Keywords

ASC, Reverse torque, Peri-implantitis, Loosening, Mechanical, Fracture

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A Review on the Efficacy of Angulated Screw Channel Implant-Supported Restorations: Clinical and Mechanical Perspectives

Abstract

Objectives: This review evaluated in vivo and in vitro evidence on angulated screw channel (ASC) systems in implant-supported prostheses and assessed mechanical stability and peri-implant outcomes compared with straight screw-access and cement-retained restorations.
Methods: PubMed, Web of Science, and ScienceDirect were searched for ASC studies published from January 2015 to March 2026. Only in vivo and in vitro investigations were included.
Results: Thirty studies met criteria: 12 in vivo and 18 in vitro. Outcomes included prosthesis survival, marginal bone loss, peri-implant indices, esthetics, technical complications, and reverse-torque or preload behavior across angulations and materials. Clinical studies reported high short to midterm survival, minimal marginal bone changes, and low complication rates, comparable with straight screw-access and cement-retained restorations. In vitro findings were inconsistent: some studies showed similar torque maintenance between straight and angulated channels, whereas others found lower reverse-torque values and greater screw or driver wear at increased angulations or after cyclic loading. Biologic outcomes were favorable, and avoidance of residual cement remained an advantage.
Conclusion: ASC restorations appear clinically viable for anterior and posterior single and multiunit restorations in the short to midterm. Long-term studies and standardized mechanical testing are needed to clarify angulation thresholds, material-specific failures, and complication patterns.

1. INTRODUCTION

The survival of screw-retained and cement-retained implant-supported restorations appears broadly comparable, although the two retention approaches are associated with different biological and technical complication profiles.1, 2 Screw-retained restorations provide predictable retrievability, facilitating prosthetic maintenance, repair, screw replacement, and access to the implant without requiring destruction of the restoration. Moreover, the absence of luting cement eliminates the risk of residual subgingival cement, which has been associated with peri-implant inflammation and disease.2-4 Ideal implant positioning of screw-retained restorations, should be established during pre-surgical planning. However, anatomical limitations may require implants to be placed at an unfavorable angulation. Cement-retained restorations have traditionally been used to compensate for tilted implants but cement-retained restorations carry a documented risk of peri-implant disease from excess of luting cement. Residual cement correlates with bleeding, suppuration, bone loss, and inflammation which often resolves after cement removal.4, 5 Deeper margins increase the risk of undetected cement, and the lack of routine radiographs following prosthesis installation may miss many deposits.5, 6 These findings favored the fabrication of ASC system as another solution as proposed by Garcia- Gazaui et al. (2015)7 in Fig. 1.

On the other hand, cement-retained restorations can be used when implants are not ideally placed which offer prefabricated angulated options, commonly around 17° or 30°. These restorations broaden indications of placement but remain angle limited and, in single-unit use and increasing the risk of the cement-related biologic risk.8in particular if the restoration margin is sub-gingival, there will be residual cement 100% of the time.9 Peri-implantitis may occur due to the excess cement leading to loss of implants and often the adjacent teeth and 80% of cases of peri-implantitis are secondary to sub-gingival cement accumulations. 5, 10 In order to overcome the drawbacks of

cement retained restorations, custom abutments and hybrid designs with a lingual screw channel and supragingival margins can be used11 or placing rubber dam around dental implant abutments to reduce the excess cement12, but all those measures will add cost and complexity and create two-screw failure modes that hinder management, so their clinical use is limited.8

Computer-aided design and manufacturing (CAD/CAM) now enable the fabrication of ASC restorations. ASC reorients the driver path by roughly 0–25° in any direction, preserves a single screw, and maintains full retrievability. The abutment aligns with the implant axis while tightening occurs off-axis, keeping the screw accessible if a complication arises.8, 13, 14 Early reports are encouraging, yet long-term clinical and mechanical performance remains incompletely defined compared with conventional straight screw channels and cement-retained restorations.14, 15

This review examines ASC efficacy from clinical and mechanical perspectives. It compares survival, biologic and mechanical complications, torque and preload behavior, esthetics, and patient-reported outcomes versus straight screw-retained and cement-retained restorations and identifies evidence gaps for future work.

Figure 1. A. Titanium bases of different CAD-CAM angled screw channel solutions.; Dynamic Abutment Solutions dynamic tibase (DY), Dess Dental Smart Solutions anglebase (DE), Nobel BioCare angulated screw channel (ASC) and Nobel BioCare universal base (UB), B. Shows the lateral aspect of the assembled systems (25◦ and 0◦ of angulations) and zirconia-based restorations along with their unique screwdrivers. Adapted from Mulla et al., (2022)[16].

2.MATERIALS AND METHODS

This review followed a staged workflow: formulation of the research question, definition of eligibility criteria, database searching, screening, data extraction, and narrative synthesis. PubMed, Web of Science, and ScienceDirect were searched for English-language publications from January 2015 to March 2026 using the terms “angulated screw channel” and “angled screw channel.” Eligible studies were in vivo and in vitro investigations evaluating ASC systems; case reports were excluded. Titles and abstracts were screened, followed by full-text assessment. Data was extracted and synthesized to evaluate ASC performance, and the screening process is summarized in Fig 2. The search was last updated on 12 March 2026.

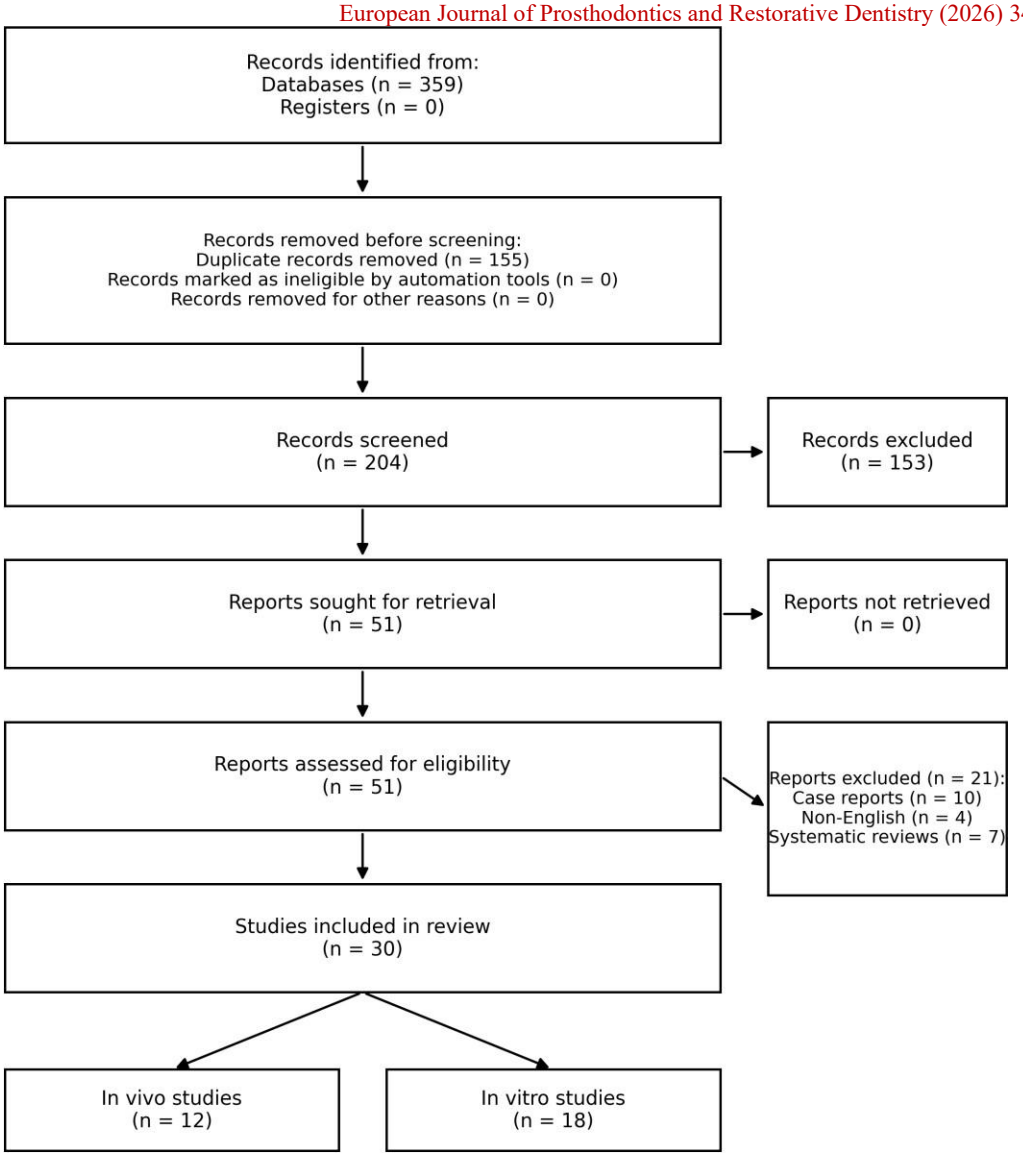

Figure 2. PRISMA 2020 flow diagram showing the literature search and study selection process.

3.RESULTS

3.1 Study selection

An initial search across PubMed, Web of Science, and ScienceDirect retrieved 359 records (151, 163, and 45, respectively; Figure 2). After removing duplicates (n = 155), 204 records were screened by title and abstract, and 153 records were excluded. Fifty-one reports were assessed in full text; 21 were excluded (case reports n = 10, non-English publications n = 4, systematic reviews n = 7). Thirty studies met the inclusion criteria (12 in vivo and 18 in vitro). The search was last updated on 12 March 2026, and no additional eligible studies were identified.

3.2 Study characteristics

The 12 in vivo studies primarily evaluated single-implant crowns in anterior esthetic and posterior molar sites, with comparators including straight screw-access restorations and/or cement-retained crowns on angled abutments. Follow-up ranged from 12 months to 70 months, with most studies reporting outcomes within the first 1–3 years. The 18 in vitro studies used standardized implant–abutment assemblies to assess screw-joint stability and restorative material behavior across varying screw-access angulations. Across both designs, ASC systems typically permitted access-channel angulation up to approximately 25°, while some studies also evaluated prefabricated angulated components around 17° and 30°. Key outcomes reported by the included studies are summarized in Tables 1 and 2.

Table 1. Summary characteristics of the in vivo vs in vitro studies.

Parameter	In vivo (no = 12)	In vitro (n = 18)
Primary purpose	Clinical performance in patients	Mechanical performance under controlled testing
Typical designs	Prospective case series, retrospective cohorts, controlled clinical studies	Bench testing with torque application and/or cyclic loading; fracture/fatigue testing
Restoration focus	Predominantly single crowns; minority multiunit restorations	Single crowns/abutments and implant–abutment assemblies; material and design comparisons
Angulation evaluated	Access-channel correction typically ≤ 25°; some reports include ~17° or 30° components	Range of access angulations, commonly straight vs angulated up to ~25° (and in some protocols up to ~30°)
Follow-up / test duration	12–70 months (most ≤ 36 months)	Torque maintenance/reverse torque and/or fatigue/fracture outcomes after standardized loading protocols
Key outcomes reported	Survival/success, marginal bone levels, peri-implant indices, esthetics, complications	Preload/reverse torque, screw/driver wear, fracture resistance, failure mode

3.3 Survival rates and clinical success (in vivo)

Across the in vivo evidence, implant and prosthesis survival were consistently high over the reported observation periods. Studies in both the esthetic zone and posterior region reported few to no implant losses and low rates of prosthesis failure, with most reported events classified as minor, manageable technical complications rather than catastrophic failures.14, 15, 17, 18

3.4 Biologic and Esthetic outcomes (in vivo)

In vivo studies that reported peri-implant parameters generally showed small marginal bone level changes and stable soft-tissue indices during follow-up. Comparative clinical studies evaluating ASC screw-retained crowns versus cement-retained controls did not demonstrate worse probing depth or bleeding outcomes with ASC, and some reported lower radiographic bone loss in the ASC group.17-19

Where esthetic indices were reported (e.g., PES/WES), ASC restorations achieved acceptable scores and were broadly comparable to cement-retained controls, supporting their use to relocate the access opening away from the facial surface without compromising overall esthetic performance.17, 18

3.5 Mechanical Complications (in vivo)

Reported technical complications were infrequent and predominantly minor, including ceramic chipping, screw loosening, and occasional retention-related events. Complications were typically managed without loss of implant support, consistent with the retrievable nature of screw-retained designs.17, 18

3.6 Mechanical performance (in vitro)

The in vitro evidence focused on screw-joint stability (torque maintenance, reverse torque value, and preload behavior), wear/deformation at the screw–driver interface, and restoration strength under static and cyclic loading. Findings were mixed, with several studies reporting comparable torque maintenance between straight and angulated access configurations, while others observed reduced reverse torque values and greater screw-head wear as angulation increased or after cyclic loading.16, 20-22 Laboratory and technical studies indicate that the fracture behavior of implant-supported ceramic restorations is influenced by the interaction between restoration geometry, ceramic composition, implant–abutment design, loading direction, and the amount of restorative material surrounding the screw-access channel.18, 23

Table 2. Comparative synthesis of clinical and mechanical outcomes of in vivo and in vitro studies.

Outcome domain	In vivo	In vitro	Key supporting studies
Survival/success	High short to midterm implant and prosthesis survival, with few failures reported.	Not applicable.	Pol et al. (2020)14 Donker et al. (2022)15 Yang et al. (2023)17 Rella et al. (2025)24
Biologic outcomes	Generally small marginal bone changes and no consistent worsening of probing depth or bleeding compared with cement-retained controls.	Not applicable.	Lv et al. (2021)19 Yang et al. (2023)17 Rella et al. (2024)18
Esthetic outcomes	Acceptable PES/WES values and broadly comparable esthetic outcomes to cement-retained restorations.	Not applicable.	Lv et al. (2021)19 Yang et al. (2023)17 Rella et al. (2024)18
Technical complications	Complications were generally infrequent and manageable and included ceramic chipping, screw loosening, and retention-related events.	Laboratory failure modes varied according to the restorative material, ASC design, angulation, and loading protocol.	Greer et al. (2017)13 Pol et al. (2020)14 Donker et al. (2022)15 Yang et al. (2023) Rella et al. (2024)18 Drew et al. (2020)23
Screw-joint stability	Reverse torque and preload were not routinely assessed clinically; reported clinical screw loosening was uncommon during short follow-up.	Findings were mixed. Some studies found torque behavior comparable to straight access, whereas others reported reduced reverse torque or greater screw/driver deformation at increased angulations or following loading.	Goldberg et al. (2019)21 Farré-Berga et al. (2020)25 Swamidass et al. (2021)22 Mulla et al. (2022)16
Restoration strength	Clinical fracture events were uncommon during the available short-term follow-up.	Fracture resistance and failure patterns were dependent on ceramic design, restorative material, remaining material bulk, ASC position, and loading conditions.	Drew et al. (2020)23 Pol et al. (2020)14 Donker et al. (2022)15

4.DISCUSSION

4.1 Evidence base and synthesis considerations

This review synthesized human (in vivo) and laboratory (in vitro) evidence on angulated screw channel (ASC) implant-supported restorations within the predefined

search window using explicit inclusion and exclusion criteria (English language; in vivo and in vitro designs; case reports excluded). Across recent publications, the evidence base remains dominated by short- to medium-term clinical studies and heterogeneous in vitro protocols, which complicates direct comparisons across implant systems, restorative materials, angulation ranges, and loading conditions.18, 24, 26 Consequently, the discussion emphasizes convergent findings and highlights where conclusions remain provisional because of limited duration, sample size, and inconsistent reporting.

4.2 Clinical efficacy of ASC restorations: implant and prosthesis survival

Across the available clinical literature, implant and prosthesis survival for single-unit ASC-supported restorations is consistently high in the short to midterm. In the most recent systematic review and meta-analysis focused on single-implant crowns, mean implant survival was 99% and prosthesis survival approached 100%, with follow-up ranging from very short intervals to more than 3 years depending on the included studies.24 These findings align with case-control data reporting 100% survival for both ASC screw-retained and cement-retained comparators over 2 years, supporting ASC as a clinically viable strategy when implants are not positioned ideally for a straight screw-access trajectory.27

However, the apparent robustness of survival outcomes should be interpreted in the context of limited long-term data and the likelihood that early survival estimates underestimate later technical events. The predominance of retrospective designs and short follow-up in several cohorts is a recurring limitation noted in the evidence syntheses.18, 26 From a clinical decision-making perspective, the current evidence supports ASC as an effective short to midterm solution for maintaining screw retainability, rather than as a proven superior approach over longer time horizons.

4.3 Peri-implant tissue response and marginal bone stability

The biological rationale for ASC is to preserve the practical advantages of the retrievability of screws and avoidance of cement-related inflammation while relocating the access channel away from esthetically or functionally undesirable positions. Residual cement around implant restorations has been associated with peri-implant inflammation and disease, supporting the conceptual biological advantage of screw-retained approaches when. 5, 28 ASC may reduce cement-associated biological risk without forcing surgical repositioning or extensive grafting purely to accommodate a straight screw-access trajectory. Empirically, pooled clinical outcomes do not indicate worse peri-implant health for ASC compared with cement-retained alternatives. In meta-analytic comparisons, marginal bone loss (MBL) and probing pocket depth (PPD) did not differ significantly between ASC and cement-retained single crowns, although point estimates often favored ASC slightly.24 Importantly, individual clinical comparative data have reported significantly lower radiographic bone loss for ASC screw-retained crowns compared with cement-retained crowns on angled abutments at both mesial and distal aspects over 2 years, while esthetic scores remained comparable.18

These findings can be interpreted in two ways. First, the absence of cement may plausibly reduce subgingival irritants and inflammatory burden, which could translate to improved bone stability in susceptible cases.18, 28 Second, the lack of consistent statistically significant differences in pooled analysis suggests that the magnitude of any biological advantage may be modest and potentially context dependent, influenced by margin depth, cementation protocols, and clinician ability to remove excess cement when cement-retained solutions are used.24

Beyond conventional clinical indices, a small subset of studies has explored immunological markers, reporting differences in inflammatory mediator profiles between angulated screw-retained and cemented restorations in the esthetic zone.17, 29 While these signals are biologically interesting, they remain difficult to interpret clinically because of short follow-up and heterogeneity in surgical and prosthetic protocols. Long-term studies linking biomarker shifts to clinically meaningful endpoints such as peri-implantitis, progressive bone loss thresholds, or intervention needs are required before immunological findings can guide routine practice.

4.4 Esthetic outcomes and prosthetic emergence considerations

Esthetic performance is a primary driver for ASC adoption, particularly in the anterior maxilla where implant angulation and bone anatomy can force facial access holes or compromise prosthetic contours. The clinical evidence suggests that ASC and cement-retained options can both deliver acceptable esthetic outcomes when implant positioning and soft tissue management are appropriate, with no consistent between group differences in pink esthetic score (PES) and white esthetic score (WES) in available comparative studies.18, 24 This indicates that ASC is best viewed as an enabling technology: it expands the set of cases where a screw-retained solution is esthetically feasible, rather than guaranteeing superior esthetics independent of surgical and prosthetic fundamentals.

4.5 Restorative design constraints and material thickness considerations

ASC design imposes restorative geometry constraints. Because angulation requires widening and reorienting the screw channel, restorative material thickness can be reduced at critical lingual or cingulum areas, particularly in zirconia-based restorations. This structural tradeoff is clinically relevant because aggressive channel angulation or insufficient ceramic thickness can increase the likelihood of chipping or catastrophic fracture despite favorable initial appearance.23, 26 Accordingly, restorative planning for ASC cases should integrate minimum thickness requirements, occlusal scheme control, and material selection.

4.6 Technical complications: frequency, type, and clinical impact

The most reported technical complications for ASC restorations in clinical studies include chipping of

veneering ceramic, screw loosening, and occasional retention-related events, with most complications manageable without implant loss.18, 26 In a case-control comparison of anterior single crowns, the ASC group experienced minor chipping events, whereas the cement-retained group experienced a debonding event, yielding comparable success rates without a statistically significant difference.18 In the systematic review of single crowns, pooled complication risk did not differ significantly between ASC and cement-retained restorations, although follow-up was often short and study designs were heterogeneous.24

Cement-retained crowns may carry biologic risks and retrieval challenges, whereas screw-retained systems (including ASC) may be more prone to mechanical maintenance events such as chipping or screw-related complications.1 Clinically, ASC can therefore be attractive when retrievability and maintenance access are priorities, provided patients are counseled regarding the possibility of minor technical interventions.

4.7 Mechanical behavior: preload, reverse torque, and screw loosening

The mechanical debate around ASC centers on whether off-axis screw driving compromises torque delivery, preload generation, and long-term joint stability. In vitro findings are mixed. Several investigations reported no meaningful differences in torque loss or reverse torque values between straight and angulated channels under standardized cyclic loading, suggesting that well-engineered ASC systems can maintain joint stability under simulated function.21, 22 In contrast, other studies observed reduced reverse torque values and evidence of screw head deformation at higher angulation ranges, implying that some designs may be more sensitive to driver angle, repeated insertion, or screwdriver screw head interface mechanics.25, 30

The reported screw loosening frequency in in vivo studies appears relatively low over 12 to 36 months windows, although this may reflect both short follow-up and publication bias toward successful cohorts.26 From a clinical engineering standpoint, the most defensible position is that screw stability in ASC systems is conditional. It depends on the specific implant system, screw head design, screwdriver engagement, connection geometry, angulation magnitude, and adherence to torque protocols. Therefore, clinicians should avoid extrapolating results from one ASC system directly to another and should treat manufacturer specific torque drivers and tightening instructions as integral components of the system rather than interchangeable accessories.

4.8 Fracture resistance and restorative material considerations

Fracture resistance is a key mechanical concern for ceramic ASC restorations because the angulated channel can reduce material thickness at the cingulum or palatal/lingual aspect. The available fracture-resistance evidence is derived largely from in vitro single-crown models in the anterior region, where angulated channels have been associated with reduced fracture loads and failure initiating in the thinnest ceramic adjacent to the channel.23, 26Across studies, reporting of monolithic versus veneered designs is not uniform; however, the underlying risk mechanism is loss of ceramic bulk around the channel, which becomes more relevant as angulation increases and remaining thickness decreases.23, 26 Despite lower laboratory fracture loads, many values still exceed typical incisal forces, which may help explain the high short-term clinical survival reported in anterior cohorts.26

In the posterior region, higher occlusal forces and parafunction may amplify these material-thickness constraints. Short-term clinical case series of full-contour (monolithic) zirconia implant crowns and molar restorations using angulated screw channels have reported favorable one year outcomes with few technical failures, suggesting that monolithic designs combined with occlusal control may mitigate fracture and chipping risk.14, 15, 31 Two practical implications follow: (1) when restorative thickness is limited, monolithic zirconia or metal-based designs may be preferable to layered ceramics, and (2) digital planning should verify minimum thickness along the intended channel trajectory and adjust contour and angulation accordingly.26, 31

4.9 Indications, contraindications, and workflow implications

ASC restorations are primarily indicated when implant angulation results in an unfavorable prosthetic screw-access trajectory, such as facial emergence in the esthetic zone or interference with the occlusal surface. By redirecting the access channel, the restoration can remain screw retained and retrievable while avoiding intraoral cementation.18, 24, 32 ASC can also reduce the need for additional surgical augmentation intended solely to improve prosthetic screw-access, although this benefit depends heavily on case selection and the planned restorative contours.26

Potential contraindications are mainly mechanical risk amplifiers rather than absolute exclusions. These include large angulation demands approaching system limits, inadequate restorative thickness around the channel, high occlusal loads, and restorative designs requiring extensive veneer layering in thin regions. In such cases, alternatives such as cement-retained crowns on custom abutments, surgical correction, or revised implant positioning strategies may offer a more predictable mechanical profile.1

Digitally driven workflows are particularly relevant for ASC because channel trajectory planning, minimum thickness control, and titanium base selection are design dependent33, 34. The clinical implication is that ASC is not merely a component choice; it is a workflow choice that requires close integration between surgical planning, CAD design, and laboratory execution.

5. CONCLUSION

Based on 12 in vivo and 18 in vitro studies identified in a search updated through March 2026, angulated screw channel (ASC) restorations show high short to midterm implant and prosthesis survival, generally stable peri-implant parameters, and esthetic outcomes comparable to cement-retained alternatives. Mechanical findings are mixed: many protocols report torque maintenance comparable to straight screw-access, but higher angulations and cyclic loading may reduce reverse-torque values, increase screw/driver wear, and decrease ceramic

fracture resistance when channel design compromises material thickness. The available evidence is limited by short follow-up, heterogeneous study designs, and inconsistent reporting of angulation ranges and restorative materials, which restricts definitive long-term guidance. Clinically, ASC is most appropriate when implant angulation would otherwise force a facial access opening or cementation, provided restorative planning preserves minimum thickness and occlusion is carefully managed. Future prospective studies with longer follow-up and standardized mechanical protocols should define angulation thresholds, material-specific failure modes, and the cumulative maintenance burden of ASC restorations.

CONFLICT OF INTEREST STATEMENT

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