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Review Article

Factors influencing implant restoration utilizing an FP1 approach

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Abstract

Fixed Prosthetic 1 (FP1) prostheses are widely utilized in implant dentistry for replacing missing teeth while maintaining a natural emergence profile. Their stability is dependent on multiple biomechanical and clinical factors, including implant placement, occlusal loading, prosthetic design, and material properties. Stability is crucial for long-term function, aesthetics, and patient satisfaction. Recent advances in digital workflows, novel biomaterials, and occlusal principles have improved outcomes in FP1 prostheses. This review comprehensively examines the factors influencing FP1 prosthetic stability, providing insights into evidence-based treatment planning and long-term clinical success.

Keywords: Full Arch Implants, FP1, all-on-4

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1. Introduction

Edentulism is a growing concern in modern dentistry, with implant-supported prostheses emerging as the preferred treatment modality for restoring function and esthetics.[1,2] The increasing prevalence of tooth loss, attributed to factors such as periodontal disease, trauma, and congenital anomalies, has led to significant advancements in prosthetic rehabilitation techniques.[3,4] Fixed prostheses (FP) are classified into three main types based on their relationship with surrounding soft and hard tissues.[5,6] This classification aids clinicians in selecting the most appropriate prosthetic solution based on patient-specific needs and anatomical considerations.[7,8]

FP1 Prostheses: These prostheses replicate the natural tooth structure, with the restoration emerging directly from the gingiva without artificial soft tissue components (**Figure 1**AÁ).[9,10] FP1 prostheses are indicated for cases where the alveolar ridge has minimal resorption, ensuring a natural emergence profile.[11,12]

FP2 Prostheses: Unlike FP1, FP2 prostheses require an extended crown length to compensate for vertical alveolar bone loss.[13] This results in a longer clinical crown, which, although functionally effective, can present aesthetic challenges due to an unnatural tooth-to-gingiva ratio (**Figure 1**B,B).[14]

FP3 Prostheses: These prostheses incorporate both the prosthetic tooth structure and artificial gingival components to compensate for significant alveolar ridge resorption.[15,16] FP3 prostheses are commonly used in cases with severe bone loss, where anatomic deficiencies must be restored both functionally and aesthetically (**Figure 1**C,C).[17,18]

Each classification has its own biomechanical and aesthetic implications. FP1 prostheses provide the most natural appearance but require precise implant positioning and adequate bone volume to ensure success.[3,6] FP2 prostheses may introduce biomechanical concerns due to the increased crown height, leading to higher torque forces.[7,12] FP3 prostheses, while highly functional in cases of severe resorption, often require a bulkier prosthetic design, which may affect speech and hygiene maintenance.[1,19] Understanding these classifications allows for better treatment planning and more predictable clinical outcomes.[10,15]

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The interocclusal space, or the vertical distance available between the edentulous ridge and the opposing dentition, plays a crucial role in determining the feasibility and design of implant-supported prostheses. For FP1 prostheses, which aim to replicate the natural dentition without artificial gingival components, a minimum of 7–10mm of interocclusal space is generally required.[1,19] This ensures adequate room for the implant, abutment, and restorative materials while maintaining a natural emergence profile and proper occlusal function. FP1 restorations rely on minimal ridge resorption and precise implant placement to maintain aesthetics and biomechanical stability.[17] For FP2 prostheses, where an extended clinical crown is used to compensate for moderate alveolar bone loss, 10–12mm of interocclusal space is typically recommended.[11,13] The increased vertical height allows for proper prosthetic contouring while maintaining structural integrity. However, due to the elongated crown, FP2 prostheses may introduce biomechanical challenges such as increased torque forces on the implants, necessitating strategic implant positioning and splinting in some cases to enhance load distribution.[12] In contrast, FP3 prostheses, which incorporate artificial gingival components to restore significant ridge deficiencies, require the greatest interocclusal space, typically 12–15mm or more.[18,19] This additional space accommodates both the prosthetic teeth and the artificial soft tissue, ensuring proper aesthetics and function. FP3 designs often require strategic material selection to balance strength, aesthetics, and hygiene considerations, particularly in cases of full-arch restorations.[8] Given the bulkier design, proper space allocation is critical to prevent phonetic challenges, difficulty in oral hygiene maintenance, and excessive occlusal forces on the implants.[16]

FP1 prostheses have been shown to provide an aesthetically superior and functionally efficient solution.[7,17] They are particularly beneficial for patients with minimal alveolar bone loss, as they allow for a seamless transition between the prosthesis and natural tissues.[9,11] However, their long-term stability is contingent on multiple biomechanical and material-related factors.[14,17] Proper case selection is crucial, as FP1 prostheses require sufficient bone volume and optimal implant positioning to ensure successful integration.[15,19] Recent advancements in digital planning, implant biomechanics, occlusal strategies, and prosthetic materials have significantly improved FP1 prosthetic outcomes.[11,16] The introduction of 3D printing and intraoral scanning technologies has further revolutionized treatment workflows, enabling greater precision in implant placement and prosthetic fabrication.[11,18]

This review comprehensively examines the critical determinants of FP1 prosthetic stability, emphasizing implant positioning, occlusal considerations, material selection, retention mechanisms, and maintenance strategies. Additionally, the role of emerging technologies such as digital workflows, CAD/CAM fabrication, and nanomaterial's in optimizing stability will be explored.[9]

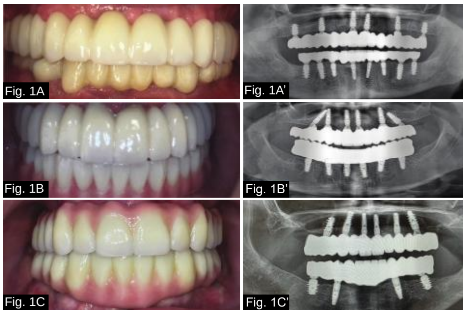

Figure 1: Intraoral photographs of FP1 implant-supported prostheses (A) and corresponding panoramic radiograph (A'), FP2 implant-supported prostheses (B) corresponding panoramic radiograph (B'), and FP3 implant-supported prostheses (C) and corresponding panoramic radiograph (A'), FP2 implant-supported prostheses (C'). Implant surgery and restorations performed by author in private practice setting in Berkeley, CA, USA.

Table 1: Key factors influencing FP1 prosthetic stability

Factor	Description	Impact on stability
Implant Positioning	Proper angulation and insertion torque	Enhances primary stability and osseointegration
Occlusal Force Distribution	Balanced occlusion and reduced lateral forces	Minimizes prosthetic failures and screw loosening
Prosthetic Material	Zirconia, lithium disilicate, CAD/CAM fabrication	Improves fracture resistance and durability
Retention Mechanism	Screw-retained vs. Cement-retained designs	Affects retrievability and risk of peri-implant complications
Maintenance Protocols	Regular occlusal adjustments and hygiene	Extends prosthetic longevity and prevents peri-implantitis

2. Biomechanical Considerations for FP1 Prosthetic Stability

2.1. Implant positioning and surgical considerations

Proper implant positioning is the cornerstone of long-term FP1 prosthetic stability. Bone quality, implant angulation, insertion depth, and primary stability all contribute to successful osseointegration and biomechanical function.[14] Ensuring optimal implant placement involves preoperative planning, utilizing cone-beam computed tomography (CBCT) to assess bone volume and density. Research indicates that an insertion torque of at least 35Ncm is necessary to achieve adequate primary stability, minimizing micro movements that could hinder osseointegration.[10] The use of customized surgical guides has been shown to enhance precision and reduce surgical trauma, leading to improved healing outcomes. Moreover, the use of guided surgery and digital workflow techniques has enhanced precision in implant placement, reducing the risk of biomechanical overload and prosthetic misalignment.[21] Additional considerations include the influence of cortical and trabecular bone quality on stability, as denser cortical bone provides enhanced mechanical retention while trabecular bone affects osseointegration dynamics.[22] The concept of immediate implant placement has also gained traction, as studies suggest it can preserve alveolar bone dimensions and improve aesthetic outcomes in select cases.

Other surgical factors also significantly influence the long-term success of FP1 prostheses. One critical consideration is the selection of an appropriate implant macro geometry, including diameter, thread design, and surface modifications, which directly impact primary stability and osseointegration.[21,23] Studies have shown that tapered implants provide superior stability in compromised bone conditions by enhancing bone-to-implant contact and reducing stress at the cortical level.[14,23] Moreover, implant site preparation techniques, such as under-drilling in low-density bone, have been found to improve primary stability by increasing mechanical retention.[10,22] The role of biologic width and soft tissue management also cannot be overstated, as achieving an adequate soft tissue seal around the implant prevents bacterial infiltration and promotes long-term peri-implant health.[12,19] Advances in bioactive implant coatings, including hydroxyapatite and titanium plasma-sprayed surfaces, have further improved osseointegration by accelerating bone healing and enhancing implant-bone contact.[20,24] Furthermore, the timing of implant loading—whether immediate, early, or delayed—plays a crucial role in influencing primary and secondary stability, requiring careful assessment of patient-specific factors such as bone quality, occlusal forces, and systemic health.[17] As technology continues to evolve, the integration of artificial intelligence and robotic-assisted implant placement may further refine accuracy, minimizing human error and enhancing surgical outcomes.[15,16]

2.2. Occlusal loading and force distribution

Occlusal forces play a vital role in the longevity of FP1 prostheses. Unfavourable occlusal loading can lead to complications such as screw loosening, prosthetic fractures, and peri-implant bone loss.[7] The incorporation of occlusal design principles, such as mutually protected occlusion and group function, has been demonstrated to mitigate negative loading effects.[11] Implementing occlusal splints in patients with para functional habits has been suggested to protect implant restorations from excessive forces. Additionally, studies have shown that splinting FP1 prostheses in cases of high occlusal loads can enhance load distribution and reduce micro-movements at the implant-abutment interface.[24] Research also highlights the significance of occlusal material properties, where softer occlusal materials may distribute forces more favourably than rigid ceramics. The utilization of digital occlusal analysis provides real-time force mapping, allowing clinicians to fine-tune occlusion and achieve balanced load distribution. Studies indicate that incorporating resilient liner materials in FP1 prostheses may help absorb occlusal forces, thereby reducing mechanical stress on implant components.

In addition to these strategies, the orientation and positioning of implants within the prosthetic framework significantly influence the distribution of occlusal forces and overall prosthetic stability.[13,14] Angulated implants, especially in cases of limited bone availability, can alter force vectors and increase the risk of screw loosening and prosthetic misfit if not properly planned.[15,17] Biomechanical studies have shown that non-axial loads increase shear forces at the bone-implant interface, which may accelerate crestal bone loss and lead to mechanical complications.[7,10] Moreover, careful attention to cusp anatomy and occlusal scheme—minimizing steep cusps and favouring shallow occlusal angles—has been shown to reduce the risk of localized stress concentrations.[16,19] Ensuring harmonious occlusion across the prosthetic arch is particularly critical in full-arch restorations, where uneven loading can jeopardize the entire prosthetic structure.[6,24] As part of an evolving digital workflow, the integration of digital articulation and virtual simulation tools further enhances occlusal planning, allowing clinicians to visualize force distribution preoperatively and make real-time adjustments during prosthetic delivery.[21] Combining these approaches with regular occlusal reassessment and patient education regarding para functional habits can significantly enhance the longevity and clinical success of FP1 prostheses.[12,18]

2.3. Biomaterials in prosthetic considerations

The choice of prosthetic materials in implant restorations is a critical factor influencing the longevity, biomechanical stability, aesthetic outcome, and patient satisfaction of FP1, FP2, and FP3 prostheses. FP1 prostheses, which mimic natural teeth without artificial gingival components, require materials with high strength, durability, and excellent aesthetics. Lithium disilicate (e.max) is a commonly used material for anterior FP1 restorations due to its translucency and aesthetic properties, while monolithic zirconia is preferred for posterior FP1 prostheses, as it offers higher flexural strength (~1000–1200mpa) and better resistance to occlusal forces.[16,18] FP2 prostheses, which require extended crown length due to vertical bone loss, must use stronger materials to withstand increased occlusal forces. Monolithic zirconia and metal-ceramic restorations (PFM - Porcelain-Fused-to-Metal) are the most common choices for FP2 prostheses, as they provide enhanced fracture resistance and load distribution.[8,11] However, PFM restorations may show aesthetic limitations due to the metal substructure, making layered zirconia with veneering ceramic an alternative option for improved anterior esthetics.[19]

FP3 prostheses, which incorporate both prosthetic teeth and artificial gingiva, require materials that balance strength, hygiene, and soft tissue integration. Full-arch monolithic zirconia prostheses are a preferred option due to their exceptional strength, low plaque accumulation, and long-term wear resistance, making them ideal for high-load applications.[7,17] However, in cases where cost, weight, or retrievability is a concern, hybrid prostheses with a titanium bar framework and acrylic or composite teeth are often used, as they provide shock absorption and ease of repair.[12,21] Alternative materials such as polyether ether ketone (PEEK) and polyether ketone ketone (PEKK) are being explored for lightweight frameworks with better stress distribution and biocompatibility. Additionally, CAD/CAM-milled PMMA (Polymethyl Methacrylate) prostheses are sometimes used as a provisional option before final prosthetic placement due to their cost-effectiveness and adaptability.[15] The selection of prosthetic material should consider patient-specific factors, including occlusal loading, aesthetic demands, hygiene maintenance, and long-term durability to ensure optimal clinical outcomes.[14]

3. Strategies for Enhancing FP1 Prosthetic Stability

3.1. Prosthetic retention mechanisms

The choice of retention mechanism directly influences prosthetic longevity. Screw-retained restorations have been favoured over cement-retained alternatives due to their retrievability and reduced risk of residual cement-induced peri-implantitis.[12] Studies highlight that screw-retained prostheses exhibit superior marginal adaptation, minimizing biological complications and improving prosthetic stability.[24] Recent advancements in retention designs have further enhanced FP1 prosthetic stability. Hybrid screw-cemented restorations, for instance, combine the benefits of screw retention with improved passive fit, reducing complications associated with misalignment.[18] Digital fabrication technologies have also allowed for greater precision in screw-channel angulation, minimizing stress on abutments and ensuring a better load distribution across the prosthesis.[15]

The evolution of retention mechanisms in FP1 prostheses has been driven by the need to balance mechanical stability with ease of maintenance and long-term biological health. While screw-retained prostheses offer clear advantages in retrievability, they also provide better control over cement remnants, which are a known risk factor for peri-implant disease.[12] In cases where achieving optimal screw access positioning is challenging due to anatomical limitations or aesthetic demands, angulated screw channels have emerged as a viable solution, allowing for screw-retained restorations even in the anterior maxilla.[15] Additionally, innovations in interface design, such as conical abutment connections, have improved the mechanical stability of both screw- and hybrid-retained prostheses by reducing micro gaps and minimizing bacterial infiltration.[20] Research also highlights the importance of selecting appropriate abutment materials, with titanium and zirconia abutments showing differing performance in terms of fit, fracture resistance, and soft tissue response.[24] As digital workflows and CAD/CAM technologies continue to evolve, the customization of retention interfaces can now be tailored to individual patient anatomy and occlusal loads, further enhancing the predictability and success of FP1 prostheses.[11] Ultimately, the ideal retention strategy should be selected based on case-specific factors, including implant angulation, prosthetic load distribution, aesthetic demands, and patient compliance with follow-up care.

3.2. Maintenance protocols and patient compliance

Routine maintenance and periodic occlusal adjustments are essential for ensuring the longevity of FP1 prostheses. Regular follow-up appointments should assess occlusal function, prosthetic wear, and peri-implant health.[18] Educating patients about oral hygiene practices and peri-implant care is crucial in preventing plaque accumulation and subsequent peri-implantitis.[19] Clinical studies emphasize the importance of monitoring bone levels around FP1 prostheses. Annual radiographic assessments and probing depth evaluations can aid in the early detection of peri-implant bone loss, allowing for timely intervention.[11] Moreover, advancements in bioactive coatings on implant surfaces have shown promise in reducing bacterial adhesion, further enhancing the long-term prognosis of FP1 prostheses.[24]

In addition to these routine maintenance strategies, patient-specific risk assessments can further enhance the long-term success of FP1 prostheses by identifying individuals at higher risk for peri-implant complications. Factors such as smoking, diabetes, and a history of periodontitis have all been associated with increased rates of peri-implant bone loss and prosthetic failure, warranting more frequent follow-up and tailored preventive strategies.[24] Adjunctive therapies, such as professional sub gingival air-polishing with glycine powder, have demonstrated efficacy in reducing peri-implant biofilm without causing surface damage to the prosthetic components. In cases where early signs of peri-implantitis are detected, non-surgical interventions including antimicrobial rinses, laser therapy, and localized delivery of antibiotics can be employed to halt disease progression before extensive bone loss occurs. Emerging technologies, such as chair side fluorescence-based bacterial detection and salivary biomarker analysis, offer promising tools for real-time monitoring of peri-implant health, allowing clinicians to intervene pre-emptively. Ultimately, a comprehensive maintenance program incorporating regular clinical evaluations, patient education, risk-based follow-up intervals, and advanced diagnostic technologies offers the best chance of ensuring the long-term stability and success of FP1 prostheses.

4. Conclusion

The key factors when determining the success of FP1 prostheses are implant positioning, occlusal force distribution, prosthetic materials, retention mechanisms, and post-placement maintenance **Table 1**. Future research should explore the potential of nanotechnology, biomimetic materials, and AI-driven digital workflows to further enhance FP1 prosthetic stability. Advances in material science, including high-performance ceramics and hybrid materials, could improve mechanical properties and aesthetic outcomes.[15] Additionally, continued investigation into biomechanical load distribution strategies may provide insights into optimizing implant-supported FP1 prostheses.[16] As digital workflows become increasingly integrated into prosthetic planning, research on AI-assisted prosthetic design is expected to yield highly customized FP1 restorations with superior fit and load-bearing capacity. Furthermore, the incorporation of smart materials that promote peri-implant tissue regeneration could revolutionize implant prosthetics in the coming years. The adoption of bioengineered scaffolds for soft tissue integration is another promising avenue that could enhance long-term success. In conclusion, FP1 prosthetic stability is a multifaceted issue influenced by implant positioning, occlusal considerations, prosthetic material selection, retention mechanisms, and maintenance strategies. Recent technological advancements in digital workflows, CAD/CAM manufacturing, and biomaterials continue to improve the predictability and success of FP1 prostheses. A multidisciplinary approach, incorporating meticulous treatment planning, evidence-based prosthetic strategies, and ongoing patient education, is essential for achieving optimal long-term clinical outcomes. Future clinical trials should assess the comparative performance of FP1 prostheses against conventional fixed prosthetic designs to further validate their effectiveness in various patient populations.

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None.

6. Conflict of Interest

None.

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