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Implant-Abutment Connection Design and Patient-Centered Outcomes: Bridging Biomechanical and Biological Performance with Patient Experience - A Critical Narrative Review

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ABSTRACT

Dental implant therapy has evolved from a survival-centered treatment philosophy toward a broader concept of success that incorporates biological stability, prosthetic reliability, function, esthetics, and patient satisfaction (1,2). The implant-abutment connection (IAC) is a critical component of the implant-prosthetic complex because connection geometry can influence load transfer, micromotion, screw-joint stability, microgap formation, microbial leakage, peri-implant tissue behavior, marginal bone remodeling, and technical complications (3-9). Systematic reviews and meta-analyses generally demonstrate more favorable marginal bone preservation with internal and particularly conical connection configurations than with traditional external hexagonal systems, whereas differences in implant survival are less consistent and survival remains high across modern systems (7,8,10). Despite extensive evidence on biomechanical and clinician-reported outcomes, comparatively little research directly evaluates whether connection-specific advantages are perceptible to patients (33,37-43). Patient-reported outcome measures (PROMs), including comfort, masticatory function, esthetic satisfaction, overall satisfaction, and oral health-related quality of life (OHRQoL), therefore provide an essential complementary perspective (33,35,37-43). This critical narrative review integrates mechanistic, biological, clinical, and patient-reported evidence and proposes a three-level framework distinguishing direct PROM evidence from clinically mediated and mechanistic outcomes. Current evidence supports favorable joint stability, sealing behavior, and marginal bone outcomes for well-designed internal conical connections, but conical and Morse-taper systems are heterogeneous and differ in taper angle, indexing, engagement geometry, machining tolerance, and screw design (11). Importantly, randomized abutment-management studies demonstrate that measurable improvements in marginal bone behavior may occur without significant differences in PROMs (25,26). Thus, biomechanical or radiographic superiority should not automatically be interpreted as patient-perceived superiority. Future trials should directly compare connection geometries while simultaneously assessing standardized clinical outcomes and validated PROMs.

Keywords: Dental implants; implant-abutment connection; patient-reported outcome measures; PROMs; internal connection; external hexagon; conical connection; Morse taper; marginal bone loss; patient satisfaction; oral health-related quality of life.

I. INTRODUCTION

Dental implants are an established treatment option for the replacement of missing teeth and the rehabilitation of partially and completely edentulous patients (1,2). Contemporary success criteria extend beyond osseointegration and implant survival to include preservation of peri-implant tissues, mechanical stability of the implant-prosthetic complex, satisfactory esthetics and function, limited maintenance requirements, and favorable patient perception of treatment (1,2,37,43).

The implant-abutment connection forms the structural interface between the endosseous implant and restorative components and has a decisive influence on load transfer, joint stability, micromotion, screw preload, fatigue resistance, and microgap behavior (3-6,11-17). These mechanical characteristics may also contribute to biological events because movement at the implant-abutment microgap can facilitate microbial leakage and inflammatory challenge adjacent to peri-implant tissues (4,9,14,15,20,21).

External hexagonal connections were historically important in the development of osseointegrated implant therapy, but their relatively shallow engagement places substantial functional

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demand on the retaining screw (3-7). Internal connections were introduced to provide deeper engagement and improved resistance to rotational and lateral forces, while internal conical and Morse-taper configurations additionally use frictional contact between tapered surfaces to enhance joint stability (5,6,11).

Clinical evidence suggests that connection configuration can influence marginal bone remodeling. Lemos et al. reported approximately 0.44 mm less marginal bone loss with internal than external connections, while survival and overall complication rates were not significantly different (7). A large meta-analysis of 45,347 implants similarly found lower pooled marginal bone changes with internal narrow-cone and tissue-level configurations than with external hexagonal and internal wide-cone/flat designs, although cumulative survival remained at least 96% across categories (10).

The term conical connection should not be treated as a uniform biomechanical category. Morse-taper systems vary in taper angle, cone height, antirotational indexing, engagement length, cone mismatch, implant wall thickness, machining tolerance, and screw geometry, all of which can influence preload, stress distribution, sealing, and fatigue behavior (11,17,44-46).

Despite the large volume of biomechanical and clinician-reported evidence, comparatively fewer studies directly evaluate the patient perspective. PROMs are increasingly recognized as important because a technically successful implant may still fail to satisfy the patient in terms of comfort, chewing, esthetics, maintenance burden, or OHRQoL (33,37-43). The purpose of this critical narrative review is therefore to integrate connection-related mechanical, biological, clinical, and patient-reported evidence and to distinguish direct PROM evidence from patient benefits that are only inferred from surrogate outcomes.

II. SEARCH STRATEGY AND METHODOLOGY

A critical narrative review approach was used to integrate biomechanical, biological, clinical, and patient-reported evidence regarding implant-abutment connection design. The review was structured around three principal concepts: connection geometry, clinical/biological outcomes, and patient-centered outcomes (4,7-11,33,37-43).

Search concepts included dental implant, implant-abutment connection, implant-abutment interface, external hexagon, internal hexagon, internal connection, conical connection, Morse taper, microgap, micromotion, bacterial leakage, microbial colonization, preload, torque loss, screw loosening, marginal bone loss, peri-implant tissue, prosthetic complication, patient-reported outcome measure, PROM, patient satisfaction, quality of life, OHIP, OHIP-EDENT, comfort, chewing, and esthetic satisfaction (4,7,9,11,33,37-43).

Priority was given to systematic reviews and meta-analyses, randomized controlled trials, prospective and retrospective clinical studies, and investigations directly reporting patient-centered outcomes. Experimental, microbiological, mechanical, and finite element studies were included when needed to explain mechanisms linking connection geometry with clinical outcomes (5,6,11-17).

Evidence was interpreted at three levels. Level I comprised direct patient-reported evidence such as OHIP, satisfaction, comfort, masticatory function, and esthetic perception. Level II comprised clinically mediated outcomes such as marginal bone loss, mucositis, peri-implantitis, screw loosening, fracture, and maintenance interventions. Level III comprised mechanistic evidence such as microgap, bacterial leakage, preload, removal torque, micromotion, stress distribution, and fatigue behavior. This distinction was used because superiority at Level II or III does not necessarily produce superiority at Level I (25,26).

III. EVOLUTION AND CLASSIFICATION OF IMPLANT-ABUTMENT CONNECTIONS

Implant-abutment connections can broadly be categorized as external, internal nonconical, and internal conical configurations, although substantial design variation exists within each group (3-7,11). Connection development has focused on improving antirotational stability, load transfer, screw-joint reliability, resistance to micromotion, microgap behavior, and peri-implant tissue stability (3-6,11).

3.1 External Hexagonal Connection

The external hexagonal connection uses a coronal antirotational hexagon with the abutment retained by a central fixation screw. Its shallow engagement provided a practical restorative interface but results in substantial dependence on screw preload for joint stability (3-7). Under cyclic and nonaxial loading, external configurations may show greater micromotion, torque loss, and microgap behavior than deeper internal designs (5,7,12-16). Clinical studies nevertheless demonstrate high survival, emphasizing that

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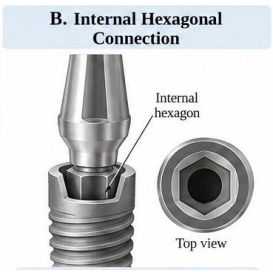
external connection is predictable rather than obsolete (7,10).

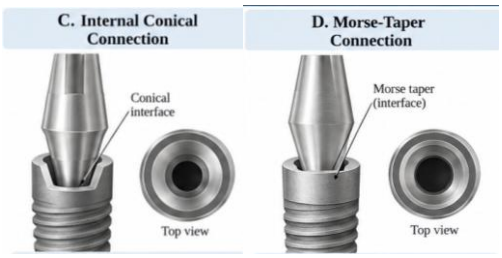
3.2 Internal Hexagonal and Flat-to-Flat Connections

Internal hexagonal and flat-to-flat connections relocate the antirotational interface within the implant body, increasing engagement depth and resistance to lateral and rotational forces (3-7). These designs reduce the lever arm acting on the retaining screw compared with external connections, but micromotion and microgap formation can still occur under loading (5,13). Their biological behavior is also influenced by platform design, placement depth, tissue phenotype, prosthetic contour, and patient factors (8-10,20-22).



3.3 Internal Conical and Morse-Taper Connections

Internal conical connections use opposing tapered surfaces that create frictional engagement and increase implant-abutment contact area (5,6,11,46). Functional loading can therefore be transferred through the conical walls in addition to the fixation screw. These systems frequently demonstrate favorable joint stability, torque maintenance, sealing behavior, and resistance to micromotion (5,6,11,16). Morse-taper performance depends on specific geometric variables. Narrower angles may increase frictional locking, whereas wider angles can improve stress distribution and resistance to microgap formation in some designs (11,17,45,46). Antirotational indexing, cone mismatch, wall thickness, and screw geometry also alter flexural strength, preload, and fatigue resistance (11). Consequently, all conical or Morse-taper systems should not be considered mechanically equivalent.



BIOMECHANICAL AND BIOLOGICAL INFLUENCE OF IMPLANT-ABUTMENT CONNECTION DESIGN

The implant–abutment connection (IAC) influences load transfer, joint stability, micromotion, microgap formation, and peri-implant tissue response. Its performance depends on connection depth, taper, surface contact, screw design, manufacturing precision, restorative geometry, and loading conditions (5,6,11-18).

External connections depend mainly on screw preload, whereas internal conical connections distribute forces through greater internal surface contact and generally demonstrate better resistance to micromotion, preload loss, and microgap enlargement (5,6,11,13-16). However, no connection completely prevents mechanical complications or microbial leakage.

Preload loss, cyclic fatigue, screw loosening, and component deformation are affected by connection geometry, tightening protocol, implant angulation, prosthetic height, framework fit, and occlusal forces (11,12,16). Conical interfaces often show lower microbial leakage because frictional engagement limits interface movement, although they are not bacteria-proof (4,14,15).

The microgap may permit bacterial penetration and movement of fluids or microbial products, contributing to peri-implant inflammation and marginal bone remodeling (4,9,19-21). Internal conical connections have shown favorablecrestal bone and peri-implant tissue outcomes, but these benefits are also influenced by implant position, tissue phenotype, emergence profile, hygiene, and restorative design (19-22).

Platform switching may further preserve marginal bone by shifting the implant–abutment junction away from the crestal bone (20-23). Similarly, minimizing repeated abutment disconnection may reduce early tissue disturbance and marginal bone remodeling (25,26).

Overall, internal conical connections provide favorable mechanical stability and

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biological sealing, but clinical success depends on the interaction between connection design, prosthetic factors, tissue characteristics, and loading conditions.

TABLE 1. CLASSIFICATION AND CLINICAL CHARACTERISTICS OF IMPLANT-ABUTMENT CONNECTION DESIGNS

Connection design	Structural characteristics	Biomechanical features	Biological/clinical considerations	Patient-centered interpretation
External hexagonal	External coronal antirotational hexagon; shallow engagement	Greater dependence on screw preload; comparatively greater micromotion and torque loss under cyclic loading (5,7,12-16)	Generally greater marginal bone remodeling than several internal designs; high survival remains achievable (7,10)	Potentially greater maintenance burden if complications develop, but direct evidence of inferior PROMs is insufficient
Internal hexagonal / flat-to-flat	Abutment engages within implant body through internal antirotational surfaces	Deeper engagement and improved resistance to lateral/rotational forces (3-7)	Clinically acceptable; some RCTs show greater bone remodeling than internal conical connections (18,19)	No strong direct evidence of worse patient perception than conical connections
Internal conical	Internal tapered surfaces with frictional engagement	Improved contact area, joint stability, preload maintenance and microgap behavior (5,6,11,16)	Frequently associated with favorable marginal bone and sealing behavior (18,19)	Prospective cohorts report excellent function and satisfaction, but mostly noncomparative (33-35)
Morse-taper type	Conical friction-fit; geometry varies by manufacturer	Performance depends on taper angle, indexing, mismatch and screw design (11)	Potentially favorable sealing and stability; high design heterogeneity (11)	Cannot assume equivalent PROMs across all Morse-taper systems
Platform-switched	Abutment narrower than implant platform	Relocates IAC inward and alters stress distribution (20-23)	Often associated with reduced marginal bone remodeling	Potential esthetic/tissue benefit plausible, but direct PROM superiority unproven

IMPLANT-ABUTMENT CONNECTION DESIGN AND MARGINAL BONE PRESERVATION

Marginal bone stability is one of the most frequently investigated clinical outcomes related to IAC design (7,8,10,18-22). Lemos et al. found approximately 0.44 mm less marginal bone loss with internal than external connections, but no significant difference in survival or overall complications (7).

Schoenbaum et al. evaluated 270 publications comprising 16,448 patients and 45,347 implants and classified configurations as external hexagonal, internal narrow cone, internal wide-cone/flat, and tissue-level (10). Internal narrow-cone and tissue-level designs demonstrated lower pooled marginal bone changes than external hexagonal and wide-cone/flat designs, while survival remained high across all categories (10).

Randomized comparative evidence also supports a potential advantage of internal conical over internal hexagonal connections. Galindo-Moreno et al. reported approximately -0.25 mm versus -0.70 mm marginal bone levels at 12 months, favoring the conical design (18). Mishra et al. similarly found statistically favorable crestal bone outcomes with internal conical connections, although effect sizes were small (19).

Connection-related bone differences must be interpreted within a multifactorial environment

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that includes implant placement depth, platform design, tissue phenotype, surface characteristics, restorative contour, occlusion, oral hygiene, periodontal history, and radiographic methodology (8-10,20-22).

Three separate questions should therefore be asked when interpreting marginal bone evidence: Is the difference statistically significant? Is the magnitude clinically meaningful? Does the patient perceive any benefit? These questions are related but not interchangeable.

TABLE 2. PRINCIPAL CLINICAL EVIDENCE RELATING CONNECTION DESIGN TO MARGINAL BONE AND CLINICAL OUTCOMES

Study	Design/sample	Comparison	Principal findings	Interpretation
Lemos et al. (7)	Systematic review/meta-analysis; 11 studies, 530 patients, 1,089 implants	External vs internal	Internal connections about 0.44 mm less marginal bone loss; survival/complications not significantly different	Supports better average bone preservation with internal connections
Schoenbaum et al. (10)	Systematic review/meta-analysis; 45,347 implants	External hex, internal narrow cone, internal wide cone/flat, tissue-level	Narrow internal cone and tissue-level showed lower pooled marginal bone changes; survival >=96%	Connection configuration affects ΔMBL more clearly than survival
Galindo-Moreno et al. (18)	12-month randomized pilot study	Internal hex vs internal conical	Approx. -0.70 mm vs -0.25 mm marginal bone level at 12 months	Supports connection-specific effect favoring conical
Mishra et al. (19)	RCT	Internal hex vs internal conical	Conical group showed favorable crestal bone, probing depth and IL-1β	Structural differences small; both clinically acceptable
Calatrava et al. (25)	12-month RCT	One-abutment one-time vs repeated disconnection	Greater bone remodeling after repeated disconnection; no PROM difference	Biological advantage did not translate into patient-perceived difference
Sanz-Sánchez et al. (26)	5-year RCT follow-up	One-abutment one-time vs conventional	No significant PROM difference at 5 years	Long-term clinical and PROM outcomes similar
Toia et al. (30)	5-year RCT	Implant-level vs abutment-level	Similar MBL and overall complication profiles	Both restorative strategies clinically acceptable

IMPLANT-ABUTMENT CONNECTION DESIGN AND TECHNICAL/PROSTHETIC COMPLICATIONS

Technical complications include screw loosening, screw fracture, abutment fracture, veneering fracture, loss of retention, prosthetic misfit, and component failure (5,6,16,30-32). Connection geometry contributes to these risks because it determines how forces are distributed between the implant, abutment, screw, and prosthesis.

Conical and Morse-taper systems generally preserve screw-joint stability more favorably under cyclic loading than external hexagonal configurations, but no connection eliminates mechanical complications (11,16). Occlusal overload, prosthetic height, implant angulation, framework misfit, material selection, parafunction, and tightening protocol remain important modifiers.

In a five-year randomized trial, Toia et al. compared implant-level and abutment-level screw-retained fixed partial dentures supported by internal conical implants and found similar marginal bone levels and overall biological and technical complication patterns (30). This demonstrates that theoretical mechanical advantages do not

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necessarily produce large clinical differences when both strategies are executed appropriately.

Multi-unit prostheses introduce the additional requirement of passive fit. Non-engaging or intermediate-abutment strategies may facilitate seating across nonparallel implants and reduce residual strain (32). Connection stability and prosthetic passivity are therefore distinct objectives, and maximum engagement is not necessarily ideal for every restoration.

Technical complications represent clinically mediated patient-related outcomes rather than PROMs. A screw loosening or fracture may require an unscheduled visit, repair, or interruption of function, but the actual patient burden should be measured rather than assumed.

DIRECT EVIDENCE LINKING IMPLANT-ABUTMENT CONNECTIONS WITH PATIENT-REPORTED OUTCOMES

Direct comparative PROM evidence remains limited. The clearest randomized evidence relates to abutment-management strategy rather than to major differences between external, internal hexagonal, and internal conical connection geometries (25,26).

Calatrava et al. compared a one-abutment one-time protocol with repeated healing-abutment disconnection. PROMs assessed comfort, appearance, masticatory function, taste, and overall satisfaction. Despite significantly greater marginal bone remodeling after repeated disconnection, PROMs did not differ significantly between groups (25).

At five years, Sanz-Sánchez et al. again found high satisfaction in both one-time and conventional abutment-management groups, with no significant PROM differences despite numerical differences in bone remodeling (26). These trials provide strong evidence that objective biological differences do not automatically produce patient-perceived differences.

Ackermann et al. reported long-term clinical and patient-reported outcomes for restorations using an internal conical connection. At five years, 87.5% of patients were maximally satisfied and the remainder were satisfied (33). This supports excellent PROMs with internal conical restorations but does not establish superiority over another connection because no parallel control group was included.

Manfrinato et al. reported substantial improvement in OHIP-EDENT after full-arch rehabilitation using zygomatic and conventional implants with conical prosthetic components. Mean total OHIP-EDENT fell from 17.44 at baseline to 1.94 at six months and 2.63 at 12 months (35). The improvement reflects the overall rehabilitation rather than the isolated effect of the connection.

de Beus et al. followed single molar zirconia restorations supported by implants with a conical connection and angulated screw channel abutments for five years. Implant survival was 100%, restoration survival 97%, and mean overall PROM score 9.1/10, despite several manageable technical complications (34). This again demonstrates that high satisfaction can coexist with technical events when function and esthetics are maintained.

Overall, internal conical connections are associated with favorable PROMs in prospective cohorts, but current evidence is insufficient to rank connection designs as external < internal hexagonal < conical/Morse taper in terms of patient satisfaction or OHRQoL.

TABLE 3. DIRECT AND SUPPORTIVE EVIDENCE ON PATIENT-REPORTED OUTCOMES

Study	Connection/intervention	PROM domains	Main findings	Evidence interpretation
Ackermann et al. (33)	Internal conical connection	Functional/esthetic satisfaction	87.5% maximally satisfied and 12.5% satisfied at 5 years	Level I supportive; noncomparative
Calatrava et al. (25)	One-abutment one-time vs repeated disconnection	Comfort, appearance, mastication, taste, overall satisfaction	No significant PROM difference despite greater bone loss after repeated disconnection	Level I direct comparative connection-management evidence
Sanz-Sánchez et al. (26)	One-time vs conventional abutment protocol	Long-term satisfaction	Mean scores >4.5; no significant group difference	Level I direct long-term comparative

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				evidence
Manfrinato et al. (35)	Conical prosthetic components in full-arch rehabilitation	OHIP-EDENT	17.44 baseline to 1.94 at 6 months and 2.63 at 12 months	Level I supportive; connection effect not isolated
de Beus et al. (34)	Conical connection + ASC molar restoration	Function, esthetics, satisfaction	PROMs improved; overall 9.1/10 at 5 years	Level I supportive; noncomparative
Barwacz et al. (36)	CAD/CAM abutments across systems	Mastication, esthetics, overall satisfaction	Very favorable patient-centered outcomes	Supportive prosthetic evidence; not connection-specific

DIRECT VERSUS INDIRECT PATIENT-RELATED EVIDENCE: A THREE-LEVEL FRAMEWORK

The patient-centered interpretation of IAC studies is strengthened by separating evidence according to its distance from the patient experience. Level I consists of direct patient-reported outcomes such as OHIP, comfort, chewing, esthetics, and satisfaction (25,26,33-43). Level II consists of clinically mediated outcomes such as marginal bone loss, recession, mucositis, peri-implantitis, screw loosening, fracture, repair, and maintenance (7-10,18-32). Level III consists of mechanistic outcomes such as microgap, bacterial leakage, preload, removal torque, micromotion, stress, and fatigue behavior (4-6,11-17).

These levels should not be treated as equivalent. A smaller microgap does not itself prove improved OHRQoL, and a statistically significant marginal bone advantage does not itself prove improved satisfaction. The randomized abutment studies directly demonstrate that Level II superiority may occur without Level I superiority (25,26).

Connection design is therefore best conceptualized as an upstream determinant. Patients are more likely to perceive downstream consequences such as stable function, esthetics, comfort, maintenance requirements, and complications than the geometry of the IAC itself.

TABLE 4. THREE-LEVEL FRAMEWORK FOR INTERPRETING CONNECTION-RELATED PATIENT OUTCOMES

Evidence level	Definition	Examples	Patient-centered interpretation
Level I - Direct PROM	Outcome reported directly by patient	OHIP/OHIP-EDENT, comfort, chewing, esthetics, satisfaction	Direct statements about patient experience are justified
Level II - Clinically mediated	Clinician-observed event that may affect patient	Marginal bone loss, recession, mucositis, screw loosening, fracture, repair	Potential patient consequence can be proposed, but is not a PROM unless measured
Level III - Mechanistic	Laboratory/biomechanical/microbiological variable	Microgap, leakage, preload, removal torque, stress, micromotion	Explains mechanisms but cannot independently establish patient benefit

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PROPOSED CONNECTION-TO-PATIENT OUTCOME MODEL

The present review proposes an integrated pathway linking connection geometry to increasingly patient-relevant outcomes. The model is conceptual rather than strictly causal and is intended to prevent inappropriate extrapolation from laboratory results to patient benefit.

Stage 1 is the connection geometry itself: external versus internal position, engagement depth, taper angle, antirotational features, platform configuration, machining tolerances, and screw geometry (3-6,11). Stage 2 is mechanical behavior, including load transfer, preload maintenance, micromotion, fatigue behavior, and rotational stability (5,6,11-17). Stage 3 is the implant-abutment microenvironment, including microgap dynamics and microbial leakage (4,14,15). Stage 4 is biological response, including inflammation, peri-implant tissue behavior, and marginal bone remodeling (7-10,18-24). Stage 5 is clinical consequence, including technical complications, maintenance, recession, mucositis, and peri-implantitis (25-32). Stage 6 is the patient experience, including comfort, mastication, esthetics, treatment burden, satisfaction, and OHRQoL (25,26,33-43).

The model helps explain why a connection may demonstrate superior mechanical or radiographic performance without producing a measurable PROM difference. Several intermediate steps exist between connection geometry and patient perception, and each step should ideally be tested rather than assumed.

TABLE 5. PROPOSED PATHWAYS LINKING CONNECTION DESIGN TO PATIENT EXPERIENCE

Connection-associated factor	Intermediate effect	Possible clinical consequence	Potential patient-related consequence
Increased connection stability	Reduced micromotion	Lower risk of screw instability	Fewer maintenance visits; stable function
Favorable preload maintenance	Reduced screw-joint instability	Lower risk of screw loosening	Reduced interruption of prosthesis use
Reduced dynamic microgap	Potential reduction in microbial exchange	More stable peri-implant environment	Potentially improved comfort/tissue health
Favorable load distribution	Reduced stress concentration	Lower component overload risk	Potentially reduced repair burden
Marginal bone preservation	Better hard-tissue support	Potential soft-tissue/esthetic stability	Potentially improved esthetic satisfaction
Reduced technical complications	Fewer repairs/replacements	Lower treatment burden	Potentially better satisfaction

CLINICAL IMPLICATIONS AND CONNECTION SELECTION

Current evidence does not support selecting a connection solely on the assumption that one design is universally superior. Connection choice should integrate biomechanical requirements, prosthetic design, restorative space, implant position, tissue phenotype, esthetic demand, occlusal loading, retrievability, component availability, and patient-related risk (11,16,18-19,30-32).

External hexagonal connections remain predictable but generally show less favorable values for several mechanical and marginal bone parameters than modern internal configurations (7,10,16). Internal hexagonal connections provide deeper engagement and reliable antirotational stability, while internal conical/Morse-taper connections frequently provide favorable frictional stability, sealing, preload preservation, and marginal bone behavior (11,16,18,19).

For single-unit restorations, antirotational engagement and joint stability are particularly important. In multi-unit restorations, passive fit and management of implant divergence may favor non-engaging or intermediate-abutment strategies (30-32).

In high-load or parafunctional situations, the entire restorative system should be optimized rather than relying on connection geometry alone. Prosthetic height, implant diameter, occlusion, restorative material, implant distribution, and maintenance strategy remain critical.

PROM evidence supports excellent patient outcomes with internal conical systems, but direct evidence proving superior satisfaction compared with external or internal hexagonal connections remains insufficient (33-35). A reasonable clinical conclusion is therefore to preferentially consider

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well-designed internal conical systems when their biomechanical advantages match the clinical situation, without claiming universal PROM superiority.

LIMITATIONS OF THE CURRENT EVIDENCE

The principal limitation is the scarcity of trials that directly compare major connection geometries while simultaneously measuring validated PROMs (25,26,33-43). Most PROM studies are noncomparative or evaluate the overall prosthetic intervention rather than isolating connection geometry.

Connection classification is heterogeneous. Systems labeled conical or Morse taper vary considerably in taper angle, indexing, cone mismatch, screw geometry, and engagement depth, limiting generalization across manufacturers (11).

Connection geometry is rarely the only variable that differs between implant systems. Surface, macrogeometry, placement depth, platform switching, abutment design, and restorative protocol can confound clinical comparisons (7,8,10,18-22).

PROM instruments are heterogeneous and are often secondary rather than primary outcomes. Many studies are powered for bone-level differences rather than for patient satisfaction, and ceiling effects may further reduce sensitivity (37-39,43).

Follow-up periods are variable and often short relative to the time over which fatigue, maintenance burden, peri-implant disease, or tissue recession may develop (10,33-35).

Mechanistic conclusions depend heavily on in vitro and finite element evidence, which cannot fully reproduce patient-specific occlusion, saliva, temperature, tissue support, parafunction, hygiene, and prosthetic misfit (11-17).

Finally, marginal bone remodeling is multifactorial and should not be attributed exclusively to connection geometry. Statistical significance should be accompanied by effect size, clinical relevance, and patient-centered interpretation.

IV. SUMMARY AND CONCLUSION

The implant-abutment connection influences the mechanical behavior of the implant-prosthetic complex and can contribute to microgap dynamics, microbial leakage, peri-implant tissue response, marginal bone remodeling, and technical complications (4-19). External hexagonal connections remain clinically successful, but internal and particularly well-designed conical configurations generally demonstrate favorable joint stability and marginal bone behavior (7,10,11,16,18,19).

Conical and Morse-taper systems should not be treated as homogeneous because geometric variables strongly influence biomechanical performance (11). Moreover, connection-related biological outcomes are embedded within a multifactorial environment that includes platform design, placement depth, tissue phenotype, prosthetic contour, occlusion, hygiene, and patient-related factors (8-10,20-23).

Prospective clinical cohorts demonstrate that internal conical connections can support restorations associated with excellent long-term function, esthetics, satisfaction, and OHRQoL (33-35). However, randomized abutment-management studies show that measurable biological advantages may occur without corresponding PROM differences (25,26).

The present review therefore distinguishes direct patient-reported evidence from clinically mediated and mechanistic evidence and proposes a Connection-to-Patient Outcome Model in which connection geometry acts as an upstream determinant rather than a direct patient outcome.

Current evidence is insufficient to conclude that one specific connection consistently produces superior PROMs. Future randomized studies should simultaneously assess standardized mechanical, biological, technical, and validated patient-reported outcomes. The clinically relevant question should therefore move beyond which connection performs best toward which connection provides the most appropriate biological, mechanical, prosthetic, and patient-centered outcome for the individual clinical situation.

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