Journal of Oral Medicine and Dental Research

Genesis-JOMDR-5(3)-67
Volume 5 | Issue 3
Open Access
ISSN: 2583-4061

Analyzing the Forces on Dental Implants with Exclusive Apical Fixation: A Critical Evaluation of Leverage and ISO 14801/2016 Testing Protocols

Luis Miguel Mesquita Santos[1], Bruno Henrique Alves Ciloto[2], Jose Luis Tavares Figueiredo[3] and Rui Pedro Leal Moreira Coelho[4*]

[1]Clinica Luís Mesquita Santos, Portugal

[2,4]Boneeasy Research center, Portugal

[3]Lusíadas Hospital Oporto, Portugal

[*]**Corresponding author:** Coelho R.P.L.M, Boneeasy Research center, Portugal.

Citation: Santos L.M.M, Ciloto B.H.A, Figueiredo J.L.T, Coelho R.P.L.M, Analyzing the Forces on Dental Implants with Exclusive Apical Fixation: A Critical Evaluation of Leverage and ISO 14801/2016 Testing Protocols. J Oral Med and Dent Res. 5(4):1-9.

Received: August 16, 2024 | **Published:** August 20, 2024

Copyright© 2024 genesis pub by Ciloto B.H.A, et al. CC BY-NC-ND 4.0 DEED. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License. This allows others distribute, remix, tweak, and build upon the work, even commercially, as long as they credit the authors for the original creation

Abstract

Dental implants with exclusive apical fixation are increasingly used as a solution for treating atrophic jaws and enabling immediate loading. However, these implants are subject to unique mechanical stresses that are not adequately addressed by the current ISO 14801/2016 testing protocols. This study explores the leverage principle as it applies to these implants, highlights the limitations of ISO 14801/2016, and suggests the need for additional testing to account for the mechanical validation of such implants.

A series of experiments were conducted using varying distances and angles to calculate the momentum, demonstrating that forces on these implants could be significantly higher than those currently tested. The findings underscore the importance of revising the ISO standards to include guidelines for implants with only apical fixation.

Keywords

Dental Implants; Apical Fixation; Leverage Effect; ISO 14801/2016; Mechanical Stability; Immediate Loading; Atrophic Jaws; Cortical Bone Engagement; Biomechanical Validation; Custom Implant Design

Introduction

Dental implants are a widely accepted solution for tooth replacement, particularly in cases of severe maxillary bone atrophy where conventional treatments are not feasible. In recent years, various techniques such as transnasal, trans-sinus, pterygoid, and palatal approaches, as well as the use of zygomatic implants, have been developed to address these challenges. These techniques often rely on implants with exclusive apical fixation, where the implant is anchored only at its apical tip, enabling immediate loading and providing an option for patients with atrophic jaws.

However, implants with exclusive apical fixation present unique mechanical challenges, particularly concerning mechanical stability due to the leverage effect. The principle of leverage, as famously stated by Archimedes, "Give me a fixed point and I will move the whole world," aptly describes the mechanical disadvantage posed by such implants. This leverage effect is not adequately considered in the ISO 14801/2016 standard, which outlines fatigue testing protocols for dental implants but assumes full implant engagement and constriction within the bone [1-2].

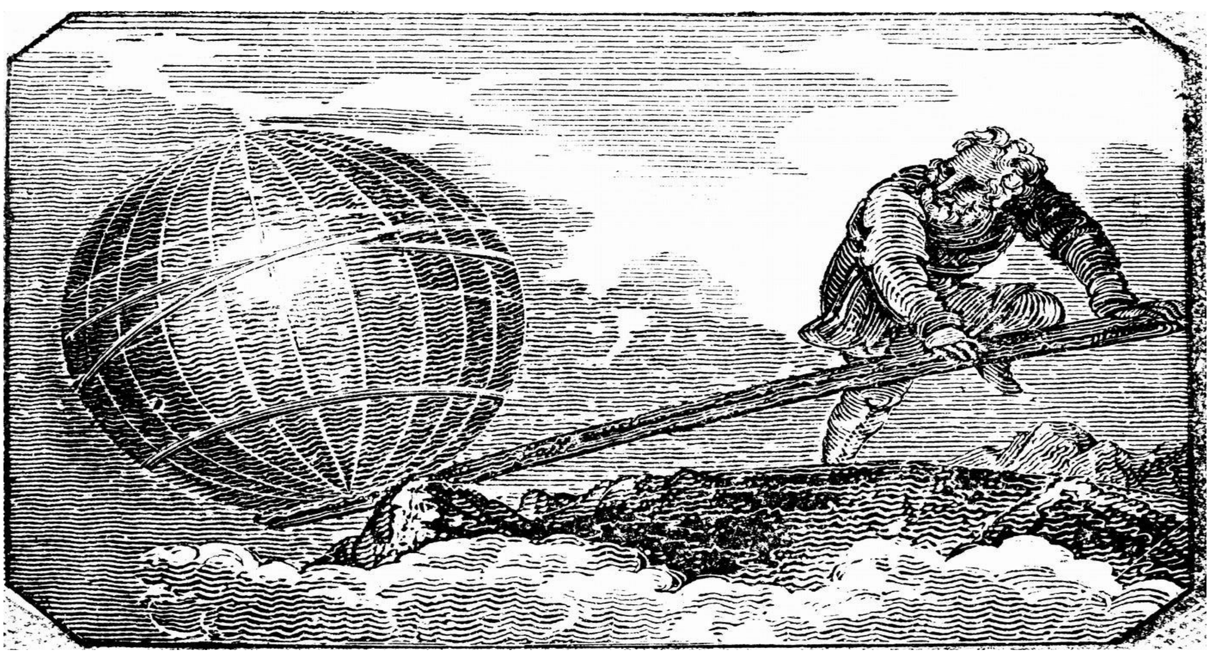

Figure 1: Representation of Archimedes moving the world using a leverage.

DOI: *https://doi.org/10.52793/JOMDR.2024.5(2)-66*

In response to these challenges, the development of individualized cortical non-leverage implants, such as those by Boneeasy, represents a novel approach. These implants are designed to maximize cortical bone engagement and minimize leverage forces, providing a mechanically stable solution for atrophic jaws. This study aims to define the leverage principle in the context of dental implants, compare it to the ISO 14801/2016 testing protocol, and propose necessary revisions to ensure comprehensive mechanical validation of these implants, particularly those used in advanced surgical techniques and individualized implant designs [14].

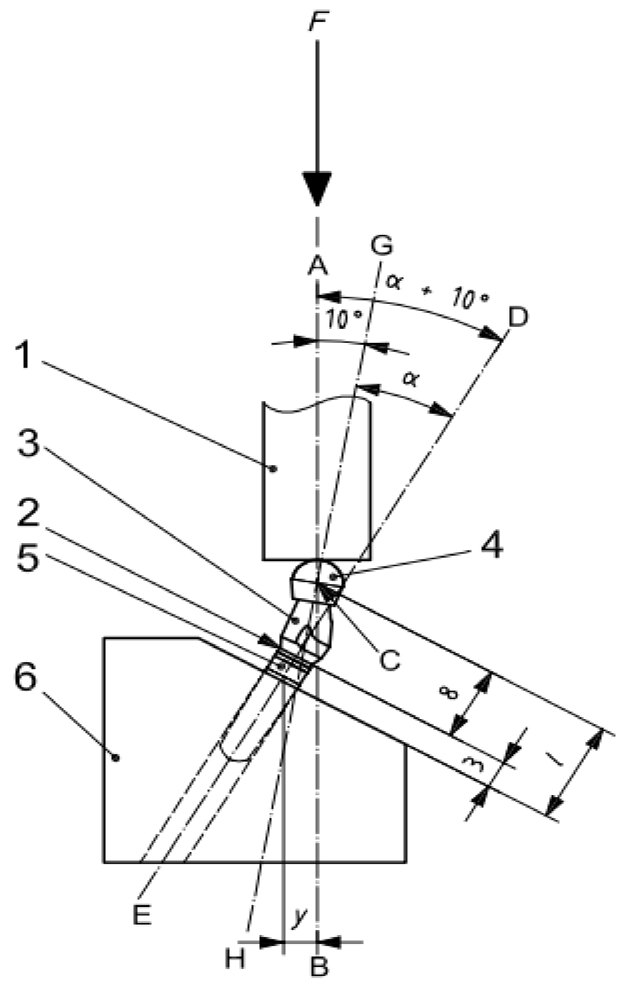

Figure 2: Image of ISO 14801/2016 Dynamic fatigue test for endosseous dental implants - validation of angled components.

Leverage Principle in Dental Implants

The leverage principle is a fundamental mechanical concept that describes how a force applied at a distance from a pivot point can generate a significant turning effect, or momentum. In dental implants with apical fixation, the implant acts as a lever, with the apical tip serving as the pivot point. The longer the distance from the point of force application to the apical fixation, the greater the momentum

DOI: *https://doi.org/10.52793/JOMDR.2024.5(2)-66*

generated, increasing the stress on the implant and the surrounding bone. This principle is not adequately considered in the ISO 14801/2016 standard, which tests implants with full engagement and constriction within the bone [3-5].

Engagement vs. Constriction

Understanding the difference between engagement and constriction is critical in analyzing implant stability. Engagement refers to the portion of the implant that is in contact with the bone, whereas constriction refers to the distance between two extreme points of the implant that are fully surrounded by bone. Implants with only apical fixation can have big engagement but low constriction, which exacerbates the leverage effect and increases the risk of mechanical failure.

Rationale for Apical Fixation Techniques

The use of implants with exclusive apical fixation has become increasingly common in the treatment of atrophic jaws, where bone quantity and quality are insufficient for traditional implant techniques. The desire for immediate loading, which allows for faster rehabilitation and improved patient outcomes, has driven the development of various apical fixation techniques:

1. **Transnasal and Trans-Sinus Implants:** These approaches involve placing implants through the nasal or sinus cavities to achieve anchorage in denser bone regions.
2. **Pterygoid Implants:** Pterygoid implants engage the pterygoid plates of the sphenoid bone, offering a stable and robust solution for posterior maxillary regions with significant bone loss.
3. **Palatal Approaches:** These techniques leverage the dense palatal bone for implant anchorage, particularly useful in cases of severe maxillary atrophy.
4. **Zygomatic Implants:** Zygomatic implants bypass the maxillary bone entirely, anchoring instead in the zygomatic bone, making them ideal for patients with extreme maxillary bone loss.

These techniques rely on the principle of achieving maximum stability through minimal bone engagement, focusing on apical fixation. However, the mechanical forces involved, particularly the leverage effect, have not been thoroughly validated under the current ISO testing protocols [6-13].

Individualized Cortical Non-Leverage Implants

As an alternative to traditional apical fixation implants, individualized cortical non-leverage implants, such as those developed by Boneeasy, are designed to address the limitations posed by leverage forces. These implants are patient-matched-designed to fit the patient's anatomy, maximizing cortical bone engagement and distributing forces more evenly across the implant. This design reduces the risk of mechanical failure by minimizing the turning effect caused by leverage.

Boneeasy's implants are fabricated using advanced 3D imaging and manufacturing techniques, ensuring a precise fit and optimal biomechanical performance. The individualized approach allows for better adaptation to the specific anatomical challenges presented by atrophic jaws, offering a potentially more reliable solution for immediate loading.

Materials and Methods

To quantify the forces exerted on dental implants with apical fixation, we utilized the momentum equation:

1. α is the angle of force application,
2. Distance is the length from the point of force application to the apical fixation,
3. Force is the applied load.

We selected distances of 6, 10, 20, and 30 mm and angles of 30º, 40º, and 50º to simulate different clinical scenarios, all tests with a load of 200N, quite normal for a masticatory force. Although these values are indicative, they provide surgeons with a reference for understanding the potential stress on implants that lack comprehensive mechanical validation under current testing protocols.

Results

The results indicated a significant increase in momentum with both increasing distance and angle. For example, at a distance of 30 mm and an angle of 50º, the generated momentum was substantially higher (459,6 N.mm) than that at a distance of 6 mm and an angle of 30º (6 N.mm). These findings suggest that implants with apical fixation are subjected to forces that exceed those tested by ISO 14801/2016, raising concerns about the adequacy of current testing protocols.

	Angle		
Exposure	30º	40º	50º
6mm	60,0 N.mm	77,1 N.mm	91,9 N.mm
10mm	100,0 N.mm	128,6 N.mm	153,2 N.mm
20mm	200,0 N.mm	257,1 N.mm	306,4 N.mm
30mm	300,0 N.mm	385,7 N.mm	459,6 N.mm

Table 1: Response Momentum on apical zone of the implant.

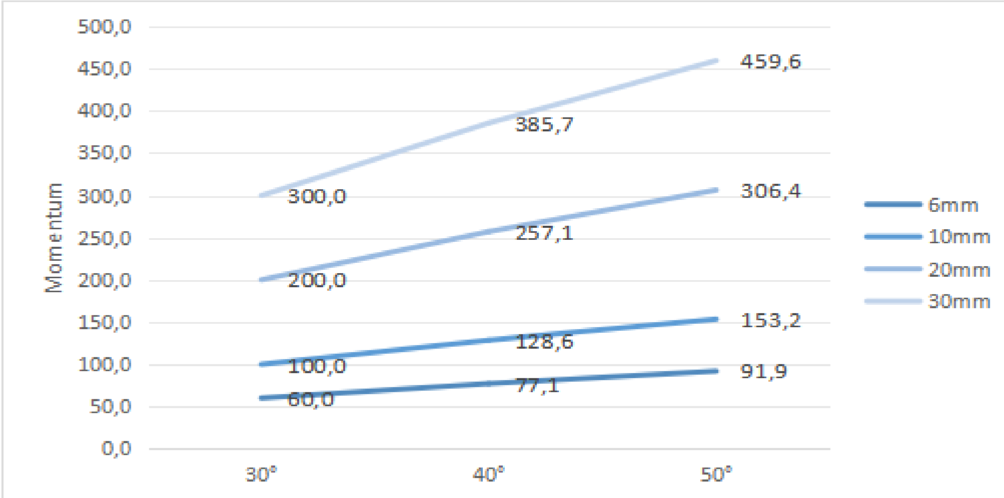

Table 2: Graphic showing the variation of the momentum according with the angle and leverage distance.

The introduction of individualized cortical non-leverage implants by Boneeasy presents a promising solution, as these implants are specifically designed to minimize leverage forces, thus potentially offering a more stable and durable option for patients with atrophic jaws.

Discussion

Our analysis reveals a critical gap in the mechanical validation of dental implants with exclusive apical fixation. The ISO 14801/2016 standard does not account for the leverage effect, which can result in underestimating the forces that such implants must withstand in clinical practice. The momentum generated by the leverage effect can compromise the stability and longevity of these implants, leading to potential clinical failures.In addition to the biomechanical challenges associated with apical fixation, zygomatic implants are always coupled with angulated prosthetic components set at angles of 17, 30, or even 45 degrees. These angulated components exacerbate lateral forces and increase the lever arm, which results in higher stress on both the implant-prosthetic interface and the fixed area of the implant. The angulated component must be taller to compensate for the angular discrepancy, further amplifying the mechanical demands on the system.

Our results indicate that in extreme cases, the loadings on implants with exposures exceeding 10 mm are critically high. This is exacerbated by the angulation of both the implant and the prosthetic components. Such angulation amplifies the biomechanical forces exerted during mastication, resulting in excessive stress on the surrounding bone. This increased force significantly raises the risk of implant failure, even when multiple anchorage points are employed. The ISO 14801/2016 standard considers implants positioned at 10 degrees plus the componente angulation with 3 mm of exposure, taking into account peri-implant mucositis and bone reduction over the years. In implantation techniques such as Branemark, Stella, and Aparicio, where the zygomatic implant is placed in the zygomatic bone with its occlusal surface supported in the anterior or posterior regions of the maxilla, bone resorption often occurs within a few months. This resorption is attributed to micromovements exceeding 50 μm, causing the entire

DOI: *https://doi.org/10.52793/JOMDR.2024.5(2)-66*

masticatory load to be transferred to the apical support of the implant. This results in obtuse angulations and extremely high moments at the support point, can lead to early failures.

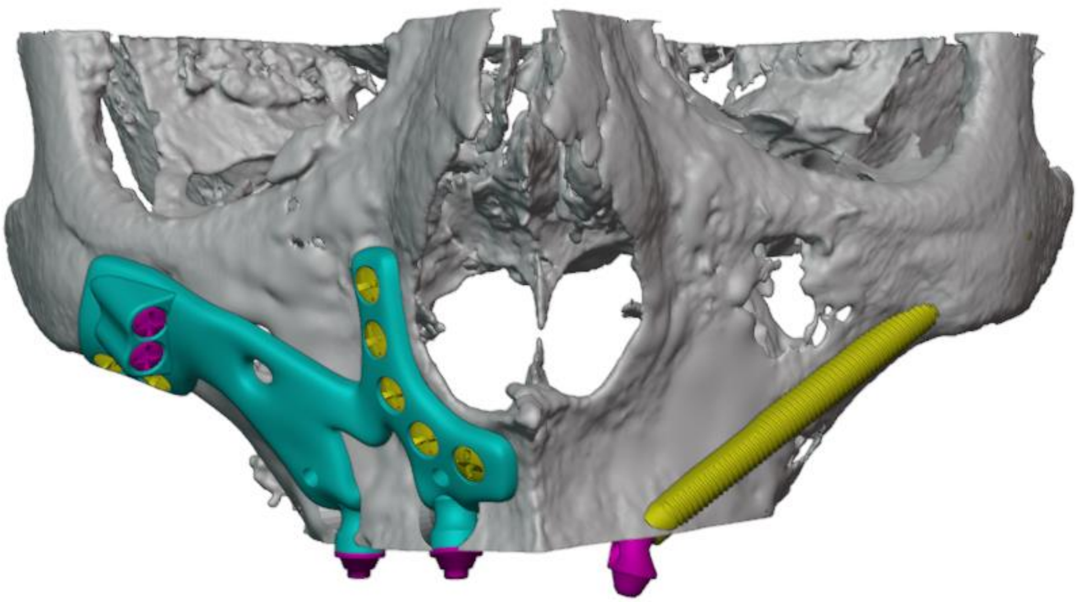

Figure 3: Comparison between Boneeasy Implantize Compact and a Zygomatic Implant, both with Multi Unit Abutment.

According to ISO 14801:2016, the standard aims to determine the maximum load applied to an implant over 5×10^6cycles. This load should be consistent with masticatory forces, applicable to both single and multiple implants. Typically, the load ranges between 90 and 180N. However, this load reflects a very low moment, as the exposure is only 3mm and the point of force application is at 11mm. When considering greater exposures and points of force application, the survival load will unquestionably fall below the forces exerted during mastication. This leads to two evident outcomes: either the patient will be unable to exert normal masticatory forces, or the implant will inevitably fail prematurely due to unfavorable clinical conditions.

Given the increasing use of apical fixation techniques for treating atrophic jaws and the demand for immediate loading, it is imperative that the ISO standards are revised to include testing protocols that adequately simulate these clinical conditions. The development of individualized cortical non-leverage implants, such as those by Boneeasy, represents a significant advancement in addressing the mechanical challenges associated with traditional apical fixation implants. These implants are designed to maximize cortical bone engagement and minimize leverage forces, providing a mechanically stable solution for atrophic jaws.

We suggest that, for the approval of zygomatic implants, the ISO 14801/2016 standard should not be used; instead, a new methodology should be developed where the lever arm is not 3 mm but considers the implant's apical fixation. This approach could ensure that all types of implants are adequately validated for clinical use, particularly those used in advanced surgical techniques and individualized implant designs.

Conclusion

This study underscores the need for revisions to the ISO 14801/2016 standard to include specific testing protocols for dental implants with exclusive apical fixation. The current standard, which evaluates implants at a 30-degree angle with 3 mm of exposure, fails to consider the leverage effect and the mechanical challenges unique to apical fixation implants. This gap in testing protocols can lead to an underestimation of the forces and stresses these implants experience in clinical settings, potentially compromising their stability and longevity.

In particular, the resorption of bone at the occlusal surface in zygomatic implant techniques, combined with micromovements exceeding 50 µm, transfers the entire masticatory load to the implant's apical support. This results in high moments at the support point, leading to early failures and lower success rates compared to implants designed to minimize leverage forces, such as those by Boneeasy. Thus, it is crucial to develop new methodologies that consider the apical fixation of implants, ensuring comprehensive mechanical validation and improving patient outcomes.

References

1. Archimedes. (2002) On the Equilibrium of Planes." In The Works of Archimedes, edited by T.L. Heath, Dover Publications.
2. ISO 14801:2016. Dentistry - Implants - Dynamic fatigue test for endosseous dental implants. International Organization for Standardization, 2016.
3. Misch CE. (1999) Implant Design Considerations for the Posterior Regions of the Mouth. Implant Dent. 8(4):376-86.
4. Meyer U. (2001) Bone Loading Characteristics of Dental Implants with and Without Apical Fixation: A Biomechanical Study. Clin Oral Imp Res. 12(6):637-43.
5. Truninger T. (2012) Fatigue and Fracture of Dental Implants: A Review. J Mec Beh Bio Mat. 9:91-105.
6. Bedrossian, E. (2010) Implant Treatment Planning for the Edentulous Patient: A Graftless Approach to Immediate Loading. Elsevier.
7. Aparicio C. (2006) A Retrospective Clinical and Radiographic Evaluation of Implants: A 110 Zygomatic 1–9-year Study. Int J Oral Max Imp. 11(2):187-94.
8. Graves SL. (2005) Pterygoid Implants for Maxillary Rehabilitation: A Review of the Literature. J Pros Dent. 94(4):324-30.
9. Boyes-Varley JG. (1997) Maxillary Palatal Implants: A Critical Review of the Literature." International Journal of Oral and Maxillofacial Implants. 12(2):217-22.
10. Maló P. (2005) Rehabilitation of Completely Edentulous Atrophic Maxillae by Immediate Function Using Quadruple Zygomatic Implants in Conjunction with Anterior Implants: A Two-Year Retrospective Study.Clin Imp Dent Rel Res. 7(1):4-14.
11. Aparicio C. (2012) Zygomatic Implants: Indications, Techniques, and Outcomes." Int J Oral Max Imp. 27(4):1006-20.
12. Stella JP. Warner MR. (2000) Sinus Slot Technique for Simplified, Predictable, Immediate Placement of Zygomatic Implants: A Technical Note." The Int J Oral Max Imp. 15(6):889-93.

13. Brånemark PI. (1998) Rehabilitation of the Edentulous Patient with Branemark System Implants. Periodontology. 17(1):104-16.
14. Santos L.M.M, Figueiredo J.L.T, Coelho R, Carvalho S, Martins I. Martins. (2024) Comparison of Zygomatic Implants and Implantize Compact from Boneeasy: A Finite Element Analysis for Bending and Safety Factor. J Oral Med and Den Res. 5(3):1-9.