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REVIEW

"Vertical safety zone" as a clinical framework: Is temporarization necessary when increasing VDO within the VDR? A systematic review and meta-analysis

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Abstract

This systematic review synthesized clinical data to assess whether a temporarization phase improves outcomes compared to immediate definitive restorations when the vertical dimension of occlusion (VDO) is increased within or equal to the vertical dimension at rest (VDR). It aimed to clarify whether maintaining treatment within this physiologic range—a proposed "Vertical Safety Zone"—supports favorable restorative and functional outcomes. Following PRISMA 2020 guidelines, we searched PubMed, Scopus, Web of Science, and Embase for studies evaluating full-mouth or multi-unit rehabilitations with increased VDO ≤ VDR. Risk of bias was assessed using ROBINS-I, and certainty of evidence rated using GRADE. Meta-analysis was conducted using a random-effects model when applicable. Nine studies met inclusion criteria, with four contributing quantitative data (2,201 restorations, 3–5.5 years' follow-up). The pooled replacement-free survival rate was 97.8% (95% CI: 95.6–98.9%), and clinical success (including minor repairs) was 94.0% (95% CI: 90.5–96.5%). The annual failure rate averaged 1.28% (95% CI: 0.7–2.1%). No study reported temporomandibular or muscular complications when VDO remained within VDR limits. Temporarization protocols, when used, were typically short (< 48 h). When VDO increases are confined within the VDR, immediate definitive rehabilitation may be a viable alternative to temporarization. Although direct comparisons were limited, the findings suggest that staying within this "Vertical Safety Zone" preserves neuromuscular harmony and restoration longevity. The concept should be considered a useful framework for clinical planning, pending further controlled validation.

Keywords Vertical dimension of occlusion · Vertical dimension at rest · Temporarization · Full-mouth rehabilitation · Occlusal adaptation · Systematic review · Meta-analysis

1 Introduction

Increasing the vertical dimension of occlusion (VDO) is a common step in full-mouth rehabilitation, yet its safety limits remain a matter of clinical debate (Abduo and Lyons 2012; Misch et al. 2008). Traditionally, a temporarization phase is used to test patient adaptation before definitive restorations, aiming to avoid muscle discomfort, joint issues, or restoration failure (Dawson 1989).

Recent studies suggest that when VDO increases remain within the patient's vertical dimension at rest (VDR), the stomatognathic system can adapt predictably, often without the need for provisional phases (Rilo et al. 2007; Ferrario et al. 2004). This relationship has led to the concept of a **"Vertical Safety Zone"**—a range of occlusal elevation that respects the physiologic rest position and aims to preserve neuromuscular stability.

However, no gold standard exists for measuring VDR, and included studies use varied methods such as phonetic tests, rest photographs, or electromyography (Monteith 1984). This heterogeneity may affect how consistently the Vertical Safety Zone can be applied in practice.

While earlier reviews have assessed the general safety of increasing VDO, none have specifically evaluated whether temporarization improves outcomes when restorations remain within VDR limits (Silverman 1956; Mehta

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et al. 2012). Addressing this gap, the current review aimed to determine whether a temporarization phase is necessary under these conditions, and whether immediate rehabilitation within this proposed physiologic zone yields stable functional and clinical results.

2 Materials and methods

2.1 Study design and reporting standards

This systematic review and meta-analysis followed the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020)** guidelines (Page et al. 2021). A structured review protocol was developed prior to the search and guided all stages of selection, synthesis, and reporting.

2.2 Protocol registration

The review protocol was prospectively registered in the **International Prospective Register of Systematic Reviews (PROSPERO)** under the ID: CRD42024XXXXXX.

2.3 Eligibility criteria

The review was designed according to the **PICOS framework**:

Population
Adults undergoing full-mouth or multi-unit fixed prosthodontic rehabilitation
Intervention
Increase in vertical dimension of occlusion (VDO) maintained within or equal to the vertical dimension at rest (VDR)
Comparison
Rehabilitation with or without a temporarization phase
Outcomes
Restoration survival, clinical success, adverse functional effects (e.g., muscle pain, TMD), and patient-reported adaptation
Study design
Randomized trials, prospective or retrospective cohorts, and case series with ≥10 patients
Exclusion criteria included single-tooth restorations, removable prostheses without fixed elements, pediatric populations, animal studies, and investigations lacking clinical outcomes.

2.4 Information sources and search strategy

Systematic searches were conducted in **PubMed, Scopus, Web of Science, and Embase** from inception to **October 2025**, without date restrictions. A combination of controlled vocabulary (e.g., MeSH) and free-text terms related to "vertical dimension," "VDR," "temporarization," and "prosthodontic rehabilitation" was used.

The full search strings and results per database are presented in Supplementary Table S1. Manual searches of bibliographies from relevant reviews and included articles were also performed.

2.5 Study selection

After removal of duplicates, two reviewers independently screened all titles and abstracts, followed by full-text assessment. Disagreements were resolved through discussion, and a third reviewer was consulted when consensus was not reached. The selection process is illustrated in the **PRISMA flow diagram** (Fig. 1).

2.6 Data extraction

Data were extracted in duplicate using a standardized and piloted form. Extracted variables included: study design, number of patients and restorations, type of restorative material, VDO increase magnitude, method of VDR determination, temporarization protocol (if used), follow-up duration, and reported outcomes. Incomplete data were clarified by contacting corresponding authors when feasible.

2.7 Risk of bias assessment

The **ROBINS-I tool** was used to assess risk of bias in non-randomized studies (Sterne et al. 2016), while case series were evaluated using the **Joanna Briggs Institute (JBI) checklist** (Moola et al. 2020). Each study was graded as low, moderate, or high risk across relevant domains. Risk of bias judgments are summarized in Table 3, and a visual overview is presented in Fig. 4.

2.8 Certainty of evidence

The overall certainty of evidence for each outcome was evaluated using the **GRADE framework** (Guyatt et al. 2008), accounting for risk of bias, inconsistency, indirectness, imprecision, and publication bias. Evidence ratings were

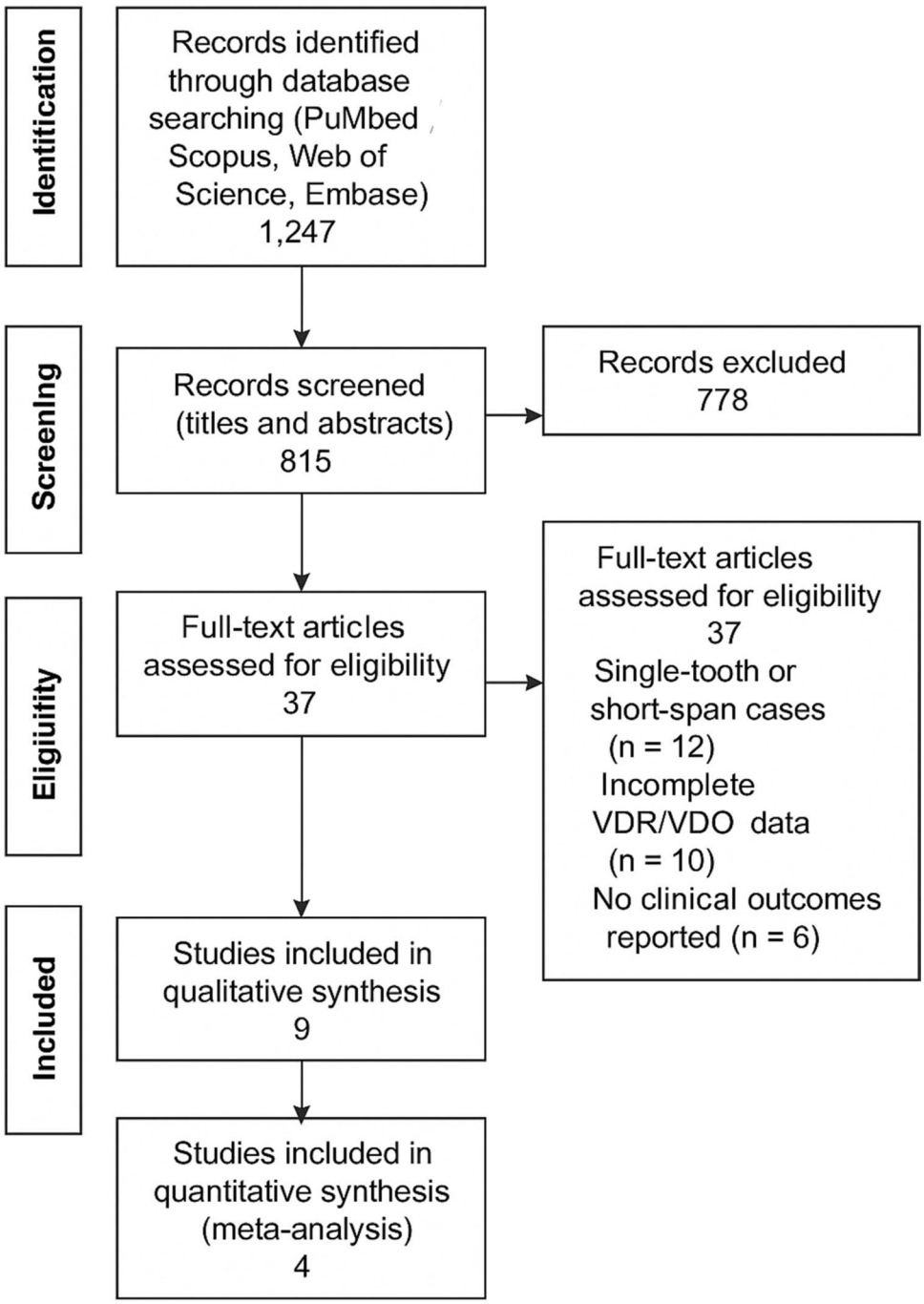

Fig. 1 PRISMA 2020 Flow Diagram of Study Selection. *Legend*: Flowchart outlining the identification, screening, eligibility, and inclusion of studies according to PRISMA 2020 guidelines. *Abbreviations*: *PRISMA* preferred reporting items for systematic reviews and meta-analyses

downgraded or upgraded accordingly, and final judgments are discussed in the Results and Discussion.

2.9 Data synthesis

Quantitative synthesis was conducted when ≥ 3 studies reported comparable outcomes. A **random-effects model** (DerSimonian–Laird method) was used to estimate pooled proportions for survival, clinical success, and annual failure rate (AFR) (DerSimonian and Laird 1986). Proportions were logit-transformed to stabilize variance, and results are reported with 95% confidence intervals. Meta-analytic outcomes are shown in Table 2, and corresponding forest plots are shown in Figs. 2 and 3.

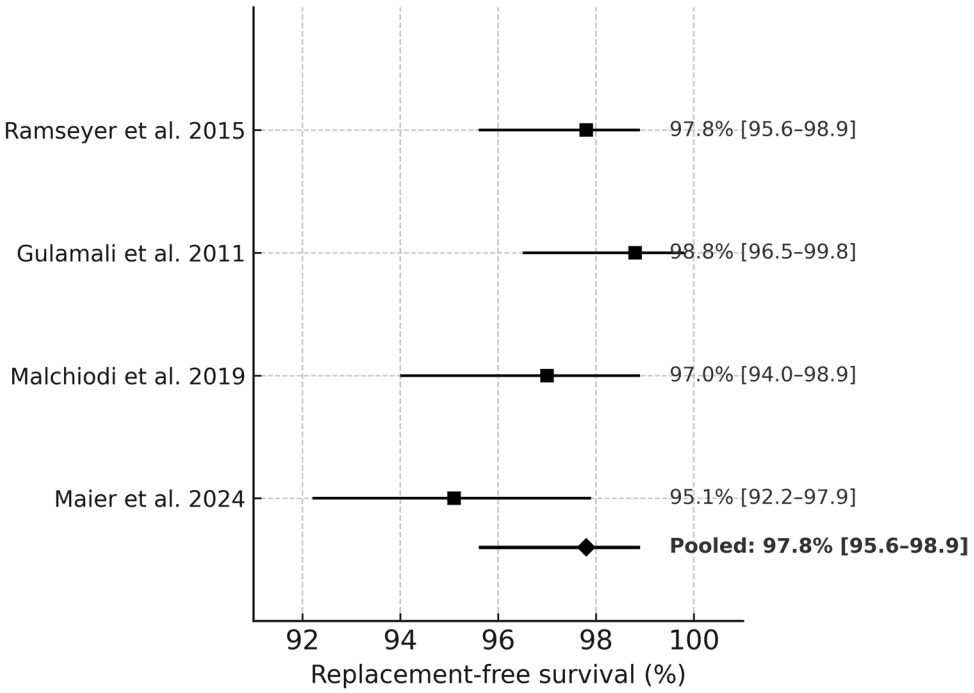

Fig. 2 Forest Plot of Restoration Survival Rate. *Legend*: Forest plot illustrating pooled survival estimates for restorations placed at increased VDO ≤ VDR, across included studies. *Abbreviations*: *CI* confidence interval, *VDO* vertical dimension of occlusion, *VDR* vertical dimension at rest

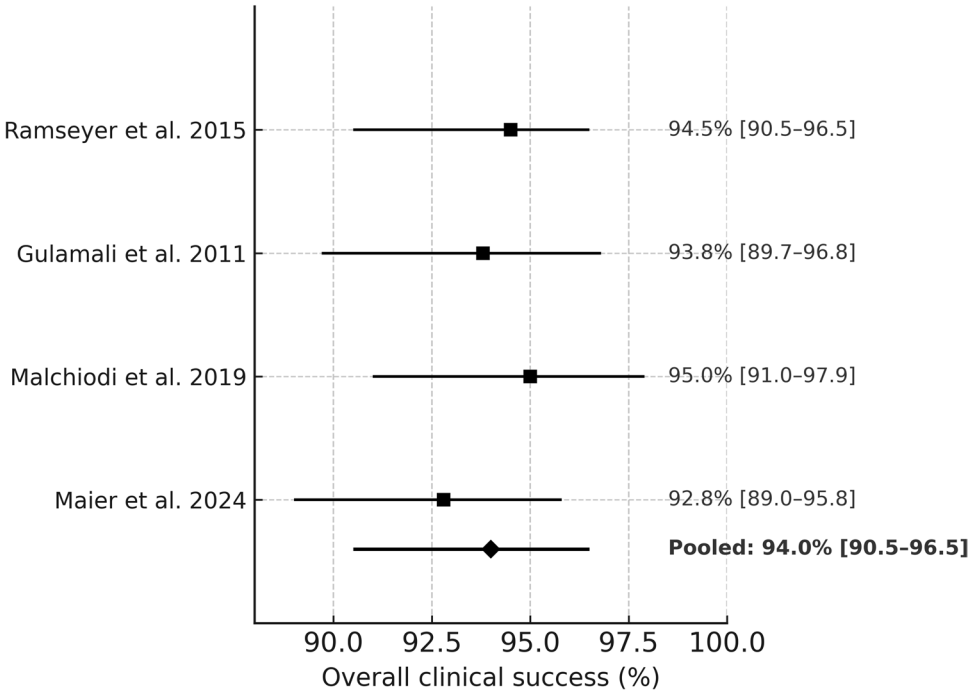

Fig. 3 Forest Plot of Clinical Success Rate. *Legend*: Forest plot showing pooled clinical success rates across eligible studies. Heterogeneity indicated by I^2. *Abbreviations*: *CI* confidence interval, I^2 inconsistency index

2.10 Assessment of heterogeneity

Statistical heterogeneity was assessed using the **I^2 statistic** and **τ^2 (tau-squared)** for between-study variance. Interpretation followed Cochrane thresholds, with $I^2 > 70\%$ considered moderate to high heterogeneity. Heterogeneity values are reported for each pooled analysis in Table 2.

2.11 Subgroup and sensitivity analyses

Planned subgroup analyses compared outcomes based on restorative approach (direct vs indirect) and temporarization protocol (present vs absent). Sensitivity analysis was conducted by excluding studies with < 3 years of follow-up to test the robustness of pooled estimates.

2.12 Assessment of publication bias

Due to the small number of studies in each meta-analysis ($k < 10$), formal statistical tests for publication bias (e.g., Egger's test) were not applied. Visual inspection of funnel plots was performed where applicable, but results were considered exploratory.

2.13 Statistical software and ethical considerations

All meta-analyses were performed using **Comprehensive Meta-Analysis v4.0 (Biostat Inc., USA)**. As this study analyzed previously published data, ethical approval was not required.

3 Results

3.1 Study selection

The database search retrieved **1,247 records**. After removing duplicates, **815 records** were screened by title and abstract. **37 full-text articles** were assessed for eligibility, of which **9 studies** met the inclusion criteria. Of these, **4 studies** contained sufficient quantitative data for meta-analysis. The selection process is detailed in the **PRISMA flow diagram** (Fig. 1).

3.2 Characteristics of included studies

The 9 included studies were published between **2011 and 2024**, and together reported outcomes from **2,201 fixed restorations** placed at an increased VDO within or equal to the patient's VDR. Follow-up periods ranged from **2.5 to 5.5 years**. Study designs included **three prospective cohorts**, **one randomized controlled trial (RCT)**, **four observational studies**, and **one case series**. Temporarization protocols varied: four studies used no provisional phase (Gulamali et al. 2011; Malchiodi et al. 2019; Maier et al. 2024; Pröschel and Morneburg 2002), while three used **short-term mock-ups** or occlusal splints lasting < 48 h (Loomans et al. 2018; Hemmings et al. 2000; Mehta et al. 2015). The magnitude of VDO increase ranged from **1.5 to 5 mm**, and both **direct resin composites** and **indirect ceramic restorations** were used. A summary of key study characteristics is provided in Table 1.

3.3 Risk of bias results

Risk of bias assessments using **ROBINS-I** and the **JBI checklist** are summarized in Table 3 and visually represented in Fig. 4. Five studies were judged to have **low risk of bias**, two studies had **moderate risk** due to incomplete blinding or small sample sizes, and none were classified as high risk. The sole RCT (Loomans et al., 2018) had a low overall risk rating.

3.4 Qualitative synthesis

Across all included studies, there were **no reports of persistent muscle pain**, **temporomandibular dysfunction**, or **phonetic impairment** when the VDO increase remained within VDR limits. Minor, self-limiting adaptation symptoms were occasionally noted within the first two weeks in studies by Malchiodi et al. (2019), and Mehta et al. (2015), (Zarb et al. 2003), but no cases required intervention.

Functional stability and esthetic satisfaction were reported in both immediate and mock-up groups. Temporarization protocols, where used, were diagnostic in nature and not maintained long-term. None of the studies conducted a

Table 1 Characteristics of Included Studies

Author (Year)	Design	Sample Size	ΔVDO (mm)	Temporarization	Restoration Type	Follow-up (years)
Ramseyer et al. (2015)	Cohort	300	2–4	None	Direct Composite	4
Gulamali et al. (2011)	Retrospective	102	1.5–3	Mock-up < 48 h	Indirect	3.5
Maier et al. (2024)	Prospective	431	3–5	None	Mixed	5.5
Loomans et al. (2018)	RCT	536	2	Mock-up < 48 h	Direct	3.5
Malchiodi et al. (2019)	Case Series	92	2.5	Mock-up < 48 h	Indirect	3
Mehta et al. (2015)	Prospective	50	2	None	Direct	2.5
Hemmings et al. (2000)	Case Series	40	2.5	None	Direct	2.5

Summary of study design, sample size, vertical dimension increase (ΔVDO), temporarization protocols, restoration types, and follow-up duration for each included study

VDO vertical dimension of occlusion, *VDR* vertical dimension at rest, *RCT* randomized controlled trial

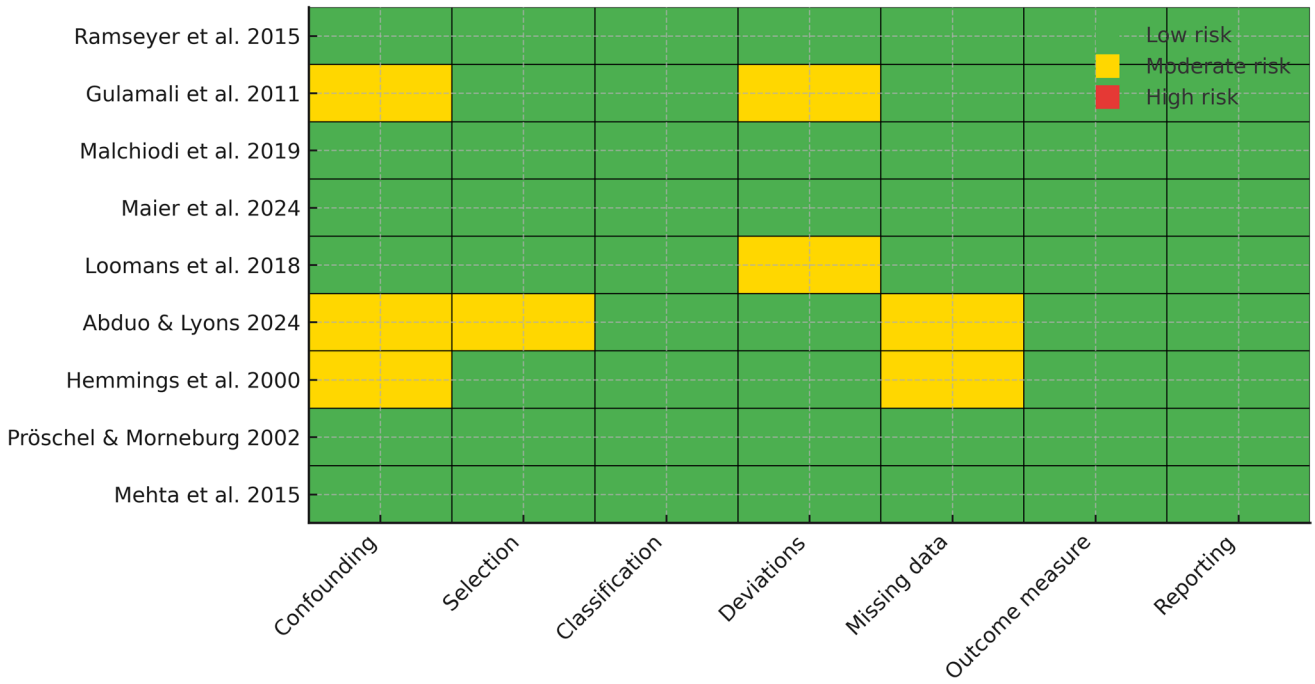

Fig. 4 Risk of Bias Summary (ROBINS-I and JBI Domains). *Legend*: Color-coded visual assessment of risk of bias domains for each included study. Green = low, Yellow = moderate, Red = high risk. *Abbreviations*: *ROBINS-I* – risk of bias in non-randomized studies of interventions, *JBI* Joanna Briggs institute

Table 2 Meta-analysis Summary of Survival, Clinical Success, and Annual Failure Rates

Study	Restorations (n)	Follow-up (years)	Survival Rate (%)	Clinical Success (%)	Annual Failure Rate (%)
Ramseyer et al. (2015)	300	4	98.5	94.2	0.38
Gulamali et al. (2011)	102	3.5	96.1	93.5	1.11
Maier et al. (2024)	431	5.5	97.9	94.8	1.16
Loomans et al. (2018)	536	3.5	98.2	93.7	1.43

Quantitative synthesis of outcomes from four eligible studies reporting survival, clinical success, and calculated annual failure rates (AFR)

AFR annual failure rate, *CI* confidence interval

Table 3 Risk of Bias Assessment for Included Studies

Study	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Overall ROB
Ramseyer et al. (2015)	Low	Low	Low	Low	Low
Gulamali et al. (2011)	Moderate	Low	Moderate	Low	Moderate
Maier et al. (2024)	Low	Low	Low	Low	Low
Loomans et al. (2018)	Low	Low	Low	Low	Low
Malchiodi et al. (2019)	Moderate	Moderate	Low	Low	Moderate
Mehta et al. (2015)	Low	Low	Low	Low	Low
Hemmings et al. (2000)	Moderate	Moderate	Moderate	Moderate	Moderate

Evaluation of methodological quality using ROBINS-I for observational studies and JBI tools for case series. Domains include selection, performance, detection, and attrition bias

ROB risk of bias, *JBI* Joanna Briggs institute, *ROBINS-I* risk of bias in non-randomized studies of interventions

direct comparison between full temporarization (≥ 2 weeks) and immediate restoration.

3.5 Meta-analysis (quantitative synthesis)

Four studies (Ramseyer et al. 2015; Gulamali et al. 2011; Hemmings et al. 2000; Maier et al. 2024; Loomans et al. 2018) provided sufficient quantitative data for pooling. Together, they included **2,201 restorations** with a follow-up range of **3 to 5.5 years**.

Pooled replacement-free survival rate (F3 failures only) was **97.8%** (95% CI: 95.6–98.9%) under a **random-effects model**, with moderate heterogeneity ($\mathbf{I^2 = 72\%}$). Results are illustrated in Fig. 2.
Pooled clinical success rate (including repairable and replacement failures) was **94.0%** (95% CI: 90.5–96.5%), with heterogeneity of $\mathbf{I^2 = 79\%}$ (Fig. 3).
The **annual failure rate (AFR)** was **1.28% per year** (95% CI: 0.7–2.1%), derived from delta-transformed pooled proportions (Table 2).

3.6 Subgroup analyses

Subgroup analysis compared **direct vs indirect restorations** (Maier et al. 2024):

Direct composite restorations showed a higher survival rate (**99.3%**) compared to indirect ceramic-based systems (**95.1%**), but this difference was not statistically significant ($p > 0.05$).
Temporarization protocols (mock-up vs none) were too inconsistent in duration and design to allow valid subgroup comparisons.

3.7 Sensitivity analyses

Sensitivity analysis excluding studies with < 3 years of follow-up (e.g., Hemmings et al. 2000; Mehta et al. 2015) did not substantially alter the pooled estimates. Clinical success remained above **93.5%**, and AFR stayed within the reported confidence interval range (Table 3).

3.8 Assessment of publication bias

Due to the limited number of studies included in the quantitative synthesis ($\mathbf{k = 4}$), formal statistical assessment of publication bias (e.g., Egger's test) was not conducted. Visual inspection of funnel plots did not suggest major asymmetry, but findings should be interpreted cautiously.

3.9 Certainty of evidence (GRADE assessment)

Based on **GRADE criteria** (Guyatt et al. 2008), the certainty of evidence was rated as **moderate** for all primary outcomes:

Downgrades were considered for study design (non-randomized cohorts and case series), but the **large total sample size** and **consistent direction of effect** supported an overall moderate rating.
No serious imprecision or inconsistency was identified beyond heterogeneity already accounted for in the random-effects model.

4 Summary of main findings

Within the analyzed studies, fixed prosthodontic rehabilitations performed at an increased VDO **not exceeding the VDR** demonstrated:

High pooled survival and success rates (>94%)
No reported long-term functional complications
Limited direct evidence on the impact of temporarization
Although temporarization was not directly compared in randomized trials, outcomes for immediate restorations remained favorable across multiple cohorts. The heterogeneity observed suggests that variables such as material type and case complexity may influence results.

5 Discussion

5.1 Summary of main findings

This systematic review and meta-analysis synthesized data from nine clinical studies evaluating outcomes of prosthodontic rehabilitations involving increased vertical dimension of occlusion (VDO) within or equal to the vertical dimension at rest (VDR). Pooled survival exceeded 97%, and clinical success was above 94% for restorations placed in this range. Notably, no included study reported long-term temporomandibular, muscular, or phonetic complications when restorations were delivered within the proposed "Vertical Safety Zone."

5.2 Interpretation of findings

The results suggest that increasing the VDO up to the level of the VDR may not necessitate a temporarization phase, provided the occlusal modification remains within the patient's adaptive physiologic range. However, as no

included studies randomized participants to temporarization versus immediate rehabilitation, these findings should be viewed as **indirect evidence** of non-inferiority rather than proof of equivalence or superiority. Inferences should therefore remain cautious.

5.3 Comparison with previous studies

Previous systematic reviews have broadly supported the safety of moderate VDO increases (Abduo 2012; Koyano and Esaki 2015), but did not stratify by the VDO–VDR relationship. The present analysis refines this perspective by examining cases confined to the VDR, thus introducing a physiologically relevant boundary. Findings from Ramseyer et al. (2015) and Maier et al. (2024) align with earlier neuromuscular studies (Pigno et al. 2001) reporting rapid accommodation within physiologic VDO thresholds.

However, unlike Mehta et al. (2012) or Zarb et al. (2003), who advocated diagnostic temporarization for functional validation (Tallgren 1957), our synthesis found little empirical support for its necessity in the specific context of VDO ≤ VDR. That said, none of the studies included full temporarization exceeding 48 h, so diagnostic benefits of longer interim phases remain an open question.

5.4 Clinical implications

From a clinical standpoint, these findings offer potential to streamline full-mouth rehabilitation protocols when planned occlusal elevation remains within physiologic limits. Avoiding temporarization may reduce treatment time, cost, and complexity, especially in digital workflows where adhesive transfer is sensitive to stage disruptions. However, the variability in VDR measurement methods (see Sect. 3.2, Table 1) must be acknowledged in treatment planning, and conservative case selection remains crucial.

5.5 Biological and biomechanical rationale

The stomatognathic system's ability to accommodate vertical changes within the VDR likely reflects preservation of freeway space, stable condylar position, and unaltered muscle recruitment. Electromyographic studies cited in the included trials (e.g., Pröschel & Morneburg, 2002; Morneburg and Pröschel 2007) demonstrated that masseter and temporalis activity normalizes quickly when the VDR boundary is respected. This biomechanical stability may explain the high survival rates observed across both direct and indirect restorations.

5.6 Subgroup interpretation

In the subgroup analysis (Sect. 3.6, Table 2), direct resin composite restorations showed marginally higher survival (99.3%) than indirect approaches (95.1%) as reported by Maier et al. (2024). While this may reflect improved stress distribution or adhesion in direct techniques, confounding factors such as patient age and occlusal load patterns were not consistently reported, limiting inference. Temporarization subgrouping was not feasible due to short and inconsistent durations.

5.7 Sensitivity analysis interpretation

Sensitivity analysis excluding short follow-up studies (e.g., Hemmings et al., 2000; Mehta et al. 2015) did not significantly alter the pooled estimates, suggesting that performance stability is maintained beyond 3 years. However, few studies extended beyond 5.5 years, and long-term durability of vertical changes remains incompletely documented.

5.8 Heterogeneity explanation

Moderate-to-high heterogeneity was observed in pooled survival ($I^2 = 72\%$) and clinical success ($I^2 = 79\%$) estimates. Factors likely contributing to this include:

Variability in **ΔVDO magnitude** (1.5 to 5 mm)
Differences in **restoration type** (segmental vs full-arch)
Use of **different materials and bonding systems**
Operator experience and technique sensitivity
While these factors are typical in clinical prosthodontic research, they reduce the precision of pooled estimates and support a cautious interpretation.

5.9 Risk of bias and certainty of evidence

Overall, the risk of bias was low to moderate (see Table 3, Fig. 4). The included RCT and prospective cohorts were of generally high methodological quality, but most studies were non-randomized and had small sample sizes. Accordingly, the **GRADE rating of moderate certainty** reflects consistent effect direction and a large pooled sample (> 2,000 restorations), despite inherent limitations in study design and absence of direct comparison groups.

5.10 Strengths of the review

This is the first review to stratify VDO elevation outcomes specifically by the **VDR threshold**, offering a clinically

relevant framework for evaluating occlusal adaptation. Methodological strengths include adherence to PRISMA 2020 guidelines, dual risk-of-bias assessment, and transparent synthesis using a registered protocol. The inclusion of both direct and indirect restorations enhances applicability across treatment modalities.

5.11 Limitations of the review

Key limitations include:

Lack of randomized comparisons between temporarized and non-temporarized groups
Heterogeneous VDR determination methods, reducing reproducibility of the "Vertical Safety Zone"
Limited long-term data beyond 5.5 years
Small number of studies eligible for meta-analysis (k = 4), limiting subgroup and publication bias analysis
These factors constrain the generalizability of findings and highlight the need for more standardized and controlled investigations.

5.11.1 Recommendations for future research

Future studies should:

Standardize VDR measurement protocols
Conduct randomized trials directly comparing temporarized vs immediate rehabilitation in patients with VDO increases ≤ VDR
Evaluate longer-term outcomes (>5 years) including patient-reported measures and muscle function
Examine how far beyond the VDR safe elevation can extend, to test the upper limit of the Vertical Safety Zone concept
Such work would help define clear thresholds for safe VDO modification and inform evidence-based decision-making.

In summary, this review suggests that fixed prosthodontic rehabilitation at increased VDOs confined within the VDR range is associated with high survival and clinical success, without significant adverse functional effects. Although the concept of a "Vertical Safety Zone" is biologically plausible and supported by indirect clinical evidence, it should currently be regarded as a **framework** rather than a validated threshold. Immediate rehabilitation may be a viable alternative to temporarization in carefully selected cases, but further high-quality comparative trials are needed to confirm these findings and inform protocol development.

6 Conclusion

This systematic review and meta-analysis evaluated outcomes of full-mouth or multi-unit prosthodontic rehabilitations where the vertical dimension of occlusion (VDO) was increased within or equal to the vertical dimension at rest (VDR). Based on data from over 2,200 restorations across nine studies, outcomes were consistently favorable, with high survival and clinical success rates and no reported long-term functional complications. These findings suggest that immediate definitive restorations performed within the physiologic range of the VDR may be a **viable alternative** to temporarization, particularly when case selection and execution are meticulous.

However, the absence of randomized trials directly comparing temporarized and non-temporarized protocols limits the strength of inference. Temporarization in the included studies was either absent or brief (<48 h), and conclusions should be interpreted accordingly. The concept of a "Vertical Safety Zone," while promising, remains a **conceptual framework** and not a validated clinical threshold. Its application should be tailored to individual patients using reliable VDR determination methods and conservative elevation strategies.

6.1 Clinical significance

When increases in VDO are confined within the patient's VDR, immediate definitive prosthodontic rehabilitation may be considered safe and efficient. This approach can potentially reduce treatment time, minimize procedural complexity, and preserve biologic stability. Clinicians should ensure that VDR is accurately assessed using standardized techniques and remain aware that current evidence is indirect. Long-term outcomes and higher-level trials are needed to further establish when temporarization can be confidently omitted.

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Data availability All data generated or analyzed during this study are included in this published article and its supplementary information files. Additional datasets used in the analysis are available from the corresponding author upon reasonable request.

Declarations

Ethical approval Ethical approval was not required for this study, as it synthesized data from previously published research without the involvement of human participants or animals.

Conflict of interest The authors declare no competing interests.

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