TITLE OF THE ARTICLE: BIOMECHANICAL AND CLINICAL RATIONALE BEHIND POSTERIORLY TILTED IMPLANTS – A REVIEW

Dr. Abinaya.R[1], Dr. Raghavendra Prasad.S[2], Dr. Koustubh Shinde [3], Dr. Chethana.K[4]

Department(s) and institution(s)

1. Postgraduate student, Department of Prosthodontics and Crown & Bridge, Sri Siddhartha Dental College and Hospital.
2. Professor & Head, Department of Prosthodontics and Crown & Bridge, Sri Siddhartha Dental College and Hospital.
3. Postgraduate student, Department of Prosthodontics and Crown & Bridge, Sri Siddhartha Dental College and Hospital.
4. Reader, Department of Prosthodontics and Crown & Bridge, Sri Siddhartha Dental College and Hospital.

CORRESPONDING AUTHOR:

Dr.ABINAYA.R

Post graduate student,

Sri Siddhartha Dental College and Hospital

Agalkote, B.H. Road, Tumkur-572107

***ABSTRACT*:**

Posteriorly tilted implants have emerged as a strategic and innovative alternative in the field of implant dentistry, particularly when anatomical constraints or limitations of bone volume present challenges to the placement of conventional axially oriented implants. These implants are intentionally angled posteriorly to avoid critical anatomical structures such as the maxillary sinus in the upper jaw or the inferior alveolar nerve in the lower jaw, thereby minimizing the need for complex surgical interventions such as sinus lifts, bone grafts, or nerve repositioning. This review article delves into the fundamental biomechanical principles underlying the use of tilted implants and examines their clinical performance in terms of long-term success rates, load-bearing capacity, and functional rehabilitation outcomes when compared to traditional axial implants. Evidence from current literature reveals that posteriorly tilted implants facilitate favourable stress distribution to surrounding bone, which may contribute to enhanced stability and reduced crestal bone loss. Furthermore, their use often translates to shorter treatment times, reduced postoperative morbidity, and lower overall treatment costs. These factors make them a particularly attractive option in full-arch prosthetic rehabilitation and other challenging clinical scenarios. As such, posteriorly tilted implants represent a reliable and cost-effective treatment modality with predictable outcomes in appropriately selected patients.

KEY-WORDS: *Tilted implants; Biomechanical principles; angulated implants; literature review.*

INTRODUCTION:

The field of Dental implantology has revolutionized in the management of edentulous patients. Conventionally, implants are placed in the axial direction to restore the function and aesthetics of the patients.[1] However, anatomical limitations in the posterior maxillary and mandibular regions, such as proximity to the maxillary sinus or inferior alveolar nerve, often complicate the implant placement.[2,3] To avoid the complex procedures like sinus lifts or nerve repositioning, posteriorly tilted implants have been introduced as an alternative.[4] This review focuses mainly on the biochemical rationale and clinical relevance of posteriorly tilted implants, providing insight into their advantages, challenges, and long-term outcomes.

Historical background of Tilted implants:

The concept of tilted implants evolved with the introduction of the All-on-4 concept by Dr. Paulo Malo in the late 1990s revolutionized this approach by advocating the use of two anterior axial and two posterior tilted implants for full-arch rehabilitation.[5] This concept gained its importance and widespread acceptance due to its clinical success rate and biomechanical efficiency.[5]

BIOMECHANICAL RATIONALE:

Stress distribution and Load transfer:

Tilted implants have the potential to improve stress distribution across the prosthetic appliances and the surrounding supporting bone.[6] Numerous Finite Element Analysis (FEM) studies explored and demonstrated that tilted implants reduce the cantilever effect by allowing the positioning of the prothesis more posteriorly.[7] The distribution of forces minimizes the concentration of stress around the crestal bone and neck of the implant surface, enhancing the long-term stability of the implant.[8]

Tilted implants and bone-implant interface dynamics:

The fundamental biomechanical advantage of tilted implants lies in their ability to engage in the denser regions of bone, especially in the anterior maxilla.[9] Unlike in the posterior maxilla, which usually consists of low-density trabecular bone and decreased vertical height due to pneumatization of the sinus, the anterior regions typically offer denser, more compact cortical bone. Like that, in mandible, tilting of the implant can help avoid the mandibular canal, with cortical bone in the mental or symphyseal region.[10]

This engagement of the high-density cortical bone potentially enhances the bone-to-implant contact (BIC) area, which is significantly associated with improved primary stability of the implant.[11] It refers to the mechanical engagement between the implant and the surrounding bone at the time of placement, and it is the preliminary factor for assessing the success rate of the immediate loading protocols. Increased primary stability reduces the micromovements and promotes favourable conditions for bone remodelling, followed by osseointegration.[9,10]

Additionally, when the biomechanical forces are transmitted effectively through the cortical bone, stress shielding is reduced, thereby preserving the peri-implant bone over time.[11,12]

Engagement of the Cortical Bone:

Posterior tilting often enables the implants to engage both buccal and lingual cortical plates, particularly in the atrophic ridges. The bicortical engagement gives higher insertion torque and mechanical stability, which are important for immediate function protocols.[13]

CLINICAL RATIONALE:

Anatomical considerations:

Due to certain anatomical constraints exhibited by the posterior regions of the maxilla and mandible, it often poses significant challenges for implant placement.[14] The posterior maxilla often exhibits reduced bone density and pneumatized maxillary sinuses, which limits the available bone height. Similarly, in the posterior mandible, the proximity of the inferior alveolar nerve restricts the vertical dimension for implant placement.[15] Posterior tilting of the implants enables the practitioner to engage better quality bone in the anterior region while bypassing these anatomical structures. This approach allows for longer implants, which enhances primary stability and bone-to-implant contact. Engaging the cortical bone, such as the nasal floor, maxillary buttress, or the lingual or palatal cortical plates, adds biomechanical advantages and facilitates long-term success.[16]

Avoidance of Grafting:

The significance of posteriorly tilted implants is the ability to avoid complex and invasive grafting procedures, such as sinus lifting procedures, vertical ridge augmentation, and inferior alveolar nerve lateralization or repositioning. These grafting techniques are often associated with prolonged treatment duration, higher patient morbidity, and expensive and variable outcomes. Tilted implants offer a graftless solution by utilizing available bone in the premaxilla or anterior mandible.[17,18]

Improved prosthetic Support:

Posteriorly tilted implants enable a greater anterior-posterior (A-P) spread, which is essential for distributing occlusal loads across the prosthesis. This wider implant distribution reduces the need for long distal cantilevers, thereby minimizing mechanical complications such as loosening of screws, framework fracture, and marginal bone loss.[19] Additionally, tilting implants improve the prosthetic emergence profile and facilitate screw-retained restorations without compromising aesthetics or access. The ability to place implants at an angle also helps align them with the natural arch curvature, improving the transmission of mechanical load and occlusal harmony.

Applications in immediate loading protocols:

It has been widely used in immediate loading protocols, especially in full-arch rehabilitations. The positioning of two anterior axial and two posterior tilted implants provides sufficient primary stability.[20] Several studies have reported that the survival rate is increased, particularly when supported by accurate surgical planning and rigid splinting via cross-arch frameworks. Immediate loading significantly improves patient satisfaction by reducing edentulous periods and providing immediate functional and esthetic outcomes.[21]

Bone Preservation and Stress Distribution:

The tilted implants reduce the risk of complications and contribute to the preservation of vital bone structures. Additionally, biomechanical studies suggest that tilted implants distribute occlusal forces more evenly along the surface of the prosthesis.[22] The tilted configuration allows better alignment with the direction of functional loads, reducing stress concentration around peri-implant bone. This contributes to long-term bone stability and reduces the risk of marginal bone loss.[23]

Cost – effectiveness and patient acceptance:

The reduced necessity for bone grafting procedures, fewer surgical interventions, and shorter treatment duration collectively make the tilted implant protocols more cost-effective. This affordability, along with functional rehabilitation, improves overall patient acceptance and satisfaction.

Clinical versatility:

Posteriorly tilted implants are adaptable across a wide range of clinical scenarios, from severely atrophic jaws to full-arch edentulous rehabilitations. They can be used in both fixed and removable prosthetic designs, which can be adopted in modern implantology, particularly in the context of immediate full-arch restorations.

CHALLENGES AND LIMITATIONS:

Despite the evolving popularity of posteriorly tilted implants, certain limitations exist. One of the primary challenges is the need for precise surgical and prosthetic planning.[24] During placement, any deviation from the planned trajectory can result in biomechanical imbalances. Improper angulation may lead to prosthetic misalignment, occlusal discrepancies, or uneven force distribution, which causes complications like screw loosening, component fractures or marginal bone loss which can compromise primary stability.[25,27] Moreover, prosthetic management of tilted implants may involve the use of angulated abutments or angled screw channels, which ultimately increase fabrication complexity and cost.[26,27]

RECENT ADVANCES:

Recent advances in digital dentistry have significantly improved the predictability and clinical success of tilted implant protocols. CBCT provides detailed three-dimensional images of the maxillofacial anatomy, allowing clinicians to accurately assess available bone, proximity to vital structures, and optimal implant angulation.[28] When integrated with CAD/CAM technology, this data enables precise virtual planning of implant positioning and prosthetic designs.[28,29]

Guided surgery, using surgical guides or dynamic systems, enhances the accuracy ofimplant placement by transforming digital plans into real-time surgical precision. It is especially beneficial in the posterior maxilla or mandible, where visibility and access are limited.[30]Another key advancement is the development of angulated screw channel (ASC) systems, which allow the prosthetic screw access to emerge through more suitable and favourable positions, such as occlusal or palatal surface. This system retains the retrievability of screw-retained prostheses.[29,31]

Custom abutments designed through CAD/CAM play an important role in adapting to the angulation of implants, giving a proper emergence profile and optimised load distribution. [30] Additionally, digital impressions using intraoral scanners reduce limitations associated with conventional impressions and streamline the fabrication of prostheses.[31] These technological advances have expanded the clinical implications of tilted implants and potentially improved treatment outcomes.

CONCLUSION:

Posteriorly tilted implants have emerged as a reliable and efficient solution in modern implant dentistry, especially for full-arch rehabilitation in patients with limited posterior alveolar bone. This approach allows clinicians to avoid anatomical restrictions such as the

maxillary sinus or the inferior alveolar nerve, thereby reducing the need for invasive bone grafting procedures. Their use leads to the enhanced key factors in contemporary dental practice. In summary, while tilted implants are not without challenges, their numerous benefits make them a milestone in graftless, full-arch rehabilitation. Continued research and technological innovations will further enhance their role in delivering functional, esthetic, and patient-centred outcomes in implant dentistry.

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