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From Retention to Resilience: A Contemporary Review of Attachment Systems in Implant-Supported Overdentures

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Abstract

Implant-supported overdentures (ISODs) offer superior retention, stability, and overall patient satisfaction compared with conventional complete dentures. The clinical success of ISOD therapy relies on selecting the appropriate attachment system to connect the overdenture to the underlying implants. Selecting the optimal attachment system is determined by several important factors, such as interarch space, implant angulation, desired resiliency, retention, bone quality, and biomechanical force distribution.

This review evaluates the biomechanical and spatial properties of seven major attachment systems, namely ball attachment, locator, extra-radicular attachment (ERA), equator, bar, magnetic, and telescopic attachments. High-retention bar and telescopic systems require substantial vertical clearance and higher costs while, low-profile stud systems such as locator and equator are better suited for patients with limited space. Magnetic attachments can be useful for patients with compromised manual dexterity.

This review also addresses recent trends in design and critical maintenance complications, such as loss of retention due to wear and tear of parts, screw loosening, denture fractures, and peri-implant disease.

In the end, achieving predictable prosthetic function and overdenture longevity depends on matching the specific biomechanical and spatial properties of the attachment to

the patient's anatomical limitations, together with strict adherence to regular maintenance protocols.

Keywords: Attachment Systems, Implant-Supported Overdentures, Types of Attachment Systems & Retention Mechanism.

Introduction

In prosthodontics, implant-supported overdentures (ISODs) have become a highly reliable and effective treatment option for edentulous patients. When compared to conventional complete dentures, ISODs provide improved retention, stability, masticatory efficiency, speech, and overall patient satisfaction[1,2]. The long-term clinical success of ISOD therapy depends on the selection of the appropriate attachment system. These mechanical devices link the removable overdenture to the underlying dental implants, providing necessary retention and stability while allowing patients to take the prosthesis out for routine cleaning and hygiene. Biomechanically, the attachment transfers the forces from chewing to the implants and surrounding hard and soft tissues. Therefore, the choice of attachment system directly influences the daily function of the prosthesis, patient comfort, tissue health, and long-term success[1,2].

The success of ISOD treatment depends on matching the right attachment to the patient's specific clinical condition rather than just on successful implant placement; it is important to thoroughly review these systems. Clinicians must carefully assess a range of biological and mechanical factors, including available interarch space, angulation of the implant, bone quality, and patient-specific factors like manual dexterity. A structured comparison of different attachment systems is essential to make informed decisions, minimize mechanical complications, and ensure predictable, long-term performance of the overdenture[1,3,4].

The primary aim of this review is to evaluate, classify, and compare the various attachment systems used in ISODs to assist clinicians in selecting the most appropriate system for each patient and ensuring long-term treatment success.

Types of Attachment Systems

A variety of attachment systems are currently available for implant-supported overdentures. These systems differ in design, how they provide retention and stability, the space they require, and their clinical use. The discussion focuses on stud attachments, including ball, extra-radicular attachment (ERA), Locator, and Equator attachments, followed by bar attachments, magnetic attachments, and telescopic attachments.

A. Stud Attachments

They are among the most commonly used unsplinted attachment systems for ISODs. They consist of two complementary components: the patrix (male component) and the matrix (female component). The patrix is attached to the implant and projects from the implant abutment, while the matrix acts as the receptacle and is incorporated into the fitting surface of the overdenture. Retention is achieved through mechanical interlocking, friction, or elastic deformation[1,3].

Depending on the design, the matrix may consist of a metal housing with replaceable parts like as O-rings, nylon inserts, or resilient caps. Stud attachments are relatively compact and are popular due to their simplicity and ease of maintenance. They are suitable for cases with limited restorative space. Common stud attachment systems include ball, ERA, locator, and equator attachments.[1,3]

i. Ball Attachment: Are a type of stud attachment in which a spherical male abutment attached to the implant fits into an elastic retentive cap incorporated into the overdenture. They are one of the most commonly used

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stud attachment systems for ISODs. It consists of a male component (patrix), which is a ball-shaped abutment attached directly to the implant, and a female component (matrix) made up of an elastic retentive cap that is housed within a metal housing combined into the fitting surface of the overdenture. Retention is achieved by the elastic engagement of the retentive cap around the spherical patrix, providing secure but resilient support of the overdenture as shown in fig 1[1,3].



Figure 1: Components of ball attachments. Source: Brand-Dental Solution Israel (DSI)

The Rhein83 OT Cap system, manufactured by Rhein83 (Italy), is one of the most widely used stud attachment systems and is available in normal and micro sphere sizes, allowing selection according to the clinical situation and available space [5]. A key advantage of the OT Cap system is the availability of colour-coded retentive caps with different levels of retention and resilience. The commonly used caps are yellow, pink, clear, and green, with additional options providing different degrees of retention and resilience. The colour-coded system helps the clinician to select the appropriate degree of retention based on the patient's needs [1,5].

The OT Cap system works as a resilient attachment because of its flat ball-head design and elastic retentive caps, which allow the overdenture to yield or move slightly during use. It is relatively simple, cost-effective, and easy to maintain, with worn retentive caps being replaceable. Ball attachments are particularly suitable for two-implant mandibular overdentures, especially when there is adequate restorative space, and the implants are relatively parallel[1,2].

Retention mechanism: Spherical patrix and elastic retentive cap (matrix) with elastic engagement provides retention and controlled resiliency. The retentive cap can be replaced when retention decreases due to wear.[1,6]

ii. ERA Attachment: Is a resilient stud attachment system manufactured by Sterngold, designed to provide retention while allowing controlled movement of the overdenture[7]. It includes a female component that is attached to the implant abutment or post and a replaceable nylon male retentive insert that is placed into the denture base, either directly in acrylic resin or within an ERA metal jacket. The attachment incorporates a universal hinge mechanism with vertical resiliency, allowing the denture to move vertically and hinge during function. This resilient movement helps reduce the direct transmission of unfavorable lateral and vertical forces to the supporting implant or abutment as shown in fig 2.[1,7]



Figure 2: Components of ERA attachments. Source-eraacademy.com

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A major feature of the ERA system is its colour-coded nylon male inserts, which provide different levels of retention and allow the clinician to modify retention based on individual needs. The standard sequence from lower to higher retention is white, orange, blue, grey, yellow, and red. The black male insert is used during the fabrication process and is replaced by the selected retentive male after processing. The ERA overdenture system is also available with angled female posts of 0°, 5°, 11°, and 17°, allowing correction of implant or abutment angulation and improve the ease of inserting the overdenture. These angled components are useful when implants are not ideally parallel[1,7].

Retention mechanism: The ERA uses a nylon male retentive insert that engages with the female component and retention is achieved through the elastic engagement of the nylon material. Unlike rigid stud attachments, the ERA permits vertical resiliency and hinge movement that reduces stress on the overdenture. The retentive males can be replaced to restore retention when wear occurs[1,2,7].

iii. Locator Attachment: The Locator attachment, manufactured by Zest Dental Solutions, is a low-profile, non-splinted stud attachment widely used for ISODs[8]. It consists of a male locator abutment that is screwed into the implant, a metal denture housing, and a replaceable nylon retention insert. Its low-profile design makes it beneficial when interarch space is limited. The Locator provides dual mechanical retention, with the nylon insert fitting into the retentive surfaces of the male abutment. Its self-aligning and pivoting design makes it easier to insert and remove the overdenture and allows for compensation of implant divergence as shown in fig.[1,3,8].

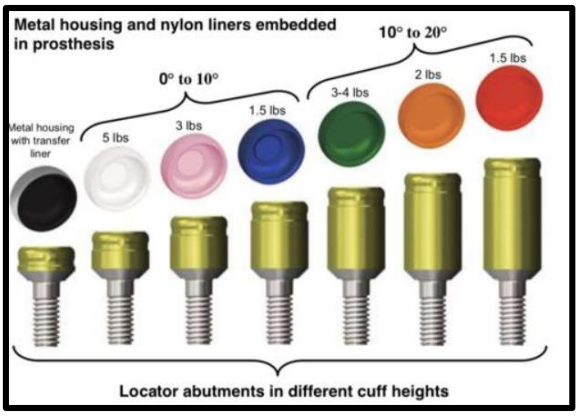


Figure 3: Components of Locator attachments source- Zest Dental solution

A newer generation is the Locator R-Tx Removable Attachment System, also manufactured by Zest Dental Solutions. It has a stronger, more wear-resistant DuraTec titanium carbon nitride coating, an improved tapered or conical abutment profile, and two external retentive surfaces that provide dual engagement of the nylon insert. The R-Tx uses pivot technology to compensate for implant divergence and reduces the need for prefabricated angled abutments[1,8]. Colour coding of Locator R-Tx retention inserts: Gray – zero retention, Blue – low retention, Pink – medium retention, and Clear – high retention. Limited-range inserts are also available for cases with lower implant divergence when a tighter fit is desired[1,2,8].

iv. OT Equator Attachment: The OT Equator, manufactured by Rhein83, is an ultra-low-profile stud attachment designed for implant-supported overdentures[5]. It has a narrow buccolingual and vertical dimension, makes it particularly useful when restorative space is severely limited. The OT Equator uses a titanium male component with a hemispherical shape that connects with an elastic nylon retentive cap located within the denture as shown in fig 4.[1,2,5].

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Figure 4: Components of OT Equator attachments. Source: RHEIN83 OT Equator Attachment

A major advancement is the OT Equator Smart Box, a titanium housing incorporating a tilting/pivoting mechanism. This mechanism allows the retentive cap to align with the Equator abutment even when implants are significantly divergent. The Smart Box makes it easier to insert the overdenture and compensate for significant implant divergence[2,5]. The system uses colour-coded elastic nylon retentive caps with varying levels of retention, including yellow, pink, clear, and violet options. When worn, these caps can be replaced and provide different levels of resilient retention[1,2,5].

Retention mechanism: The hemispherical male abutment is engaged by a single external elastic cap on the OT Equator. The Smart Box acts as a pivoting housing for the cap, allowing the cap to tilt and accommodate implant divergence while maintaining engagement.[2,5]

Clinical Advantages and Challenges of Stud Attachments

Stud attachments are generally simple, cost-effective, easy to fabricate and maintain, and require less restorative space than many other types of splinted attachment systems. Since the implants are not splinted, individual hygiene access around each implant is facilitated, and worn retentive components like O-rings, nylon inserts, or retentive caps can usually be replaced without replacing the entire attachment. Their resilient design allows a degree of controlled movement of the denture during function. However, stud attachments also have certain limitations. A common maintenance issue is loss of retention due to retentive component wear, which requires periodic replacement or adjustment. The angle of implant, interarch space, repeated insertion and removal of the overdenture, and uneven occlusal loading can all have an impact on their performance. Compared with splinted bar attachments, individual stud attachments may provide less cross-arch stability, particularly when implants are significantly divergent. Therefore, proper implant positioning, selection of the retentive component, accurate processing, occlusal control, oral hygiene, and regular maintenance are important for predictable long-term performance of stud attachments[2,3,9,10].

B. Bar Attachments

The bar attachment is a type of splinted system in which two or more implants are connected by a rigid bar. The overdenture has clips, riders, or sleeves that attach to the bar and offer retention and stability. By splinting the implants, the bar helps distribute functional loads across multiple implants and provides greater cross-arch stabilization than individual stud attachments. Bar attachments are available in different cross-sectional designs, including the Hader bar, Dolder bar, and round bar[1,3,11].

Hader bar: It has a keyhole-shaped cross-section and generally functions with a plastic clip or rider. It permits controlled rotational movement of the overdenture, giving some degree of stress-breaking action. Because of

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its resilient behaviour, it can provide favourable stress distribution around the implants[3,12].

Dolder bar: It is commonly available as an egg- or ovoid bar shape and can be designed as a resilient or rigid joint. A resilient Dolder bar allows for limited vertical and rotational movement of the overdenture, whereas a rigid Dolder-type design provides more restricted movement and greater stability[1,3].

Round Bar: It has a circular cross-section and is engaged by a corresponding clip or rider incorporated into the overdenture. It permits relatively greater rotational movement of the prosthesis, making it a more resilient bar design. However, its circular section can undergo greater deformation compared with stiffer bar designs. Round bars may provide lower retention than Hader bars but can reduce stresses on clips and prosthetic screws in certain situations[1,2].

Types of Bar Joints: Based on the amount of movement permitted between the bar and the clip/rider, bar systems can broadly be described as resilient bar joints, rigid bar joints, and hybrid bar designs. Resilient bar units permit controlled vertical and/or rotational movement, thereby allowing some denture movement and reducing the direct transfer of unfavourable forces to the implants. Rigid bar units restrict movement and provide maximum stabilization, resulting in a greater proportion of functional forces being transferred directly to the splinted implant assembly, as shown in fig 5.[3,11,12,13].

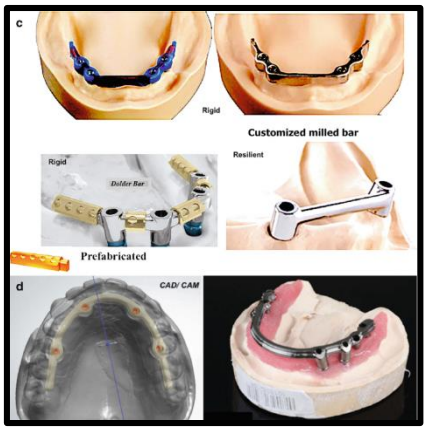


Figure 5: Types of bar attachments. Source - https://link.springer.com/chapter/10.1007/978-3-031-37582-8_4

Classification of bar attachment systems:

1. **Rigid Bar-Unit Systems**: Here, the overdenture is closely coupled to the bar and movement between the bar and the retentive element is minimal. They provide strong stabilization and resist rotational displacement, but increased rigidity may transfer a greater amount of functional forces to the splinted implant assembly. These systems require careful implant positioning, framework accuracy, and adequate bone-support.
2. **Resilient Bar-Unit Systems:** These systems permit controlled vertical and/or rotational movement between the clip and bar. The movement acts as a stress-breaking mechanism and allows the denture to function with some tissue-supported movement. The Dolder resilient design is a common example of this principle.
3. **Hybrid Bar Systems:** Hybrid designs combine a bar with individual or additional attachment components, or incorporate different degrees of rigidity/resiliency within the same prosthetic design. They can be selected when the clinician wants the splinting and cross-arch stabilization of a bar while retaining some resilient movement or individualised retention. Their

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design is more complex and therefore requires accurate laboratory fabrication and careful maintenance[3,12].

Retention mechanism: Retention is achieved by a clip, rider or sleeve engaging the external surface of the bar. The retentive element is integrated into the overdenture and mechanically engages the bar during insertion, resisting vertical and horizontal dislodging forces. The number, material, and position of the clips influence the overall retention and stability of the overdenture[6,12].

Clinical Advantages and Challenges of Bar Attachments.

Bar attachments provide excellent cross-arch stabilization and can be advantageous when several implants need to be splinted or when implant distribution is less favourable for independent stud attachments. Their major challenges are the greater restorative space requirement, higher laboratory complexity, increased cost, and more demanding hygiene procedures beneath the bar. Clip wear or fracture may lead to loss of retention, while framework misfit, bar fracture, screw loosening, or excessive cantilever length can create mechanical complications. The bar should therefore be designed with adequate hygiene access, appropriate implant distribution, and controlled cantilever dimensions. Regular evaluation of the clips, screws, bar, and peri-implant tissues is essential[6, 10, 14,15].

C. Magnetic Attachments

Magnetic attachments are low-profile, non-mechanical retentive systems that use magnetic attraction between a ferromagnetic keeper attached to the implant abutment and a rare-earth magnet assembly incorporated into the overdenture. The magnet may be made of neodymium–iron–boron or samarium–cobalt and is enclosed within a protective casing as shown in fig 6.[1, 16 & 17]

The magnet assembly is housed within the denture base, while the keeper is attached to the implant abutment. Magnetic attachments have a low vertical profile, making them useful when interarch space is limited. The magnetic attraction automatically aligns and seats the overdenture, making insertion and removal particularly easy for elderly patients and those with reduced manual dexterity[1,16]. Since magnetic systems offer relatively little resistance to horizontal displacement, they transmit lower lateral forces to the implants and supporting bone, which can be advantageous where reduced lateral force transmission is desired. However, corrosion or damage to the protective casing can result in loss of magnetism and decreased retention, so adequate sealing and maintenance are important[1,16].

Retention Mechanism: Retention results from the attractive magnetic force between the rare-earth magnet and the ferromagnetic keeper, not mechanical interlocking[1,16].

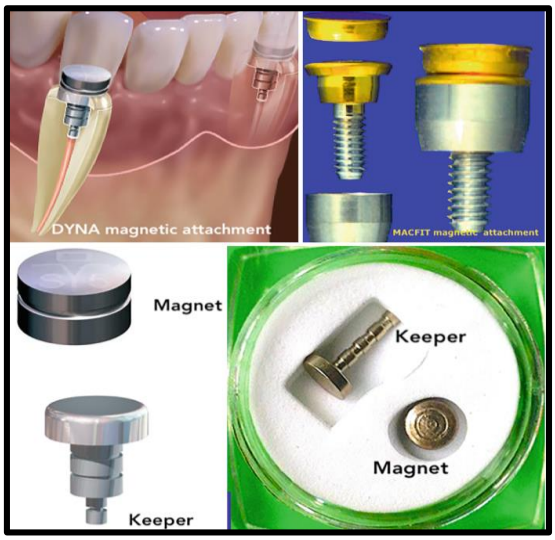


Figure 6: Components of magnetic attachments. Source https://link.springer.com/chapter/10.1007/978-3-031-37582-8_6

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Clinical advantages and challenges of Magnetic attachments.

Magnetic attachments are particularly useful when easy seating and removal are important, especially for patients who have difficulty aligning or manipulating mechanical attachments. Their low profile can also be useful when restorative space is restricted. However, magnetic retention is generally less resistant to horizontal displacement than mechanical attachments, so lateral stability may be reduced. Corrosion, damage to the protective casing, loss of magnetic force, or displacement of the keeper can compromise retention. Careful sealing, inspection of the magnetic components, and regular maintenance are therefore important. They may also be less suitable when very high mechanical retention and resistance to lateral movement are required[2,10, 16, 18]

D. Telescopic Attachments

Telescopic attachments, also known as double crowns, crown-and-sleeve copings or Konus crowns, are frictional attachment systems. They consist of a primary (inner) coping that is permanently cemented or screw-retained to the implant abutment and a secondary (outer) coping incorporated into the overdenture. The secondary coping fits over the primary coping and provides retention, support, and stabilization to the removable prosthesis, as shown in fig 7.[19, 20 & 21].



Figure 7: Components of telescopic attachments. Source: https://doi.org/10.1007/978-3-031-37582-8_5

Telescopic attachments provide good force distribution and horizontal stabilization, with occlusal forces being directed more along the long axis of the implant, allowing the overdenture to be removed for hygiene and maintenance[19,22].

They are broadly classified into cylindrical, conical, resilient, and modified telescopic designs. In the cylindrical type, the primary coping has parallel walls and retention is obtained by frictional contact between the primary and secondary copings. It provides high retention but is technique-sensitive and may undergo progressive wear with continuous surface contact. In the conical type, the primary coping has tapered walls and retention is produced mainly by a wedging effect when the secondary coping is completely seated[19,22].

Resilient telescopic designs allow controlled vertical movement of the overdenture under functional loading, whereas rigid telescopic designs provide greater stability with a definite seating position. The amount of retention is influenced by the taper angle, surface area of contact, number and distribution of abutments, and material combination; increasing the taper generally decreases retention[19,20].

Retention mechanism: Retention is primarily produced by frictional contact in cylindrical telescopes and wedging action in conical telescopes between the primary and secondary copings. Resilient or hybrid designs may incorporate controlled movement or additional retentive elements[19,20].

Clinical Advantages and Challenges of Telescopic Attachments.

Telescopic attachments provide excellent support, stabilization, and a defined path of insertion, and their broad contact surfaces can contribute to favourable force distribution. They can also allow the overdenture to be designed with a splinted effect when multiple primary

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copings are used. The principal challenges are high laboratory and clinical technique sensitivity, the need for an accurately controlled path of insertion, and maintenance of the frictional surfaces. Wear or alteration of the coping surfaces can change retention over time, and correction or replacement may be more complicated than replacement of a simple nylon insert. Adequate interarch space, precise framework fabrication, good oral hygiene, and regular assessment of the primary and secondary copings are therefore required[19,20].

Table 1: Summary and Comparison of Types of Attachments

Parameter	Ball	Era	Locator	Ot equator	Bar	Magnet	Telescopic
Interarch distance	Moderate; ~10–12 mm	Low–moderate; ~8–10 mm	Low; ~8–9 mm	Very low; ~7–8 mm	High; ~13–15 mm	Low–moderate; ~9–10 mm	High; ~10–14 mm
Bone quality	Good–moderate; preferably adequate bone support	Good–moderate; useful where resilient movement is desired	Good; versatile in varying bone conditions	Good; useful where low profile and controlled resiliency are needed	Good bone quality preferred, particularly for rigid/splinted designs	Can be useful when minimizing lateral force is important	Good bone quality preferred because of relatively rigid coupling
Retention mechanism	O-ring/elastic ring engaging spherical ball	Resilient nylon male engaging female socket	Nylon insert engages retentive surfaces on Locator abutment	Elastic retentive cap engaging Equator abutment	Clip/rider engages bar	Magnetic attraction between magnet and ferromagnetic keeper	Friction, wedging and close adaptation between primary and secondary copings
Rigidity	Resilient	Highly resilient	Semi-resilient	Resilient	Rigid or resilient, depending on bar design	Non-rigid/non-mechanical	Rigid
Wear parts	O-ring	Replaceable nylon male	Replaceable nylon insert	Replaceable retentive cap	Clips/riders	Magnet/keeper components; casing integrity important	Coping surfaces may wear; requires periodic assessment
Angulation correction	Limited; best with relatively parallel implants	0°, 5°, 11°, 17° angled components available	High; conventional Locator and R-Tx provide divergence compensation	High; Smart Box can accommodate significant divergence	Generally requires good parallelism; special designs may compensate	Very high/free path of insertion; self-adjusting	Can correct implant angulation through customized/tapered copings, but requires controlled path of insertion
Complexity	Low	Moderate	Low	Low–moderate	High	Low	High
Cost	Low–moderate	Moderate	Moderate	Moderate	High	Moderate	High
Lateral stability	Good	Moderate	Good	Good	Excellent	Low	Excellent
Allowed movement	Vertical and rotational	Vertical resiliency +	Limited vertical/rotatio	Resilient vertical/rotational	Minimal movement in rigid	Free/self-aligning movement with low	Minimal movement;

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	movement	rotation	nal movement	movement	bar; controlled rotation in resilient bar	lateral resistance	primarily rigid frictional coupling
Hygiene	Good; individual attachments facilitate cleaning	Good	Good; easy access around individual attachments	Good because of very low profile and individual design	More difficult; cleaning beneath bar is required	Good	Moderate; requires meticulous cleaning around copings
Maintenance	O-ring replacement and periodic adjustment	Nylon male replacement	Frequent insert replacement/retention adjustment	Retentive cap replacement	Clip replacement, bar/component maintenance	Magnet/casing inspection and replacement when required	More technique-sensitive; coping adjustment and maintenance required
Profile height	Moderate	Low–moderate	Low (~2.5 mm attachment height)	Very low (~2.1–2.5 mm depending on component)	High	Low	High
Overall biomechanical character	Resilient, simple, economical	Highly resilient, tissue-supportive	Low-profile, resilient, versatile	Ultra-low profile, resilient, high angulation compensation	Maximum splinting and cross-arch stabilization	Lowest lateral force transmission but lower retention	Rigid, highly retentive and stable

The comparison (Table 1) demonstrates that attachment selection should be based on the combination of interarch space, implant angulation, desired resiliency, retention, hygiene, maintenance, and biomechanical requirements, rather than on retention alone[1,2, 23,24]

Conclusion

ISOD attachment systems offer different advantages in terms of retention, stability, stress distribution, space requirements, maintenance, and patient comfort. No single attachment system can be considered universally superior, and selection should be individualized according to implant number and distribution, bone quality, implant angulation, interarch space, prosthetic requirements, hygiene, patient dexterity, and economic considerations.

Resilient attachments such as ball, ERA, locator, and OT equator provide controlled movement and are useful where stress relief and limited space are important, whereas bar and telescopic systems provide greater splinting, stability, and rigidity. Magnetic attachments offer low-profile designs and reduced lateral force transmission but provide comparatively lower retention.

Overall, careful selection and regular maintenance of the attachment system are essential for achieving predictable biomechanical performance, peri-implant health, and long-term success of implant-supported overdentures.

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