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CBCT based Radiographic Assessment of Implant Stability at Different Post-Operative Timings as Seen in Patients with Primary and Secondary Osteoporosis: A Clinical (Original Research) Study

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ABSTRACT:

Aim: This study aims to assess implant stability at various post-operative time points in patients with primary and secondary osteoporosis using CBCT evaluation.

Materials and Methods: This study evaluated 45 patients with a missing mandibular right first molar who sought implant placement. Participants, aged 35 to 60 and diagnosed with primary or secondary osteoporosis, underwent thorough screening and provided informed consent. Cone Beam Computed Tomography (CBCT) scans assessed bone density and implant size. Surgical procedures were performed by the same operator using a standardised protocol, including local anaesthesia and a mucoperiosteal flap for implant placement. Healing abutments were fitted after two months, with prostheses placed three months later. The cohort was divided into three groups: Group 1 (15 patients with primary osteoporosis), Group 2 (15 with secondary osteoporosis), and Group 3 (15 without osteoporosis). Implant stability was assessed through radiofrequency analysis and ongoing CBCT diagnostics, focusing on the radiographic stability of implants across different osteoporosis statuses.

Statistical Analysis and Results: The study involved 45 patients (ages 35 to 60) with missing mandibular first molars, consisting of 25 males and 20 females, categorized into three groups based on osteoporosis status: Group 1: 15 patients with primary osteoporosis, monitored for implant stability via radiofrequency analysis at various intervals up to 16 weeks post-implantation, alongside Cone Beam Computed Tomography (CBCT). Group 2: 15 patients with secondary osteoporosis, assessed using the same methods. Group 3: 15 patients without osteoporosis, with similar monitoring. Results (ISQ values) were as follows: Group 1: Immediately after placement (49±5 Ncm), 1-2 weeks (52±3 Ncm), 1-3 months (55±2 Ncm), 16 weeks (57±2 Ncm). Group 2: Immediately after placement (48±6 Ncm), 1-2 weeks (51±5 Ncm), 1-3 months (54±3 Ncm), 16 weeks (56±3 Ncm). - Group 3: Immediately after placement (70±8 Ncm), 1-2 weeks (72±9 Ncm), 1-3 months (75±7 Ncm), 16 weeks (78±6 Ncm). A one-way ANOVA was conducted for a comprehensive statistical analysis across all groups, highlighting significant differences in implant

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stability.

Conclusion: This study concluded that patients with secondary osteoporosis face increased implant instability and a higher risk of complications like peri-implantitis, leading to potential implant failure. In contrast, non-osteoporotic patients show better implant stability four months post-surgery, emphasising the importance of bone health for osseointegration. The findings highlight the need for further research on the factors affecting implant stability in various osteoporosis classifications to improve clinical practices and patient outcomes in dental implantology.

Introduction

Osteoporosis is a progressive skeletal disorder marked by a significant decrease in bone strength, resulting in an elevated risk of fractures from minimal trauma. Often asymptomatic until a fracture occurs, this condition predominantly affects women, primarily due to two factors: a lower peak bone mass throughout their lifespan and an accelerated rate of bone loss during menopause driven by hormonal changes.[1,2] The condition can be classified into two main categories: primary and secondary osteoporosis. Primary osteoporosis typically arises as a natural consequence of ageing and hormonal fluctuations, particularly impacting postmenopausal women due to diminished estrogen levels. This form can lead to significant bone weakening, heightening fracture susceptibility.[3,4] Conversely, secondary osteoporosis develops secondary to specific medical conditions or prolonged corticosteroid use that adversely affect bone density and health. Conditions such as hyperthyroidism, rheumatoid arthritis, and diabetes are implicated in this variant, further increasing the likelihood of serious health complications.[5-7] Despite a range of effective treatment modalities, including lifestyle adjustments, nutritional supplements, and pharmacotherapy aimed at enhancing bone density, a considerable portion of individuals diagnosed with osteoporosis remain untreated. This underscores the urgent need for enhanced awareness, education, and proactive intervention strategies within both the healthcare sector and the broader community.[8,9] In the field of dental practice, ensuring the stability of dental implants in patients with osteoporosis is essential for achieving long-term success and optimal functionality. The stability of these implants can be effectively quantified using resonance frequency analysis (RFA), a sophisticated technique designed to monitor implant stability over time. RFA accomplishes this by measuring variations in resonance frequency as the implant gradually integrates with the surrounding bone tissue. Following the surgical placement of an implant, it's not uncommon for initial stability to experience a temporary decline due to the body's natural healing processes. However, with successful osseointegration the biological integration of the implant with bone stability typically improves over the following months, enhancing the implant's reliability.[10,11] Several factors play a critical role in determining the overall stability of dental implants. These include the diameter of the implant, its anatomical positioning within the jawbone, and the quality and density of the adjacent bone tissue. Each of these elements must be carefully considered and optimised to facilitate the successful integration of the implant and ensure a durable, long-lasting result for the patient.[12] In addition, the advent of cone beam computed tomography (CBCT) has transformed the landscape of dental imaging. This cutting-edge technology provides high-definition, three-dimensional representations of maxillofacial structures, surpassing the capabilities of traditional two-dimensional imaging techniques like panoramic and periapical radiographs. While these conventional methods can leave gaps in visualisation, especially in complex anatomical regions, CBCT offers enhanced clarity and precision, crucial for accurate diagnosis and treatment. The improved visualisation capabilities afforded by CBCT allow for meticulous anatomical assessments, particularly in challenging cases where precise implant placement is critical. Furthermore, CBCT contributes significantly to diagnostic accuracy and paves the way for meticulous treatment planning. It offers comprehensive insights into the intricacies of bone morphology and the spatial relationships between various anatomical structures. Ultimately, this advanced imaging technique not only enhances clinical outcomes but also prioritises patient safety and satisfaction within dental therapies.[13,14] This study aims to assess implant stability radiographically at various post-operative time points in patients with primary and secondary osteoporosis using CBCT evaluation.

Materials and Methods

This study was designed to comprehensively evaluate a cohort of patients who presented with the specific clinical condition of a missing mandibular right first molar and subsequently sought a reliable replacement method. The study was planned, conducted and

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completed in the Department of Prosthodontics and Crown & Bridge of Navodaya Dental College. Initially, the study set out to include a total of 50 patients; however, the finalized sample comprised 45 individuals, all of whom expressed a definitive interest in undergoing implant placement along with the associated implant-supported prosthesis for the restoration of the missing right mandibular first molar. The selection criteria for inclusion in the study were rigorously defined. Only those individuals within the age spectrum of 35 to 60 years, who had a confirmed absence of the right first molar, and were diagnosed with either primary osteoporosis or secondary osteoporosis were eligible to participate. Conversely, a set of exclusion criteria was established, which ruled out individuals exhibiting mental instability, current smokers, patients with documented allergic reactions to medications, or those presenting with any other significant systemic conditions that could potentially complicate the treatment process or healing. Before the commencement of any implant procedures, exhaustive screening was carried out on each participant. This was coupled with securing informed consent, which served to verify that all patients fully understood the nature of the procedures, their benefits, and potential risks, thus ensuring their willingness to participate in the study. To effectively evaluate bone density and determine the appropriate implant size for each patient, Cone Beam Computed Tomography (CBCT) scans were utilized. This advanced imaging technique allowed for precise assessments that were critical in identifying osteoporosis, a condition that notably compromises trabecular bone density in the maxillofacial region. To uphold consistency throughout the study, all surgical procedures were performed by the same operator utilizing a standardized implant kit. Each patient began the procedure with a chlorhexidine mouth rinse, designed to reduce the risk of postoperative infection. Following this, local anesthesia was administered, with particular emphasis on an inferior alveolar nerve block to ensure optimal analgesia and patient comfort. A precise incision was made using a 15-scalpel blade to create a mucoperiosteal flap, which provided surgical access to the underlying bone while meticulously preserving adjacent soft tissues. The implant was subsequently placed within the prepared osteotomy site with a focus on achieving accurate positioning and stability. Upon successful implant placement, the mucoperiosteal flap was carefully repositioned, and secure sutures were applied to promote an effective healing process. At the two-month mark post-implant placement, healing abutments were fitted onto the implants, and the corresponding implant-supported prostheses were placed three months later. The study population of 45 patients was further stratified into three distinct cohorts for analytical purposes: Group 1: This cohort consisted of 15 patients diagnosed with primary osteoporosis. The stability of the implants was meticulously evaluated through radiofrequency analysis at various postoperative intervals, specifically immediately following implant placement, at 1-2 weeks post-placement, at 1-3 months post-placement, and extending up to 16 weeks post-implantation. These evaluations were conducted in conjunction with ongoing CBCT diagnostics to provide a multifaceted view of implant stability. Group 2: This group also included 15 patients, but with a diagnosis of secondary osteoporosis. Similar to Group 1, these patients were monitored for implant stability using the same parameters and timings as previously outlined. Group 3: The final cohort consisted of 15 patients who were not diagnosed with osteoporosis. Like the other groups, they were assessed for implant stability following the same structured timeline. Rigorous statistical analyses were conducted across these three cohorts to uncover any significant differences in implant stability influenced by the presence or absence of osteoporosis. The primary objective of this comprehensive study is to evaluate the radiographic stability of implants at various postoperative time points in patients diagnosed with primary and secondary osteoporosis, employing advanced CBCT evaluations for an in-depth analysis of the findings.

Statistical Analysis and Results

In this study, we conducted all statistical analyses using SPSS software version 29.0, which is widely regarded as a robust tool for statistical computing and data analysis within the social sciences. To assess the significance of our findings, we employed the chi-square test, which is particularly suitable for analysing differences in proportions among various groups. This approach enabled us to carry out a thorough and rigorous comparison of categorical data, ensuring that our results accurately represent the underlying trends and relationships present in the dataset.

Results

The study focused on a varied group of 45 patients, aged between 35 and 60 years, who were specifically chosen for their lack of mandibular first molars. This cohort included 25 males and 20 females, with their demographic information carefully recorded in Table 1 for thorough analysis. To gain a deeper understanding of how bone density affects implant stability, the participants were divided into three clearly defined groups based on their osteoporosis status. This condition is well-known for its detrimental impact on bone health and overall structural integrity, making it a

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critical factor in evaluating the stability of dental implants. Group 1was made up of 15 patients diagnosed with primary osteoporosis. This subgroup underwent rigorous evaluation of implant stability, employing advanced radiofrequency analysis at various postoperative intervals. These intervals included assessments immediately after implant placement, as well as at 1-2 weeks, 1-3 months, and up to 16 weeks post-implantation. To further enrich the data, Cone Beam Computed Tomography (CBCT) was utilised to evaluate the quality and architecture of the bone surrounding the implants, providing a detailed picture of the treatment area. Group 2 consisted of 15 patients diagnosed with secondary osteoporosis, which can arise from multiple factors, including advanced age or specific health conditions. These patients were monitored for implant stability using the same parameters and timelines as Group 1, ensuring that data collection methods were consistent across the study for accurate comparative analysis. Group 3 included 15 patients who did not have osteoporosis, serving as a control group. This group was evaluated for implant stability at the same intervals as the previous cohorts, offering a baseline against which the other groups' results could be compared. The findings for each group are thoroughly summarised in the following tables. Table 2showcases the results for Group 1, illustrating the progression of implant stability through the Implant Stability Quotient (ISQ) values measured at various stages: immediately after placement (49±5 Ncm), at the 1–2-week mark (52±3 Ncm), at 1-3 months (55±2 Ncm), and at 16 weeks post-implantation (57±2 Ncm). Table 3 presents comparable data for Group 2, where the ISQ values were recorded as follows: immediately after placement (48±6 Ncm), at 1-2 weeks (51±5 Ncm), at 1-3 months (54±3 Ncm), and at 16 weeks (56±3 Ncm). In contrast, Table 4 outlines the results for Group 3, which exhibited significantly higher ISQ values: immediately after placement (70±8 Ncm), at 1-2 weeks (72±9 Ncm), at 1-3 months (75±7 Ncm), and at 16 weeks (78±6 Ncm).These results highlight a pronounced disparity in implant stability among the various groups, suggesting that osteoporosis has a critical impact on the success of dental implants. To provide more in-depth insights, Table 5 offers an extensive statistical analysis using one-way ANOVA to elucidate the significance of the observed differences in implant stability among the cohorts. This analysis underscores the importance of recognising the varying impacts of osteoporosis on implant outcomes and emphasises the necessity for tailored management strategies in patients with differing osteoporosis statuses to optimise their treatment success.

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

Age Group (Yrs)	Male	Female	Total	P value
35-40	7	5	12	0.06
41-45	6	4	10	0.04*
46-50	5	4	9	0.07
51-55	4	4	8	0.60
56-60	3	3	6	0.40
Total	25	20	45	*Significant
*p<0.05 significant				

Graph 1: Patients demographic distribution and associated details

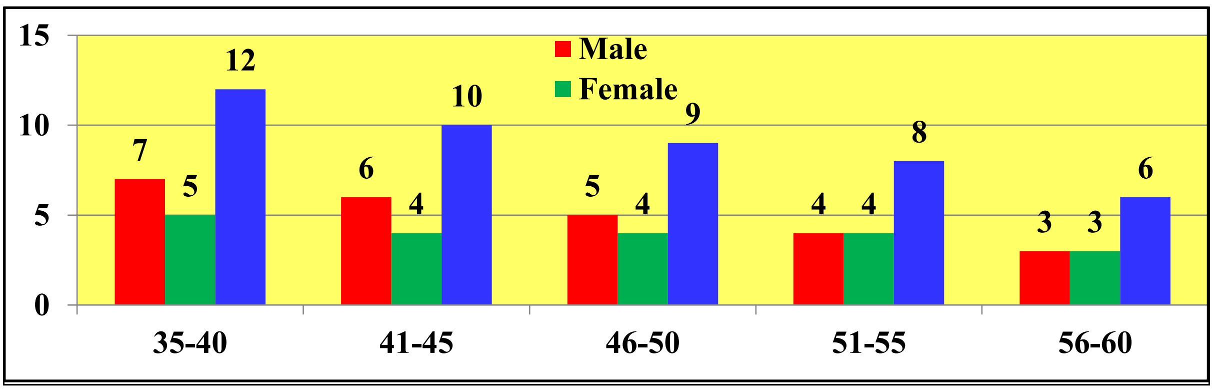

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Table 2: Group 1 (n=15) implants were placed, and the stability of the implants was assessed at various post-operative intervals in patients diagnosed with primary osteoporosis through radiofrequency analysis. A statistical evaluation was performed utilising the Pearson Chi-Square test to determine the significance of the findings

Postoperative Timings	ISQ value	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Immediately after placement	49±5Ncm	5	2.15	1.056	1.230	2.24	2.052	1.0	0.50
1-2 Weeks	52±3Ncm	3	1.07	1.045	1.043	1.09	1.034	1.0	0.06
1-3 Months	55±2Ncm	4	1.08	1.073	1.045	1.11	1.056	1.0	0.02*
Up to 16 Weeks	57±2Ncm	3	1.07	1.045	1.043	1.09	1.034	1.0	0.06
*p<0.05 significant									

Table 3: Group 2 (n=15) implants were placed, and the stability of the implants was assessed at various post-operative intervals in patients diagnosed with secondary osteoporosis through radiofrequency analysis. A statistical evaluation was performed utilising the Pearson Chi-Square test to determine the significance of the findings

Postoperative timings	ISQ value	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Immediately after Placement	48±6Ncm	6	2.17	1.066	1.245	2.45	2.065	1.0	0.40
1-2 Weeks	51±5Ncm	4	1.08	1.073	1.045	1.11	1.056	1.0	0.02*
1-3 Months	54±3Ncm	3	1.07	1.045	1.043	1.09	1.034	1.0	0.06
Up to 16 Weeks	56±3Ncm	2	1.06	1.035	1.040	1.06	1.024	1.0	0.04*
*p<0.05 significant									

Table 4: Group 3 (n=15) implants were placed, and the stability of the implants was assessed at various post-operative intervals in patients diagnosed without osteoporosis through radiofrequency analysis. A statistical evaluation was performed utilising the Pearson Chi-Square test to determine the significance of the findings

Postoperative Timings	ISQ value	n	Stat. Mean	Std. Dev.	Std. Error	95% CI	Pearson Chi-Square Value	df	p value
Immediately after Placement	70±8Ncm	3	1.07	1.045	1.043	1.09	1.034	1.0	0.06
1-2 Weeks	72±9Ncm	4	1.08	1.073	1.045	1.11	1.056	1.0	0.02*
1-3 Months	75±7Ncm	4	1.08	1.073	1.045	1.11	1.056	1.0	0.02*
Up to 16 Weeks	78±6Ncm	4	1.08	1.073	1.045	1.11	1.056	1.0	0.02*
*p<0.05 significant									

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Table 5: 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	4	1.125	1.372	1.2	0.01*
Within Groups	17	2.223	0.429	–	
Cumulative	124.15	02.502	*p<0.05 significant		

Discussion

Prideaux M et al reviewed in their study that osteoporosis is a multifaceted and progressive disease that predominantly affects the skeletal system, leading to a significant reduction in bone density and structural integrity. This condition increases the susceptibility of bones to fractures, particularly in areas such as the hips, spine, and wrists. Osteoporosis occurs when there is an imbalance in the natural processes of bone remodelling, where two specialised types of bone cells play crucial roles: osteoclasts, which are responsible for the resorption or breakdown of bone tissue, and osteoblasts, which are involved in the formation of new bone. When the activity of osteoclasts surpasses that of osteoblasts, the result is a net loss of bone mass, weakening the overall structure of bones.[15-17] Siddiqui JA included in their study that there are two primary classifications of osteoporosis. The most prevalent form is known as primary osteoporosis, which is typically associated with the ageing process and significant hormonal changes, particularly those that occur during menopause in women. This category further divides into two subtypes: postmenopausal osteoporosis, which primarily affects women in the years following menopause due to a decrease in estrogen levels that normally help maintain bone density; and senile osteoporosis, which tends to occur in older adults as a natural part of ageing, often related to long-term calcium and vitamin D deficiencies, as well as other age-related factors.[18,19] Park JC et al showed in their study that the second classification, secondary osteoporosis, arises as a consequence of underlying medical conditions such as hyperthyroidism, rheumatoid arthritis, or gastrointestinal disorders that affect nutrient absorption or due to the side effects of certain medications, including long-term corticosteroids. Lifestyle factors, including prolonged inactivity, smoking, excessive alcohol consumption, and inadequate dietary intake of calcium and vitamin D, can also contribute to the development of secondary osteoporosis, disrupting the delicate balance of bone health.[20,21] Devlin H et al included in their study that in the realm of dental implants, the notion of "stability" holds significant importance and is a foundational element in the success of the procedure. This stability pertains to how effectively the dental implant integrates with the surrounding jawbone. This integration is crucial in determining whether the implant can immediately withstand the pressures of chewing or if a necessary period for healing and osseointegration is required before it can be functionally used.[22] Mellado-Valero A et al reviewed in their study that several anatomical and biological factors come into play regarding this stability. Notably, the height, width, and overall density of the bone at the implant site heavily influence how well the implant will perform. Typically, implants that are longer and wider tend to offer greater stability, making them more reliable for supporting functional loads. In certain circumstances, dental professionals may need to enhance bone volume through surgical procedures, such as bone grafting or maxillary sinus elevation. When performed correctly, these procedures do not compromise implant stability and can provide the necessary support for successful integration.[23,24] Pauwels R et al showed in their study that the landscape of modern dentistry has been transformed by the introduction of Cone Beam Computed Tomography (CBCT), an extraordinary diagnostic tool that has revolutionised imaging in the field. This advanced three-dimensional imaging technique captures highly detailed and high-resolution images of dental structures, providing a comprehensive view that can be examined from various angles. The implementation of CBCT is particularly advantageous for a wide array of dental procedures, from the precise placement of implants and the execution of intricate root canal therapies to the careful planning of orthodontic treatments. The unparalleled clarity in assessing anatomical structures that CBCT offers significantly enhances treatment planning and outcomes, ultimately leading to improved patient care and satisfaction in dental practices.[25,26]

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Conclusion

In the context of this study, the author thoroughly evaluated implant stability at various post-operative time points in patients diagnosed with both primary and secondary osteoporosis, utilizing Cone Beam Computed Tomography (CBCT) for a detailed assessment. The findings indicated and concluded that patients suffering from secondary osteoporosis may experience a moderately greater level of prolonged instability, accompanied by an elevated risk of complications, such as peri-implantitis, when compared to those with primary osteoporosis. Additionally, it was observed that patients without osteoporosis demonstrate significantly greater implant stability four months post-operation. These results highlight the need for more extensive research aimed at deepening our understanding of the underlying mechanisms involved and improving clinical practices and applications in the field of dental implantology in the future.

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