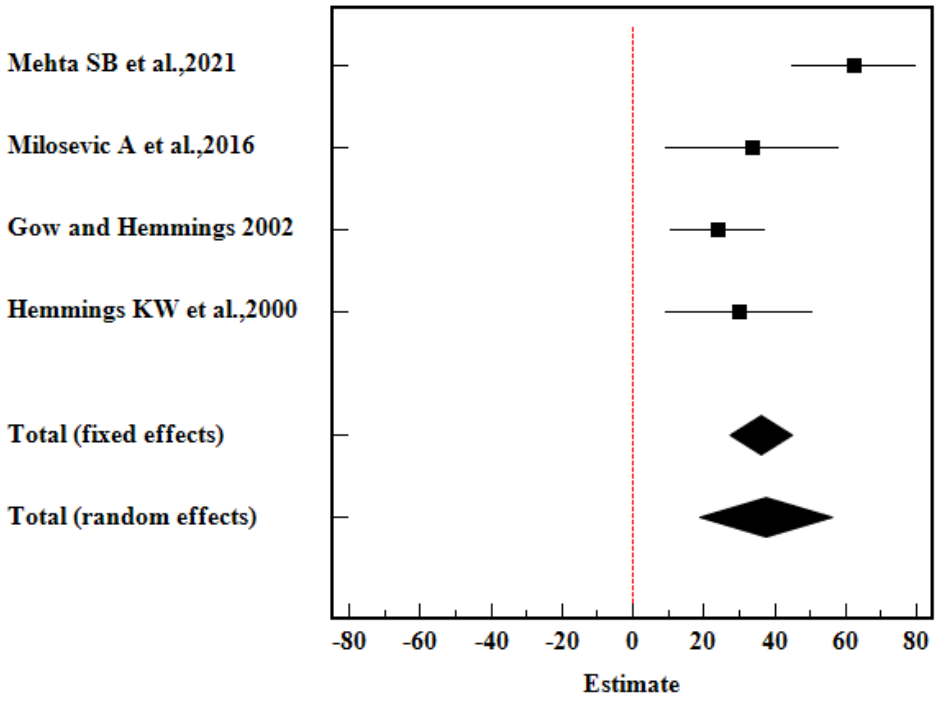


Figure (20): Forest plot for Time to failure\mn

Failure:

12 studies mentioned **failure** shows significant heterogeneity between studies with event rate 9.94%

I^2 value was very high 93.85% this suggests inconsistency between the studies contributing in the variation of observed failure.

Significance level: The significance level is stated as "<0.0001*", which means that the observed heterogeneity is statistically significant, variability in the results across studies is attributed to genuine differences in studies and unlikely to be caused by chance alone.

In this study RCT studies, cohort, case series were included, and it is predictable to have a significant variability among studies when all are included in one analysis.

Table (19): Meta-Analysis for Failure

Study	Number of restoration	Event	Event rate (%) (Proportion)	95% CI of rate (%)
Tew MI et al.,2022	4	0	0.000	0.000 to 60.236
Crins et al.,2021	408	62	15.196	11.853 to 19.053
Mehta SB et al.,2021	1269	34	2.679	1.862 to 3.724
Milosevic et al.,2016	1010	71	7.030	5.531 to 8.785
Vailati et al. 2013	204	0	0.000	0.000 to 1.792
Al-Khayatt et al.,2013	85	13	15.294	8.403 to 24.732
Attin et al. 2012	75	0	0.000	0.000 to 4.800
Hamburger et al.,2011	332	23	6.928	4.442 to 10.214
Poyser NJ et al.,2007	169	10	5.917	2.874 to 10.612
Bartlett et al. 2006	32	16	50.00	31.887 to 68.113
Gow & Hemming 2002	75	10	13.333	6.583 to 23.157
Hemmings et al.,2000	104	11	10.577	5.400 to 18.137
Total (random effects)			8.209	4.618 to 12.714
Test for heterogeneity				
Q			178.8996	
DF			11	
Significance level			<0.0001*	
I^2 (inconsistency)			93.85%	
95% CI for I^2			91.00 to 95.80	

Q: Total variance for heterogeneity **I^2: Observed variance for heterogeneity**
CI: Confidence interval (LL: Lower limit – UL: Upper Limit) **DF: Degree of freedom**

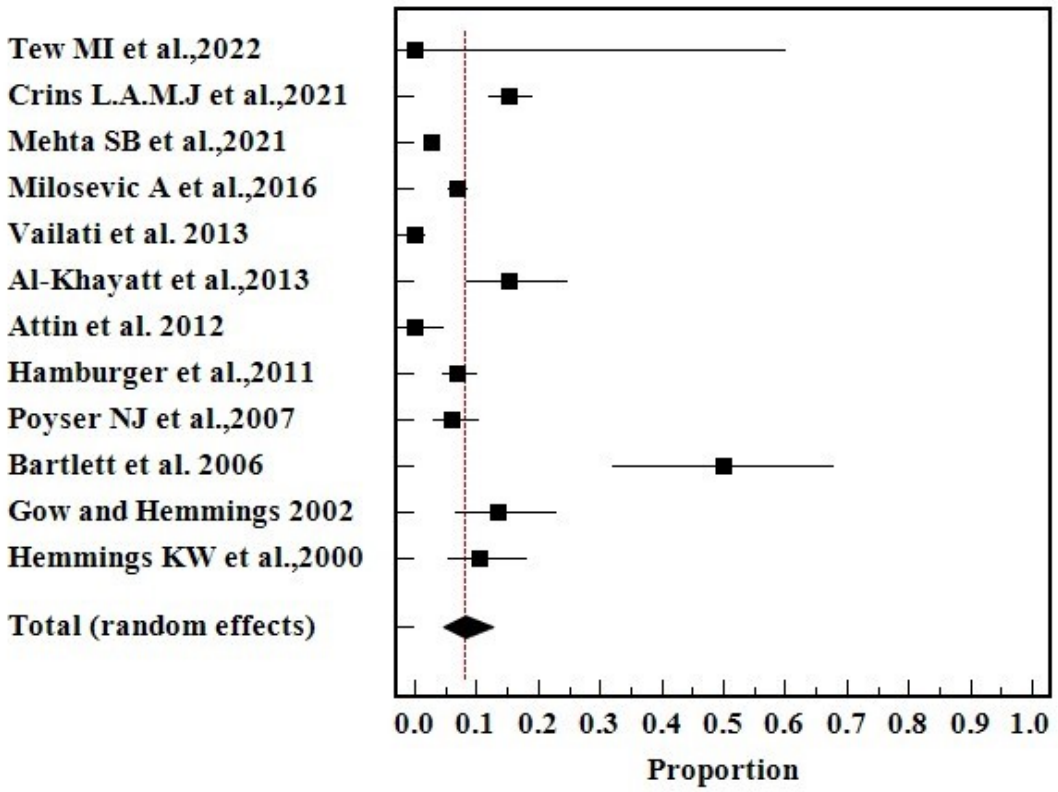


Figure (21): Meta-analysis for failure

Post-operative night guards appliances

Only one investigator [7] delivered acrylic splints (night guards) after restorative treatment to **all** the patients included in the study to protect the restorations. And the functional survival rate in this study was proven to be 100%.

In 3 other studies [18,26,72] post operative occlusal acrylic splints were not prescribed at the outset; however, where failure was subsequently reported due to fracture or wear because of bruxism tendencies, a night guard was subsequently advised. Patients who showed parafunctional habits and were prescribed night guards were (10%,60%,30%). Of the total of patients included in their studies. [18,26,72]

One study [44] settled for advising patients with multiple fractures to wear night guard without specifying the kind of occlusal splint nor the exact number of patients suffering from the fractures.

All the other investigator did not mention the use of any occlusal splint post operatively. [4,7,8,21,31,47,58,69]

Patients´ Satisfaction using (VAS):

5 of the included studies reported patients satisfaction in a visual analog score (VAS); all of them found patients' satisfaction to be between (good – high) regarding the performed treatment. [7,26,31,58,72]

DISCUSSION

Tooth wear represents an irreversible, multifactorial, non-carious loss of dental hard tissues based on erosive, abrasive and/or attritional effects. Epidemiological data suggest that tooth wear is becoming increasingly common, especially in younger populations, with prevalence and extent rising with age. Apart from epidemiological concerns, tooth wear may manifest itself in severe forms and lead to tooth hypersensitivity, loss of vertical dimension of occlusion, esthetic impairment, and compromised oral health-related quality of life at the individual patient level. [64]

In the current study, we aimed to assess the increasing of vertical dimension in worn dentition using fixed, minimal invasive, direct and indirect restorations through A systematic Review and Meta-analysis.

A total of 12 studies, consisting of 354 participants were included in this review. The mean age was 43.9 years, with main complaint being sensitivity and teeth deteriorating functionally as well as esthetically.

Restorative procedures used mainly were direct in 8 [4,7,26,31,44,47,58,69] studies while only 1 of the included studies reported the use of indirect restorations in the rehabilitation of tooth wear [21] . Additionally, 3 studies reported a combination of direct and indirect restorations. [8,18,72]

Indeed, comparative studies with direct vs. indirect restorative techniques are scarce in the current literature. Contradictory discoveries were perceived concerning the type of restoration with better clinical performance.

In our review, the use of direct restoration in tooth wear patients was more favorable with higher success rate [18], as per Crins et al concluded in his study that indirect composite is not suitable for use in severe tooth wear patients, whereas satisfactory performance was recorded after 3 years of follow-up in direct composite restorations for anterior and posterior teeth. However, this contradicts with the study of Vailati et al [72] ,also included in this review, and the study of Jaeggi et al which recommends the use of an indirect restorative material when the VDI exceeds 2 mm; the reason of this recommendation from Jaeggi point of view is that restoring the anatomy and occlusion is difficult and depends on the sculpting skills of the dentist. [34]

Another study, Barlett [8] et al, concluded a contraindication of direct and indirect composite restorations in wear dentition.

Different protocols were performed in the included studies in order to increase the vertical dimension intraorally; these were mentioned in details in results. However, in most cases, an estimation of the required increase in OVD was done prior to the treatment on mounted casts, and a diagnostic wax up was found favorable and helpful to transfer accurately the amount of increase in vertical dimension intraorally. This correlates with literature recommendations while increasing vertical dimension.[2,61]

Regarding to site distribution in current review, teeth worn was reported equally in anterior and posterior areas; 3 studies reported the wear to be in anterior [21,47,72] ,3 in the posterior [7,8,69] and 2 reported a combination between anterior and posterior area.[18,26]

Different approaches were used to rehabilitate whole dentitions; although technique variations could be a factor limiting the comparison among different studies, all AFR were still acceptable. When the Dahl approach was used, only anterior or posterior teeth were restored with composite restorations, leaving the other region without any occlusal contact until the occlusion is reestablished by itself after a follow-up period that varied between (2-13) months, the AFR found ranged from 0% to 13.3% with mean failure of 6.7% in periods from 12 to 34 months of follow-up. [21,31,47,58,69]

Some of the studies restored all teeth affected by wear, starting in the anterior region as a reference and had 6.9% AFR Hamburger JT et al.[26] Other studies Attin T et al [7] restored all of the affected teeth by starting from the posterior region to establish the occlusal vertical dimension. In this study the mean of functional survival rate from the first and second cohort study (94.9% and 100%) respectively was calculated and reported to be (97.5%) leading to failure rate of 2.5% as mentioned, only the restorations that needed to be replaced was considered as failure.

In current review, there are different restorative materials used like metal onlays [69] , anterior Feldspathic Veneers [72], palatal Veneers and Tabletops [18], direct Resin

Composite restorations Anterior and Posterior ((using: Clearfil AP-X, Spectrum®, Microfilled composite, Hybrid resin composite, fine Hybrid resin composite Herculite XRV composite, Durafill composite, Ceromer and microfilled composite).[4,7,21,26,31,44,47, 58,72]

For the definitive treatment procedure, both composite resin and glass ceramics were the most commonly used restoratives and were used in at least 10 of the included studies. [4,7,8,21,26,31,44,47,58,72]

According to the literature, composite resin seems to be a suitable restorative material for restoring worn dentition. [45]

However, there isn´t enough evidence in the superiority of any restoration technique to ensure the best clinical performance and outcomes when treating worn dentition.[30]

In Barlett et al randomized clinical trial direct and indirect restorations were performed, occlusal vertical dimension was increased only 2 to 3 mm, a diagnostic wax up of the proposed vertical dimension was made, and a silicone matrix was made to guide placement of the resin composite. Despite all the previously mentioned, a total failure of 50% ((22%) fractured and (28%) lost) was reported. The investigator in this study concluded that direct and indirect resin composites for restoring worn posterior teeth is contraindicated. [8]

The high failure rate might be explained by the fact that the restorations were made of micro-filled composites, which have been shown to possess very low physicomechanical properties, such as flexural strength and might therefore be contraindicated for extensive restorations under high masticatory load like the posterior teeth. [23] This correlates as well with the study of Hemming et a [31] which stated that Hybrid composites had shown to perform better than microfill composites in cases with dental wear.

In the long term, there seems to be little difference between direct and indirect composites. [74] Therefore, other indirect materials are indicated for long-term stability; glass ceramic (lithium disilicate) and gold are preferred. [16,24]

Traditional ceramic/gold full crowns in the posterior worn teeth had an AFR of 2.6 % in a six years follow-up, showing root canal therapies, extractions and crown re-cementation as the clinical complications associated to the indirect treatment failures.[66] Indirect palatal ceromer veneers had an AFR of 6.9 % in a 2 years follow-

up, [21] not representing a greater advantage when compared to direct composites. Similar AFR of 6.7 % in a 10 years follow-up and, was found in another study which compared indirect and direct hybrid composites. [25]

Increase in OVD shows insignificant heterogeneity between studies with event rate 81.725% [47,58,69] ,and an average of vertical dimension increase of 2.3 mm. [7,8,18,26,31,58,69]

The VDI was tested before treatment in some of the included studies; [72] .This step was determined to be a useful and common step in literature usually performed with a removable occlusal appliance..

However, Crins reported in an updated randomized clinical trial that a removable appliance is not indicated to functionally test the increased VDO prior to restorative treatment in patients with tooth wear. [17]

According to previous studies, testing the VDI is only needed when the remaining interocclusal rest space after rehabilitation will be less than 2 to 3 mm. [45,70]

Increasing the occlusal vertical dimension seems to be a safe procedure (signs and symptoms tend to be self-limiting) and well accepted up to 5 mm. [1] The testing periods was not common in this study, as the maximal increase in vertical dimension in the included studies did not exceed 5 mm. If necessary, testing the VDI for a period of at least 1 month for 24 hours a day is probably advised. [45] In addition, Abduo concluded that testing patient acceptance or adaptation with a removable method is less predictable than with a fixed method. [1]

12 studies included in this study mentioned failure shows significant heterogeneity between studies with event rate 9.9% .

In comparison to Tauböck TT et al.; who used direct composite restoration in order to restore severly worn dentition and increase the vertical dimension, found that three out of 164 restorations needed replacement and were therefore considered as failures. The success rate of the restorations was 78.0% at 10.7 years. The functional survival of the restorations was 98.2%. [68]

Previous studies with observation times up to four years also found high success rates of full rehabilitations with direct composite build-ups for treatment of severe tooth wear [26,40].

Summery

Tooth wear is loss of dental hard tissue due to non-carious processes and can be identified as attrition, abrasion, or erosion . Tooth wear may impact on an individual's perception of daily life and should be carefully considered . Moreover, an increased incidence of tooth wear is reported in young populations, which could represent an emerging dental problem for future generations . Irrespective of epidemiological concerns or even etiological factors, at an individual level, tooth wear may become severe and in many clinical situations, a restorative treatment has to be considered because severe tooth wear may result in loss of vertical dimension of occlusion, tooth sensitivity, decreased oral health related quality of life and aesthetic complaints .

In these cases, the choice of the restorative strategy should be based on evidence based treatment protocols. However, the most common published studies are single case reports or case series showing direct and indirect restorative techniques.

The traditional restorative treatment for greater amounts of tooth loss is the fabrication of indirect restorations such as crowns and onlays instead of the use of direct approaches. Recently, "minimally invasive treatment concepts" with partial covering all-ceramic restorations became also recommended. However, direct resin composites have the potential for direct rehabilitation of severely worn dentitions as well, with the advantages of having relatively low cost and preservation of sound tooth tissues, also this approach is less invasive than tooth preparation for indirect restorations.

In the current study, we aimed to assess the increasing vertical dimension in worn dentition using fixed, minimal invasive, direct and indirect restorations through A systematic Review.

A total of 12 studies, consisting of adult patients suffering from teeth wear and loss in vertical dimension were included in this review. 354 cases were included with mean age was 43.9 years.
Minimal invasive, fixed and adhesive restorative procedures were performed for all patients.

Anterior and Posterior Region suffered from wear and were treated equally in the included studies.

In current review the most common restorative materials resin composite restorations, followed by ceramic veneers and metal onlays.

The increase in OVD in all the studies did not exceed 5 mm, with event rate 81.725%. this showed insignificant heterogeneity between studies, which can be due to the fact that the studies are reasonably similar to each ither regarding the effect being measured (increase od VDO).

All the included studied had follow-up period of minimum 12 months, and they all reported failure event, failure shows significant heterogeneity between studies ranging between 0% and 50% with an event rate of 9.94%.

Limitations

Considering limitations of this study, meta-analysis showed significant heterogeneity in some of the tests such as failure, attrition and bruxism. This can limit the evidence of the outcomes due to the high variation between studies reporting the treatment outcomes.

Statistical heterogeneity exists in our systematic review due to the fact that the true effects are being evaluated differently between studies with variation in sample size, interventions, follow-up period, design quality, or outcomes measured.

It is also important to consider the variability in research methodologies and characteristics as not only Randomized clinical trials were included in our search but cohort studies (prospective and retrospective) and case series were included as well.

However, meta-analysis was performed only for articles that had clearly reported teeth wear and thoroughly reported the restorative procedure in a minimal invasive way.

In conclusion, despite the extensive effort and analyses, precise answers to meta-analytic questions about subjective issues is certainly hard to get in case of critical limitations in the data included in the Meta-analyses.

Conclusion

There is no strong evidence supporting a specific material and technique to restore teeth with severe tooth wear. Although resin composite appears to be a feasible option to restore teeth with moderate to severe wear, additionally, indirect minimal invasive technique is showing a promising results.

In this systematic review, 91% of the included studied found direct and indirect minimal invasive techniques to be safe, promising and successful ways to re-establish the loss in vertical dimension.

Rehabilitation of posterior wear is especially challenging due to high masticatory load and therefore may require higher maintenance.

Dahl´s concept in the anterior as well as posterior region was suggested and advised in some of the included studies as a minimal invasive and safe approach to gain adequate interocclusal clearance for the final restorations.

Clinical studies are necessary to produce more definitive conclusions.

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Supplementary details (1) Study protocol

Type of Study: A Systematic review

Search strategies:

This systematic review will be conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Rethlefsen et al., 2021).

The search terms including Fest, minimal invasive direct , indirect restoration, worn teeth

Participants/population:

All adult patients of any age, ethnicity and gender with tooth wear and loss of vertical dimension

Intervention(s), exposure(s)

Comparator(s)/control

Not relevant as outcome measure is evaluation of efficiency and complication rate

Main outcome(s):

Increase of vertical dimension and restore worn dentition techniques

Additional outcome(s):

None

Data extraction (selection and coding):

Title and abstracts retrieved from the primary search (from Electronic database, related citations and references and hand search) will be screened to identify articles that may meet our inclusion criteria. Full text of relevant articles will then be reviewed.Irrelevant article and article not meeting our inclusion criteria will be then excluded. Data will pulled out of the included studies using excel review sheet form according to:

- Study authors & year
- Study design
- Number of participants (sample size
- Age of the participants
- Preoperative patients' complains and symptoms
- Steps of treatment plan
- Occlusal positioning if mentioned

- Type of provisional if any
- Type of restorations
- Type of materials
- Location and quantity of the increased OVD in mm
- Use of an occlusal splint if any
- Follow-up period
- Survival and postoperative complications

Risk of bias (quality) assessment:

In the included papers, the quality assessment evaluation for Randomized, Non-Randomized clinical trials and Prospective studies was preformed using Cochrane collaboration tools with the help of 24 items used by Heyashi et. al.The Risk of Bias assessment for observational studies (excludind prospective) was performed using NewCastle Ottwawa Quality Assesment

Strategy for data synthesis:

A qualitative synthesis (systematic review) will be done, and heterogeneity using forest plot and I^2 statistics package will be performed to determine if a quantitative synthesis can be done.

Analysis of subgroups or subsets:

- Occlusal positioning of definitive restoration
- Testing period of VDI
- Interim stage techniques
- Types of restorative materials
- Direct and indirect definitive restorative techniques
- Follow-up period and protective appliance

Studies included:

Inclusion: case series with >=2 participants, cohort studies (prospective and retrospective), randomised and non-randomised studies to treatment groups.

Condition or domain being studied:

Dental domain: tooth wear/Attrition, increase of vertical dimension, fixed and minimal invasive approach.

List of Tables

List of Figures

-Figure (11-12): Posterior and generalized tooth wear:

Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die vorliegende Masterthesis gemäß § 11 der Prüfungsordnung selbstständig verfasst und keine anderen als die angegebenen Hilfsmittel und Quellen benutzt habe.

Ferner erkläre ich, dass diese Arbeit bisher von mir weder bei der Universitätsmedizin Greifswald der Ernst-Moritz-Arndt-Universität Greifswald noch einer anderen wissenschaftlichen Einrichtung zum Zwecke der Erlangung des Mastertitels M.Sc. eingereicht wurde.

_____ _____

Ort, Datum Unterschrift

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Publikationen:

1- Shebib G, Mahaini S, Mahaini L, Kordaß B, Survival and complication rates of porcelain laminate veneers made from different ceramic materials. A Systematic Review, Approved in 10.2020 due to publication in in International Journal of Clinical Dentistry, August 2022.

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