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# In Vivo Evaluation of the Early Implant Screw Loosening as Affected by Different Types of Angulated Abutments and altered Loadings: An Original Research Study

**Dr. Pratik Gupta[1], Dr. Manmeet Gulati[2], Dr. Manmohit Singh[3], Dr. Sumit Verma[4], Dr. Archana Queen[5], Dr. Puneet Sharma[6]**

[1]Professor, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India (Corresponding Author)

[2]Professor and Head, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India

[3]Professor, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India

[4]Senior Lecturer, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India

[5]Senior Lecturer, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India

[6]Reader, Department of Prosthodontics and Crown & Bridge, Desh Bhagat Dental College & Hospital, Mandigobindgarh, Fatehgarh Sahib, Punjab, India

**Corresponding Author:** Dr. Pratik Gupta

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**KEYWORDS**

Implant, Screw Loosening, Angulated Abutments, Implant Loading, Radiofrequency Analysis, Osseointegration, Alveolar Bone, Implant Stability Quotient

**ABSTRACT:**

Aim: This study aims to evaluate the early implant screw loosening as affected by different types of angulated abutments and altered loading.

Materials and Methods: A total of 50 patients sought replacement for a missing mandibular right first molar, with 36 choosing dental implants. Eligibility included voluntary consent, good health, and sufficient alveolar ridge condition, while immunocompromised individuals, smokers, and those with mental health or substance abuse issues were excluded. A Cone Beam Computed Tomography (CBCT) evaluation was performed before surgery, and participants used chlorhexidine mouthwash. Under local anaesthesia, a mucoperiosteal flap was reflected for implant placement. Two months later, a healing abutment was added, and by three months, the implant-supported prosthesis was fitted. The 36 patients were divided into two groups: Group 1 received angulated abutments (15°, 25°, 35°), while Group 2 had straight abutments. Implant mobility was assessed at three- and six-month post-placement, with nine patients receiving immediate loading.

Statistical Analysis and Results: This study involved 36 patients, consisting of 21 males and 15 females from diverse backgrounds. Patients were divided into two groups for comparison. Group 1 included 18 patients fitted with implant-supported prostheses featuring angulated abutments at 15°, 25°, and 35°. Their stability was evaluated using advanced radiofrequency analysis. Group 2 also had 18 patients but received traditional straight abutments. After three months, Group 1 showed an average Implant Stability Quotient (ISQ) of 45.1 ± 5 Ncm at 35°, which improved to 50.1 ± 4 Ncm after six months. In Group 2, ISQ values were recorded as 55.5 ± 4 Ncm for immediate loading and 65.4 ± 5 Ncm for delayed loading after three months, rising further to 69.4 ± 4 Ncm and 72.4 ± 5 Ncm, respectively, after six months. The data underwent one-way ANOVA analysis also.

Conclusion: This study concluded that as the angle exceeds upto 35 degrees, the risk of loosening increases at both three- and six-month post-implant placement. Immediate loading creates greater stress on the implant-abutment connection, leading to higher mobility and a greater chance of loosening due to compromised screw tightness. The authors anticipate for further research to better understand these mechanisms and improve clinical practices.

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**Introduction**

The utilization of dental implants has surged in recent years, driven by several key factors, including a growing aging population, a corresponding rise in tooth loss among older adults, and significant advancements in implant technology. The success of these implants largely hinges on a process known as osseointegration, wherein the implant fuses with the alveolar bone. This critical process is influenced by various factors, including the overall health of the patient, the quality of the bone, the materials used for the implant, the specific surface treatments applied, and the protocols followed during loading.[1-3] However, despite their benefits, dental implants can face complications, with screw loosening and fractures being among the most common failures. These issues are particularly prevalent at the implant-abutment junction, where components meet.[4] Screw loosening, for example, can occur due to a loss of preload—essentially the initial tension that keeps the screw secure. Research indicates that the failure rates for single crowns can be as high as 12.7%. When screws become loose, they can lead to serious complications, such as the formation of granulation tissue and infections, and they are also more susceptible to fractures when subjected to load.[5,6] The process of screw loosening unfolds in two distinct stages. Initially, there is a sliding movement between the threads, which gradually reduces the preload. If this reduction continues and falls below a critical threshold, it triggers a counter clockwise movement of the screw. Several factors contribute to this loosening process, including the choice of materials, the delivery systems used for torque, and the overall quality of manufacturing. One of the primary causes of variability in preload can be traced back to improper tightening torque during installation.[7,8] To effectively diagnose screw loosening in dental implants, practitioners often utilize an array of non-invasive techniques that combine advanced technology with clinical expertise. Among these methods are radiography, which allows for detailed imaging of the implant site, and Finite Element Analysis (FEA), a sophisticated computational technique that simulates the physical forces acting on the implants. Additionally, resonance frequency analysis plays a pivotal role in assessing implant stability by detecting variations in vibrational frequencies.[9,10] The Osstell ISQ® is a notable diagnostic tool designed to measure vibration frequency variations accurately. It produces an Implant Stability Quotient (ISQ), with lower values indicating potential loosening. Utilizing such advanced techniques enhances early issue detection and supports the long-term success of dental implants, ensuring patient satisfaction and oral health.[11,12] This study aims to evaluate the early implant screw loosening as affected by different types of angulated abutments and altered loading.

**Materials and Methods**

A total of 50 patients initially presented with the primary complaint of a missing mandibular right first molar, actively seeking replacement options to restore their oral functionality and aesthetics. Among these patients, 36 expressed a strong interest in pursuing dental implant placement combined with implant-supported prostheses as their preferred solution. The inclusion criteria for this study were meticulously crafted to ensure the selection of appropriate candidates. Participants were required to voluntarily agree to participate in the study and sign a comprehensive informed consent form that outlined the details of the procedure. Additionally, candidates were required to be in good physical and mental health, with a well-formed or moderately formed residual alveolar ridge, which is crucial for successful implant integration. Only systemically healthy subjects, exhibiting adequate bone quantity and quality at the intended implant site, were considered eligible. Motivation for implant therapy, coupled with evidence of good oral hygiene practices, was also essential. The age range for participants spanned from 35 to 60 years and included both males and females, offering a diverse cohort. Conversely, certain individuals were excluded. There were immune-compromised patients, smokers, those with mental health issues, and individuals with a documented history of substance abuse, as these factors could adversely influence healing and implant success. Prior to the surgical implantation, a Cone Beam Computed Tomography (CBCT) evaluation was conducted to comprehensively assess the targeted area, ensuring optimal planning for the procedure. To maintain a high standard of hygiene, all participants were instructed to rinse their mouths with chlorhexidine mouthwash. Subsequently, a meticulous inferior alveolar nerve block was administered to anesthetize the area (with long buccal and lingual nerve block), significantly reducing

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discomfort during the surgical intervention. A precise incision was made using a 15-scalpel blade, allowing for the careful reflection of a mucoperiosteal flap, which provided access to the underlying bone. Once the flap was elevated, the dental implant was deliberately placed within the meticulously prepared site. After ensuring the implant was securely positioned, the flap was delicately repositioned to cover the implant, and sutures were expertly applied to promote stable healing throughout the recovery process. Two months following the placement of the dental implants, a healing abutment was gently positioned to encourage optimal tissue integration and promote a healthy environment for further restoration. By three months post-surgery, the implant-supported prosthesis was successfully constructed and fitted for the patients, marking a significant milestone in their treatment journey. The implant placement and implant-supported prosthesis were performed by a single operator using the same implant kit system. This comprehensive study involved a total of 36 patients, divided into two groups. Group 1 included 18 patients who received implant-supported prostheses with angulated abutments set at angles of 15°, 25°, and 35°. Mobility in this group was assessed through radiofrequency analysis. Group 2 also consisted of 18 patients, with these individuals receiving straight abutments for their implant-supported prostheses. Mobility for this group was evaluated via radiofrequency analysis at both 3 months and 6 months post-placement. Among all the patients, 27 underwent the placement of delayed loading prostheses, utilizing the three distinct types of angulated abutments set at the specified angles of 15°, 25°, and 35°. This structured approach allowed for a thorough examination of screw loosening in relation to abutment angles and loading conditions. The assessment of implant mobility was conducted with meticulous attention to detail, utilizing radiofrequency analysis at two crucial intervals: three months and six months following the installation of the implant-supported prosthesis featuring the various angulated abutments. In this cohort, 9 patients were selected to receive immediate loading of both the implant and the implant-supported prosthesis. Their mobility was also diligently evaluated through radiofrequency analysis (Osstel) at the three- and six-month post-placement intervals, providing valuable insights into the stability of the implants. This study investigates early implant screw loosening, examining how variations in angulated abutments and loading protocols may impact this issue, ultimately aiming to improve practices in dental implantology.

**Statistical Analysis and Results**

In this investigation, we utilized SPSS software version 29.0 for our statistical evaluations. The chi-square test was used to assess the significance of our results and to analyze the differences in proportions among the groups. This method enabled a thorough comparison of categorical data, guaranteeing a precise representation of trends and relationships within the dataset.

**Results**

This comprehensive study engaged a diverse cohort of 36 patients, encompassing both male and female participants from various backgrounds. In Table 1, a detailed statistical overview illustrates the age and gender characteristics of these individuals, while Graph 1 vividly portrays the demographic landscape, revealing a balanced composition of 21 males and 15 females involved in the research. The patient population was systematically categorized into two distinct groups for comparative analysis. Group 1 comprised 18 patients who were fitted with state-of-the-art implant-supported prostheses, featuring innovative angulated abutments meticulously positioned at precise angles of 15°, 25°, and 35°. The stability and mobility of the implants within this group were rigorously assessed through advanced radiofrequency analysis, ensuring a thorough evaluation of their performance. In contrast, Group 2 also included 18 patients, who received traditional straight abutments for their implant-supported prostheses. Table 2 provides a comprehensive look at Group 1 (n=18), detailing the placement of the prostheses with varying angulated abutments at the specified angles. The mobility of these implants was critically analyzed through radiofrequency analysis after a three-month period of use, aimed at gauging their functional reliability. The statistical scrutiny, employing the Pearson Chi-Square test for robust accuracy, recorded the Implant Stability Quotient (ISQ) value at a 35° angle, revealing an average of 45.1 ± 5 Ncm. Subsequently, Table 3 presents follow-up results for Group 1 (n=18), documenting the patients' continued treatment over an additional six months with the angulated abutments. The implant mobility was reassessed through radiofrequency analysis, indicating

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an encouraging improvement in the ISQ value at 35°, now elevated to 50.1 ± 4 Ncm. Meanwhile, Table 4 elucidates the findings for Group 2 (n=18), in which an implant-supported prosthesis was strategically positioned under modified loading conditions. After three months, the mobility of the implant was meticulously measured through ongoing radiofrequency analysis. The statistical evaluation once more harnessed the power of the Pearson Chi-Square test, demonstrating distinct ISQ values for both immediate and delayed loading interventions, recorded at 55.5 ± 4 Ncm and 65.4 ± 5 Ncm, respectively. As the results for Group 2 (n=18) expanded after six months of acclimatization to the implant-supported prosthesis under the adjusted loading scenarios, Table 5 encapsulates these insightful findings. The ISQ values for immediate loading rose significantly to 69.4 ± 4 Ncm, while those for delayed loading reached an impressive 72.4 ± 5 Ncm, underscoring the adaptation of the patients to their prosthetic devices. Finally, Table 6 offers a thorough evaluation of the accumulated data across all groups through the application of one-way ANOVA. This analysis provides critical insights into the overall performance and reliability of the prosthetic interventions under review, setting the stage for future studies and advancements in the field of implant dentistry.

**Table 1:** Age & gender based statistical description of contributing patients

| Age Group (Yrs) | Male | Female | Total | P value |
|---|---|---|---|---|
| 35-40 | 6 | 3 | 9 | 0.04* |
| 41-45 | 5 | 5 | 10 | 0.40 |
| 46-50 | 3 | 2 | 5 | 0.01* |
| 51-55 | 3 | 2 | 5 | 0.30 |
| 56-60 | 4 | 3 | 7 | 0.50 |
| Total | 21 | 15 | 36 | *Significant |
| *p<0.05 significant | | | | |

**Graph 1:** Patients demographic distribution and associated details

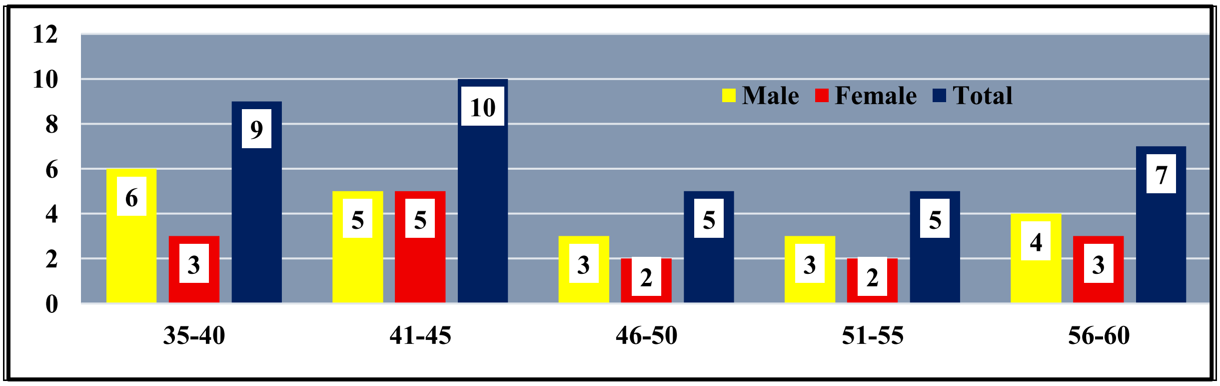


**Table 2:** Group 1 (n=18), an implant-supported prosthesis was placed using 15°, 25°, and 35° angulated abutments. The mobility of the implant was assessed using radiofrequency analysis after three months of implant-supported prosthesis use, and statistical analysis was performed using the Pearson Chi-Square test

| Angulated abutments | ISQ value | n | Stat. | Std. Dev. | Std. Error | 95% CI | Pearson Chi-Square | df | p value |
|---|---|---|---|---|---|---|---|---|---|

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | | | | Value | | |
| 15° | 70.1±6Ncm | 6 | 2.24 | 2.120 | 2.157 | 2.46 | 2.156 | 1.0 | 0.02* |
| 25° | 65.4±6Ncm | 6 | 2.12 | 1.016 | 1.140 | 2.24 | 2.032 | 1.0 | 0.80 |
| 35° | 45.1±5Ncm | 6 | 1.07 | 1.239 | 1.059 | 1.44 | 1.048 | 1.0 | 0.56 |
| *p<0.05 significant | | | | | | | | | |

**Table 3:** Group 1 (n=18), an implant-supported prosthesis was placed using 15°, 25°, and 35° angulated abutments. The mobility of the implant was assessed using radiofrequency analysis after six months of implant-supported prosthesis use, and statistical analysis was performed using the Pearson Chi-Square test

| Angulated abutments | ISQ value | n | Stat. Mean | Std. Dev. | Std. Error | 95% CI | Pearson Chi-Square Value | df | p value |
|---|---|---|---|---|---|---|---|---|---|
| 15° | 75.1±6Ncm | 6 | 2.45 | 2.098 | 2.065 | 2.56 | 2.676 | 1.0 | 0.02* |
| 25° | 72.2±5Ncm | 6 | 2.20 | 1.236 | 1.220 | 2.30 | 2.045 | 1.0 | 0.50 |
| 35° | 50.1±4Ncm | 6 | 1.10 | 1.109 | 1.140 | 1.90 | 1.067 | 1.0 | 0.67 |
| *p<0.05 significant | | | | | | | | | |

**Table 4:** Group 2 (n=18), an implant-supported prosthesis was placed at altered loading, and the mobility of the implant was determined through radiofrequency analysis after 3 months of having the implant-supported prosthesis. Statistical analysis was performed using the Pearson Chi-Square test

| Different Loading | ISQ value | n | Stat. Mean | Std. Dev. | Std. Error | 95% CI | Pearson Chi-Square Value | df | p value |
|---|---|---|---|---|---|---|---|---|---|
| Immediate Loading | 55.5±4Ncm | 9 | 2.56 | 2.188 | 2.175 | 2.66 | 2.776 | 1.0 | 0.01* |
| Delayed Loading | 65.4±5Ncm | 9 | 2.13 | 1.233 | 1.240 | 2.60 | 2.267 | 1.0 | 0.30 |
| *p<0.05 significant | | | | | | | | | |

**Table 5:** Group 2 (n=18), an implant-supported prosthesis was placed at altered loading, and the mobility of the implant was determined through radiofrequency analysis after 6 months of having the implant-supported prosthesis. Statistical analysis was performed using the Pearson Chi-Square test

| Different Loading | ISQ value | n | Stat. Mean | Std. Dev. | Std. Error | 95% CI | Pearson Chi- | df | p value |
|---|---|---|---|---|---|---|---|---|---|

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| | | | | | | | Square Value | | |
|---|---|---|---|---|---|---|---|---|---|
| Immediate Loading | 69.4±4Ncm | 9 | 2.76 | 2.297 | 2.377 | 2.76 | 2.786 | 1.0 | 0.01* |
| Delayed Loading | 72.4±5Ncm | 9 | 2.14 | 1.203 | 1.245 | 2.65 | 2.278 | 1.0 | 0.40 |
| *p<0.05 significant | | | | | | | | | |

**Table 6:** Estimation amongst all studied groups using one-way ANOVA

| Variables | Degree of Freedom | Sum of Squares ∑ | Mean Sum of Squares m∑ | F | Level of Sig. (p) |
|---|---|---|---|---|---|
| Between Groups | 2 | 1.350 | 1.342 | 1.2 | 0.001* |
| Within Groups | 17 | 2.213 | 1.675 | _ | |
| Cumulative | 125.10 | 04.152 | *p<0.05 significant | | |

**Discussion**

Kwok V et al reviewed in their study that the success of implant therapy relies on a delicate equilibrium between biological and mechanical elements, with the majority of complications stemming from mechanical problems instead of issues with the implants themselves. Frequent difficulties include the loosening or breaking of screws, micro-movements, and fractures occurring within the implant-prosthetic system.[13,14] Monje A et al showed in their study that angled abutments, particularly those ranging from 15 to 45 degrees, present unique challenges by introducing transverse forces that can lead to screw loosening due to off-axis loading and micro movements. These abutments are especially useful in all-on-four and all-on-six protocols for edentulous patients[15,16] Srivastava S. et al included in their study that selecting the appropriate collar length for abutments is essential; although longer collars may be needed for aesthetic reasons, they can also amplify vertical cantilever forces, leading to increased stress on screws. While a direct link between collar length and screw loosening has not been proven, longer collars could potentially result in greater cantilever forces. It is recommended that clinicians reduce cantilever lengths whenever feasible.[17,18] Huang Y et al reviewed in their study that the link between the implant fixture and the abutment is crucial, as the abutment plays a vital role in supporting the prosthetic device. The initial tightening, which guarantees a secure screw connection, is significantly affected by mechanical elements. Studies clearly show that screws often become loose as a result of constant pressure from chewing forces. This pressure can disengage the screw threads and create bending forces that significantly weaken the initial tightening. As a result, screws are more prone to vibrations and loosening, especially on uneven surfaces. To prevent joint separation, it is vital to maintain adequate tightening, recognizing that up to 10% of the initial tightening can be lost on smooth contact surfaces.[19,20] Sakamoto S et al reviewed in their study that several factors influence the retention screw's preload in an implant-supported prosthesis, including component fit, the rigidity of the superstructure, implant positioning, occlusal morphology, insertion torque, and lubrication. Variations in surface roughness can also decrease clamping force, undermining stability. Innovations such as Zimmer Dental's friction-fit abutment system enhance stability by creating a robust connection with the implant, thereby minimizing micro movement and risks of loosening.[21,22] Badenes-Catalán J showed in their study that Resonance frequency analysis (RFA) is a valuable tool employed to assess implant stability, yielding the Implant Stability Quotient (ISQ), which correlates with insertion torque—a crucial indicator of primary stability. While the reliability of RFA in denser bone continues to be investigated, it remains a significant component in ensuring long-term implant success and patient satisfaction. Primary mechanical stability is essential for achieving osseointegration and maintaining biological stability, characterized by the absence of mobility between the implant and bone. High insertion torque is indicative of strong engagement, making various evaluation methods, including RFA, vital for promoting long-term success in implant therapy.[23]

**Conclusion**

Within the limitations of this study, the authors investigated the impact of various angles of angulated abutments and loading conditions on early implant screw loosening. They found and concluded that as the angle of the abutment increases, particularly beyond 35 degrees, the risk of implant loosening also increases both three and six months of placing an implant-supported prosthesis. The study highlighted that immediate loading of the implant creates greater stress on the implant-abutment connection compared to delayed loading, resulting in more significant mobility and a higher likelihood of early loosening. This is due to the immediate forces potentially compromising the initial screw tightness, leading to screw fatigue and loosening before sufficient bone healing occurs. The authors emphasized the need for further comprehensive research to deepen the understanding of these mechanisms and improve clinical applications in the future.

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