ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 8, Issue – 3, June – 2025, Page No. : 52 - 60

Narrow Diameter Implants (NDIs): A Prosthodontic Review

[1]Dr. Bhushan Krishna Chalmela, Post Graduate Student, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

[2]Dr. Ulhas Tandale, M.D.S, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

[3]Dr. Kishor Mahale, M.D.S, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

[4]Dr. Smita Khalikar, M.D.S, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

[5]Dr. Vilas Rajguru, M.D.S, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

[6]Dr. Sonali Mahajan, M.D.S, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

Corresponding Author: Dr. Bhushan Krishna Chalmela, Post Graduate Student, Maharashtra University of Health Sciences, Nashik Government Dental College and Hospital, Chhatrapati Sambhajinagar

Citation of this Article Dr. Bhushan Krishna Chalmela, Dr. Ulhas Tandale, Dr. Kishor Mahale, Dr. Smita Khalikar, Dr. Vilas Rajguru, Dr. Sonali Mahajan, "Narrow Diameter Implants (NDIs): A Prosthodontic Review", IJDSIR- June – 2025, Volume – 8, Issue – 3, P. No. 52 – 60.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Narrow diameter implants (NDIs), typically defined as implants with diameters between 2.5–3.5 mm, have become a critical option in contemporary implantology, particularly for the prosthodontic rehabilitation of cases with limited horizontal bone availability or restricted mesiodistal space. This review explores the indications, biomechanical considerations, prosthetic implications, surgical protocols, materials science, and long-term outcomes associated with NDIs, with attention to evidence-based clinical recommendations.

Keywords: narrow diameter implants, mini implants, implant dentistry, bone atrophy, prosthetic rehabilitation, implant success rate

Introduction

The advent of osseointegrated dental implants has revolutionized modern prosthodontics by offering predictable and long-term solutions for partial and complete edentulism. Since the pioneering work of Brånemark in the 1960s, dental implants have evolved dramatically, both in design and application, and have become the gold standard for fixed and removable prosthetic rehabilitation[1].

Conventional dental implants typically range from 3.75 mm to 4.2 mm in diameter, dimensions that require sufficient alveolar bone volume both buccolingually and mesiodistally to ensure proper implant positioning, primary stability, and subsequent osseointegration. However, in cases of severe horizontal bone resorption — particularly common in the anterior mandible or maxillary lateral incisor regions - placement of standard diameter implants often necessitates additional bone augmentation procedures, including guided bone regeneration, autogenous bone block grafting, or ridge splitting[2],[3]

These augmentation procedures, although well-documented, increase surgical morbidity, cost, and treatment time, and may not be feasible or acceptable for all patients, especially those with systemic health issues, limited financial resources, or anatomical constraints. To overcome these challenges, narrow diameter implants (NDIs), typically defined as implants with diameters between 2.5 mm and 3.5 mm, have emerged as an alternative for prosthetic rehabilitation in narrow edentulous spaces or horizontally deficient ridges[4],[5].

The development and clinical use of NDIs align with the prosthodontic principles of minimizing surgical invasiveness while maximizing functional and esthetic outcomes. Their application has been particularly successful in scenarios such as replacement of mandibular incisors, maxillary lateral incisors, or supporting overdentures in severely resorbed mandibular ridges without the need for bone augmentation[6],[7]. Furthermore, advances in implant materials, surface modifications, and digital surgical planning have expanded the indications for NDIs, improving both primary stability and long-term clinical success[8],[9].

Despite these advantages, NDIs present inherent biomechanical challenges due to their reduced diameter and smaller bone-implant contact area, making them more susceptible to mechanical complications such as implant or abutment fracture[10],[11], and placing greater demands on prosthetic planning to ensure load distribution and minimize overload

This review article aims to provide a comprehensive overview of narrow diameter implants by exploring their clinical indications, biomechanical behavior, materials and surface technologies, surgical and prosthetic protocols, long-term clinical outcomes, and potential complications. Through critical appraisal of the existing literature, it seeks to guide clinicians and researchers in making evidence-based decisions regarding the use of NDIs in prosthodontic practice, while identifying areas for future research and innovation.

Here’s the graphical timeline showing the key milestones in the development of narrow diameter implants (NDIs):

✓ **1965** — Brånemark introduces the concept of osseointegration.

✓ **1990s** — Mini-implants introduced for transitional denture stabilization.

✓ **Early 2000s** — Small-diameter and narrow-diameter implants (2.5–3.5 mm) developed for definitive prosthetic use.

✓ **2004** — First long-term clinical studies published on NDIs[13].

✓ **2010s** — Advancements in surface technologies: SLA, plasma-sprayed, nanostructured coatings. Titanium alloy (Ti-6Al-4V) widely adopted.

✓ **2020s** — Integration of CAD/CAM workflows, guided surgery, CBCT imaging, and artificial intelligence in implant planning.

✓ **Future** — Development of customized patient-specific implants using additive manufacturing (3D printing).

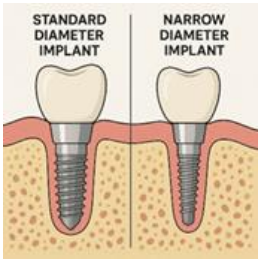

Figure 1: Schematic showing comparison between standard and narrow diameter implants in a cross-sectional ridge.

Classification of Narrow Diameter Implants

NDIs can be classified based on diameter as follows:

- Mini implants: <2.5 mm (typically for transitional or overdenture support)
- Small diameter implants: 2.5–3.0 mm
- Narrow diameter implants: 3.0–3.5 mm (primary focus for definitive prosthetic use)

Figure 2: Small, narrow and mini diameter implants

For prosthetic applications, NDIs in the 2.5–3.5 mm range are primarily used for definitive restorations in narrow ridges [5].

Clinical Indications

Prosthodontically, NDIs are indicated in:

- Edentulous sites with ≤5.5 mm mesiodistal space (e.g., mandibular incisors, maxillary lateral incisors)
- Horizontal bone deficiencies (<5 mm width) without simultaneous augmentation
- Retention of overdentures with locator or ball attachments
- Patients with systemic or local contraindications to augmentation procedures [6]
- Rehabilitating narrow interradicular spaces
- Immediate loading in edentulous patients using overdentures

Figure 3: Intraoral photograph showing limited ridge width in the mandibular anterior region suitable for narrow diameter implant placement.

Advantages of Narrow Diameter Implants

- Minimally invasive: NDIs often eliminate the need for bone grafting procedures.
- Shorter healing time: Due to reduced trauma and surgical intervention.
- Cost-effective: Reduced need for additional procedures lowers overall treatment cost.
- Greater patient acceptance: Less invasive procedures and reduced postoperative discomfort enhance patient compliance.

Figure 4: Patient post-operative smile following placement of NDIs with minimal surgical intervention.

Limitations and Challenges

- Reduced mechanical strength: Smaller diameter may lead to increased risk of implant fracture, especially under high occlusal loads.
- Prosthetic limitations: Smaller platform may restrict prosthetic options and esthetic outcomes.
- Technique sensitivity: Requires precise surgical and prosthetic planning to avoid complications.
- Bone-implant contact area: Reduced diameter results in smaller surface area for osseointegration.

Figure 5: Fractured narrow implant under occlusal stress, highlighting mechanical limitations.

Biomechanical Considerations

From a biomechanical standpoint, NDIs present higher stress concentration at the crestal bone due to their reduced diameter and smaller bone-implant contact area (Nedir et al., 2006). Finite element analysis (FEA) have demonstrated that splinting narrow implants can reduce micromovement and improve stress distribution under functional loads, particularly in the anterior region where occlusal forces are lower[11]. Posterior use should be approached cautiously due to increased risk of mechanical complications[3].

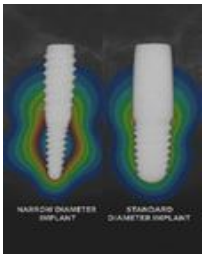

Figure 6: Radiographic comparison of stress distribution around narrow vs. standard diameter implants

Materials and Surface Modifications

NDIs are fabricated predominantly from Ti-6Al-4V titanium alloy, offering superior tensile strength compared to commercially pure titanium (Shibli et al., 2013). Surface topography modifications such as sandblasted, large-grit, acid-etched (SLA) and plasma-sprayed coatings aim to optimize the osteoconductive properties, enhancing early osseointegration[1]. Emerging nanostructured surfaces are under investigation for further improving osseointegration rates[8].

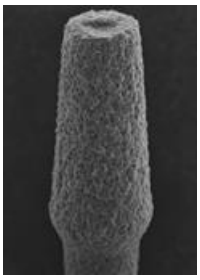

Figure 7: SEM image showing surface topography of etched narrow implant.

Surgical protocols

Prosthodontically driven implant placement with NDIs relies on precise osteotomy preparation using minimal trauma protocols to preserve bone viability.

- **Guided surgery** utilizing CBCT and CAD/CAM-generated surgical templates facilitates accurate three-dimensional positioning[12].
- **Flapless techniques** minimize soft tissue disruption, though require sufficient keratinized mucosa and careful preoperative evaluation[7].
- **Submerged vs. Non-submerged healing** is determined by implant stability and soft tissue management requirements.
- A **postoperative periapical radiograph** should be taken which demonstrates the correct placement of NDI, reflecting adherence to surgical protocols that ensure proper angulation, parallelism, and bone

engagement for optimal osseointegration and prosthetic alignment.

Figure 8: Intraoperative photo showing flapless placement of a narrow diameter implant in the maxillary lateral incisor region.

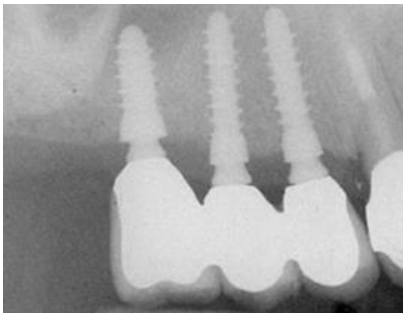

Figure 9: Postoperative periapical radiograph showing correct positioning of a 3.0 mm diameter implant.

Prosthetic Considerations

Due to the reduced prosthetic platform, NDIs often require the use of CAD/CAM-fabricated customized abutments to optimize emergence profile and soft tissue contour, particularly in the esthetic zone[2]. For overdenture applications, splinting two NDIs with locator attachments provides sufficient retention, but clinicians must account for reduced implant rigidity[7]. Single crowns are generally limited to the anterior region where occlusal loads are within the mechanical limits of the implant system.

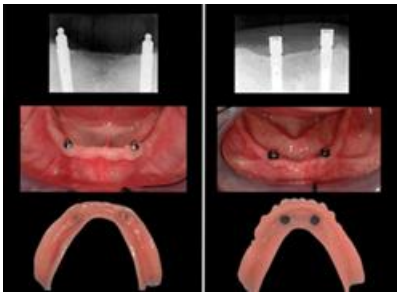

Figure 10: Intraoral photograph of final restoration using two narrow diameter implants supporting a mandibular overdenture.

Clinical Outcomes and Survival Rates

Systematic review report 5-year survival rates for NDIs between 90–98%, comparable to standard diameter implants when proper case selection and prosthetic planning are applied. Key prognostic factors include implant site, bone quality, loading conditions, and prosthetic design[8],[3]

Numerous studies have consistently shown that narrow diameter implants (NDIs) achieve high survival rates, comparable to those of standard diameter implants, when used in appropriately selected clinical scenarios. A systematic review and meta-analysis by Sanz-Sánchez et al. (2018) reported cumulative 5-year survival rates of NDIs ranging from 94% to 98%, with minimal marginal bone level changes, especially when placed in anterior regions or for overdenture support. Similarly, Urdaneta et al. (2021) confirmed that NDIs exhibit marginal bone loss patterns similar to regular-diameter implants, emphasizing that biomechanical considerations and prosthetic design, rather than diameter alone, are the key determinants of success.

In posterior regions, where occlusal loads are higher, recent randomized trials such as Marković et al. (2021) have shown that narrow implants can perform comparably to regular-diameter implants when occlusal loading is carefully managed and splinted restorations are employed. Regarding immediate or early loading

protocols, a multicenter RCT by Cannizzaro et al. (2019) demonstrated that narrow implants loaded immediately or early in the edentulous mandible maintained high survival rates at one year, with no statistically significant differences in peri-implant bone levels compared to conventionally loaded implants.

From a prosthetic perspective, esthetic outcomes in the anterior maxilla have been assessed by Fabbri et al. (2020), who found that NDIs offer excellent pink and white esthetic scores at the 5-year mark, provided that soft tissue management and customized abutments are used to optimize emergence profiles. Overall, long-term clinical outcomes suggest that with proper case selection, prosthetic planning, and occlusal management, NDIs are a predictable solution for both fixed and removable prosthetic rehabilitation.

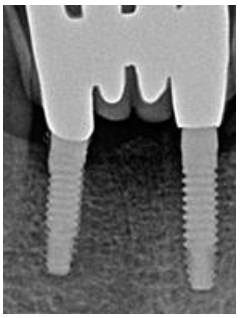

Figure 11: Radiograph at 1-year follow-up showing stable bone levels around narrow diameter implants.

Complications

The most common prosthodontic and surgical complications associated with NDIs include:

- **Implant fracture** under excessive occlusal forces, particularly in posterior sites (Flanagan, 2008)
- **Screw loosening or fracture** due to limited abutment dimensions
- **Peri-implant marginal bone loss** exacerbated by poor hygiene or overload (Shibli et al., 2013)
- **Esthetic compromises** due to restricted platform-switching options in thin tissue biotypes[2]

Figure 12: Clinical case showing peri-implantitis around NDI due to poor oral hygiene.

Recent Advances and Innovations:

- Use of zirconia NDIs for improved esthetics and biocompatibility
- Development of hybrid implants with narrow coronal and wider apical regions
- Enhanced imaging and planning tools such as CBCT and digital workflow
- Immediate loading protocols with improved implant designs

Figure 13: 3D printed surgical guide used for guided placement of narrow diameter implants.

Future Directions

Future research in prosthodontics aims to integrate zirconia-based NDIs for enhanced esthetics, hybrid implant designs combining narrow coronal and wider apical sections for better load distribution, and the incorporation of artificial intelligence to refine digital treatment planning[1]. Additive manufacturing (3D printing) holds potential for patient-specific customized implant solutions.

The future of narrow diameter implant therapy is closely tied to advances in digital dentistry, material science, and personalized implantology. The integration of CAD/CAM workflows, cone beam computed

tomography (CBCT), and guided surgery has already improved the precision of implant placement, reducing surgical invasiveness and optimizing prosthetic outcomes[22].

On the materials front, recent systematic reviews [21] have underscored the increasing use of zirconia abutments and all-ceramic restorative systems on NDIs, particularly in esthetically demanding regions, due to their excellent soft tissue biocompatibility and superior esthetic integration compared to titanium.

Looking ahead, the incorporation of artificial intelligence (AI)-driven treatment planning and additive manufacturing (3D printing) holds the potential to revolutionize NDI applications by enabling customized, patient-specific implant designs that can optimize stress distribution and adapt precisely to individual anatomic constraints. Furthermore, emerging surface technologies such as nanostructured bioactive coatings are under investigation to further enhance the speed and quality of osseointegration, potentially broadening the indications for NDIs, including in compromised bone situations.

Ongoing research, including large-scale multicenter clinical trials and real-world data analyses, will be essential to refine clinical protocols, establish robust long-term data beyond the current 5–10 year horizon, and expand the prosthodontic applications of narrow diameter implants in both fixed and removable prosthetics.

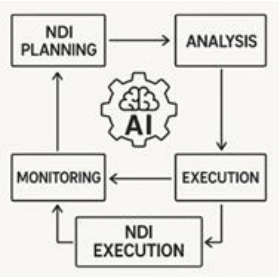

Figure 14: Conceptual diagram showing integration of AI in NDI planning and execution.

Discussion

Narrow diameter implants (NDIs), defined as implants with diameters between 2.5 mm and 3.5 mm, have become an essential solution in prosthodontics, particularly for cases with limited bone width or restricted mesiodistal space. The article emphasizes that NDIs address the challenges posed by conventional implants, which often require additional bone augmentation procedures that increase cost, complexity, and surgical morbidity. NDIs offer a minimally invasive, cost-effective alternative, especially useful in areas like the anterior mandible or maxillary lateral incisor regions where space is constrained.

One key highlight of the article is the strong clinical evidence supporting NDIs, showing survival rates between 90–98% over five years, which is comparable to standard diameter implants when placed under appropriate conditions. The success of NDIs largely depends on precise surgical and prosthetic planning. Due to their smaller size, they have a reduced bone-implant contact area, making them more susceptible to mechanical complications such as implant or abutment fracture. However, advances in materials, such as the use of titanium alloys and enhanced surface treatments (e.g., sandblasted or nanostructured coatings), have improved their mechanical and biological performance.

The article also points out the growing integration of digital workflows, CAD/CAM technologies, and guided surgery, which enhances the precision of NDI placement and optimizes prosthetic outcomes. Looking ahead, future innovations like AI-driven treatment planning and 3D-printed customized implants hold promise for expanding the indications and improving the performance of NDIs.

While NDIs are particularly successful in the anterior region and for overdenture retention, their use in

posterior sites remains cautious due to higher occlusal loads. Overall, the article underscores that narrow diameter implants have become a predictable, patient-friendly solution in prosthodontic practice, provided clinicians understand their limitations, plan carefully, and apply evidence-based protocols.

Conclusion

NDIs have become indispensable in the prosthodontic management of narrow ridges and limited spaces, providing a less invasive, cost-effective solution. Their successful integration into clinical practice requires a comprehensive understanding of their biomechanical limits, surgical nuances, and prosthetic considerations. Continued innovation and long-term data will further solidify their role in contemporary implant prosthodontics.

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