Relationship between Age, Gender, and Implant-Related Parameters on Primary Implant Stability: A Retrospective Clinical Study

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Abstract :

Background

Primary stability is a critical factor for the success of dental implants, as it ensures effective osseointegration and favorable long-term outcomes. It is influenced by several variables, including patient characteristics, implant design, and surgical techniques. However, the combined effect of these factors remains insufficiently understood.

Aim

This study aimed to analyze the relationship between age, gender, implant dimensions (length and width), and primary stability to identify factors that significantly impact implant stability.

Materials and Methods

This retrospective study analyzed data from 2,310 patients who underwent dental implant placement at SIMATS between June 2019 and December 2024. Patients aged 18 years or older, with adequate residual bone volume and no contraindicating medical conditions, were included. Primary stability was measured using insertion torque (Ncm). Statistical analyses, including chi-squared tests, were performed to assess the association of primary stability with age, gender, implant site, height, and width.

Results

The study included 1,294 male and 1,016 female participants with a mean age of 41.54 ±13.43 years. Statistical analysis revealed no significant association between primary stability and age ($p > 0.05$), gender ($p = 0.572$), or implant width ($p = 0.933$). However, implant height ($p = 0.001$) and implant site ($p = 0.092$) showed significant influence on stability, with longer implants providing enhanced stability due to increased bone-implant contact.

Conclusions

Implant height and placement site significantly affect primary stability, while age, gender, and implant width have minimal impact. Tailoring implant selection and surgical protocols to account for implant dimensions, bone density, and optimal insertion torque (25–45 Ncm) can improve clinical outcomes.

Keywords

Dental implants, primary stability, implant height, insertion torque, osseointegration, patient factors, implant site.

Introduction

The success of dental implants largely depends on achieving primary stability, which is essential for effective osseointegration and the differentiation of bone cells [1-2]. Primary stability refers to the absence of implant movement immediately after surgical placement [3]. Several factors influence osseointegration and can help reduce treatment time, including surgical techniques, bone density and quality, and implant geometry. These factors collectively determine the initial stability of the implant, defined as the lack of movement following insertion [4-6].

The measurement of implant stability is the implant stability quotient (ISQ) and ranges from 1 (lowest implant stability) to 100 (highest implant stability) [7-8] Reported ISQ values for successful implants range from 57 to 82 [9]. However, ISQ values at implant insertion should be ≥60 to achieve sufficient implant stability [10,11].Although micro movements, which affect implant stability, cannot be directly measured, various methods are used to evaluate stability. Among these, resonance frequency analysis (RFA) is commonly employed, with the implant stability quotient (ISQ) and insertion torque (IT) serving as indirect indicators of initial stability [12] . The ISQ scale ranges from 1 to 100, where higher values indicate greater stability [13] . Additionally, insertion torque (IT) measurements offer insights into the mechanical engagement between the implant and bone during placement [14].

Insertion torque (IT) is the rotational force required to place a dental implant into the bone, measured in Newton centimeters (Ncm). It serves as a key indicator of primary stability, reflecting the level of mechanical engagement between the implant and surrounding bone. Higher insertion torque values, typically between 35-50 Ncm, suggest strong initial stability, particularly in denser bone types (Type I & II), making implants more suitable for immediate loading. In contrast, lower insertion torque (<25 Ncm) is often associated with softer bone (Type III & IV), which may require a delayed loading approach to minimize micro movement and enhance osseointegration. However, excessive insertion torque (>50-70 Ncm) can lead to bone compression, necrosis, and marginal bone loss, potentially compromising implant success. Ideally, a moderate insertion torque (30-45 Ncm) provides a balance between stability and proper bone healing, reducing the risk of over-compression while promoting successful osseointegration.

Studies have explored the role of implant macro design on stability. Cylindrical implants, for example, may provide different stability outcomes compared to tapered implants due to variations in their mechanical engagement within the bone [15]. Implant diameter and length also play pivotal roles. While wider implants tend to offer greater stability, the relationship between

implant length and primary stability is more complex. Research by Östman et al. and Miyamoto et al. found that longer implants might reduce stability in some cases, particularly if they feature a narrower coronal portion to facilitate insertion [16-17].

Patient-specific factors, such as age and gender, add another layer of complexity. Bone quality typically diminishes with age, particularly in postmenopausal women due to hormonal changes that lead to reduced bone density, potentially affecting primary stability [18]. Gender differences have been reported inconsistently in the literature, with some studies suggesting that women achieve higher ISQ values due to denser cortical bone, while others found no significant gender-based differences in implant stability [19].

Osseointegration, first described by Brånemark, depends on the interplay of these factors. Implant design, surgical technique, and patient-specific attributes, such as bone density and health status, contribute to the long-term success of implants. Advances in implantology, including surface modifications like roughened surfaces or biomimetic coatings, have further improved osseointegration by enhancing the bone-implant interface [20].

This retrospective study aims to analyze the combined impact of patient demographics (age and gender) and implant dimensions (length and diameter) on primary stability. By identifying patterns and correlations, the findings will help optimize implant selection and treatment planning for diverse patient populations. Understanding these interdependencies is vital for improving the predictability of clinical outcomes, minimizing complications, and advancing evidence-based implantology. This study provides valuable insights into how the interplay of patient-specific factors and implant characteristics influences primary stability, offering practical guidance for clinicians in selecting appropriate implants and planning treatments tailored to individual patient needs.

Materials and Methods

Study Design

This retrospective study was carried out by analyzing the patient records from June 2019 to December 2024. The study design was reviewed and approved by the Ethical Committee of SIMATS (Ethical approval number. IHEC/SDC/MSIMPLANT-2405/24/274).

Study Population

This retrospective study was carried out by analyzing the patient records from June 2019 to December 2024. Data from 2350 patients who underwent dental implant placement for replacement of missing teeth in the Department of implantology, SIMATS, were included in the study.

The data for this study was obtained from the hospital's digital dental records management system, known as the Dental Information Archiving Software. The inclusion criteria specified that patients must be 18 years or older, have no medical conditions or histories that would contraindicate surgery, and have a healing period of 4 to 6 months following tooth extraction. Additionally, eligible patients needed adequate residual alveolar bone volume to ensure primary implant stability without requiring prior or simultaneous bone augmentation and must demonstrate good oral hygiene practices.

Exclusion criteria included the presence of systemic or psychological conditions that preclude oral surgery, a history of neoplastic diseases or prior treatment with bisphosphonates, smoking, pregnancy or breastfeeding, untreated periodontal disease, less than 2 mm of keratinized tissue, and upper arches. Case records with incomplete information were also excluded from the analysis.

Parameters Assessed

- Demographic details - Patient name, patient identity number, age, and sex.
- Implant parameters - Implant site, Implant height, Implant width, Primary stability (measured using Manual insertion torque - IQ value)

Statistical Analysis

All descriptive data were analyzed using frequency distributions; Chi-square test was performed to assess the relationship between all the parameters and Primary stability. Statistical significance was set at $p < 0.05$. Analyses were conducted with a statistical software SPSS version 23.0 (Statistical Package for the Social Sciences).

Results

A total of 2310 patients were included in the study, out of which 1294 were males and 1016 were females. The age group of the patients ranged from 18 years to 77 years. Table 1 describes the characteristics of the study participants and the implant parameters.

Table 1 : Characteristics of the study participants & Implant parameters :

Age (mean ± SD)	41.54 ± 13.43
Gender (male:female)	1.27:1
Insertion torque IQ value - Maxillary anterior (mean ± SD)	38.00 ± 7.47
Insertion torque IQ value - Maxillary posterior (mean ± SD)	37.80 ± 7.47
Insertion torque IQ value - Mandibular anterior (mean ± SD)	38.85 ± 7.08
Insertion torque IQ value - Mandibular posterior (mean ± SD)	37.71 ± 7.35

Chi-squared test was conducted to analyze the relationship between primary stability and various factors, including gender, age, implant site, implant width, and implant height. The results indicated no significant correlation between age and primary stability. Figure 1 illustrates that the association between gender and primary stability was not statistically significant (P-value: 0.572). However, a significant relationship was observed between primary stability and implant site, with a P-value of 0.092, as shown in Figure 2. Figure 3 demonstrates that implant width had no

statistically significant impact on primary stability. In contrast, Figure 4 reveals a significant association between primary stability and implant height (P-value: 0.001), suggesting that implant height plays a role in determining primary stability.

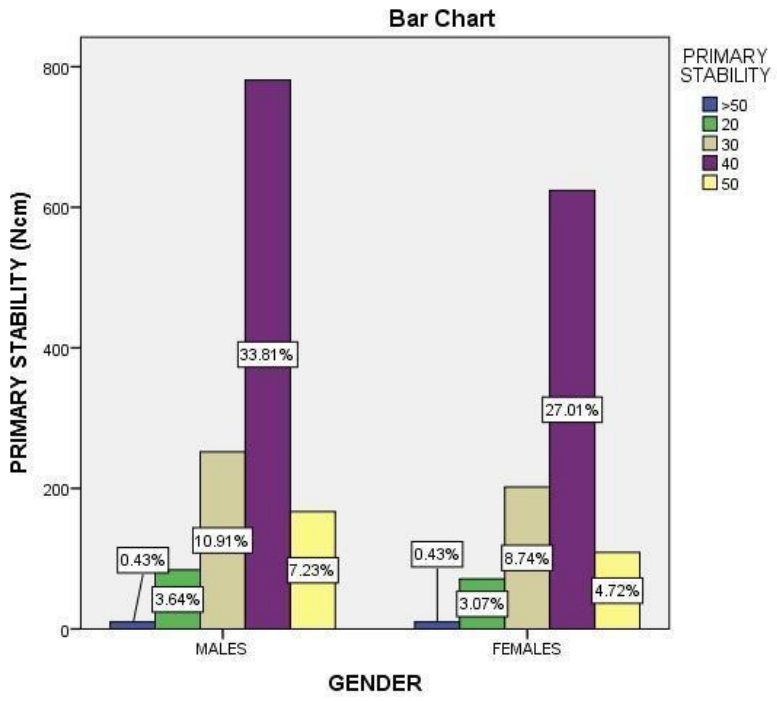

Fig 1: Bar graph depicting the relationship between Gender and Primary Stability. X axis represents the Gender and Y axis represents the Primary stability. Green colour denotes primary stability as 20 Ncm, Light green colour denotes primary stability as 30 Ncm ,Purple colour denotes primary stability as 40 Ncm, Purple colour denotes primary stability as 50 Ncm and Blue colour denotes primary stability as more than 50 Ncm. Chi square test was done and association between Gender and Primary Stability was found to be statistically insignificant (P value = 0.572 i.e Significant). Therefore primary stability has no influence on gender .

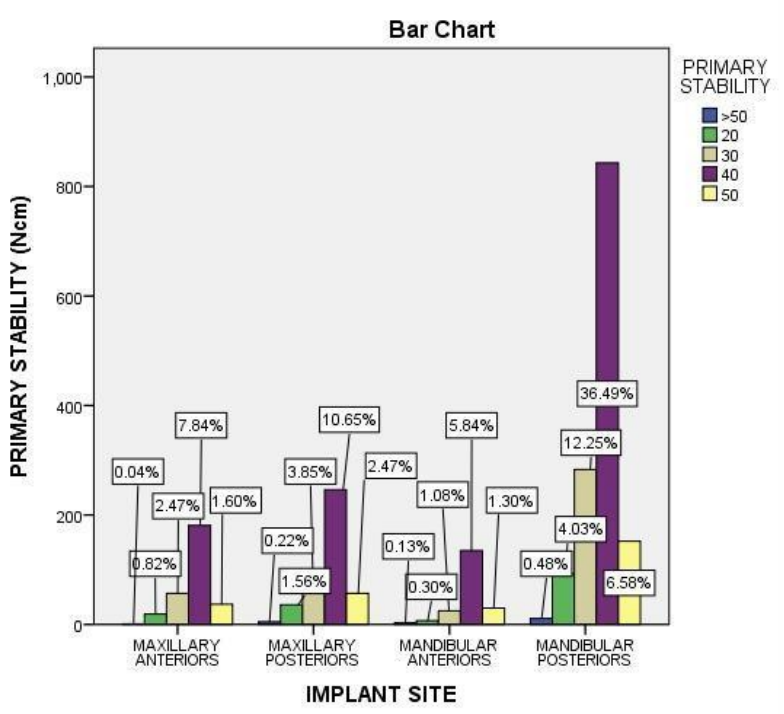

Fig 2 : Bar graph depicting the relationship between Implant Site and Primary Stability. X axis represents the Implant site and Y axis represents the Primary stability. Green colour denotes primary stability as 20 Ncm, Light green colour denotes primary stability as 30 Ncm ,Purple colour denotes primary stability as 40 Ncm, Purple colour denotes primary stability as 50 Ncm and Blue colour denotes primary stability as more than 50 Ncm. Chi square test was done and association between Implant site and Primary Stability was found to be statistically significant (P value = 0.092 i.e Significant). Therefore primary stability has influence on site of Implant placement.

Fig 3 : Bar graph depicting the relationship between Implant width and Primary Stability. X axis represents the Implant width and Y axis represents the Primary stability.Chi square test was done and association between Implant width and Primary Stability was found to be statistically insignificant (P value = 0.933 i.e insignificant). Therefore primary stability has no influence on width of Implant placement.

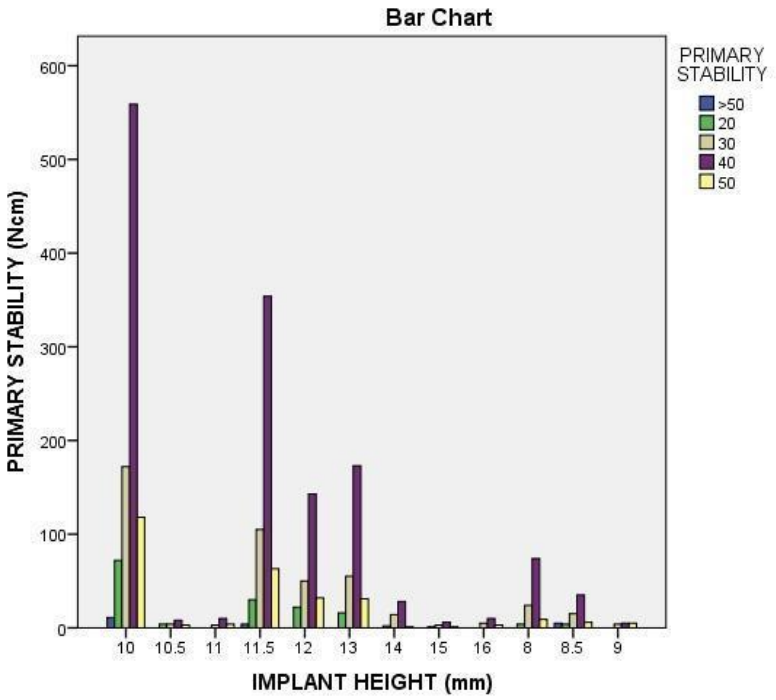

Fig 4: Bar graph depicting the relationship between Implant Height and Primary Stability. X axis represents the Implant Height and Y axis represents the Primary stability. Green colour denotes primary stability as 20 Ncm, Light green colour denotes primary stability as 30 Ncm ,Purple colour denotes primary stability as 40 Ncm, Purple colour denotes primary stability as 50 Ncm and Blue colour denotes primary stability as more than 50 Ncm. Chi square test was done and association between Implant height and Primary Stability was found to be statistically significant (P value = 0.001 i.e Significant). Therefore primary stability has influence on height of Implant .

Discussion

Choosing an implant that ensures sufficient primary stability within the bone bed is crucial for successful clinical outcomes. Primary stability is influenced by factors such as bone quality, surgical technique, and implant design. In areas with low bone density, the implant's macrodesign must support adequate stability. Generally, primary stability improves with increased implant length and width, making longer and wider implants preferable. However, their placement requires adequate alveolar crest thickness to accommodate them properly.

Insertion torque plays a vital role in establishing primary stability during dental implant placement. It refers to the rotational force needed to secure the implant into the bone, indicating the bone's resistance to the implant. A higher insertion torque often signifies strong mechanical engagement with the bone, which is crucial for immediate loading and overall implant success. However, excessive torque may compress the bone, potentially leading to necrosis and impaired osseointegration. On the other hand, low insertion torque can result in inadequate stability, increasing the likelihood of implant failure. The ideal insertion torque depends on factors such as bone quality, implant design, and surgical approach, with a recommended range of 25–45 Ncm to ensure both stability and proper biological integration [5]

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This study emphasizes the complex factors influencing the primary stability of dental implants, with implant height showing a significant effect (P = 0.001), while implant width (P = 0.933) and gender (P = 0.572) had no statistically significant impact. Longer implants enhance stability by increasing the bone-implant contact area and distributing forces more evenly, although caution is needed to avoid complications when engaging less dense apical bone. Although wider implants are thought to improve stability, their impact may be minimal in cases with sufficient cortical bone. Gender differences in bone density do not consistently influence primary stability, likely due to factors such as cortical bone thickness. Bone quality and surgical techniques, including under-preparation of osteotomies in softer bone, are critical to achieving stability, with insertion torque (25–45 Ncm) and resonance frequency analysis (RFA) being key indicators. Implant design features, such as tapered threads for soft bone or cylindrical designs for dense bone, as well as surface enhancements to promote osseointegration, are crucial for success. While age itself does not directly affect stability, changes in bone density with age may require adjustments to surgical protocols, healing times, or loading strategies. This highlights the importance of individualized implant planning based on a patient's unique anatomical and biomechanical characteristics [22-24].

Conclusion :

This study demonstrates that implant height and placement site significantly influence primary stability, whereas age, gender, and implant width exhibit no statistically significant impact. Increased implant length enhances stability by maximizing bone-implant contact. These findings emphasize the need for precise implant selection and surgical planning based on implant dimensions and bone quality to optimize osseointegration and clinical success.

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