

The Biomechanical Basis of Narrow (2.0-mm) One-Piece Dental Implants

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Abstract

Background: Narrow one-piece implants in the 2.0-mm class are increasingly considered for horizontally deficient ridges, reduced mesiodistal spaces, and simplified graft-avoidance protocols. Their clinical attraction is clear, but their reduced diameter places them at the edge of implant biomechanics, where bending fatigue, crestal stress concentration, and load direction become decisive [3-5,20].

Objective: To synthesize the biomechanical rationale for the use of 2.0-mm one-piece implants and to propose a theory-based framework explaining when they may function predictably, with particular attention to the use of multiple implants as a stress-sharing strategy. [3-5,14-19]

Sources: Evidence was drawn from systematic reviews, laboratory fatigue studies, finite element analyses, strain-gauge experiments, and prospective clinical studies on category-1 narrow implants and mini-implants, especially one-piece systems in the 1.8-2.5 mm range. [3-19,21-24]

Content: The central biomechanical penalty of a 2.0-mm implant is loss of bending reserve. This increases dependence on cortical support, bone quality, crown height control, and axial loading. One-piece design removes the screw-joint interface but likely shifts stress to the continuous narrow transmucosal-cervical segment. Multiple narrow implants improve biomechanics by reducing force per implant, shortening effective lever arms, and redistributing strain across a broader support polygon. Experimental models show lower peri-implant microstrain with increasing implant number, while clinical studies suggest favourable long-term outcomes for overdenture stabilization and selected low-load anterior restorations [1,2,6-19,21,24].

Conclusion: A 2.0-mm one-piece implant should not be viewed as a miniaturized conventional implant but as a moment-sensitive implant system. Its success depends on converting a slender, fatigue-vulnerable geometry into a low-moment, well-supported, load-sharing restoration. Biomechanically, multiple 2.0-mm implants are more defensible than a solitary 2.0-mm implant in many situations because they transform the problem from single-implant bending to distributed support [5,14-19].

Keywords: mini dental implants; one-piece implants; narrow-diameter implants; biomechanics; fatigue; stress distribution; splinting; mandibular overdentures

Introduction

Implant diameter is a primary biomechanical determinant because it influences both stress transfer to peri-implant bone and the structural resistance of the implant itself. Classical finite element work showed that increasing diameter has a greater effect than increasing length on reducing crestal strain, and later analyses confirmed that stress remains concentrated mainly at the implant neck and in the crestal cortical bone [1,2].

That principle becomes especially important when the diameter approaches 2.0 mm. At that point, the implant no longer behaves simply as a narrower version of a standard implant; it becomes a mechanically constrained device whose long-term survival depends heavily on fatigue behaviour, off-axis loading, prosthetic lever arms, and the quality of cortical engagement. Reviews and meta-analyses on narrow implants consistently show that the risk profile worsens as diameter decreases, with implants below 3.0 mm behaving less favourably overall than standard-diameter implants [3-5].

For this reason, the biomechanical discussion of 2.0-mm one-piece implants must be indication-specific. The best direct evidence comes not from routine posterior fixed crowns, but from category-1 narrow implants and mini-implants used in overdenture stabilization, very narrow ridges, and selected low-load anterior fixed indications [3-5,11-13].

Why 2.0 mm Changes the Biomechanics?

The most important mechanical consequence of reducing implant diameter is the loss of resistance to bending. As implant diameter decreases, the metal core available to withstand cyclic loading becomes smaller, and this disproportionately increases the risk of fatigue failure. Laboratory fatigue studies consistently show that narrower implants tolerate lower static and cyclic loads. In particular, narrow implants have shown atypical fatigue behaviour and earlier fatigue-related failure than wider implants, while failure analysis demonstrates that fracture commonly initiates in thin cervical or threaded regions where stress concentration is greatest [6-9].

In practical terms, the main problem for a 2.0-mm implant is not insertion torque or immediate survival alone. The more relevant question is whether the implant can survive repeated subcritical bending over time. This makes fatigue more important than single-load strength. Studies on implant diameter and fatigue strength show a consistent reduction in ultimate failure load and fatigue cycles as diameter narrows [6-9].

This is why a 2.0-mm implant should be thought of as a moment-sensitive system. The critical variable is not only force magnitude, but the bending moment generated when that force acts through a crown, an emergence profile, or an oblique occlusal contact. That principle also explains why higher crown-to-implant ratios and inclined loading

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Citation: Chirag A Chamria*, The Biomechanical Basis of Narrow (2.0-mm) One-Piece Dental Implants. Jour of Clin & Med Case Rep, Imag 2026; 5(4): 1188.

increase peri-implant stress and mechanical risk [20,24].

Bone-Side Biomechanics: Narrower Implant, More Preserved Bone

A narrow implant is mechanically weaker as a piece of metal, but it can still be biomechanically rational if it preserves a better surrounding bone envelope. Finite element studies have shown that cortical thickness, bone quality, and implant diameter all significantly affect peri-implant stress. The highest stress values are generally found around the implant collar, and the effect of smaller diameter becomes more severe in poorer-quality bone and under oblique loading [1,2,20]. This helps explain the paradox of narrow implants. A wider implant usually reduces stress, but only if the host ridge can accommodate it without sacrificing buccal or lingual cortical support. In a very narrow ridge, placing a wider implant may overconsume bone, while a 2.0-mm implant may preserve a more favourable circumferential bone envelope. In such cases, the relevant question is not whether 2.0 mm is mechanically stronger than 3.5 mm—it is not—but whether the combined bone-implant system is more favourable in the available anatomy [2,20].

Accordingly, diameter reduction may be partly offset by better cortical preservation, especially when the prosthetic design minimizes lateral load. This does not cancel the structural penalty of a smaller core, but it can improve the biologic side of the biomechanical equation [2,20].

What the One-Piece Design Likely Changes

One-piece implants remove the implant-abutment screw and the detachable junction found in two-piece systems. Systematic review data suggest that one-piece and two-piece implants show broadly similar short-term survival and complication rates, although some two-piece configurations may demonstrate less marginal bone loss [10]. For 2.0-mm one-piece implants, the likely biomechanical effect is not elimination of risk, but redistribution of risk. The benefit is a simpler restorative complex with no abutment screw to loosen. The trade-off is that the same narrow titanium or Ti alloy core must carry load continuously from the prosthetic head through the transgingival region into the bone. In a very slender implant, that likely concentrates cyclic bending demands in the cervical-transmucosal segment. This interpretation is consistent with diameter-related fatigue and failure studies, though direct head-to-head data specifically on exact 2.0-mm one-piece fixed implants remain limited [6-10].

Clinical Evidence Relevant to 2.0-mm One-Piece Implants

Direct long-term clinical evidence for exact 2.0-mm one-piece implants is still limited, so most interpretation must be drawn from one-piece mini-implants in the 1.8-2.5 mm range. In edentulous mandibles, prospective and long-term observational studies have reported very favourable outcomes for one-piece mini-implants retaining overdentures. Enkling et al. reported very high 5-year survival and success with associated improvement in oral function, and Schenk et al. reported 100% implant survival at 10 years for four 1.8-mm one-piece mini-implants retaining mandibular overdentures in horizontally atrophied mandibles [11,12].

For fixed support, the available evidence is more limited and more selective. Ćorić et al. studied fixed-type one-piece category-1 narrow implants (≤ 2.5 mm) replacing mandibular incisors with single crowns or small bridges and found small marginal bone level changes, acceptable success and survival, and improved patient-reported outcomes over 5 years. Importantly, this was a low-load anterior indication, not a posterior molar indication [13]. Taken together, these

findings suggest that category-1 one-piece implants can work clinically, but mainly when the loading environment is favourable or the load is shared, as in overdenture support or selected anterior restorations. The literature does not support treating a solitary 2.0-mm posterior implant as biomechanically equivalent to a regular-diameter posterior implant [3-5,11-13].

Multiple Implants and Stress Distribution

The strongest biomechanical argument in favour of narrow one-piece implants is not that each implant is individually strong, but that multiple implants can share load. When several narrow implants are used together, the force per implant decreases, the support polygon broadens, the effective lever arm shortens, and peak peri-implant strain is redistributed. This turns the problem from isolated bending into distributed support [14-19].

Experimental data support this interpretation. In an in vitro molar model, two 2.5-mm implants connected through a single crown generated lower peri-implant microstrain than a single regular-diameter implant, although off-axis loading still increased strain substantially [14]. More recent in vitro work with Ti-Zr mini-implants demonstrated that implant number matters greatly. Puljic et al. found that peri-implant micro strains in two-mini-implant overdenture models were almost twice those in four-mini-implant models, and unilateral loading increased strains more than bilateral or anterior loading [16]. Petricevic et al. extended this model to two, three, and four Ti-Zr mini-implants and showed that increasing implant number reduced peri-implant strain. In their study, two-implant models under unilateral 300-N loading produced almost 3000 microstrain on the loaded side and over 2500 microstrain on the opposite side, whereas increasing the number of implants reduced the strains to more favourable levels. They also found that loading position and force magnitude significantly influenced strain, with unilateral high-force loading being the most critical condition [17]. These findings suggest a practical biomechanical rule: a single 2.0-mm implant is a high-moment solution; multiple 2.0-mm implants are a load-sharing solution. The latter is fundamentally more defensible, especially in overdenture stabilization, narrow anterior spans, and situations where the clinician can keep forces axial and reduce cantilever effects [14-17].

For a 2.0-mm core implant, the nominal bending fracture load is approximately 100.4 N under perpendicular loading; when two such implants are rigidly connected, total system capacity may approach 200.8 N under, but decreases substantially under eccentric loading. The apparent increase in load-bearing capacity at 45° reflects a reduction in the transverse bending component relative to the implant axis, indicating that force direction is a major determinant of failure risk in narrow implants. From a biomechanical perspective, implant angulation may be advantageous when it helps align functional loads more axially and reduce bending moments, although this advantage remains highly configuration-dependent.

Splinting: Helpful, but Not Universally Protective

Splinting is often assumed to improve narrow-implant biomechanics because it can distribute load across multiple implants and reduce lateral force concentration. Terrats et al. directly compared fatigue behaviour of unitary and splinted narrow implants and concluded that splinting reduces lateral forces, improves force distribution, and minimizes stress on implants [15]. However, the effect of splinting is not identical in all implant-number scenarios. Puljic et al. found that splinting two Ti-Zr mini-implants did not reduce peri-implant strain enough to match the more favourable behavior of four unsplinted mini-implants. In other words, splinting may help, but it cannot fully compensate for an insufficient number of supporting implants under

high unilateral load [16]. Clinical fixed data also suggest nuance. In the mandibular incisor study by Ćorić et al., splinted and unsplinted fixed-type mini-implants both performed acceptably over 5 years, with no statistically significant survival difference. That suggests splinting is not an automatic requirement in every low-load anterior case [13].

Thus, from a biomechanical perspective, splinting should be seen as a modifier, not a universal rescue. For exact 2.0-mm one-piece implants, splinting is most logical when the restoration is exposed to higher bending moments, when multiple implants are available, or when distributing load is more important than maximizing hygiene access or retrievability [13,15-17].

A Proposed Biomechanical Framework

The biomechanical fate of a 2.0-mm one-piece implant can be understood as a balance between mechanical demand and mechanical capacity.

Mechanical demand rises with posterior placement, high bite force, unilateral chewing, parafunction, increased crown height, high crown-to-implant ratio, inclined contacts, cantilevering, and poor bone quality [14,17,20,24]. Mechanical capacity rises with dense cortical engagement, preservation of the surrounding ridge, favourable axial loading, reduced occlusal table width, low crown height, stronger alloy composition, multiple implants, and where appropriate splinting [2,15-20,22,23]. A single 2.0-mm one-piece implant succeeds when the clinician drives demand low enough that the small implant remains below its fatigue and strain thresholds over time. Multiple 2.0-mm implants work because they increase system capacity not by making each implant stronger, but by dividing the force across several supports. [15-19]

Clinical Implications

From a biomechanical standpoint, multiple narrow one-piece implants are usually more rational than a solitary narrow one-piece implant, especially when the available ridge is narrow and the treatment goal is denture retention, stabilization of a prosthesis, or load

sharing across [11-19]. By contrast, a solitary 2.0-mm one-piece implant used for a high-load posterior single crown remains a demanding mechanical proposition. The literature supports caution there, not prohibition, because the evidence is limited and the load environment is much less forgiving [3-5,14,20,21].

Limitations

This review is theory-driven and necessarily extrapolates from broader category-1 narrow-implant data, one-piece mini-implant overdenture cohorts, anterior fixed mini-implant studies, and in vitro or finite element analyses. Direct long-term evidence specifically on exact 2.0-mm one-piece implants supporting routine posterior fixed crowns remains sparse. Therefore, the framework proposed here should be understood as a biologically and mechanically grounded model rather than a substitute for indication-specific prospective trials [3-5,11-21].

Conclusion

The biomechanical basis of narrow (2.0-mm) one-piece dental implants is best explained not by osseointegration alone, but by the relationship between diameter, bending moment, cortical support, and load sharing. A 2.0-mm one-piece implant has little bending reserve and therefore demands a low-moment restorative environment. Its safest biomechanical role is not as a miniature substitute for a standard posterior implant, but as an anatomy-adapted implant used where bone preservation, multiple support points, and controlled loading can compensate for reduced core diameter. The use of multiple 2.0-mm one-piece implants is particularly compelling because it converts an otherwise fatigue-sensitive geometry into a distributed support system with lower peak strain per implant. In biomechanical terms, that is the real logic of the narrow one-piece implant concept [5,14-19].

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