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Dynamic Abutments in Implant Prosthetic Rehabilitation: A Review of Design, Performance, and Clinical Utility

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Abstract

Non-ideal implant angulation remains a frequent challenge in implant prosthodontics, compromising esthetics, screw access positioning, and retrievability of implant-supported restorations. Dynamic abutment systems have emerged as an alternative solution, enabling redirection of the screw access channel while maintaining a coaxial implant–abutment interface. This narrative review evaluates the design principles, biomechanical performance, clinical applications, and limitations of dynamic abutment systems in implant-supported rehabilitation. Evidence from in vitro studies, finite element analyses, clinical reports, and systematic reviews indicates that, within manufacturer-recommended angulation limits, dynamic abutments demonstrate torque preload, screw stability, and microgap behaviour comparable to conventional screw-retained systems. Clinically, they provide versatility in anterior esthetic zones, posterior areas with limited access, and full-arch restorations, while facilitating digital workflows. Although current evidence supports their short- to medium-term reliability, long-term clinical studies are required to establish definitive treatment guidelines.

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Introduction

Implant-supported prosthetic rehabilitation is a key component in modern restorative dental practice. Its success is attributed to its long-term results related to function, appearance, and patient satisfaction. ^[1,2] However, for

implant restorations to succeed, there must be precise alignment between the implant direction and the intended prosthetic axis. ^[3]

In everyday clinical practice, anatomical limitations, bone

loss, and restricted surgical access often lead to less-than-ideal implant angles, especially in the aesthetic and posterior areas. These differences can cause misalignment of the screw access channels, alter emergence profiles, and ultimately affect the esthetic appearance.^[4,5] In the past, differences in implant angulation were usually managed with angled abutments or cement-retained prostheses. Although these methods can achieve satisfactory prosthetic alignment, they each come with challenges.

To address these limitations, dynamic abutment systems have been introduced. These systems allow for redirection of the screw access channel, usually up to 25° to 30°, without changing the implant abutment interface.^[6] As a result, the system combines the benefits of screw-retained restorations, such as easy maintenance and retrievability, with the esthetic and positional flexibility that was previously possible only with cemented designs.

Despite these developments, significant differences among commercially available systems still exist. This article thoroughly examines the evolution, design principles, and operation of dynamic abutment systems. It also aims to gather recent laboratory and clinical data comparing dynamic abutments with traditional restoration methods.

It highlights gaps in the current literature that need more research and outlines the pros and cons of different system designs. By compiling available data, this review intends to clarify how effective dynamic abutments are in creating stable, functional, and visually appealing implant restorations.

Review of Literature

The influence of implant angulation on biomechanical performance has been extensively studied. Finite element

analyses and in-vitro studies have shown that increased implant angulation can alter stress distribution within the implant–abutment complex and surrounding bone, potentially affecting long-term stability.^[4,5] These findings highlight the importance of achieving optimal prosthetic alignment in implant-supported restorations.

Conventional approaches, such as angled abutments, often concentrate stress at the implant abutment junction, which may affect screw stability and the response of the surrounding marginal bone.^[7] Cement-retained restorations generally provide better esthetic outcomes, but they make retrieval more difficult and can cause inflammation around the implant due to leftover cement.^[8]

Recent studies evaluating angulated screw channel systems have demonstrated that dynamic abutments exhibit biomechanical performance comparable to conventional screw-retained restorations. Parameters such as torque maintenance, preload stability, stress distribution, fracture resistance, and microgap behaviour have been reported to remain within clinically acceptable limits when used within recommended angulation ranges.

Although early clinical reports indicate favourable outcomes, including stable marginal bone levels and minimal mechanical complications, the current evidence is largely based on laboratory studies and short-term observations. Variations in abutment geometry, maximum angulation correction, and screw–driver design can influence the preload stability, stress distribution, and how well they perform over time.^[9] Thus, there is a need for ongoing standardisation of system parameters and long-term clinical studies to create evidence-based guidelines for the best use of dynamic abutments in implant prosthodontics.

TABLE I: Summary of Key Studies on Dynamic Abutments and Angulated Screw Channel Systems

YEAR	AUTHOR	STUDY TYPE	KEY FINDINGS
2015	Berroeta E et al. ^[6]	Clinical case report	Demonstrated use of dynamic abutment to redirect screw access from labial to palatal, avoiding cement-related complications.
2015	Bulaqi HA et al. ^[38]	Finite element analysis	Suggested that retightening, friction, and surface characteristics influence long-term screw stability.
2017	Sakamoto S ^[42]	Technical report	Highlighted the esthetic benefits of angulated screw channel systems in managing labial screw access in anterior regions.
2018	Goldberg J et al. ^[14]	In vitro study	No significant difference in removal torque or fracture resistance between angulated and axial screw tightening.

2018	Ferreira JR et al. ^[28]	In vitro study	Shown good fatigue resistance and acceptable microgap behavior comparable to conventional abutments.
2019	Hu E et al. ^[40]	In vitro study	Reverse torque decreased with increasing angulation but remained within clinically acceptable limits.
2020	Nakka C et al. ^[29]	Case report	Reported stable bone levels, no complications, and good esthetic outcomes over a 3-year follow-up.
2020	Swamidass RS et al. ^[18]	In vitro study	Slight torque loss observed in angulated systems; retightening improved preload stability.
2022	Rasaie V et al. ^[33]	Systematic review	Reported high survival rates and minimal complications with angulated screw channel systems.
2023	Varshney N et al. ^[43]	In vivo study	Demonstrated comparable biological and esthetic outcomes with no increased bone loss.
2024	Albakri A et al. ^[44]	Narrative review	Confirmed reliability of ASC systems with minor mechanical limitations under high load.
2024	Rella E et al. ^[45]	Case-control study	Shown 100% survival and reduced bone loss compared to cement-retained restorations.
2024	Khaledi AA et al. ^[46]	In vitro study	No significant reduction in fracture resistance; torque remained within acceptable limits.
2025	Atieh MA et al. ^[8]	Systematic review & meta-analysis	Found comparable outcomes with slight torque reduction at higher angulations; long-term data are limited.

Abbreviations: FEA – Finite Element Analysis; ASC – Angulated Screw Channel

Design of Dynamic Abutments

The evolution of dynamic abutment systems stems from the need to overcome the mechanical and esthetic compromises associated with conventional angled abutments. ^[3,10]

In conventional angled abutments, the entire abutment is fabricated at a predetermined angle, whereas in dynamic

abutments, the implant–abutment connection remains coaxial. The correction occurs within the screw channel inside the abutment. This design enables clinicians to modify the direction of the screw access hole—typically up to 25° to 30° from the implant’s long axis without altering the underlying connection geometry. (Figure I)

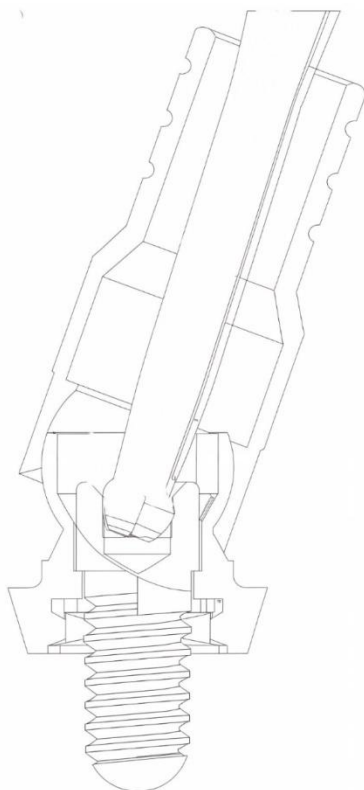


FIGURE I: Schematic illustration of a dynamic abutment system showing angulated screw channel engagement while maintaining a co-axial implant–abutment interface.

This innovation maintains a precise fit at the implant-abutment connection. It ensures that the abutment and implant interface stays parallel to the implant's long axis, which results in a more even distribution of stress. ^[11,12]

Components of Dynamic Abutments

The Dynamic Abutment consists of a base with a semisphere on which a burnout chimney sits, and which can be freely moved to deviate from the axis by up to 28

degrees. The fixation screw is unique. The screw has a hexalobular head shape that can be engaged with a hexagonal faceted sphere screwdriver at various angles between 0 and 28 degrees, with 360-degree freedom of rotation ⁽⁶⁾ (Figures II and III). This allows tightening the abutment screw at an orientation different from the centre axis of the implant. They permit tightening and retrieval from an oblique direction while maintaining full screw preload and stability. ^[13,14]

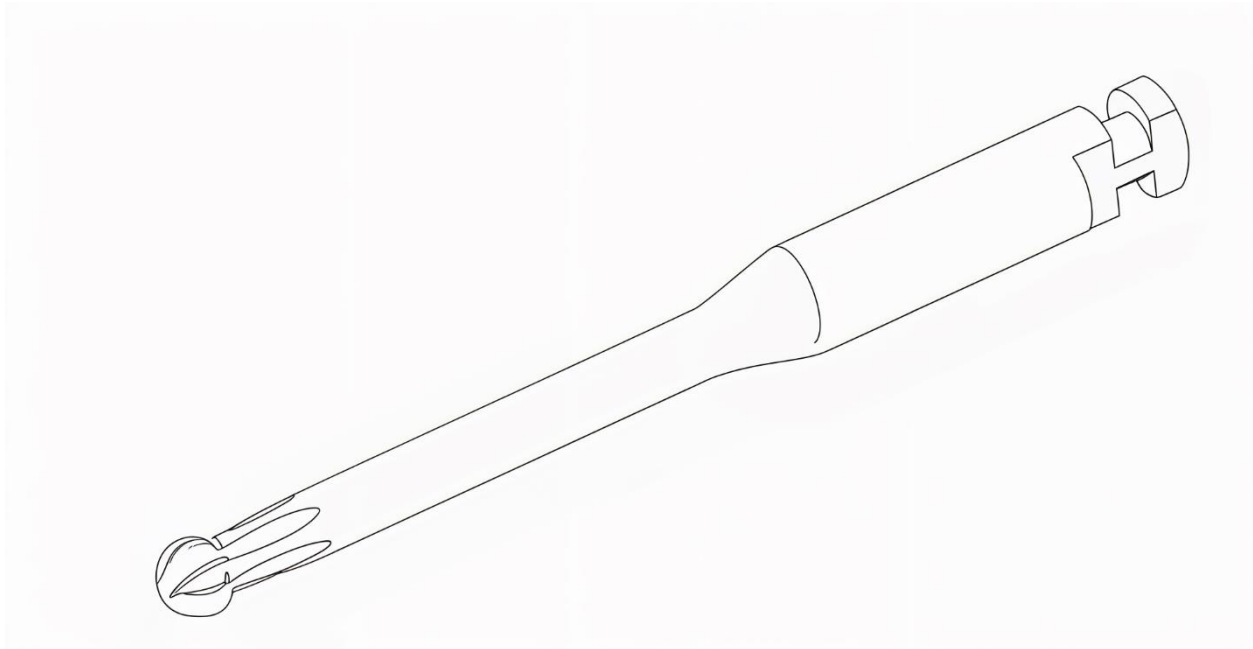


FIGURE II: Hexalobular driver system used for angulated screw engagement, enabling off-axis torque application during placement and retrieval of dynamic abutment screws.



FIGURE III: Modified hexalobular screw head design facilitating angulated engagement and effective torque transmission in dynamic abutment systems.

Dynamic abutments are available in various materials, each chosen for a specific purpose. Titanium bases are widely used for their high strength and biocompatibility, forming the structural foundation of the system. ^[15] Zirconia

superstructures or hybrid designs are used when excellent aesthetics are needed, especially in front restorations where translucency and colour matching matter. Some systems also use CAD/CAM-milled parts, which allows for precise

customisation of angulation and fit.^[16]

The design flexibility also allows for their use in both single-tooth and multi-unit restorations, broadening their use in various prosthetic situations. This abutment is designed to work with the following implant systems: Straumann, Dentsply Astra Tech, Nobel Biocare (Brånemark system, Replace, Standard and Multiunit abutments), Biomet 3i, BTI, Phibo TSA, Eckerman, Zimmer, Klockner, DIO, and Ankylos implants.^[17]

Biomechanical Considerations and Performance

The biomechanical behaviour of dynamic abutments has been a major focus of research, as any modification to the screw access pathway has the potential to influence load transfer and joint stability.

Torque Maintenance and Screw Stability

Torque maintenance refers to the ability of the abutment screw to maintain the applied preload over time, while screw stability refers to the ability of the screw to resist loosening under functional forces. These factors are crucial for the lasting success of implant-supported restorations because a loss of preload can cause screw loosening, microgap formation, bacterial infiltration, and possible complications around the implant.

Several in-vitro studies have shown that dynamic abutments are capable of maintaining torque values comparable to a straight screw-retained system. No differences in torque loss were noted when compared with straight screw retained systems.^[18,19] Although slightly lower reverse torque values have been reported at higher angulations, these variations are typically not clinically significant.^[20]

The favourable mechanical performance of dynamic abutments can be attributed to their coaxial implant–abutment interface, allowing forces to be transmitted along the long axis of the implant. Furthermore, the hexalobular screw head in dynamic abutments spreads forces uniformly across the contact surface, which ensures effective torque transmission, even when engaged at an inclined angle.^[11,21]

Stress Distribution and Load Transfer

Stress distribution refers to the pattern in which functional forces are transmitted and distributed through the implant–

abutment complex and surrounding bone tissues.

Load transfer refers to the pattern in which forces are transmitted from the prostheses to the implant and finally to the bone tissues.

An optimum system would facilitate an equal distribution of stresses along the long axis of the implant, reducing the risk of mechanical failure and bone resorption around the implant.

Finite element analyses (FEA) have clarified how dynamic abutments behave under functional loads. Most models indicate that changing the screw channel direction does not result in clinically significant stress concentrations at the implant-abutment interface or surrounding bone, as long as the angulation stays below 30°.^[22,23] This favourable behaviour of dynamic abutments is due to their design as dynamic systems confine the angulation to the screw channel, thereby preserving axial load transmission.

As a result, the pattern of distribution of stresses in dynamic abutments is similar to that in straight abutments, with slightly increased stress concentrations at the abutment neck and screw head.^[24,25] This increased stress concentration is due to screw engagement but is well beneath the critical limits associated with material fatigue or bone resorption.

Fracture Resistance

Fracture resistance is the ability of the prosthetic components to withstand functional or parafunctional forces without failure.

While there is limited literature specifically on Dynamic Abutment systems, in-vitro studies show that removal torque values at different angles are similar and acceptable within clinical limits.^[23] By allowing redirection of the screw access channel, these systems facilitate improved positioning of occlusal forces, thereby reducing lateral forces within the prosthetic components.

Wider studies on angled screw channel (ASC) restorations suggest that fracture resistance and stress distributions stay well within safe clinical limits, even when the screw is angled up to around 25°. The results are similar to those of straight-channel designs.^[19]

The type of material used has a significant impact on overall performance. Titanium bases tend to resist deformation more effectively, while zirconia components provide

superior aesthetics with slightly lower yet clinically acceptable strength. ^[19,26] Fracture resistance tests with monolithic zirconia and hybrid zirconia-titanium restorations show that the angle of the screw channel does not significantly weaken the structure. Even at angles of 25° to 30°, fracture loads were higher than normal chewing force.

Microgap Formation

Microgap formation refers to the presence of a microscopic space at the implant–abutment interface, which may permit bacterial infiltration and micromovement under functional loading

conditions. From a clinical point of view, this is important since it has the potential to induce peri-implant inflammation, marginal bone loss, and mechanical complications. ^[27]

In dynamic abutment systems, the implant-abutment interface remains unchanged since the angulation is restricted to the screw access channel. This preservation of the original interface ensures that the fit between the implant and abutment is maintained, thereby limiting excessive microgap formation.

Research on dynamic and angulated abutments shows that when the right torque protocols are applied, their microgap performance is similar to that of straight abutments. ^[28] A biomechanical analysis of the Dynamic Abutment's preload behaviour reveals that while the torque angle can affect preload, it usually stays within the limits recommended by manufacturers.

Clinical Indications and Applications

Dynamic abutment systems expand clinical versatility without altering the implant–abutment interface by allowing redirection of the screw access channel.

Correction of Non-Ideal Implant Angulation

One of the primary indications for dynamic abutments is the prosthetic management of implants placed with unfavourable angulation due to anatomical constraints such as limited bone volume, maxillary sinus proximity, mandibular nerve location, or ridge morphology.

In such cases, dynamic abutments permit correction of the

screw access trajectory, enabling screw-retained restorations even when implants are not aligned with the ideal prosthetic axis. ^[8,29]

Alternative to Cement-Retained Restorations

Dynamic abutments are a reliable alternative to cement-retained prostheses in situations where implant angulation requires cementation. The risks of residual cement, such as peri-implant inflammation and bone loss ^[30], make dynamic abutments a safer choice. They allow for the use of screw-retained designs that can be easily removed. ^[31,32]

Management of Posterior Implant Restorations

In posterior regions, particularly in tilted implants or limited space at molar sites, dynamic abutments help redirect the screw channel to more favourable positions for occlusion. This makes it easier to access screws for tightening and maintenance while preserving occlusal morphology and material thickness. ^[33]

Full-Arch and Multi-Unit Restorations

For complex cases involving full-arch or multi-unit restorations, where implant angles often differ, dynamic abutments simplify achieving ideal screw access. ^[34] They can simplify the prosthetic design, reduce the need for angled multi-unit abutments, and enhance the ability to retrieve the final prosthesis.

Chairside and Laboratory Advantages

From a clinical view, dynamic abutments decrease the need for complex surgical corrections or custom angled abutments. Their compatibility with CAD/CAM fabrication allows for precise control of screw channel orientation during the digital design phase. This makes the process more predictable and reduces the need for laboratory redo work. ^[35,36]

Dynamic Abutments as an Alternative to Multi-Unit Abutments

Multi-unit abutments are pre-fabricated abutments with a platform that can be angled (e.g., 0°, 17°, 30°, 45°) relative to the implant-connection interface. MUAs correct implant angulation through the use of an additional

intermediary component compared with a one-piece screw retained or custom abutment.^[37]

Dynamic abutments allow internal redirection of the screw access which eliminates the need for extra components, thereby reducing the number of prosthetic interfaces and the potential for mechanical complications. Furthermore, by maintaining a more direct load path, dynamic abutments support more predictable stress distribution within the implant–bone interface.

Clinically, unlike MUAs, where the restorative height is increased, dynamic abutments are advantageous, especially when there is limited interocclusal space. This allows for better control of the contour, emergence, and material thickness of the crown. This is particularly important for the anterior region, where screw access placement is a priority, as well as esthetics.^[29] Moreover, dynamic abutments can be easily incorporated into a digital workflow, enhancing treatment predictability and reducing laboratory complexity. While MUAs remain essential in cases requiring extensive angulation correction or full-arch standardisation, dynamic abutments provide a more conservative and efficient alternative in appropriately selected cases.

Discussion

Dynamic abutment systems have been recognised as a reliable approach in dealing with non-ideal implant angulation while retaining the benefits of screw-retained restorations.^[8,33] Moreover, biomechanical studies, including finite element analysis, have consistently confirmed that favourable results can be obtained as long as implant angulation is maintained within specified ranges.^[38-40]

The studies carried out by Wei et al.^[19] and Opler et al.^[20] revealed that there was no significant effect on torque retention in cases where screw channel angulation was involved. This suggests that screw retention stability can be maintained even in cases where there is non-ideal implant placement.

In addition, Huang et al.^[24] found that although there was an increased effect on stress around the abutment neck and screw head due to implant angulation, this was found to be within physiological limits. This suggests that dynamic abutment systems can be used while ensuring that there is

no increased risk of screw loosening or bone resorption.

From a structural perspective, fracture resistance studies demonstrate that angulation does not significantly weaken restorations, with fracture loads exceeding normal masticatory forces.^[19,42] This supports their clinical use in load-bearing areas.

Microgap-related studies, such as those by Ferreira et al.^[28], further indicate that dynamic abutments exhibit behaviour comparable to conventional systems when appropriate torque protocols are followed. This is important in minimising bacterial leakage and peri-implant complications.

Berroeta et al.^[8] presented an early clinical case report describing the use of the Dynamic Abutment® system to redirect screw access up to 28° in the anterior region. The restoration remained screw-retained, avoiding cement use and its associated biological risks. Although limited to a single case, this report demonstrated the clinical feasibility of dynamic abutments in esthetically challenging situations. Further clinical evidence has strengthened these findings. Nakka^[29] reported successful rehabilitation of multiple unfavourably angulated implants using dynamic abutments, with stable marginal bone levels and no mechanical complications over a three-year follow-up.

Current evidence therefore supports their biomechanical reliability in situations requiring angulated screw access, although long-term clinical studies remain limited.

Dynamic abutments have shown versatility in various clinical situations. Their compatibility with digital workflows and CAD/CAM fabrication often makes treatment planning more predictable.^[35] It also improves efficiency for both clinicians and dental laboratories.

Overall, available laboratory and clinical evidence suggests that dynamic abutment systems are a reliable option for correcting screw access angulation.

Limitations

Even though the current biomechanical studies and short- to medium-term clinical results look promising, we still need to be careful. The majority of the available evidence comes from lab research and finite element analysis.

While these studies are useful, they cannot fully replicate the complex biological, mechanical, and functional intraoral

conditions. Only a few long-term randomised clinical trials have evaluated survival rates, peri-implant tissue response, and both technical and biological complications.

Another important issue is the differences among various commercial systems. Variations in maximum angulation correction, screw design, and material make it difficult to compare results directly or draw consistent conclusions. Therefore, we need more well-designed long-term clinical studies to establish clearer protocols and stronger, evidence-based guidelines for everyday practice.

Conclusion

Dynamic abutment systems have emerged as a practical and innovative advance in implant prosthodontics. They offer a conservative and efficient way to handle unfavourable

implant angles while keeping the main benefits of screw-retained restorations.

By shifting the screw-access channel without changing the implant-abutment interface, these systems improve prosthetic positioning, boost esthetics, and maintain retrievability. Current evidence shows that dynamic abutments perform well from a biomechanical standpoint. They distribute stresses well, resist fractures under working loads, and display acceptable microgap behaviour. Their flexibility makes them especially helpful in esthetic areas, hard-to-reach posterior regions, and full-arch restorations. With further high-quality clinical research, dynamic abutments have the potential to become a more standardised and widely accepted solution for managing angulation-related challenges in implant dentistry.

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